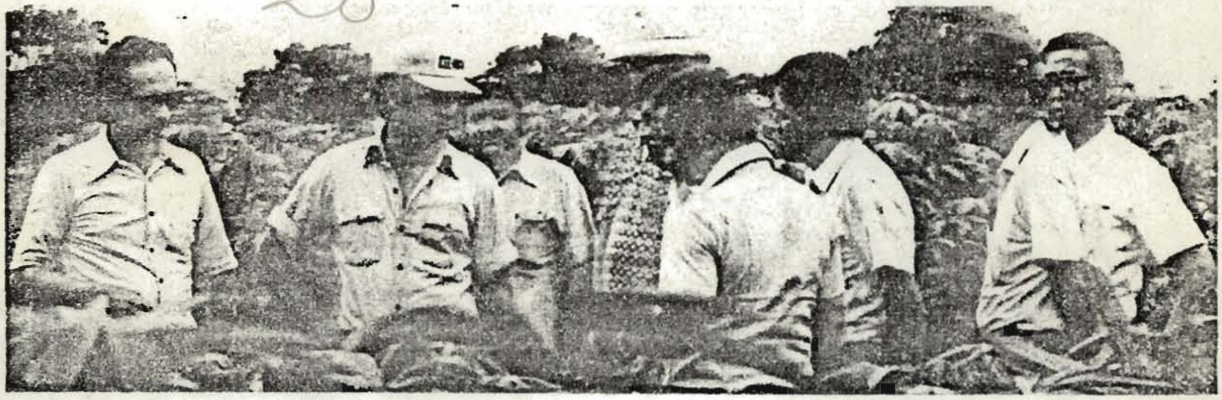
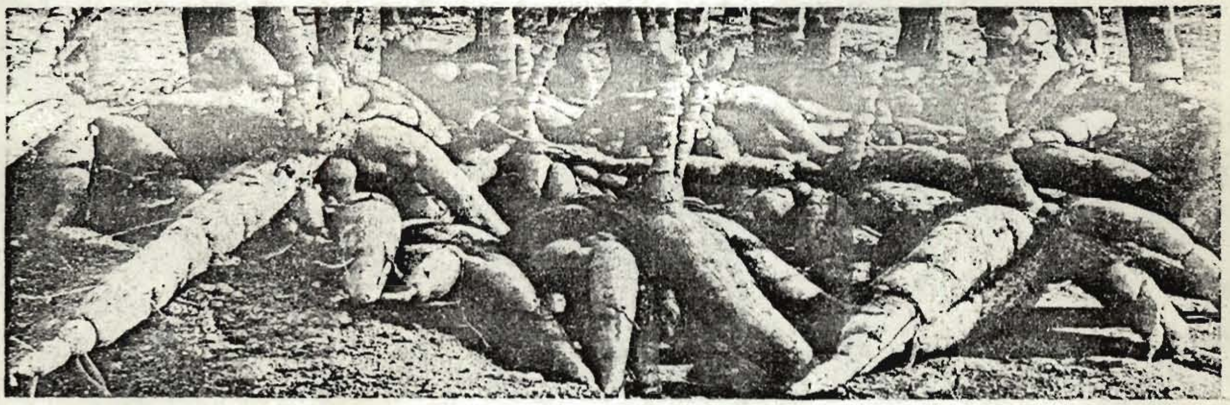
Preliminary draft

Book II

cassava production course





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Reading Materials for the Intensive Course on

RESEARCH FOR CASSAVA PRODUCTION 1978

BOOK II

(The articles herein are rendered in the version as received from the authors)

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CONTENTS

BOOK I

GENERAL ASPECTS ON PRODUCTION COSTS

Fernando Bernal Niño *

Importance

Planning and control are the most important functions in administration because decision making is done through them; in the productive process. Cost accounting is a fundamental tool to exert those functions and within them the relative production costs. These refer to expenditures caused when using goods and services during the process of production in a given period of time.

In measuring the economic results of a crop, cattle or forest explotations production costs are the starting point. However, for this type of business, especially family type, record keeping and evaluation of results is somewhat difficult. This is due to the fact that farmers do not keep precise records, the existence of mixed exploitation causes combined costs, the proportion of fixed costs is high, yields vary at every period, there exists a deliberate under or over-estimulation of costs and a great variability in technology, crop management, administration hability, efficiency levels, etc.

Because of the above reasons it is difficult to generalize about production costs even if exploitations are classified by sizes, use of a certain technology, type of soils and other relevant factors. This is why in a given exploitation the only real costs are those which have already occurred, while budgeted or estimated costs are always subject to risk of considerable variation due to controlable or incontrolable factors. In spite of the governments, finnancing and marketing institutions, among others, need to establish certain average production costs, to serve as guides for credit policies or to determine sustentation prices which will guarantee a minimum profit, to handle input availability or simply to measure gross income. Certain models exist, which may give close idea on the production costs.

We mentioned before that the basis for evaluation and control of the business underlie greately in the production costs, because they are the result of multiplying a labor in which certain quantities of goods and services are used, by a given price.

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* Superintendent: Carimagua Experimental Station.

This factorization gives production costs more relevance and a more universal usefullness because, even if prices vary from place or from time to time, parameters or levels of use are indeed subject of analysis and comparison for planning and control.

Uses of production costs

If we accept costs as sacrifice because they represent money and/or products which must be paid in exchange for a service or good, we can take them as a measure in the traditional way. If we also accept them as those expenditures which participate somehow in the production process and the investment of which is done hopping they will bring benefits, we can think in the inmediate profit which they may give, allowing us to measure the extent of profit obtained.

The reason for their existance is the aid they represent to the management to perform a better task in the handling of the business. Their most important aspects can be summarized as follows :

- They allow the establishment of the economical performance of the enterprise.

- To measure the profit obtained from the money and goods invested in the farm.

- To know the use given to each of the available resources.

- To know the credit capacity of the enterprise.

- To determine different alternatives of production.

- To select technology levels for adoption.

- To determine different investment alternatives.

- To elaborate budgets and to determine flux of cash.

Seen from another point of view, production costs are used in administration to evaluate inventories, to planning and control the enterprise and price fixation. This means that with the knowledge of production costs it is possible to :

a. quantify the availability of products as harvested and non harvested products.

b. to plan by use of selection of objectives and means to achieve them, in a predictable way.

c. mantain control by observing the behavior of the production factors, to determine the extent to which things are comming out as planned, and

d) given the product a price equivalent to the production costs plus a profit wish allow us more security when acting in the market.

Recommendations for the estimation of production costs

Considering the importance and the utilization of production costs, as referred above, it is convenient to considere some guides in arriving to an estimate as close as possible to reality.

It frequently happens that costs, do not represent reality for several reasons: first because they are not considered wholly and second because there is lack of criterion to differ fixed costs to the different productive periods, applying to each one of them their corresponding share of cost.

On the other hand, some costs are estimated in a subjective or imprecise form because of a lack of records or a defficient utilization of them. Records produce formation on hand labor, amounts of inputs used, income and expenses, use of machinery, equipment, irrigation, etc. With the efficient use of records we tend to minimize the error when we estimate production costs.

Many agricultural enterprises, work with several lines; in other words they plant more than one crop. This implies the existence of some related production costs which makes the analysis of profits for each crop, more difficult. To avoid this, it is recommendable to separate them in the proportion they are utilized in each crop giving, that those less profitable "lean" on those which are more profitable.

It is also usefull to observe, and analize the use given to each one of the production factors and the resources used, separately; in this way efficiency levels and difficulties may be known and the proper adjustments may be carried out.

When production costs are considered at farm level, specially medium and small farmers, a distortion relative to family-hand labor, frequently occurs, because it is not quantified in spite of being a normal cost.

Something similar happens with that part of the produce consumed or enjoyed by the family, which must be considered as a common income which must be kept in mind.

Types of production costs

In revising the literature related with these topics, we find a wide range of terms which refer to different types of costs such as, inactivity costs, controllable, uncontrollable, explicit and implicit, differential, avoidable, expired, nonexpired and many more which, even though little mentioned, are explicable to agricultural administration. The reason they are little used in this field is the different conditions surrounding the production process at farm level. When certain conditions can be controlled in industrial production, the costs behave in a different way, without this meaning that in other type of industries, no considerable variability exits in costs, such as happens in the agri-business.

We will mention the most usefull and the most frequently utilized production costs in agricultural enterprises :

a) Fixed costs

Fixed costs are those costs which have no relationship with the volume of production. They will not vary if the production increases a few kg or decreases a number of kgs. They reffer to a given period and to a given fluctuation, called "proper fluctuation". This means that fixed costs can decrease substantially if the levels of activity decrease radically.

The most important fixed costs are :

- Rent paid for land
- Interest for mortgage
- Taxes on fixed capital (land)
- Redeeming of mortgages
- Maintaining fixed capital
- Opening and maintenance of irrigation and drainage ditches
- Insurance for fixed capital.

b) Variable costs

Variable Costs are those which fluctuate within the total in direct proportion to the changes in volume of production such as:

- Land preparation
- Planting
- Cultivating
- Application of fertilizers
- Application of insecticides
- Application of herbicides
- Manual harvesting
- Mechanized harvesting
- Internal transport
- Weeding of ground and irrigation and drainage ditches
- Irrigation
- Transplant
- Seed
- Fuel
- Machinery repairs

- Fertilizers
- Insecticides
- Herbicides
- Transportation
- Packing, boxes, (materials)
- Interest on rent
- Interest on credits
- Redeeming of credits
- Rental of machinery
- Rental of working animals
- Transportation within the farm
- Insurance and reserves for unforseen

c) Total and unitary costs

They represent the sum of variable plus fixed costs, all which are involved in production. The unitary cost is calculated by dividing the total cost by some unit bases. This basis must be the statistical production element, like tons, hectares, etc. This procedure is usefull for planning and control effects.

d) Opportunity costs

Opportunity costs reffer to the income not perceived due to the decision of utilizing the available resources in a certain crop instead of another activity. It is a great aid in decision making because it covers different investment alternatives.

In other words it means resigning to some benefit because resources are dedicated to a certain activity.

e) Disbursable costs

Disbursable costs are the most important for the farmer. They reffer to negotiations in cash in the buying of goods or services applicable to the productive process.

In the case of subsistence agriculture the disbursable costs are greately reduced since the family labor and the use of chemical products do not cause to many cash expenditures.

f) Not-disbursable costs

They are oftenly subestimated because they do not mean a cash expenditure. Frequently they consist of fixed costs like in the case when the owner is the administrator, or techinical asistance when the technician is the owner, family labor, depreciation, etc.

g) Direct and Indirect costs

These are costs which are directly or indirectly affected by the crop production. The most common direct costs are:

- Land preparation (machinery, hand labor)
- Planting (seed, hand labor)
- Fertilization (fertilizers, application)
- Insect and disease control (chemical products, application)
- Weed control (herbicides, hand labor)
- Theft
- Harvesting (recolection, bags, transport)

The following among others, are considered indirect costs:

- Land rental
- Technical assistance
- Administration
- Interest on capital

As we have seen, costs, besides being many and variate, may be classified in several ways. This causes doubts, sometimes among managers, in the placing of a cost under one or another category, especially between fixed and variable costs.

When we want to totalize costs, categorizing them is no problem. However, when we want to make an analysis of the cost-volume profit relationship, or any other type of financial analysis, which reflects the use of fixed and variable factors for control and evaluation, then it makes sense to try to classify them carefully.

SUMMARY

Administration relies a good portion of its functions in the data obtained from production costs. With them it is possible to carry out more objectively, activities like planning, control, decision making, and the efficiency evaluation of all the resources intervening in production.

The determination of costs is not always simple due to the lack of records, the existence of combined costs especially in mixed enterprises, variations, in production, technological level and crop handling.

Their recollection must be careful and must reflect the real situation, without sub or overestimating the costs. It must be kept in mind that a good portion of them, even though not disbursable, constitute a sacrifice or opportunity cost that the producer must quantify.

Costs have many and variate classifications depending on the purpose and the use. The most common in agro-business are the fixed, variable, opportunity, total and unitary, disbursable and not disbursable, direct and indirect costs.

Only with reliable, complete, and in time information on production costs, may the farmer have reliable data concerning the development of his agricultural enterprise and the economical results of the activity.

PLANNING OF THE CASSAVA CROP

Julio Cesar Toro M.*
Ernesto Celis A. **

Like any other crop, cassava presents critical stages not only from the physiological point of view but also plant protection and imput requirements.

A general picture of all possible problems and needs of the crop is desirable, accordingly with the available economic resources. Cassava seed or planting material is not as readily available as beans or corn seed, and this is the first problem encountered by the farmer who wishes to plant cassava for the first time or that wishes to change variety or increase the crop area.

The space that cassava stakes or cuttings occupies during transportation is an important aspect. A 9 ton cap. (25 m^3) truck, can transport approximately 50.000 stakes 20 cm long and 2-3 cm diameter, if the material is still uncut, i.e. entire stem pieces. If the material is already cut into 20 cm stakes, it is best to pack it in sackcloth bags of 500 stakes each. In this manner the truck capacity is increased by 4000 stakes per cubic meter, because by eliminating useless material the space is more efficiently exploited.

A clear idea of cassava production costs, not only in economic terms but in terms of physical units discriminated by labors, could be a very usefull tool in the planning of the cassava crop. Thus, the needs for labor, capital and other inputs, as well as their flux, are known.

It is important to notice that a budget for a crop is useful, but it is only an approximation because the conditions are different even for the same field from one cassava crop to another. It is recommended, as a consequence, to adjust the production costs to each particular case and keep a 10 percent for unforseen expenses.

Land preparation is obviously different, the same as the soils and facilities of the farmer differ.

Because the costs can vary as much as from 5000 to 25000 Colombian pesos, it is best to develop a concrete example as the following, of a farmer with 5 ha. in the Cauca State:

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** Research Assistant. CIAT

Climate and soil characteristics:

pH 5.5
% M.O. 3.5
P 8.0 ppm (Bray II)
K 18.0 Me/100 g of soil
Clay loam
Average temperature 25°C
Precipitation 1.300 mm
Topography level with slight slopes
(Machinery is available for land preparation)

CASSAVA PRODUCTION COST

Item	Unit	Price	Amount/ha	Cost/ha Col $
A. Land preparation				
1. Plowing	hour	150	4	600
2. Disking				
a. First	hour	250	1.5	375
b. Second	hour	300	0.5	150
3. Furrowing 2 m. distance				
a. Machine	hour	100	1.0	100
b. Helpers	hour	12	1.0	12
B. Seed				
1. Cost of the seed at the crop site (unpicked)	thousand of stakes 20 cm. long	80	10	800
2. Fixing and pilling of the plant material which will supply 10.000 stakes	Day's wages man/day	100	2	200
3. 25 m3 truck (9 ton)* fee 200 km distance	trip	2000	1/5	400
4. Three men to load and unload the truck	trip	420	1/5	84
5. Supervisor	trip	300	1/5	60

* A 9 ton truck, completely loaded with cassava stems (25 cm3) will carry a weight of only 4 tons.

	Item	Unit	Price	Amount/ha	Cost/ha
6.	Cutting and packing of 20000 stakes (20 cm.)	Day's wages	50	3.0	150
7.	Sack bags to pack and treat the stakes *	bag	3	20	60
8.	Fungicide for seed treatment	gr.	6.4	150	9.60
9.	Labor for seed treatment	hour/man	6.25	2.5	15.65
10.	In-farm transportation of the seed	Bag	5.oo	20	100
C.	Planting				
1.	Hand labor	Day's wages	50	5	250
2.	Supervisor **	Day's salary	100	1/2	50
D.	Weed control				
1.	Karmex	Kg.	165	3	495
2.	Hand labor	Day's wages	50	2.5	125
3.	Use of back sack sprayer	Use/ha	20	1	20
E.	Weed control hand labor (45 days after planting) ***	Day's wages	50	12	600
F.	Thrip control after 60 days				
1.	Diostop	litre	200	1/2	100
2.	Hand labor	Day's wages	50	2	100
3.	Use of back sack sprayer	Use/ha	20	1	20
G.	Weed control (after 75 days) hand labor	Day's wages	50	12	600

* The bag costs 6.oo but can be used twice.

** 10 workers supervising may plant 1 ha in 1/2 day

*** Could be at 60 days depending on rains

	Item	Unit	Price	Amount/ha	Cost/ha
H.	Weed control (after 120 days)	Day's wages	50	15	750
I.	Thrip control (after 150 days)				
	1. Diostop	Litre	200	1/2	100
	2. Hand labor	Day's wages	50	3.0	150
	3. Use of sprayer	Use/ha	20	1.	20
J.	Weed control (after 240 days) with machete	Day's wages	50	10	500
K.	Watchman (after 6 months) (5 ha)	6 months salary	13.650	1/5	2,730
L.	Ant control during all growing cycle (clordane)	Kg	40	3	120
M.	Harvest				
	1. Pulling * and packing	Kg	0.20	20,000	4,000
	2. Packing sacks (90 kg each)	Sack	8.oo	222	1,776
	3. Supervisor for pulling and weighing during 45 days for the harvest of 5 ha	45-day salary	6,750	1/5	1,350
N.	Land rental	ha/year	1,800	1	1,800
O.	Cost excluding harvest				11,646.25
P.	Interest 18% (12 months)				2,096.32
Q.	Total for harvest				7,126.oo

* Each man pulled and packed 500-700 kg/day. At an average of 600 kg/man. 33 man/days are required.

	Item	Unit	Price	Amount/ha	Cost/ha
R.	Interest for harvest cost 3% (2 months)				213.78
	TOTAL COST				21,082.35

SUMMARY OF PRODUCTION COSTS

	Item	Cost/ha	% of total cost
1.	Land preparation	1,237.00	5.87
2.	Seed	1,879.25	8.91
3.	Planting	300.00	1.42
4.	Weed control with preemergent herbicide	640.00	3.04
5.	Manual weed control	2,450.00	11.62
6.	Insect control	610.00	2.89
7.	Watchman	2,730.00	12.95
8.	Harvest	7,126.00	33.80
9.	Land rental	1,800.00	8.54
10.	Interest	2,310.00	10.96
	Total	21,082.35	100%

NET INCOME

Selling Unit	Price	Amount/ha	Income/ha
Kg	2.30	20,000	46,000
Value of the produce/ ha			46,000
Cost/ha			21,082
Income excluding % profit for administration and technical assistance			24,918
20 percent administration and technical assistance			4,983
		Net income/ha	9,935

cost/benefit relation $\frac{B}{C}$ $\frac{46,000}{21,082}$ 2.18

Keep in mind that this set of production cost is related to a particular Colombian situation, and may be used as an example. However, input costs will differ in different localities, countries and time.

ADMINISTRATION CONCEPTS OF CASSAVA CROP PRODUCTION

Fernando Bernal Niño

Introduction

Agricultural activities have envolved and are no longer considered exclusively as a family employment and subsistence action, becoming a competitive labor, handled as an enterprise.

Any one who does not handle his agri-business as an enterprise risks being eliminated from competition and becoming inefficient. This means that only the most efficient compete favorably, maintaining adequate levels of production and profitability.

Professionals working in production with basic knowledge of administration have become necessary thanks to the rapid technological development, the scarcity of food, the increasing production costs, and the enterprise concept of agri-business. These seem to be the desirable characteristics for personnel working in crop production, to channel agricultural technology to an economical optimum.

Combining these two disciplines under proper conditions, a more rational use of scientific knowledge of production factors is possible, to obtain satisfactory results in an enterprise, which, like the agricultural one, involves, considerable risks and investment.

Scope of Agricultural Administration

Being the purpose of administration to make the best possible use of physical, human and financial resources, which intervene in the productive process, it must necessarily develop the following functions:

a) Planning
b) Work organization
c) Direction
d) Decision making
e) Integration
f) Evaluation and control

Whatever the degree of development of the enterprise, the functions mentioned, applied to the resources, covering the production, finantial and marketing phases.

In agricultural enterprises, normally some questions arise on whose answers rely the success or failure of the farmer.

From the analysis of situation such as what: how much and where to produce; how much and how to invest, and to whom and how to sell, many trascendental answers result in agricultural activity, many of them are in the hands of the administrator.

Planning of the crops.

Planning is one of the activities in which technique and administration must combine in order to: observe the availability of resources, formulate objectives, select alternatives, determine technical coefficients, estimate prices, costs and incomes and the manner in which some labors such as: land preparation, selection of seed, densities, use of chemicals, hand labor, packing, transport, etc. will be performed.

Only by the technical-administrative analysis of the above concepts it is possible to make an evaluated ordenation of expenses, incomes and investments for a more convenient utilization of physical human and finantial resources.

Diminution of uncertainty

Even though cassava competes with comparative advantage in relation with some other crops a certain degree of uncertainty still exists related to the general performance of the crop and to the final economic results. Administration of production handless some means which allow a diminishing of uncertainty on the results. In general, the aspects which present higher degree of uncertainty are:

a) Production levels
b) Price behaviour
c) Technological variations
d) Ecological conditions
e) Government regulations
f) Demand for the product
g) Behaviour of production costs

As may be observed there exist many motives for uncertainty which in different degrees affect not only this crop but all of the others too. This means, it is necessary to have a capable, active, and with good vision administration which is able to execute and evaluate results.

Also, there are many ways of reducing uncertainty by means of a good administration. Planning production with certain elasticity, keeping enough cash available, insurance against losses, diversification of income sources, buying or selling under contracts and making proper decisions by analyzing technical alternatives, may help to obtain higher profits in an continuous way, with less uncertainty.

Analysis of the results

The main goal of an efficient administration is to optimize the use of physical, human and finantial resources since this represent the basis for the management of an agricultural enterprise. To know whether this optimization of resources is being achieved, administration must seek information on important aspects such as:

a) The yields of cassava harvests in order to know the income when it is transformed in cash or goods.
b) The cost and quality of the goods and services used for the production of cassava.
c) The handling of the credit and interest.
d) The government taxes acco~ding to regulations of each country.
e) The finantial structure of the enterprise.
f) Depreciation of fixed costs.
g) The quality of the harvested product and the prices expected for it.

With the above information it would be possible to evaluate the economical result of a cassava field crop; i.e. measure the yields and profits. The administration must keep in mind that not always the maximum profits must be seeked but the highest benefits possible with the available resources and limitations. With this criterion, it is possible, under certain circunstances, that the administration focus its efforts into maximizing profits or minimizing losses.

The analysis of costs and the economical evaluation have such importance that deserve to be treated separately in independent conferences, however, it should be mentioned that the main factors affecting physical and economical results of commercial cassava production are:

a) Size of the field cropped
b) Yield per hectare
c) Labor efficiency
d) The percentage of "enterprise effort" spent in the crop.
e) The amount of hand labor, material and capital used in each unit.
f) An efficient marketing.

Many additional factors exist which condition the physical and economical results of the production. However, some of them belong to specific conditions and their determination and evaluation are under the criterion of the administrator.

Record keeping

Records are the most important working tool of administration because with them a better objectiveness is obtained in analyzing costs, incomes, outputs and the efficiencies.

The manager dedicates a high percentage of his time to this task since it yields information on personnel, equipment, expenditures, inventaries, debts, etc. All these records allow us to measure the development of activities in respect to the expected performance. This means that with appropriate records it is possible to except the function of control.

When deciding what records to keep from an agricultural enterprise in general, we must have in mind what do we wish to know, what do we wish to control or to measure. In other words, all the records kept must be usable.

The records are kept in farms designed according to the needs and circunstances, they must be easy to obtain, concrete, simple and adequate to the conditions of the enterprise. Otherwise, they may result useless for the determination of important features as:

a) Finantial status of the exploitation
b) Information for the elaboration of budgets, taxes, insurances, credits and interest payments.
c) Knowledge on the existences of goods and services.
d) Historical records of the farm.
e) Choosing between alternatives in decision making processes.

Work organization

The efficiency of an enterprise is due greately to the way the work itself is organized and this is precisely the goal with all production factors.

The ordering of the crop production activities in function of time and space, inputs and materials required for each activity, the assigning of tasks to the available resources, are topics, which have to do with organization and performance of the work. This is a fundamental part of the administrator's job.

A first logical step to achieve the organization of the job is the knowledge itself of the labors relevant to the crop. At least the following labors must be accomplished to obtain a good cassava crop.

a) Preparation of the land
b) Planting
c) Replanting
d) Weeding
e) Application of fertilizers
f) Application of insecticides
g) Harvesting
h) Packing.

We must know beforehand which inputs will be necessary. Which and how much seed, fertilizers, insecticides, tools, will be required. Next, it is fundamental to know when the different labors will be done, who will perform each labor and the inputs or resources each one of them will use.

Activity chronograms or Gantt programing, are a great aid because they provide an integral view of the productive process.

Other very usefull methods are the C.P.M. (Critical path method) and PERT (Program evaluation and review techniques), especially when the exploitations are complex due to its size, diversification and projections.

SUMMARY

An efficient administration of production is a determinant factor for the achievement of technical and economical objectives. Even though cassava is considered as having comparative advantages over other agricultural alternatives, it must be kept in mind that by an adequate planning, work organization, evaluation and control of the productive process, the uncertainty of these enterprises may be diminished, and a higher profitability may be expected.

On the other hand, technical development of the cassava crop moves rapidly towards the obtention of high yielding varieties with low input levels. This raises hopes of governments and privates who find cassava as basic food in the animal and human diets. Everything which guarantees the efficiency of production factors at farm level is of great importance in enhancing the productive package.

Administration involves risk and uncertainty, production levels, price behaviors, law regulations, offer and demand, production costs performance and multidisciplinary capacity. This is why, when we speak of agricultural administration, we think of the need for professionals inagriculture which act with economical, social, statistical, and mathematical criteria, applying it to the process of cassava production.

COSTS AND USE OF INPUTS IN CASSAVA PRODUCTION IN COLOMBIA:

A BRIEF DESCRIPTION

Rafael O. Díaz
Per Pinstrup-Andersen
Rubén Darío Estrada

Introduction

Until recently, agricultural scientists and public policy makers paid little attention to cassava. With a growing awareness of the importance of the crop as a stable food in tropical countries and its potential as a livestock feed, the situation is changing. Within five years, two international agricultural research institutes have created multidisciplinary cassava research teams (1) some national research programs are receiving increased support, and new national programs are being created. (2) Private industry and bankers indicate an increasing interest in cassava production, processing and export as profitable investment opportunities and some governments are becoming aware of the crop's potential in promoting agricultural development and contributing to foreign exchange. (3)

Future demands for dried cassava as a livestock feed appear to be strong both within and outside producing countries. (4) This results partly from increased feed grain prices and partly from cassava's efficiency in producing carbohydrates.

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(1) Centro Internacional de Agricultura Tropical (CIAT), Colombia and International Institute for Tropical Agriculture (IIATA), Nigeria.

(2) In addition to public funds from the producing countries, national and international research on cassava is supported by a number of agencies such as the International Development Research Centre (IDRC), Canada, and the Office of Development Assistance (ODA), England.

(3) Schemes to expand cassava production for export and domestic livestock feed are being developed in a number of countries such as Indonesia and Malaysia.

(4) A recent study by Truman Phillips indicates strong future demand for dried cassava in Europe ("Cassava Utilization and Potential Markets". International Development Research Centre, Ottawa, Canada, 1974). Other potentially good markets include Japan. Furthermore, the demand for livestock feed is rapidly increasing in most cassava producing countries.

To realize the demand potential, however, cassava yields must be focused on the problems at the farm level. However, because of lack of emphasis on the crop in the past, relatively little is known about the cassava production process and the relative importance of factors limiting production and productivity.

Therefore, the economists within the CIAT Cassava Program decided to emphasize research to obtain data on the production process. The analysis reported here briefly describes the cropping systems, resource use and costs among Colombian cassava producers. This report should be considered preliminary. A more comprehensive study of the production process and the relative importance of factors limiting production and productivity is in progress.

After a brief discussion of the methodology, the sample is described. Then a presentation of the results follows and the report terminates with a brief summary and a discussion of the implications for future research and public policy.

A set of tables summarizing the data obtained from the survey may be obtained from CIAT.

METHODOLOGY AND SAMPLE DESCRIPTION

Data Collection

On the basis of available secondary data, information was collected from farmers in 18 departments of Colombia (Figure 1). While secondary data on cassava production and area are weak, the selected departments appear to account for approximately 92 percent of the national production and 80 percent of the total area (1969).

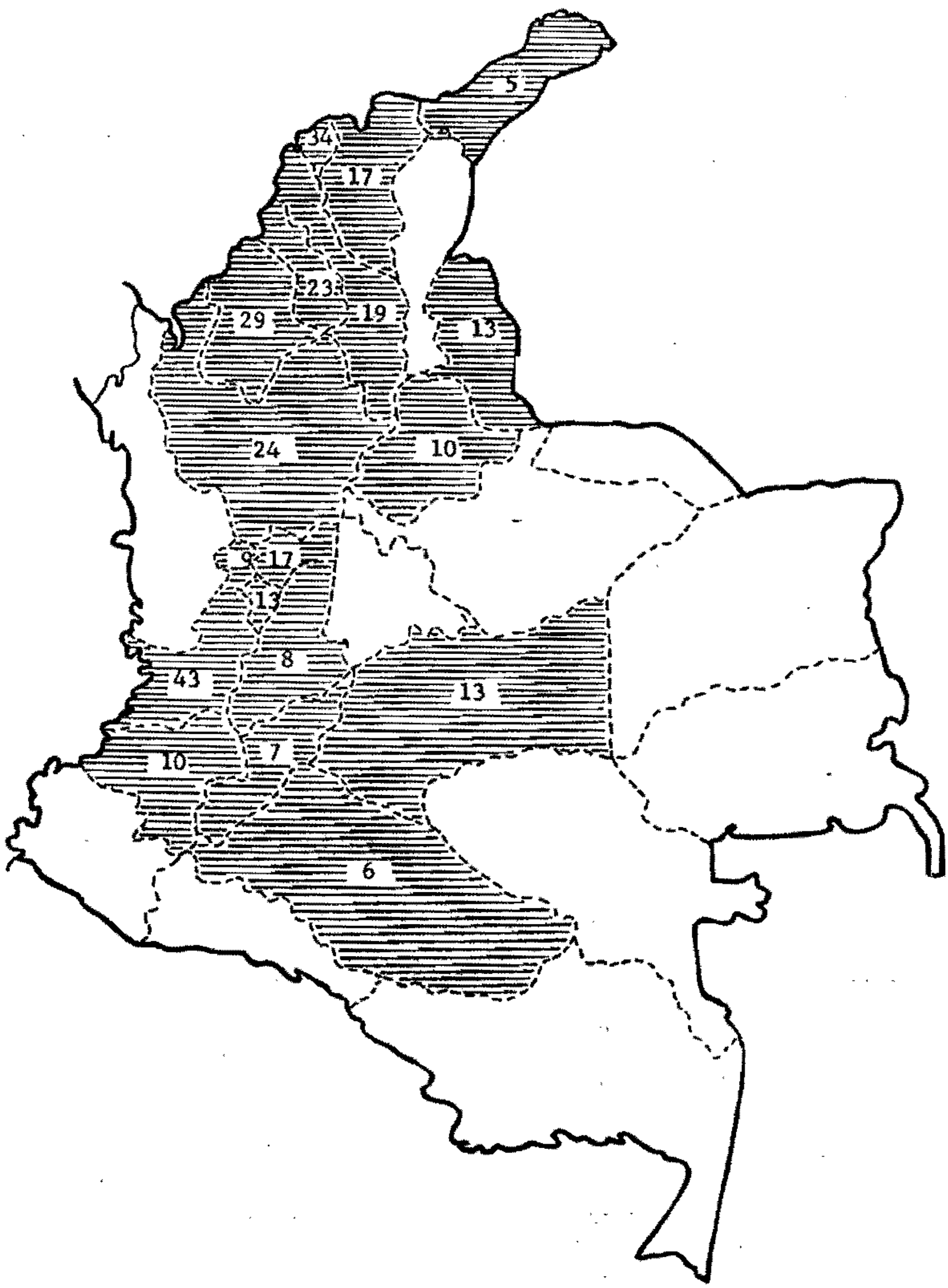
As no information is available to permit identification of all cassava producers, either nationally or in the selected departments, random sampling was not possible. A partial list of cassava producing regions and producers within these regions was developed from information provided by local extension and credit representatives, cassava wholesalers and retailers. A sample of 300 cassava producers was selected from this list. Information was obtained by interviewing each farmer once.

Data Analysis

Because of the preliminary nature of the data, analysis was limited to calculation of simple and weighted averages, totals and percentage distributions.

For data analysis, the sample farms were divided into three groups according to topography, as follows:

Fig. 1 Number of farmers interviewed by region



Zone I: Cassava growers on flat land outside the North Coast Region.
Zone II: Cassava growers on mountainous slops.
Zone III: Cassava growers in the North Coast Region

Within each zone the sample farms were stratified according to size of cassava area as follows:

Strata 1: Less than 2 ha.
Strata 2: 2.0 - 3.99 ha.
Strata 3: 4.0 - 9.99 ha.
Strata 4: 10.0 ha. and more.

Finally for certain parts of the analysis, the sample farms were divided into two groups, i.e. whether land was prepared manually or mechanically.

Sample description

Forty-two percent of the sample farms were located in the North Coast Region, 30 percent in mountainous areas and 28 percent on flat land. About 40 percent of the sample farms had less than two hectares of cassava and 15 percent had 10 hectares or more. For obvious reasons, almost all the farmers growing cassava on mountainous slopes prepared land manually. It is less obvious why only one-third of the farmers on flat lands and less than half of the farmers in the North Coast Region used machinery for land preparation. Mechanical land preparation is most common on large farms.

Average size of the sample farms was 5 hectares. The average farm size in Zone I was 9 ha and about 3.5 ha in Zones II and III.

About 20 percent of the farmers interviewed owned the land on which they produced cassava. Almost two-thirds were sharecroppers, while the rest paid cash rent.

PRODUCTION PRACTICES

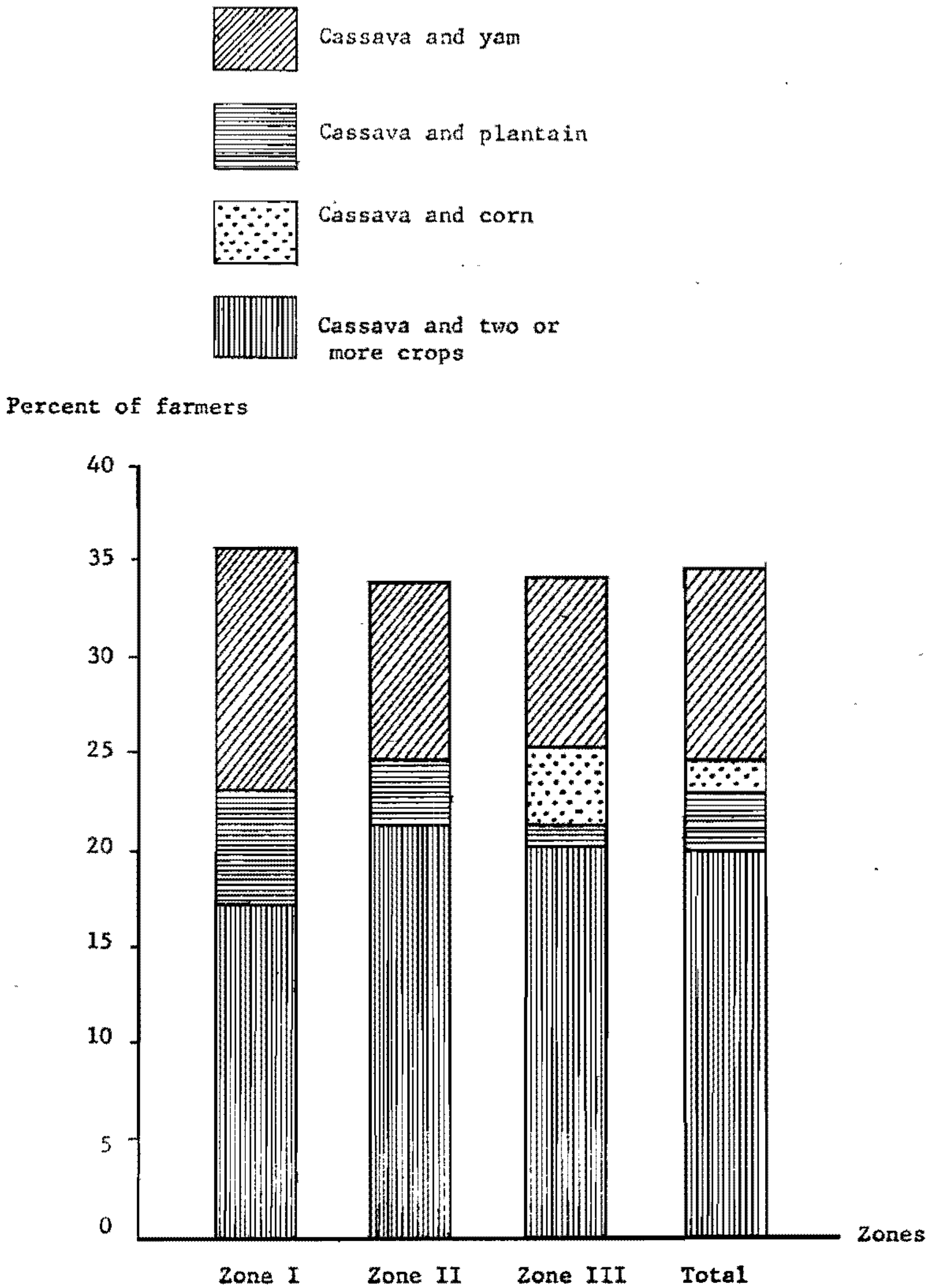
Cropping systems

About one-third of the farmers interviewed in each of the zones grew cassava mixed with other crops. Maize was most frequently found intercropped with cassava, followed by plantain, coffee, yams and beans (Figure 2).

Land preparation and planting

Manual land preparation is usually rudimentary and limited to land clearing and weeding. About 5 percent of the farmers in Zone I planted on ridges while this practice was almost non-existent in the other zones. About one-third of the farmers planted stakes horizontally, a practice most common outside the North Coast Region.

Figure 2. Mixed Cropping Systems



The average plant population was 8,800 plants/ha but the number varied greatly among the sample farms (Table 1).

The most commonly used planting distance was 1 x 1 meter, followed by 1.2 x 1.2 meters. Most farmers interviewed plant one stake per site (83%) while 17 percent plant two stakes together. The latter practice is most frequent in Zone 1 (35% of the farmers), less important in Zone II (25%) while none of the farmers interviewed in Zone III planted two stakes together. About 27 percent of the farmers in each zone re-planted. No farmer treated stakes against pathogens.

About one-third of the farmers grew two or more crops of cassava consecutively in the same field. The others either practiced crop rotation or planted cassava on virgin land.

Five percent of the farmers grew the variety Llanera. On the rest of the farms, the varieties grown were identified by 56 local names.

Weeding

No mechanical or chemical weed control was performed on the sample farms. About half of the farmers weeded three times during the growing season while 26 percent weeded four times (Fig. 3). The average number of weedings was 3.2.

Harvesting and length of growing season

All harvesting was manual. The length of the growing season depends on ecological conditions, variety, availabilty of labor for harvesting, cassava prices, and other factors. The majority of the farmers in Zones I and II harvested cassava at an age of 12-14 months while 13 percent harvested at 10-12 months and another 13 percent at 14-16 months. In the North Coast Region, one-third of the producers harvested at 6-8 months while the rest harvested between 8 and 14 months (Figure 4). The average crop age at harvest was 12.7, 12.5 and 9.1 months for zones I, II and II, respectively.

INPUT USE

Labor

The level of mechanization in cassava production in Colombia is low and limited to land preparation on a small proportion of the cassava-producing farms. Furthermore, as will be indicated later in this report, the use of labor-caving chemical technology, such as herbicides, is almost non-existent. Hence, cassava production requires a considerable amount of labor. Tables 2 and 3 show the labor used in each production activity by zone, farm size and method of land preparation. The total labor use was estimated at 88 man-days/ha under mechanized land preparation and 110 man-days/ha if

Table 1. Average plant population and range of distribution (plant/ha)

	Range of distribution (plants/ha)								Average
	2,000 to 6,000		6,000 to 10,000		10,000 to 14,000		14,000 to 16,000		(plant/ha)
	No.	%	No.	%	No.	%	No.	%	
ZONE I	7	8.4	13	15.7	57	68.7	6	7.2	9,999
ZONE II	9	10.0	23	25.5	51	56.7	7	7.8	9,500
ZONE III	28	22.0	51	40.2	47	37.0	1	0.8	7,579
TOTAL	44	14.7	87	29.0	155	51.6	14	4.7	8,800

Figure 3. Number of weedings

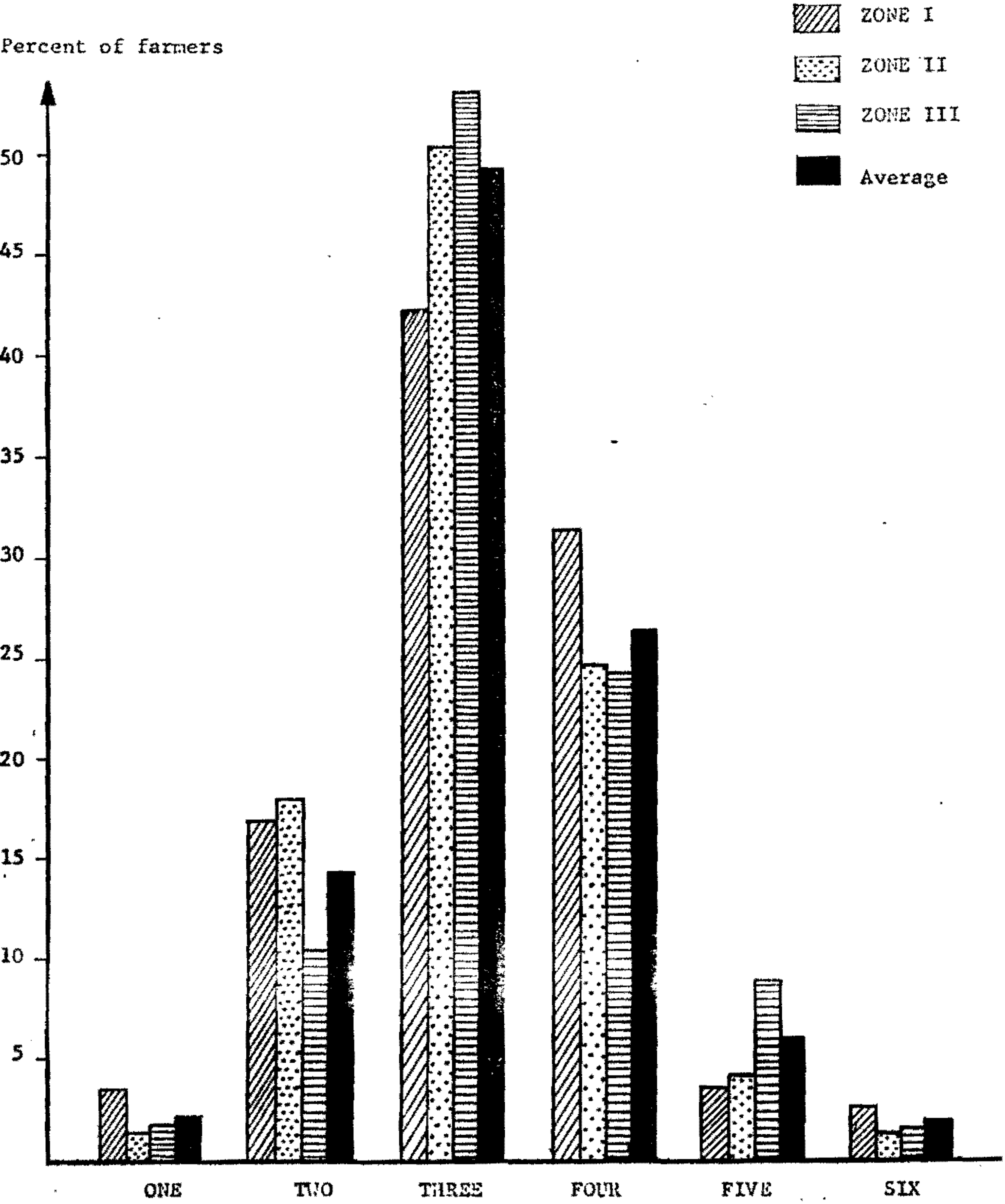


Figure 4. Length of growing season in months

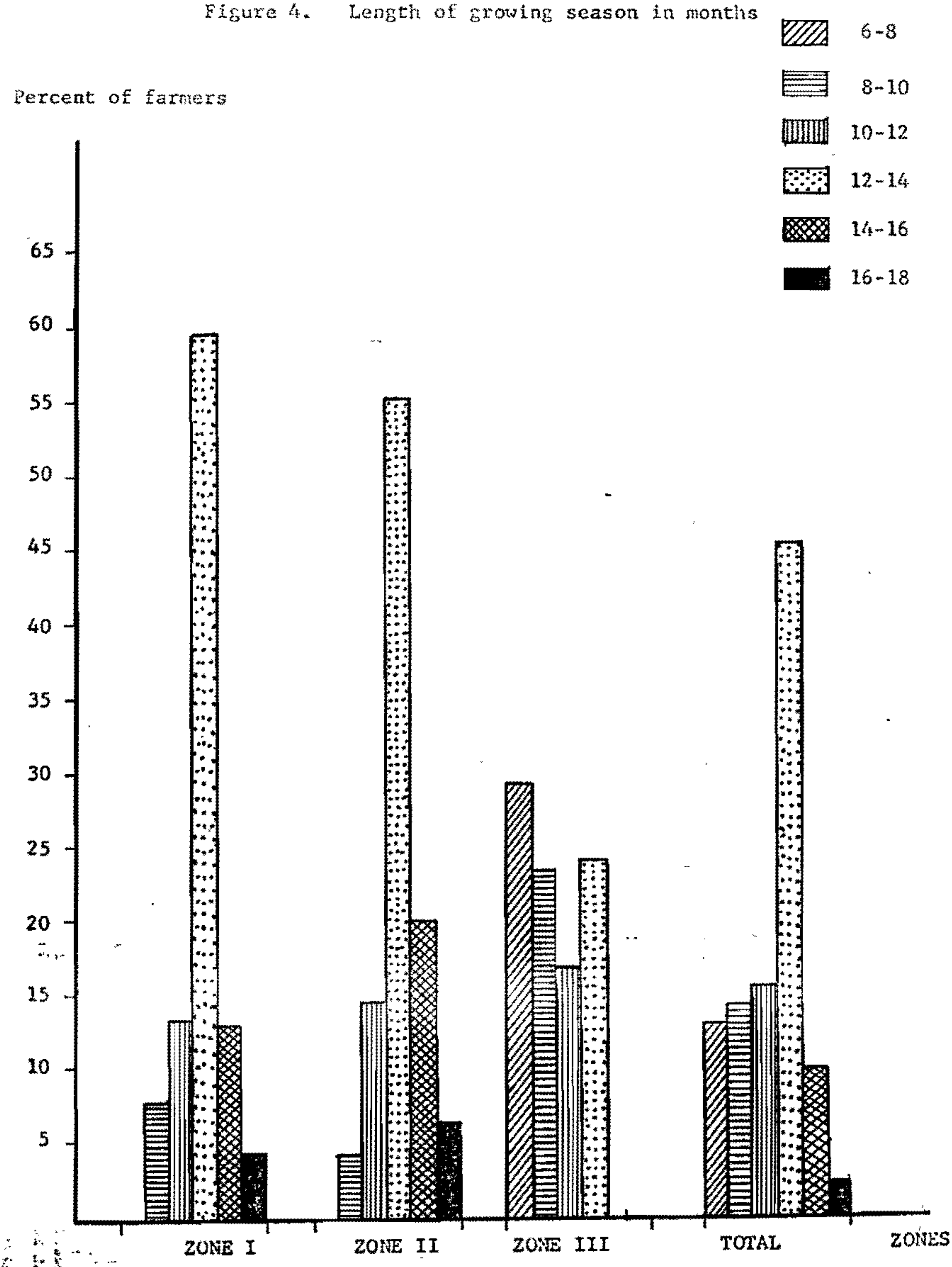


TABLE 2

Estimated labor use in the production of cassava per hectare with mechanical land preparation.

ZONE I	0 - 2 has		2 - 4 has		4 - 10 has		10 or more has		Weighted average	
	Man days per ha	%	Man days per ha	%	Man days per ha	%	Man days per ha	%	Man days per ha	%
ACTIVITY										
Planting	4.0	5	12.6	13	8.5	9	7.7	6	8.6	8
Re-planting	0.5	1	0.7	1	0.4	1	0.4	1	0.5	1
Weeding	37.3	43	57.8	58	48.5	52	59.1	47	53.7	50
Apl. fertilizers	0.4	1	0.6	1	1.3	1	1.2	1	1.0	1
Apl. insecticides	0.3	1	0.3	1	0.5	1	0.4	1	0.4	1
Harvesting	32.7	38	20	20	23.2	24	47	38	33	31
Packing	9.5	11	6.6	6	11.1	12	8	6	8.7	8
TOTAL ZONE	84.7	100	98.60	100	93.50	100	123.8	100	105.9	100
ZONE II										
Planting	-	-	17.5	18	15.3	17	-	-	16.8	18
Re-planting	-	-	0.3	1	0	0	-	-	0.2	1
Weeding	-	-	43.6	45	49.3	55	-	-	45.5	48
Apl. fertilizers	-	-	0	0	0	0	-	-	0	0
Apl. insecticides	-	-	0.2	1	0.3	1	-	-	0.2	1
Harvesting	-	-	19.9	21	18.2	20	-	-	19.3	20
Packing	-	-	13.9	14	5.8	7	-	-	11.2	12
TOTAL ZONE	-	-	95.4	100	88.90	100	-	-	93.2	100
ZONE III										
Planting	7.7	12	9.3	13	-	-	6.8	8	8.0	12
Re-planting	0.3	1	0.3	1	-	-	0	0	0.3	1
Weeding	41.0	66	40.1	56	-	-	53.3	60	42.3	61
Apl. fertilizer	0	0	0.2	1	-	-	1.0	1	0.2	1
Apl. insecticides	0.3	1	0	0	-	-	0	0	0.2	1
Harvesting and packing	12.6	20	20.6	29	-	-	26.8	31	16.2	24
TOTAL ZONE	61.9	100	70.5	100	-	-	87.9	100	67.2	100
AVERAGE ALL ZONES										
Planting	5.9	8	13.1	15	11.9	13	7.3	6	9.1	10
Re-planting	0.4	1	0.4	1	0.2	1	0.2	1	0.3	1
Weeding	39.2	52	47.2	51	48.9	53	56.2	53	46.8	53
Apl. fertilizers	0.2	1	0.3	1	0.7	1	1.1	1	0.5	1
Apl. insecticides	0.3	1	0.2	1	0.4	1	0.2	1	0.3	1
Harvesting and packing	27.4	37	27.0	30	29.2	32	40.9	38	30.7	34
TOTAL ZONES	73.4	100	88.2	100	91.3	100	105.9	100	87.7	100

TABLE 3

Estimated labor use in the production of cassava per hectare with manual land preparation. Average by farm size.

	0 - 2 has		2 - 4 has		4 - 10 has		10 or more has		Weighted average	
ZONE I ACTIVITY	Man days per ha	%	Man days per ha	%	Man days per ha	%	Man days per ha	%	Man days per ha	%
Land preparation	20.0	19	20.8	22	18.2	16	20.8	19	20.0	19
Planting	7.9	7	10.5	11	9.2	8	12.3	11	10.3	9
Re-planting	1.2	1	0.8	1	0.6	1	0.2	1	0.7	1
Weeding	31.7	30	39.2	41	46.3	41	50.7	47	43.3	41
Apl. fertilizers	0	0	0	0	0	0	0.3	1	0.1	1
Apl. insectecides	0	0	1.2	1	0	0	0.1	1	0.4	1
Harvesting	40.6	39	14.5	15	22.8	20	16.5	15	21.5	20
Packing	4	4	8.8	9	16	14	6	5	9.0	8
TOTAL ZONE	105.40	100	95.8	100	113.1	100	106.9	100	105.3	100
ZONE II										
Land preparation	37.5	31	30.7	27	36.6	32	48.8	33	35.1	29
Planting	14.2	11	13.7	12	13.2	11	9.5	6	13.3	11
Re-planting	0.4	1	0.6	1	0.4	1	0.5	1	0.5	1
Weeding	40.4	34	37.8	33	46.7	41	68.0	46	42.8	36
Apl. fertilizers	1.2	1	0.4	1	0	0	0	0	0.5	1
Apl. insecticides	3.0	2	0.8	1	0.2	1	0.3	1	1.2	1
Harvesting	20.3	16	23.0	20	12.5	11	15.6	10	20	17
Packing	4.9	4	5.7	5	3.7	3	4.6	3	5.1	4
TOTAL ZONE	121.9	100	112.7	100	113.3	100	147.3	100	118.5	100
ZONE III										
Land preparation	22.3	24	17.5	19	0	0	-	-	19.6	21
Planting	9.3	10	8.5	9	10.7	10	-	-	9.2	9
Re-planting	0.5	1	1.1	1	0.3	1	-	-	0.6	1
Weeding	43.0	46	51.0	55	47.0	45	-	-	45.2	48
Apl. fertilizers	0	0	0	0	0	0	-	-	0	0
Apl. insecticides	0	0	0.5	1	0	0	-	-	0.1	1
Harvesting and packing	17.9	19	14.5	15	45.9	44	-	-	19.1	20
TOTAL ZONE	93.0	100	93.1	100	103.90	100	-	-	93.8	100
TOTAL ZONES										
Land preparation	26.6	25	23.0	20	18.3	16	34.8	27	25.0	24
Planting	10.5	9	10.9	10	11.0	10	10.9	8	10.8	10
Re-planting	0.7	1	0.8	1	0.4	1	0.4	1	0.6	1
Weeding	38.4	35	42.7	38	46.7	42	59.4	45	43.7	41
Apl. fertilizers	0.4	1	0.1	1	0	0	0.2	1	0.3	0
Apl. insecticides	1.0	1	0.8	1	0.1	1	0.2	1	0.6	1
Harvesting and packing	29.2	27	22.1	29	33.6	30	21.3	17	24.9	23
TOTAL ZONES	106.8	100	100.4	100	110.1	100	127.2	100	105.9	100

land was prepared manually. Weeding, accounting for about 40 percent of total labor requirements, is the most labor-consuming activity (Figure 5). Next follows harvesting and packing with a little less than 30 percent of the labor needs, land preparation (22) and planting (10).

Labor use per hectare increases with increasing size of cassava area. This primarily results from increased labor use in weeding as cassava area increases.

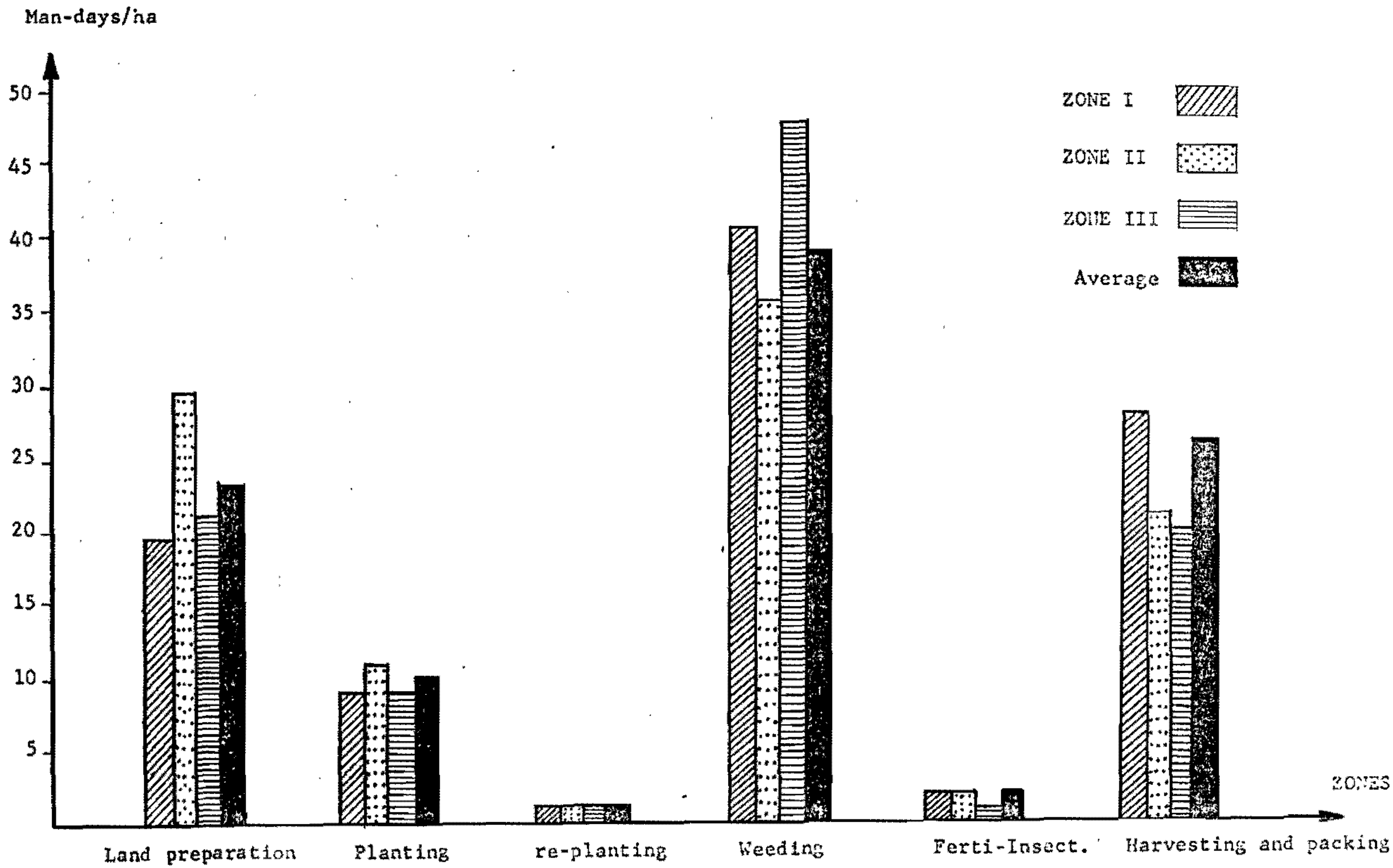
The largest labor requirements per hectare were found where cassava was produced on mountainous slopes (Zone II) and land was prepared manually (119 man-day/ha). The lowest labor requirements were noted in the North Coast Region where land was prepared mechanically (67 man-days/ha). The primary reason for this relatively large difference in labor requirements are expected to be: (1) Difference in method of land preparation, (2) a shorter growing season in the North Coast Region, (3) the more difficult working conditions on the slopes, and (4) the more favorable soil conditions in the North Coast Region. Labor requirements in the North Coast Region are lower than those on flat lands outside the region, regardless of land preparation method, primarily because of differences in harvesting costs.

A considerable variation of labor requirements was found among activities within each zone. About 38 percent of the farmers used from 10 to 20 man-days/ha for land preparation. Six percent used less, 30 percent used 20 - 30 man-days/ha and about 25 percent used more. All the farmers interviewed in the North Coast Region used 10 - 30 man-days/ha. About half of the farmers used 5-10 man-days/ha for planting, 16 percent used less and 34 percent used more. Only seven percent of the farmers used less than 20 man-days/ha for weeding, 39 percent used 20-40 man-days and a little more than half of the farmers used more than 40 man-days/ha. Most of the farmers in Zones I and II use 20-40 man-days/ha for harvesting and packing, while the majority of the farmers in Zone III use less than 20 man-days/ha.

About 8 man-days were used to produce a ton of cassava, if land were prepared mechanically, and 10 man-days, if prepared manually. Labor requirements per ton of cassava vary considerably among farm sizes (Table 4). This variation results partly from variation in labor use per hectare and partly from variations in yields. While the former was explained previously, this analysis does not provide sufficient information to explain yield variations (see section on yields).

Additional analysis of current labor use in cassava production in Colombia and expected impact of the introduction of mechanical, biological and chemical technology on labor requirements are presented in: "Present and Potential Labour Use in Cassava Production in Colombia" by Per Pinstrup-Andersen and Rafael O. Díaz.

Figure 5. Labor use by activity (farmers preparing land manually)



(Paper presented at the Third International Symposium on Tropical Root Crops, Ibadan, Nigeria, December 2 - 9, 1973. Copies available from CIAT).

Seed

About 70 percent of the farmers obtained stakes from their previous crop, 16 percent purchased stakes and 15 percent obtained them free from neighbors and friends. Virtually all the farmers in the North Coast Region obtained stakes from their own crop. It may be expected that the level of adoption of stakes from improved varieties will be higher among farmers who normally purchase stakes. If this expectation holds true, we may expect a greater ease of adoption outside the North Coast Region than within.

Fertilizers

Fifteen of the 300 farmers interviewed (5%) used fertilizers for cassava. Fertilizer use was most frequent among farmers on flat land outside the North Coast Region (Figure 6). Where fertilizer was used, the quantities per hectare were small.

Insecticides

Twenty-seven percent of the farmers used insecticides for cassava. This practice appears to be most common in the North Coast Region and least common on flat lands outside that region (Figure 6).

Herbicides

None of the farmers interviewed used herbicide for cassava.

PRODUCTION COSTS

Estimated variable costs of production are shown in Tables 5, 6, 7, 8 and 9. A daily wage of Col $20 was assumed for all zones. Hence, labor costs were estimated by multiplying labor use by 20. Input costs were obtained from the survey. Labor costs account for about 60 percent of total variable costs on farms, where machinery was used for land preparation and 90-95 percent when the land was prepared manually.

Investments in fertilizer and insecticides increase with increasing farm size. This reflects the somewhat higher level of technology on large farms and may explain in part the higher yields on larger farms and discussed later. Total variable costs are higher on farms where land was prepared with machinery than on farm with manual land preparation. This is related partly to higher costs of mechanized land preparation and partly to higher levels of input use. Variable costs in the North Coast Region are considerably below those for the other regions. Average variable costs for all the sample farms were estimated to be Col. $2,400.oo/ha.

Table 4. Labor use in the production of cassava (man-days/ton) Average by farm size.

Mechanical land preparation	0 - 2 has	2 - 4 has	4 - 1- has	10 or more	Weighted average
ZONE I	5.1	9.2	5.6	7.1	6.8
ZONE II	-	12.8	7.4	-	10.4
ZONE III	7.1	10.9	-	6.3	7.6
TOTAL MECH. LAND PREPARATION	5.8	10.7	6.4	6.7	7.9
Manual land preparation					
ZONE I	5.6	11.4	9.9	11.6	9.4
ZONE II	16.6	6.0	17.5	18.2	9.1
ZONE III	11.1	11.8	8.9	-	10.9
TOTAL MANUAL LAND PREPARATION	9.3	8.6	11.2	14.7	9.7

(-) Data not available

Figure 6. Fertilizer and insecticide use

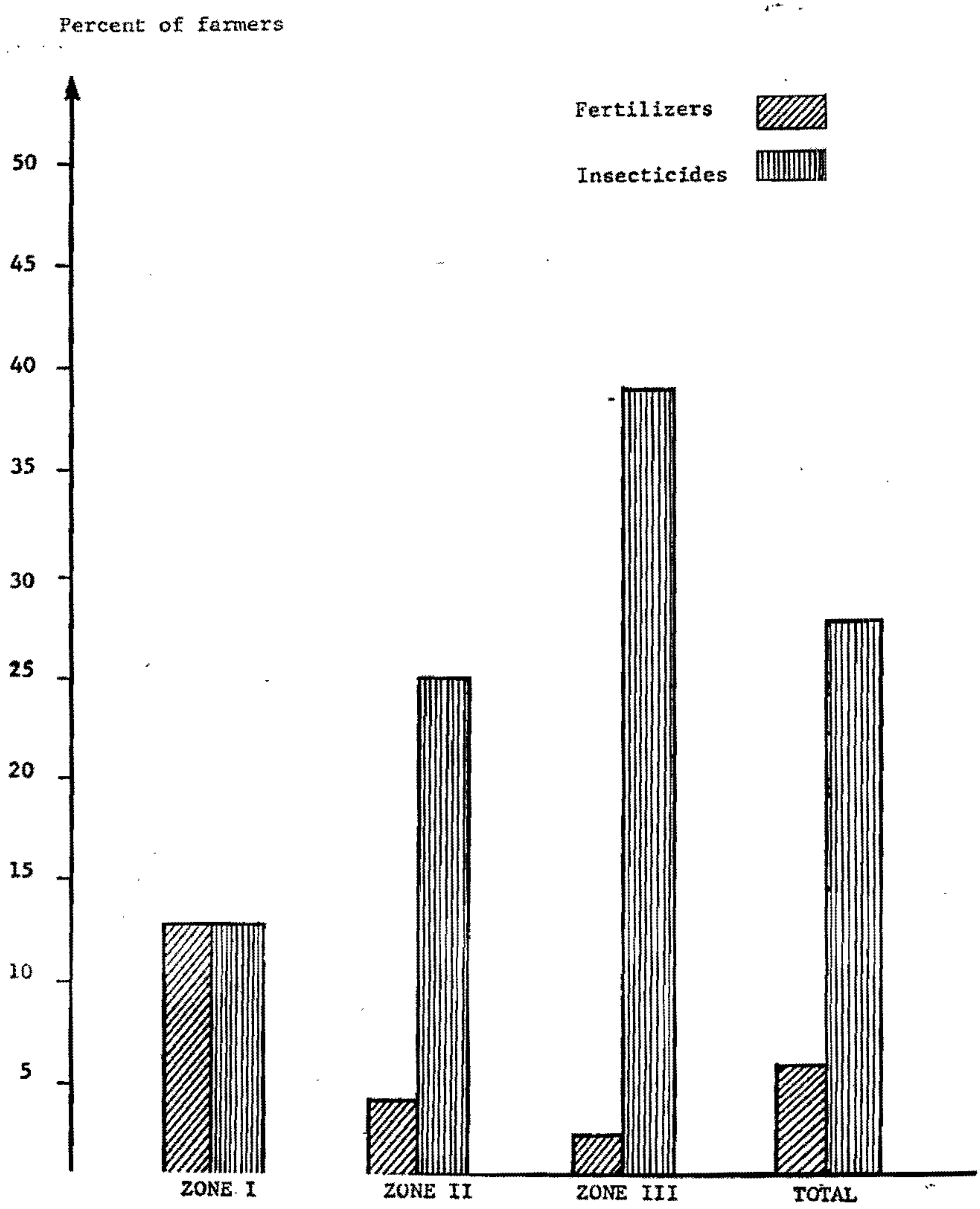


TABLE 5

Estimated variable production costs per hectare of cassava for Zone I

Mechanical land preparation	0 - 2 has		2 - 4 has		4 - 10 has		10 or more has		Weighted Average	
	$/ha	%	$/ha	%	$/ha	%	$/ha	%	$/ha	%
Land preparation	650.00	23	897.11	29	950.00	30	853.68	23	869.72	26
Planting	80.00	3	252.00	8	170.00	5	154.00	4	172.00	5
Re-planting	10.00	1	14.00	1	8.00	1	8.00	1	10.00	1
Weeding	746.00	26	1156.00	37	970.00	31	1182.00	33	1074.00	33
Apl. fertilizers	8.00	1	12.00	1	26.00	1	24.00	1	20.00	1
Apl. insecticides	6.00	1	6.00	1	10.00	1	8.00	1	8.00	1
Harvesting	654.00	23	400.00	13	464.00	15	940.00	26	660.00	20
Packing	190.00	7	132.00	4	222.00	7	160.00	4	174.00	5
TOTAL	2344.00	85	2869.77	94	2820.00	91	3329.00	93	2987.72	92
INPUTS										
Seed	366.25	13	100.89	3	106.32	3	172.00	5	157.38	5
Fertilizers	30.00	1	88.69	2	169.27	5	44.69	1	87.38	2
Insecticides	9.00	1	9.89	1	27.27	1	37.50	1	25.62	1
TOTAL INPUTS	405.25	15	199.47	6	302.86	9	254.19	7	270.38	8
TOTAL VARIABLE COST	2749.25	100	3069.24	100	3122.86	100	3583.87	100	3258.10	100
Manual land peparation										
Land preparation	400.00	18	416.00	19	364.00	15	416.00	17	400.00	17
planting	158.00	7	210.00	10	184.00	8	246.00	10	206.00	9
Re-planting	24.00	1	16.00	1	12.00	1	4.00	1	14.00	1
Weeding	634.00	28	784.00	37	926.00	38	1014.00	43	866.00	37
Apl. fertilizers	0	0	0	0	0	0	6.00	1	2.00	1
Apl. insecticides	0	0	24.00	1	0	0	2.00	1	8.00	1
Harvesting	812.00	36	290.00	14	456.00	19	330.00	14	430.00	18
Packing	80.00	3	176.00	8	320.00	13	120.00	5	180.00	7
TOTAL	2108.00	93	1916.00	90	2262.00	94	2138.00	92	2106.00	91
INPUTS										
Seed	168.00	7	183.17	8	153.55	6	153.92	6	164.28	7
Fertilizer	0	0	0	0	0	0	42.77	1	12.93	1
Insecticides	0	0	33.50	2	0	0	1.23	1	9.72	1
TOTAL INPUTS	168.00	7	216.67	10	153.55	6	197.92	8	186.93	9
TOTAL VARIABLE COST	2276.00	100	2132.67	100	2415.55	100	2335.92	100	2292.93	100

(-) Data not available
(*) Estimated man-day value $20.00

TABLE 6

Estimated variable production cost per hectare of cassava for Zone II

Mechanical land preparation	0 - 2 has		2 - 4 has		4 - 10 has		10 or more has		Weighted average	
	$/ha	%	$/ha	%	$/ha	%	$/ha	%	$/ha	%
Land preparation	-	-	955.33	31	803.33	30	-	-	904.66	31
Planting	-	-	350.00	11	306.00	11	-	-	336.00	11
Re-planting	-	-	6.00	1	0	0	-	-	4.00	1
Weeding	-	-	872.00	28	986.00	37	-	-	910.00	31
Apl. fertilizers	-	-	0	0	0	0	-	-	0	0
Apl. insecticides	-	-	4.00	1	6.00	1	-	-	4.00	1
Harvesting	-	-	398.00	13	364.00	14	-	-	386.00	13
Packing	-	-	278.00	9	116.00	4	-	-	224.00	7
TOTAL	-	-	2863.33	94	2581.33	97	-	-	2768.66	95
INPUTS										
Seed	-	-	146.00	5	67.06	2	-	-	119.69	4
Fertilizers	-	-	0.00	0	0	0	-	-	0	0
Insecticides	-	-	5.00	1	10.00	1	-	-	6.66	1
TOTAL INPUTS	-	-	151.00	6	77.06	3	-	-	126.35	5
TOTAL VARIABLE COST	-	-	3014.33	100	2658.39	100	-	-	2895.01	100
Manual land preparation										
Land preparation	750.00	29	614.00	26	732.00	29	976.00	32	702.00	28
Planting	284.00	11	274.00	11	264.00	10	190.00	6	266.00	10
Re-planting	8.00	1	12.00	1	8.00	1	10.00	1	10.00	1
Weeding	808.00	31	756.00	32	934.00	38	1360.00	45	856.00	34
Apl. fertilizers	24.00	1	8.00	1	0	0	0	0	10.00	1
Apl. insecticides	60.00	2	16.00	1	4.00	1	6.00	1	24.00	1
Harvesting	406.00	15	460.00	19	250.00	10	312.00	10	400.00	16
Packing	98.00	4	114.00	4	74.00	3	92.00	3	102.00	4
TOTAL	2438.00	94	2254.00	95	2266.00	92	2946.00	98	2370.00	95
INPUTS										
Seed	94.89	4	83.31	3	183.35	7	53.42	1	99.28	3
Fertilizers	19.50	1	4.40	1	0	0	0	0	6.98	1
Insecticides	25.15	1	7.85	1	1.54	1	11.88	1	11.51	1
TOTAL INPUTS	139.54	6	95.56	5	184.89	8	65.30	2	117.77	5
TOTAL VARIABLE COST	2577.54	100	2349.56	100	2450.89	100	3011.30	100	2487.77	100

TABLE 7

Estimated variable production cost per hectare for cassava for Zone III

Mechanical land Preparation	0 - 2 has		2 - 4 has		4 - 10 has		10 or more has		Weighted average	
	$/ha	%	$/ha	%	$/ha	%	$/ha	%	$/ha	%
Land preparation	378.52	21	393.50	21	-	-	520.00	20	398.92	20
Planting	154.00	9	186.00	10	-	-	136.00	5	160.00	8
Re-planting	6.00	1	6.00	1	-	-	0	0	6.00	1
Weeding	820.00	47	802.00	42	-	-	1066.00	41	846.00	44
Apl. fertilizers	0	0	4.00	1	-	-	20.00	1	4.00	1
Apl. insecticides	6.00	1	0	0	-	-	0	0	4.00	1
Harvesting and packing	252.00	14	412.00	21	-	-	536.00	21	324.00	17
TOTAL	1616.52	93	1803.50	96	-	-	2278.00	88	1742.92	92
INPUTS										
Seed	111.79	6	70.59	3	-	-	203.17	8	112.86	6
Fertilizers	0	0	0	0	-	-	83.00	3	9 88	1
Insecticides	7.04	1	3.9	1	-	-	4.00	1	5.93	1
TOTAL INPUTS	118.83	7	74.49	4	-	-	290.17	12	128.67	8
TOTAL VARIABLE COST	1735.35	100	1877.99	100	-	-	2568.17	100	1871.59	100
Manual land preparation										
Land preparation	446.00	23	350.00	18	0	0	-	-	392.00	19
Planting	186.00	9	170.00	8	214.00	8	-	-	184.00	9
Re-planting	10.00	1	22.00	1	6.00	1	-	-	12.00	1
Weeding	860.00	43	1020.00	51	940.00	43	-	-	904.00	45
Apl. fertilizers	0	0	0	0	0	0	-	-	0	0
Apl. insecticides	0	0	10.00	1	0	0	-	-	2	1
Harvesting and packing	358.00	18	290.00	14	918.00	42	-	-	382.00	94
TOTAL	1860.00	94	1862.00	93	2078.00	94	-	-	1876.00	94
INPUTS										
Seed	98.66	5	111.30	6	101.17	5	-	-	101.81	5
Fertilizers	0	0	0	0	0	0	-	-	0	0
Insecticides	13.93	1	14.95	1	21.58	1	-	-	14.71	1
TOTAL INPUTS	112.59	6	126.25	7	122.75	6	-	-	116.52	6
TOTAL VARIABLE COST	1972.59	100	1988.25	100	2200.75	100	-	-	1992.52	100

(-) Data not available

TABLE 8

Estimated variable production cost per hectare of cassava average, all zones

Mechanical land preparation	0 - 2 has		2 - 4 has		4 - 10 has		10 or more has		Weighted average	
	$/ha	%	$/ha	%	$/ha	%	$/ha	%	$/ha	%
Land preparation	514.26	22	748.87	27	876.67	30	686.84	22	674.29	25
Planting	118.00	5	262.00	10	238.00	8	146.00	4	182.00	7
Re-planting	8.00	1	8.00	1	4.00	1	4.00	1	6.00	1
Weeding	784.00	34	944.00	34	978.00	32	1124.00	36	936.00	34
Apl. fertilizers	4.00	1	6.00	1	14.00	1	22.00	1	10.00	1
Apl. insecticides	6.00	1	4.00	1	8.00	1	4.00	1	6.00	1
Harvesting and packing	548.00	24	540.00	20	584.00	20	818.00	26	614.00	23
TOTAL	1982.26	88	2512.87	94	2702.67	93	2804.84	91	2428.29	92
INPUTS										
Seed	239.02	10	105.82	4	86.69	3	187.58	6	167.12	6
Fertilizers	15.00	1	29.56	1	84.64	3	63.84	2	40.99	1
Insecticides	8.02	1	6.26	1	18.63	1	20.75	1	12.10	1
TOTAL INPUTS	262.04	12	141.64	6	189.96	7	272.17	9	220.21	8
TOTAL VARIABLE COST	2244.30	100	2654.51	100	2892.63	100	3077.01	100	2648.50	100
Manual land preparation										
Land preparation	532.00	23	460.00	19	366.00	15	696.00	25	500.00	21
Planting	210.00	9	218.00	9	220.00	9	218.00	8	216.00	9
Re-planting	14.00	1	16.00	1	8.00	1	8.00	1	12.00	1
Weeding	768.00	33	854.00	35	934.00	39	1188.00	43	864.00	35
Apl. fertilizers	8.00	1	2.00	1	0	0	4.00	1	6.00	1
Apl. insecticides	20.00	1	16.00	1	2.00	1	4.00	1	14.00	1
Harvesting and packing	580.00	25	442.00	27	672.00	28	426.00	16	530.17	25
TOTAL	2132.00	93	2008.00	93	2202.00	93	2544.00	95	2142.17	93
INPUTS										
Seed	120.51	5	125.92	5	146.02	6	103.67	3	124.34	5
Fertilizers	6.50	1	1.47	1	0	0	21.39	1	5.33	1
Insecticides	13.03	1	18.77	1	7.71	1	6.56	1	13.59	1
TOTAL INPUTS	140.04	7	146.16	7	153.73	7	131.62	5	143.26	7
TOTAL VARIABLE COST	2272.04	100	2154.16	100	2355.73	100	2675.62	100	2285.43	100

TABLE 9

Estimated variable production cost per hectare of cassava average for all farmers

	0 - 2 has		2 - 4 has		4 - 10 has		10 or more has		Weighted average	
	$/ha	%	$/ha	%	$/ha	%	$/ha	%	$/ha	%
Land preparation	523.13	23	604.44	24	621.34	23	691.42	24	569.96	23
Planting	164.00	7	240.00	9	229.00	9	182.00	6	195.16	8
Re-planting	11.00	1	12.00	1	6.00	1	6.00	1	9.52	1
Weeding	776.00	34	899.00	35	956.00	35	1156.00	39	869.50	36
Apl. fertilizers	6.00	1	4.00	1	7.00	1	13.00	1	6.28	0
Apl. insecticides	13.00	1	10.00	1	5.00	1	4.00	1	9.16	0
Harvesting and packing	564.00	23	491.00	23	628.00	23	622.00	21	557.90	24
TOTAL	2057.13	90	2260.44	94	2452.34	93	2674.42	93	2217.48	92
INPUTS										
Seed	179.77	8	115.87	4	116.36	4	145.63	5	139.04	6
Fertilizers	10.75	1	15.52	1	42.32	2	42.62	1	21.03	1
Insecticides	10.53	1	12.52	1	13.17	1	13.66	1	11.65	1
TOTAL INPUTS	201.05	10	143.91	6	171.85	7	201.91	7	171.72	8
TOTAL VARIABLE COST	2258.18	100	2404.35	100	2624.19	100	2876.33	100	2389.20	100

To estimate total production costs, an average value of land of Col. $15,000/ha and an annual land rent of 12 percent were assumed. Using an average land value rather than the actual value for each farm biases production costs upward in regions with low land values and downwards in regions with high land values. However, it was not possible to obtain reliable land value data for the sample farms. Hence, total costs are estimated as an average of all sample farms. Transportation costs were obtained from survey data and interest charges on operating capital were assumed to be 24 percent per year. Finally, an amount equal to 20 percent of total costs thus far estimated was added to cover costs not previously included such as administration, protection from robbery of the crop, etc.

Under these assumptions, average total costs were estimated as Col. $6,586/ha and Col. $598/ton as follows:

	Pesos/ha	Pesos/ton
Average variable costs	2,390	217
Land rent	1,800	164
Transportation costs	720	65
Interests on working capital	576	52
Other costs	1,100	100
Total cost	6,586	598

At the exchange rate of Col. peso $20 to one U.S. Dollar the cost per ton is thus approximately US$30. This is considerably higher than the price paid to the cassava producer in the major cassava exporting country, Thailand. Hence Colombia does not presently appear to be competitive in the world market. The introduction of yield increasing technology could reduce rapidly per unit costs and bring Colombia into a competitive position in so far as the price of raw material for processed cassava products are concerned.

YIELD

Table 10 shows estimated yields by zone and farm size. Overall average yield was estimated to be 11 tons/ha. Yields were relatively low in the North Coast Regions while they were high on flat lands outside the region (Zone I). Although yields appeared to be higher on large than on small farms, no definite relationship between yield and farm size was established.

Because of the preliminary nature of the data, no attempt was made to explain yield differences among zones and farm sizes. However to get some idea of the relative importance of yield-limiting factors beyond production practices and inpunt utilization, the sample farmers were asked about their principal problems in cassava production, the sample farmers were asked about their principal problems in cassva production. Farmers perceived excess water during the rainy season as the most important problem. Other problems mentioned included robbery from the field, diseases and insects.

Table 10. Estimated yield of cassava (tons/Hectare)

	0 - 2 has	2 - 4 has	4 - 10 has	10 or more has	Weighted average
Mechanical land preparation					
ZONE I	16.47	10.71	16.56	17.44	15.59
ZONE II	-	7.48	11.96	-	8.97
ZONE III	8.75	6.49	-	14.05	8.84
TOTAL MECH. LAND PREPARATION	12.61	9.23	14.26	15.76	11.13
Manual land preparation					
ZONE I	18.82	8.41	11.41	9.22	11.18
ZONE II	7.34	18.85	6.48	8.10	13.00
ZONE III	8.37	7.88	11.70	-	8.58
TOTAL MANUAL LAND PREPARATION	11.51	11.71	9.86	8.63	10.92
TOTAL ALL FARMERS	12.06	9.97	12.06	12.21	11.03

CREDIT AND TECHNICAL ASSISTANCE

About one-third of the sample farmers obtained credit for the production of cassava. Two-thirds of the farmers that obtained credit had less than three hectares of cassava, and the amount of credit usually was less than $3,000/ha. Caja Agraria was the credit source most generally mentioned.

Ten farmers (3 percent) reported receiving technical assistance for cassava production. Six of these farmers were in Zone I.

MARKETING AND PRICES

Slightly more than half of the farmers sold the cassava on the farm while the rest brought it to the market place for sale. Seven farmers sold cassava for processing, the rest was sold for direct human consumption. Only three farmers (all in Zone I) sold their cassava while still in the ground, i.e. the buyer was responsible for harvesting.

Cassava is frequently produced far from consumption centers and roads are often poor or non-existent. Furthermore, cassava is a bulky product. Hence, transportation problems are frequent and costs high. Trucks are used most frequently. Although, many farmers use animals, primarily donkeys, to transport the cassava either to the market or to the road where it is transferred to a truck, bus or jeep.

The average of the prices paid to the sample farmers prior to the period of the survey was Col. $769/ton. A considerable difference was found between prices paid to samll farmers and those paid to larger ones. Farmers with a cassava area of less than 2 hectares received 70 percent of the price paid to farmers with 10 hectares or more (Table 11). It is not clear from the survey data why this price differential exists. One explanation may be economies of size in transportation and other marketing activities. Furthermore, it is likely that small farms tend to be further removed from road and consumption centers than larger ones, hence transportation costs are high and visits of cassava buyers more infrequent. However, additional research is needed to explain satisfactorily the existence of the price differential. The issue seems suffciently important to warrant such research.

FARM RETURNS

Given the preliminary nature of the data, the large variation in costs, prices and yields among farms and the lack of accurate estimates of land values, any estimation of net returns to the farmer is at best superficial. Furthermore, both prices and costs have increased considerably since the survey was completed. However, it appears cassava prices have increased more than production costs. Hence, the net returns estimated here are likely to be less than those prevailing at the time this report was written.

Table 11. Average price of cassava received in each size group (Col. $/ton)

	0 - 2 has	2 - 4 has	4 - 10 has	10 or more	Weighted average
ZONE I	681.87	736.69	1061.56	1117.40	948.82
ZONE II	917.52	800.93	820.45	900.77	868.21
ZONE III	513.31	687.41	907.41	684.70	587.52
TOTAL	656.21	741.68	954.00	955.07	769.36

With the qulifications mentioned above, the average net returns were estimated to be Col. $1,896/ha and Col. $171/ton and estimated as follows:

	Pesos/ha	Pesos/ton
Value of production	8,482	769
Total costs	6,586	598
Net returns	1,396	171

SUMMARY AND CONCLUSIONS

This report describes the cassava production process in Colombia. The description is brief and the information is preliminary. Emphasis is placed on a description of production practices, input use and costs. The results from this study provided guidelines for a more comprehensive analysis of factors limiting cassava production and productivity now in progress.

Data for the analysis reported here were obtained from 300 farms in 17 departments of Colombia.

The cultural practices on most of the sample farms consisted of (1) land preparation, in most cases rudimentary, (2) planting, (3) weeding and (4) harvesting. In addition, re-planting and application of insecticides and fertilizers were carried out on some farms. Cassava was intercropped with maize, plantain, coffee, yams or beans on one-third of the sample farms.

The level of technology in cassava production was low. Mechanized land preparation was found on a small number of farms. No other use of machinery in cassava production was reported. Use of fertilizers and insecticides was limited, and no herbicides were applied. None of the sample farmers applied irrigation. The use of credit and technical assistance for cassava production was limited.

It may be concluded that cassava production in Colombia is based on traditional production methods with land and labor accounting for a large majority of the resources used.

Labor use per hectare varied from 67 man-days in the North Coast Region where land was prepared mechanically to 119 man-days on montainous slopes with manual land preparation. On the average, farmers using mechanical land preparation spent 88 man-days/ha while 110 man-days/ha were used where land was prepared manually. Weeding was the most labor-consuming activity followed by harvesting/packing, land preparation and planting. Labour use per ton of cassava was estimated at about 8 and 10 man-days for mechanical and manual land preparation, respectively.

Average yield of cassava was estimated at 11 ton/ha with considerable variation among farms. No definite relationship was found between yield level and farm size.

Total costs were estimated to be Col. $6,586/ha and Col.$598/ton. Net returns were estimated to be Col. $1,896/ha and Col.$171/ton. Given the preliminary nature of the analysis and the lack of reliable data on certain costs components, estimated total costs and revenues should be considered as approximate magnitudes rather than exact figure. The reliability of the estimates will be tested on the basis of results from a more comprehensive study presently underway.

Prices received by farmers vary considerably. Small farmers seem to receive considerably lower prices than larger ones. On the average, the price received by the farmer with less than two hectares of cassava is about 70 percent of the price received by the farmer with more than four hectares. The relationship between price level and farm size is particularly marked in the North Coast Region where farmers with less than two hectares received about 60 percent of the price received by farmers with 10 hectares or more. With respect to economies of scale in cassava production in Colombia it appear that price differentials are more important than cost and yield differentials. However, additional data are needed to verify this finding.

On the basis of this analysis, additional research is recommended on the following subjects:-

1. Factors explaining yield differences among farms and regions. This research should focus on identifying limiting factors and estimating their relative importance for production and productivity. Such work is now in progress.

2. The role of intercropping. Emphasis should be place on (a) estimating relative net return and risk from alternative cropping systems using present and improved technology, and (b) the farmer's expectation of net benefits from alternative systems.

3. The relationships between farm size and prices received by farmers. The findings of this study should be verified and if they are confirmed, efforts should be made to explain the price differential.

It is not the purpose of this study to suggest priorities in biological research related to cassava. However, results from the study suggest that research be carried out:

1. to estimate the relationship between level of weeds and cassava yields. Work on this subject is in progress.

2. to identify inexpensive means of weed control in cassava.

3. to estimate the impact of alternative degrees of land preparation on cassava yields. Land preparation accounts

for a considerable portion of total production costs on some farms while it is of little importance on others. Controlled experiments are needed to determine the pay-off from improved land preparation.

It is expected that the more comprehensive study now in progress will provide information useful for establishing further priorities in biological research on cassava.

CASSAVA PRODUCTION IN COLOMBIA : A TECHNICAL DESCRIPTION [1]

Rafael Orlando Diaz D. *

Introduction

As in all tropical contries, knowledge about the cassava production processes in Colombia has been limited compared with other crops like corn, rice or sugar cane.

Due to the importance of cassava as a staple food in the diet of the low income portion of the population and to its potential as an energy source for animals and humans, official and private institutions have shown a great interest for this crop.

This situation motivated the International Centre for Tropical Agriculture, CIAT to initiate a study on cassava to serve the needs of the cassava research workers, with the following goals: (1) to describe the cassava production processes, (2) to identify factors associated with low yields, (3) to estimate production costs and other economic indices. Efforts were directed to suplying information usefull in decision making to define research priorities.

Scientists from the CIAT cassava program participated in the analysis of data in the following areas: Pathology, Entomology, Soils, Agronomy, Physiology, Statistics, Weed control and Economics.

General results from this analysis are given in this paper. The complete report is composed of 14 sections written and revised by one or more experts in each area. **

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1 Centro Internacional de Agricultura Tropical, CIAT.

* Cassava Economics.

** See: "Descripción Agroeconómica del proceso de cultivar yuca en Colombia". Edición preliminar CIAT, 1977. Incluye los siguientes temas:

Diaz, R.O. y P. Pinstrup-Andersen. Importancia de la yuca en Colombia. pp.

Franklin D.L., P. Pinstrup-Andersen y R.O. Diaz. Metodología y Descripción de la muestra. pp.

Díaz, R.O., J.C. Toro y U. Varón. Características de la producción y sistemas de siembra. pp.

Díaz, R.O., R. Howeler y U. Varón. Descripción de los suelos utilizados para el cultivo de la yuca. pp.

Díaz, R.O. y J.C. Lozano. Enfermedades presentes en el cultivo de la yuca. pp.

Díaz, R. O., A. C. Belloti y A. Van Shoonhoven. Descripción de los insectos presentes en el cultivo de la yuca en Colombia. pp.

Díaz, R. O., P. Pinstrup-Andersen y J. Doll. Las malezas y las prácticas de control de yuca. pp.

Díaz, R.O., P. Pinstrup-Andersen. Usos de insumos y nivel tecno - lógico. pp.

Pinstrup-Andersen P. y R. O. Díaz. Análisis económico de la producción de yuca. pp.

Pinstrup-Andersen P. y R. O. Díaz. Estimación de pérdidas en el rendimiento de la yuca causadas por factores limitantes. pp.

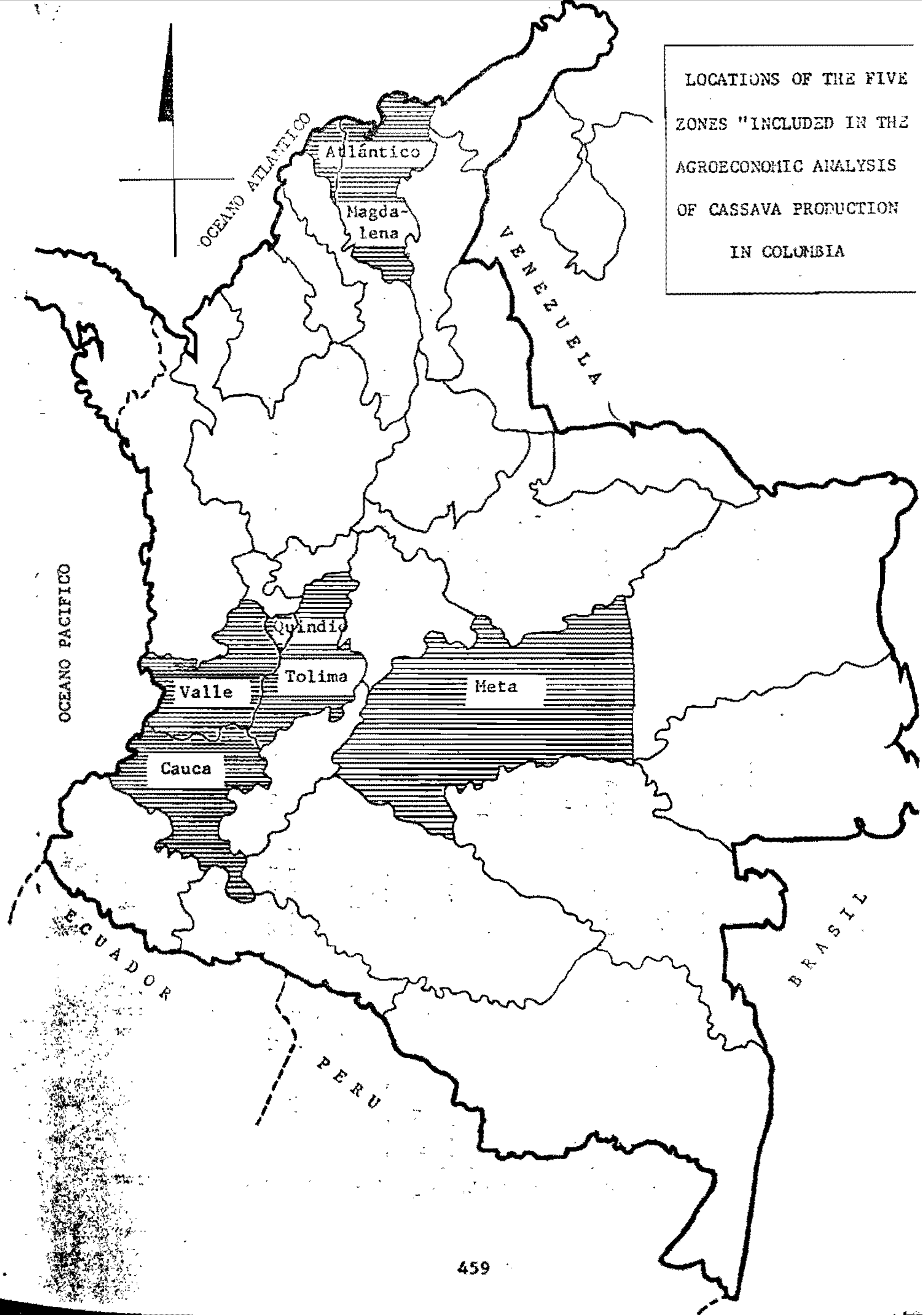
Pinstrup-Andersen P. y R. O. Díaz. Resumen y conclusiones. pp.

SAMPLING DESCRIPTION AND METHODOLOGY

The procedure followed was: (1) gathering of data from a representative and predetermined sample of farmers and (2) analysis of the data. Basic information was collected by agronomists and economists with previous field training. The field team visited periodically each one of the cassava farmers during the entire production cycle. The data describes: (1) all production activities and planting systems, (2) soil types, based on samples taken at each visited site, (3) disease, insects, weeds and water problems based on direct field observations; (4) estimates on inputs utilized and production costs for each of the studied zones.

For the present analysis, a sample of 300 cassava growers were selected. Each farmer was visited three times during the 12 month growing period of the plant. At each visit the age of the crop was a) less than 4 months, b) 4 to 8 months and c) 8 to 12 months.

In order to obtain a representative sample, five regions where cassava grows under different climatic conditions, covering tempered areas as well as tropical zones, were selected (Fig. 1) table 1, shows the number of farmers, states under survey, altitude and average annual



LOCATIONS OF THE FIVE ZONES "INCLUDED IN THE AGROECONOMIC ANALYSIS OF CASSAVA PRODUCTION IN COLOMBIA

TABLE 1. SAMPLE DESCRIPTION BY DEPARTMENT AND THEIR AVERAGE ALTITUDE AND TEMPERATURE FOR THE FIVE ZONES.

Zone	Farms		Dept. under Observation	Altitude Above sea Level (m) Average	Temperature °C Average
	No.	%			
I	61	21.6	Cauca	1230	22
II	64	22.6	Valle and Quindio	1200	22
III	59	20.8	Tolima	815	26
IV	55	19.4	Meta	370	27
V	44	15.6	Atlántico and Magdalena	30	30
TOTAL	283	100.0			

Source: R. O. Díaz and Per Pinstrup-Andersen, " Descripción Agro-económica del Proceso de Producción de Yuca en Colombia", CIAT, Cali, Colombia, 1975, mimeo, p. B-5.

rainfall was over 1000 mm at all zones.

PRODUCTION PRACTICES

Cassava is grown all year round in Colombia, always matching with the begining of the rain seasons which vary according to the region. The system is flexible and generally there are two dry periods during the year.

The length of the period between planting and harvesting varies between zones due principally to the climate. The lower the altitude the higher the temperature and the shorter the growing cycle which ranges from 10 to 14 months.

Approximately 40 percent of the farmers planted cassava intermixed with others crops (Table 2) the main of which was corn, a basic product in the Colombian diet (Figure 2).

Most of the production activities are performed by using man-day labor (Table 3). Approximately one half of the farmers prepared the land by means of machinery, in the montaineous region some use oxen or simply clean up the area with a "machete".

Little variation occurred among small (less than 2 ha.) and large (10 or more ha.) farmers in relation to the number of stakes planted per site and the planting density per hectare. Small farmers plant cassava in the same plot more times, compared with the large farmers (Table 4). Planting distances most frequently used were 1M X 1M.

Weed control is one of the most important activities in the cassava production process because it uses a large proportion of the variable costs. The first weeding is done during the first two months after planting. The second and third cleanings are done between 4 and 6 months respectively, depending on the type of weed and on the rainfall. Three cleanings were the most frequent but there were cases like zone V where 6 weedings were needed, probably due to the low planting density of the cassava plants (Figure 3).

Most of the growers utilized the rains as water supply for the plants. Drainages existed at all zones. The "hilling" a practice which consists of gathering soil around the plant was closely related to weeding.

SOILS

Most of the soils in the visited farms were average in the organic matter content, had less than 15 ppm of the P and less than 0.2 meq/100

TABLE 2. CROPPING SYSTEMS, LOT SIZES AND PLANT POPULATION FOR TOTAL FARMS

Cropping System	Percent of Farms.	Lot Size (ha.)	Percent of Area	Plant Population (Plants/ Ha.)		
				Cassava	2nd Crop	3nd. Crop
Cassava alone	61.7	2.41	68.3	10,260		
Cassava-maize	22.3	1.28	13.4	9,160	5,484	
Cassava bean	3.7	2.56	4.4	9,636	19,991	
Cassava-plantain	4.6	4.83	10.0	8,731	608	
Cassava-Coffee	0.4	1.00	0.2	5,100	3,300	
Cassava-maize-bean	1.8	0.90	0.6	8,660	5,420	7,920
Cassava-plantain-coffee	0.4	1.92	0.3	9,800	600	5,000
Cassava-maize-dioscoreacea	0.7	0.88	0.3	10,550	5,650	7,200
Cassava-maize-plantain	1.1	1.00	0.5	8,400	4,633	667
Cassava-maize-sesame	1.1	0.58	0.3	7,333	4,133	8,030
Cassava-maize-sorghum	0.4	0.50	0.1	6,900	3,300	3,300
Cassava-with other crops	1.8	1.33	1.6	7,800		

Source: R. O. Díaz and Per Pinstrup-Andersen (eds) (1977), op. cit., p. C-2.

FIGURE 2. INTERCROPS PLANTING SYSTEMS

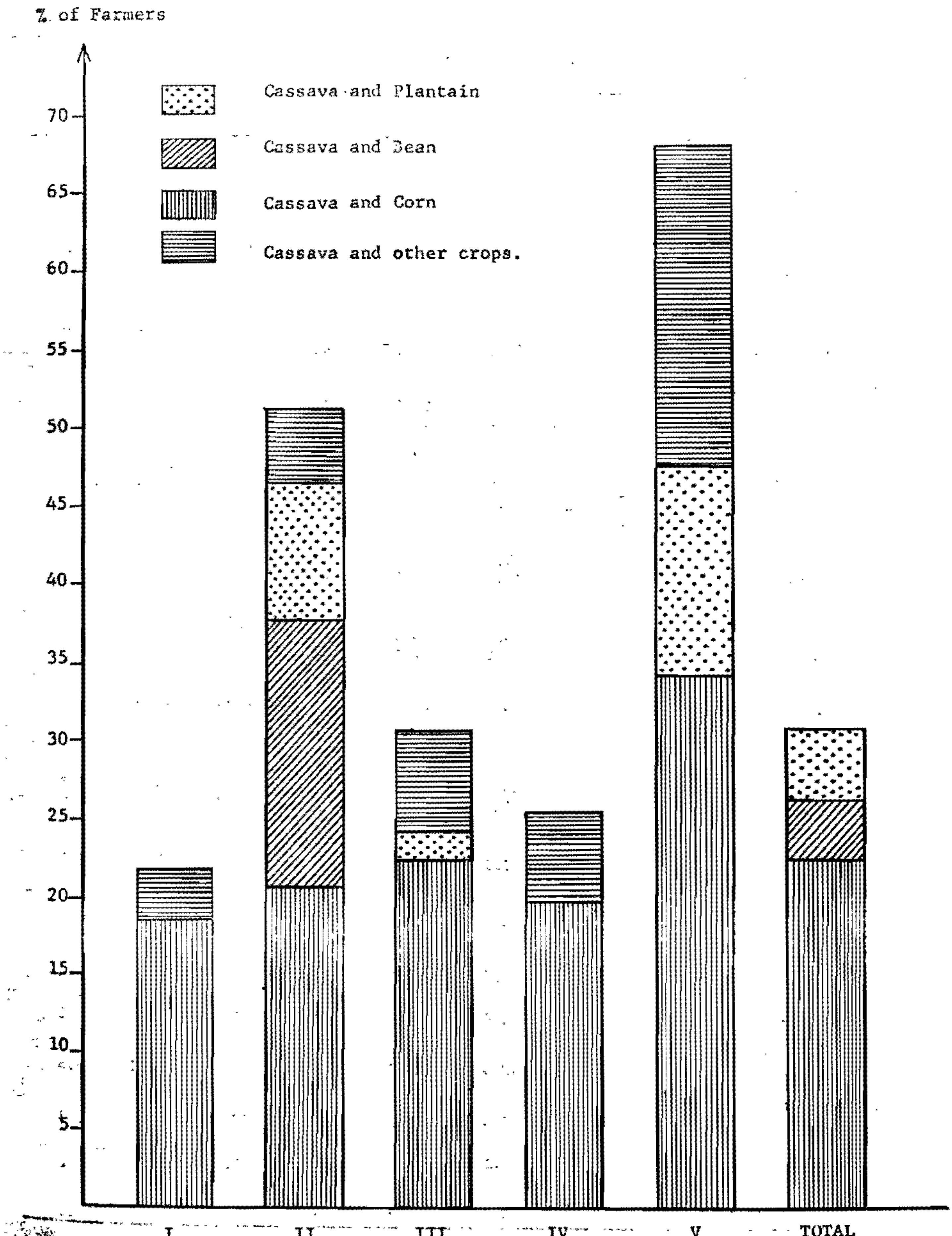


TABLE 3. PRODUCTION PRACTICES FOR TOTAL ZONES.

Source: R. O. Díaz and Per Pinstrup-Andersen (eds) (1977), op.cit. p. C-4

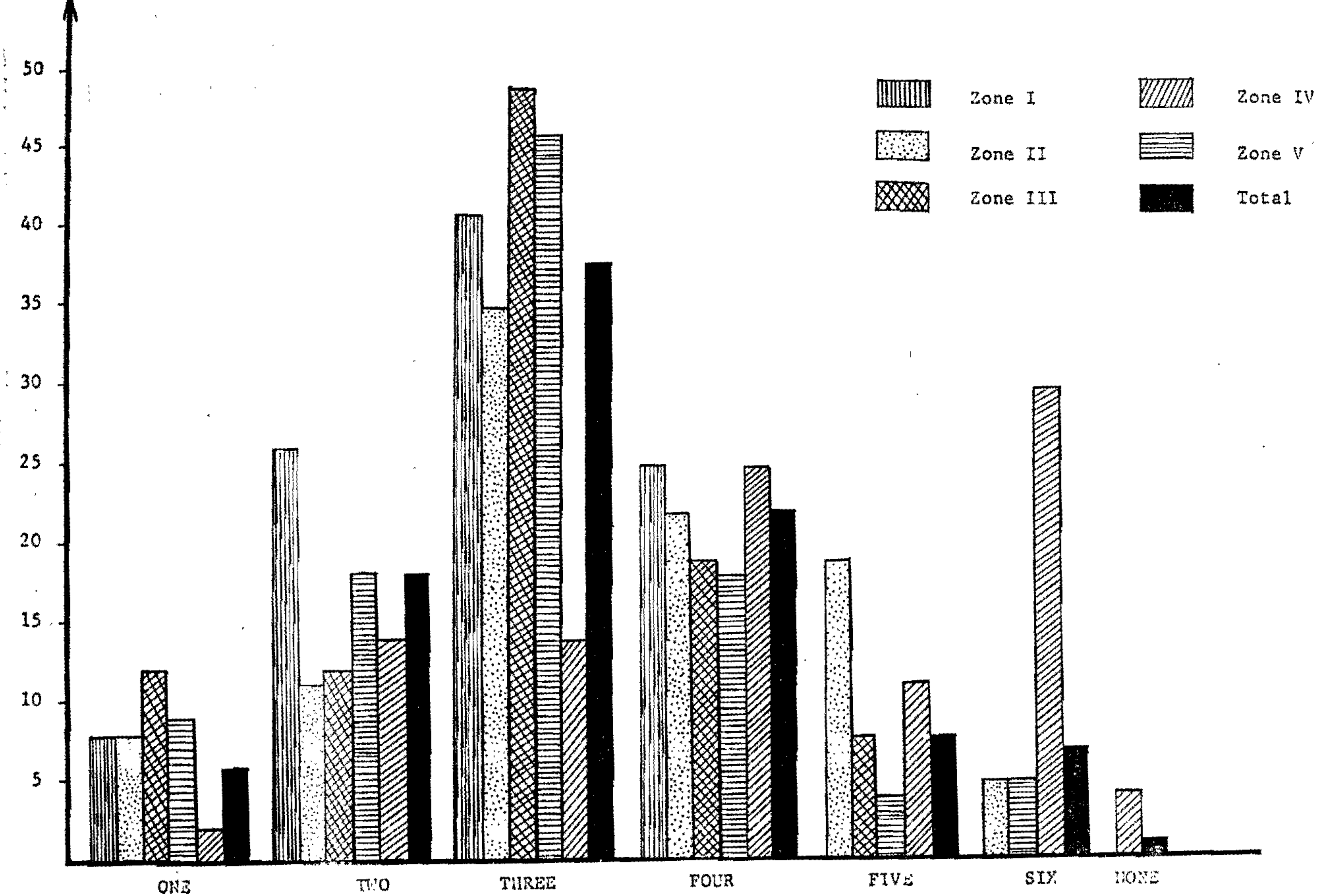
Activity	I	II	III	IV	V	Total
Land Clearing:						
Mechanically	0.0	0.0	0.0	0.0	9.1	1.4
Manually	8.2	0.0	3.4	5.5	15.9	6.0
Land Preparation:						
Mechanically	0.0	76.6	3.4	76.4	54.5	41.3
Manually	98.4	20.3	96.6	23.6	36.4	56.2
Topography:						
Flat land	4.9	71.9	13.6	100.0	95.5	54.4
Mountainous slopes	95.1	28.1	86.4	0.0	4.5	45.6
Plotting:						
Mechanically	0.0	20.3	0.0	7.3	0.0	6.0
Manually	27.9	20.3	42.4	9.1	9.1	22.6
Furrows mountainous slopes:						
Coutour line	88.5	4.7	78.0	0.0	2.3	36.7
Slope following furrow	6.6	23.4	8.5	0.0	2.3	8.8
Planting:						
Mechanically	0.0	0.0	0.0	0.0	0.0	0.0
Manually	100.0	100.0	100.0	100.0	100.0	100.0
Planted on:						
Soil level	98.4	85.9	100.0	98.2	100.0	96.1
Ridges	1.6	14.1	0.0	1.8	0.0	3.9
Stakes from:						
Previous crop	52.5	56.3	64.4	52.7	45.5	54.8
Purchased	37.7	23.4	0.0	12.7	22.7	19.4
Stakes planted:						
Horizontally	86.9	93.8	100.0	96.4	0.0	79.5
Inclined	13.1	6.2	0.0	3.6	100.0	20.5
Re-planting:						
Manually	29.5	42.2	16.9	45.5	56.8	37.1
Irrigation:						
Manually	0.0	0.0	0.0	0.0	27.3	4.2
Drainages:						
Manually	3.3	7.8	1.7	5.5	13.6	6.0
Hilling:						
Manually	1.6	1.6	0.0	1.8	0.0	1.1
Apl. Fertilizers:						
Manually	18.0	35.9	8.5	20.0	9.1	19.8
Apl. Insecticides:						
Manually	98.4	56.3	79.7	85.5	36.4	72.8
Apl. Fungicides:						
Manually	0.0	3.1	0.0	1.8	0.0	1.1
Apl. Herbicides:						
Manually	0.0	10.9	0.0	3.6	0.0	3.2

TABLE 4. PLANTING SYSTEMS FOR TOTAL ZONES. AVERAGE BY FARMS SIZE.

DESCRIPTION	SMALL (0-1.99 Ha.)			MEDIUM (2-9.99 Ha.)			LARGE (10 or more Ha.)			TOTAL		
		Ranks			Ranks			Ranks			Ranks	
	Average	Low	High	Average	Low	High	Average	Low	High	Average	Low	High
Stake per site	1	1	2	1	1	2	1	1	2	1	1	2
Stakes per hectare	10764	3900	28400	11250	3000	22600	10487	3000	24600	10884	3000	28400
Planting in the same field	2	1	6	2	1	6	1	1	6	2	1	6
Planting distances:												
Furrows (cms)	111	70	180	107	70	180	114	80	200	111	70	200
Plants (cms)	102	60	150	98	50	180	101	70	150	100	50	180

Source: R.O. Díaz and Per Pinstrup-Andersen (eds.) (1977), op. cit., p. C-6

FIGURE 3. NUMBER OF WEEDINGS PERFORMED IN CASSAVA FOR THE FIVE ZONES STUDIED



gr of R. The most frequent PH was 5.5 and a little more than one third of the sample had no interchangeable Al. Determination for Sodium saturation showed that only zone V, might presents problems due to excess of this element (Table 5).

Calcium-Magnesium (Ca/Mg) relationship in the soil must be larger than 1 to avoid problems due to Mg excess or Ca deficiency. Apparently, in most of the analyzed soils this relationship was higher than 1 and had an average C.I.C. of 15 meq/100 gr. of soil. Distribution for texture between clayed, loam, silty and sandy, was: 16: 44: 20: 20% for all farmers.

DISEASES

Severity of the observed diseases was greater during the rainy season. At all plantations under 1200 m over sea level, all diseases due to Cercospora spp. were important because of its high incidence and severity. Phoma leaf spot is one of the most important diseases affecting yield in plantations above 1200 m over sea level.

Cassava bacterial blight and superelongation, are limiting factors in the production of plantations affected in spite of the low incidence during time when survey was performed (Table 6).

Due to the low severity of the Rust and the Cassava ash, these two diseases are considered of little economic importance. Frog root sking was limiting production in spite of being localized in zone I, and could be of great economic importance.

In general, it can be concluded that cassava can suffer serious pathological problems, which can decrease yields considerably. Disease incidence appears to be highly related with environmental and edafic conditions.

INSECTS

Numerous insects were found in all the studied regions. These include thrips, gallmidge, mites, white fly, horn worm, chrysomelids, greenleafhooper, tingids and leaf cutter ants (Table 7). Species localized at specific zones like stem borers zones I and II, termites in zones III, IV, V and earthworms in zone II.

The fact that the insects reported were found at all the visited zones could lead to conclude that environmental conditions have little influence in the presence of some species, but could have something to do as to their population. It was observed, in a general way, that as the altitude over sea level descends, and average temperature increases,

TABLE 5. SOIL CHARACTERISTICS BY FARM SIZE. AVERAGE FOR ALL ZONES

DESCRIPTION	SMALL (0-1.99 Ha.)		MEDIUM (2-9.99 Ha.)		LARGE (10 or more H)		TOTAL	
	%	Average	%	Average	%	Average	%	Average
Organic Matter (%):								
Low (-1)	4.9	0.40	3.4	0.50	0.9	0.90	2.8	0.50
Half (1-4)	56.8	2.80	48.3	2.90	55.7	2.80	53.7	2.80
High (4 or more)	38.3	6.00	48.3	6.20	43.4	5.50	43.5	5.90
Phosphorus (ppm P-Bray II):								
15	71.6	3.80	77.0	2.80	62.6	3.40	69.6	3.40
15	28.4	89.40	23.0	61.30	37.4	64.90	30.4	70.60
Potassium (m.e/100 gm):								
.20	69.1	0.15	81.6	0.15	67.0	0.14	72.1	0.15
.20	30.9	0.49	18.4	0.52	33.0	0.60	27.9	0.55
pH:								
5.5	54.3	4.90	66.7	4.80	58.1	4.80	60.1	4.80
5.5	45.7	6.30	33.3	6.40	40.9	6.00	39.9	6.20
Aluminum (m.e/100 gm):								
3	34.6	1.08	37.9	1.55	39.1	0.95	37.5	1.17
3	20.9	4.92	31.1	5.46	25.2	3.00	25.8	4.83
Sodium Saturation:								
15%	97.5	1.20	98.9	1.10	99.1	0.70	98.6	0.90
15%	2.5	19.70	1.1	16.00	0.9	13.00	1.4	18.30
Calcium/Magnesium:								
1	6.2	0.80	6.9	0.80	10.4	0.70	8.1	0.70
1	93.8	3.40	93.1	3.20	89.6	3.80	91.9	3.50
Exchange Capacity (m.e/100 gm):								
15	40.7	8.60	47.1	11.20	52.2	11.20	47.3	10.60
15	59.3	22.40	52.9	22.70	47.8	21.00	52.7	22.00
Texture:								
Clayed	16	-	16	-	15	-	16	-
Loam	46	-	50	-	37	-	44	-
Silty	18	-	20	-	22	-	20	-
Sandy	20	-	14	-	26	-	20	-

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.) (1977), op. cit., p. D-5

TABLE 6. PROPORTION OF CROPS IN WHICH DISEASES WERE PRESENT DURING THE SECOND VISIT IN EACH ZONE. *

DISEASE	PERCENT OF FARMS I	II	III	IV	V	TOTAL
Cassava ash (<u>Oidium manihotis</u>)	46	56	76	13	9	42
Phoma leaf spot (<u>Phoma</u> sp.)	41	42	0	0	0	18
Superelongation (<u>Sphaceloma</u> sp.)	2	0	63	24	0	18
Cassava bacterial blight (<u>Xanthomonas manihotis</u>)	2	0	14	25	29	13
Sooty mold disease (<u>Several fungi</u>)	3	2	7	0	0	2
Rusts (<u>Uromyces spp.</u>)	0	0	3	0	0	1
Root rotting (<u>Several fungi</u>)	2	3	0	0	0	1

* 4 to 8 months after planting.

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.) (1977), <u>op. cit.</u>, p. E-7

TABLE 7. PROPORTION OF CROPS IN WHICH INSECTS WERE PRESENTED DURING THE SECOND VISIT IN EACH ZONE.*

INSECTS	I	II	III	IV	V	TOTAL
Thrips (*Frankliniella williamsi*)	59	88	100	95	86	85
Gallmidge (*Fam. Cecidomyidae*)	25	44	69	66	84	56
White Fly (*Bemisia* sp y *Trialeurodes* sp.)	70	14	37	24	70	42
Fruit Fly (*Anastrepha* sp.)	7	75	14	5	9	24
Mites (*Oligonychus peruvianus*)	7	9	41	9	43	20
White Fly (*Aleurotrachelus* sp.)	48	5	12	0	5	14
Shoot Fly (*Silba péndula*)	8	30	3	24	0	14
Leaf Cutter Ants (*Atta* spp)	18	5	24	13	2	13
Tingids (*Vatiga manihotae*)	16	3	7	7	0	7
Horn worm (*Erinnyis ello*)	0	2	0	0	11	2

* 4 to 8 months after planting.

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.) (1977), *op. cit.*, p F-8

TABLE 8. PORCENTAGE OF GRASS, BROADLEAF, SEDGES AND FERN WEEDS IN THE CASSAVA FIELDS OF FIVE ZONES DURING THREE VISITS.

Weed Types	PERCENTAGE OF EACH WEED TYPE					
	Zone I	Zone II	Zone III	Zone IV	Zone V	Avg.
First visit						
Grasses	27.1	27.5	15.7	23.3	32.4	25.4
Broadleaves	62.5	57.5	78.1	60.5	58.8	62.9
Sedges	8.3	12.5	3.1	14.0	8.0	9.7
Ferns	2.1	2.5	3.1	2.3	0	2.0
Second visit						
Grasses	20.9	26.2	24.2	27.5	37.2	28.4
Broadleaves	74.5	59.5	69.0	57.5	51.2	63.8
Sedges	2.3	11.9	3.4	12.5	11.6	6.2
Ferns	2.3	2.4	3.4	2.5	0	1.6
Third visit						
Grasses	20.6	30.8	29.4	33.3	27.8	27.9
Broadleaves	75.9	61.6	64.7	61.9	63.8	65.9
Sedges	0	3.8	0	0	8.4	3.1
Ferns	3.5	3.8	5.9	4.8	0	3.1

Source: R. O. Díaz and Per Pinstrup-Andersen (eds) (1977), op. cit., G-4

TABLE 9. THE TEN PRIMARY AND SECONDARY NOXIOUS WEED SPECIES WITH THE HIGHEST PLANT POPULATION IN EACH OF THE FIVE REGIONS[1]

Zone I	1000's pl/ha	Zone II	1000's Pl/ha	Zone III	1000's Pl/ha	Zone IV	1000's pl/ha	Zone V	1000's pl/ha
Tridax Procumbens	340	*Tridax procumbens*	240	*Bidens pilosa*	134	*Digitaria sanguinalis*	247	*Cyperus rotundus*	1296
Leptocloa filiformis	300	*Paspalum conjugatum*	230	*Ageratum conyzoides*	90	*Cyperus rotundus*	233	*Cyperus rotundus*	522
Commelina diffusa	260	*Commelina diffusa*	225	*Imperata cylindrica*	80	*Paspalum conjugatum*	210	*Digitaria sanguinalis*	360
Homolepsis atuvensis	160	*Leonotis nepetaefolia*	190	*Pteridium aquilinum*	79	*Bidens pilosa*	187	*Cynodon dactylon*	260
Sida acuta	151	*Ageratum conyzoides*	150	*Richardia scabra*	70	*Paspalum notatum*	164	*Stachytarpheta cayennensis*	240
Setaria geniculata	140	*Desmodium tortuosum*	150	*Cyperus luzulae*	60	*Imperata cylindrica*	111	*Mimosa pudica*	180
Bidens pilosa	131	*Cyperus diffusus*	133	*Stachytarpheta cayennensis*	56	*Stachytarpheta cayennensis*	110	*Boerhaavia decumbens*	164
Hyparrhenia rufa	120	*Eleusine indica*	131	*Hyparrhenia rufa*	52	*Panicum maximum*	110	*Corchorus orinocensis*	147
Imperata cylindrica	104	*Dichromena ciliata*	120	*Andropogon bicornis*	50	*Richardia scabra*	107	*Cyperus luzulae*	146
Ageratum Conyzoides	101	*Pteridium aquilinum*	120	*Borreria loevis*	50	*Euphorbia hirta*	100	*Eleusine indica*	124
	181		169		72		158		344

1/ Based on results of second farm visit and occurring on at least 3% of the farms in a given zone.

Source: R. O. Díaz and Per Pinstrup-Ande.. .. (eds.) (197.), *op. cit.*, p. G-13 the proportion of plantations affected by some insects, especially by thrips, gallmidge, white fly and termites, increased. On the other hand, white fly and tingids, tend to be more frequent at higher altitudes.

WEEDS

Bread leaf weeds were the most common at all zones, they are estimated as 62 to 65 percent of all weed species (Table 8). A slight change occurred in the presence of grasses,weeds and sedges in advanced plantations.

Surprisingly Pteridium aquilinium was the most common and Bidens pilosa and Cyperus rotundus were serious problems in certain zones. Significant variations occurred between zones in relation with the frequency of the species encountered, however, several weeds were common for many zones. Species with the higher population density did not coincide with those more frequently found (Table 9). Most of the grasses, annual weeds, sedges and broadleaf weeds found, are susceptible to the more commonly recommended herbicides, but more research is needed for some perennial weeds like P. aquilinium and sida spp.

USE OF INPUTS

A high proportion of cassava farmers used insecticides specially for ant control, while use of chemical fertilizers, fungicides and herbicides was limited (Table 10). The use of machinery for land preparation varied between zones and was determined principally by the topography and the size of the farm. Zone II was the most advanced respect to the use of technology which was very limited at zones I, III, and V.

The use of chemical inputs like fertilizer, insecticides, fungicides and herbicides was less common among small farmers (Table II). The same situation occurred with use of credit and technical assistance.

The average size of seed increased from zone I to zone V in 17, 18, 19 and 26 cm. respectively (Table 12). In zone V the farmers sustained that high temperatures dissecate the above ground portions of the stake and for that reason they use long stakes, to facilitate rooting.

ECONOMICAL ANALYSIS

The average estimated yield was inferior to 7 ton/ha. with a great variation from 0 to more than 40 ton/ha (Table 13). Yields tend to be

TABLE 10. USE OF INPUTS FOR TOTAL ZONES, OF FARMERS.

INPUT	I	II	III	IV	V
Fertilizer	18.0	35.9	8.5	21.8	13.5
Insecticides	96.7	56.2	79.7	89.1	36.4
Fungicides	0	3.1	0	1.8	0
Herbicides	0	10.9	0	3.6	0
Purchased seed	41.0	23.4	0	12.7	22.7
Credit	29.5	12.5	10.2	23.6	20.5
Technical Assistance	8.2	6.3	27.1	1.8	9.1
Mechanical Land Preparation	0	81.3	3.4	80.0	52.3

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.) (1977), op. cit., p. H-2

TABLE 11. PERCENTAGE DISTRIBUTION OF INPUT USED AVERAGE BY FARM SIZE.

INPUT	SMALL (0-1.99 Ha.)	MEDIUM (2-9.99 Ha.)	LARGE (10 o more Ha.)	TOTAL
Fertilizer	12.3	24.1	21.7	19.8
Insecticides	63.0	85.1	70.4	72.8
Fungicides	0.0	2.3	0.9	1.1
Herbicides	0.0	3.4	5.2	3.2
Purchased seed	14.8	20.7	21.7	19.4
Credit	7.0	25.0	23.0	18.0
Technical assistance	7.0	8.0	15.0	9.0
Mechanical Land Preparation	32.1	25.3	60.0	41.3

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.) (1977) op. cit.,p H-2

TABLE 12. SEED CHARACTERISTICS FOR TOTAL ZONES, AVERAGE BY FARM SIZE

DESCRIPTION	SMALL (0-1.99 Ha.) Average	SMALL Rank Low	SMALL Rank High	MEDIUM (2-9.99 Ha.) Average	MEDIUM Rank Low	MEDIUM Rank High	LARGE (10 or more Ha.) Average	LARGE Rank Low	LARGE Rank High	T O T A L Average	TOTAL Rank Low	TOTAL Rank High
ZONE I												
Age (days)	12	2	45	20	5	90	25	2	75	18	2	90
Size (cms)	17	10	25	17	12	20	20	15	25	17	10	25
Nudes (No.)	5	3	6	5	3	6	6	4	6	5	3	6
ZONE II												
Age (days)	11	1	21	13	2	50	15	1	60	14	1	60
Size (cms)	17	12	25	18	12	25	18	12	30	18	12	30
Nudes (No.)	5	3	6	5	3	6	5	3	6	5	3	6
ZONE III												
Age (days)	12	2	30	12	2	30	12	1	45	12	2	45
Size (cms)	16	15	23	18	15	20	17	10	20	18	10	23
Nudes (No.)	5	3	7	5	3	7	5	3	7	5	3	7
ZONE IV												
Age (days)	6	1	15	20	1	90	13	1	60	14	1	90
Size (cms)	18	15	20	18	12	25	19	10	25	19	10	25
Nudes (No.)	5	4	6	5	3	7	5	3	6	5	3	7
ZONE V												
Age (days)	12	1	90	28	1	90	14	2	30	17	1	90
Size (cms)	26	18	30	25	15	30	27	20	35	26	15	35
Nudes (No.)	7	5	10	8	5	15	7	6	10	7	5	15
TOTAL												
Age (days)	11	1	90	19	1	90	14	1	60	15	1	90
Size (cms)	19	10	30	18	12	30	19	10	35	19	10	35
Nudes (No.)	5	3	10	5	3	15	5	3	10	5	3	15

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.) (1977), op. cit., p. II-7

TABLE 13. AVERAGE YIELDS OF CASSAVA FOR TOTAL ZONES, AVERAGE BY FARMS SIZE (Ton/Ha.)

	Average	Low	High	Tipical Desviation
ZONE I :				
Small	4.5	0.4	11.7	3.6
Medium	4.0	0.1	15.6	3.3
Large	5.7	1.2	10.0	2.3
Total	4.4	0.1	15.6	3.3
ZONE II :				
Small	7.9	0.5	24.6	8.1
Medium	12.8	4.2	31.5	7.6
Large	14.2	3.4	52.0	10.7
Total	12.6	0.5	52.0	9.8
ZONE III :				
Small	2.8	0.5	9.0	2.1
Medium	2.7	0.5	8.0	1.9
Large	3.5	1.0	15.7	3.3
Total	3.0	0.5	15.7	2.6
ZONE IV :				
Small	5.9	3.0	8.4	1.9
Medium	7.4	1.7	18.5	4.6
Large	5.7	0.4	14.1	3.7
Total	6.2	0.4	18.5	3.8
ZONE V :				
Small	3.0	0.6	7.0	1.9
Medium	4.2	1.2	10.0	3.0
Large	4.8	0.3	10.0	3.8
Total	3.7	0.3	10.0	2.8
TOTAL :				
Small	4.3	0.4	24.6	4.3
Medium	5.9	0.1	31.5	5.4
Large	7.9	0.3	52.0	8.0
Total	6.2	0.1	52.0	6.5

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.) (1977), op. cit., p. I-2 higher for large farmers compared to small ones, 7.9 and 4.3 ton/ha respectively. This situation was more noticeable at Valle and Quindio sites. Zone I, with 14 and 8 tons/ha.

In spite that yields were considerably low, the use of labor for cassava production was estimated in 86 man-days per hectare, varying from 66 in zone IV to 106 in zone I (Table 14). More than one half of this hand labor was utilized for weed control. Land preparation, planting and harvesting employed around 30 percent (Figure 4).

The months of april and may took the highest proportion of man-days in zones I, II and III maninly for land preparation, plantig and weeding. At zones IV and V in august, the utilization of hand labor is intensified (Figure 5).

The average variable production costs were estimated in $400/ha (table 15 and 16) and $640/ton of cassava produced (Table 17). The variable costs per hectare range from $300 in zone I to $5000 in Zone II. Almost one half of the variable cost are due to weeding and one fifth to land preparation. It is important to notice that only 8 percent of the variable costs were due to the value of inputs used in the process (Figure 6).

The average total cost of production was estimated at $6000/ha to $1000/ton.[2] (Table 17). The cost per hectare tends to be higher at large farms due to the value of land rental, estimated al 10 percent of its value, to the cost of administration, surveillance and packing, but the cost per ton produced tends to be smaller because of larger productions. At zone III where the lowest yields occurred, the cost per ton were slightly bigger than $1600/ton and zone II, with the highest costs, the cost per ton was the lowest.

The highest production value was obtained at zone II, over $25000/ha and the lowest at zone V, close to $4000/ha. The profits for the cassava farmers which are net income and to land payment, were higher than $19000/ha in zone II, and negative in zone V (Table 18).

The sharecropper system in the production of cassava in Colombia is frequent. The sharecroppers pay one third or one half of the produce to the land owners. The latter manner is the most common. At zones III, IV, and V estimated net incomes for the sharecroppers were negative (Table 19).

Estimations indicate negative or low net incomes for some zones, but it must be considered that part of the hand labor used by the farmers is compared by family members, which in this case has been considered as a spenditure. The proportion of family labor used by the farmers was of: 42.4, 19.9, 67.4, 48, 52, 45.1 percent for zones I, II, III, IV, V and total of farmers respectively.

2/ US$240/ha and US$40/ton. Rate of exchange, $25 to one dollar.

TABLE 14. ESTIMATED LABOR USE IN THE PRODUCTION OF CASSAVA PER HECTARE BY ZONES.

ACTIVITY	I		II		III		IV		V		TOTAL	
	Average	%	Average	%	Average	%	Average	%	Average	%	Weighted Average	%
Land clearing	1.4	1	0.0	0	0.5	1	0.8	1	3.7	4	1.2	1
Land preparation	33.1	32	6.5	8	12.0	15	3.7	6	8.0	9	13.1	15
Plotting	2.5	2	0.5	1	1.4	2	0.1	0	0.4	0	1.0	1
Planting	7.5	7	9.8	12	11.9	14	10.1	16	10.0	11	9.9	11
Replanting	1.4	1	1.0	1	0.6	1	1.3	2	3.2	3	1.4	2
Hilling	0.1	0	1.7	2	0.0	0	0.1	0	0.0	0	0.5	0
Irrigation	0.0	0	0.0	0	0.0	0	0.0	0	3.4	4	0.6	1
Drainages	0.2	0	0.4	0	0.0	0	0.1	0	0.3	0	0.3	0
Apl. fertilizers	1.3	1	1.1	1	0.5	1	0.3	5	0.9	1	0.9	1
Apl. insecticides	5.3	5	1.6	2	3.4	4	3.4	0	1.2	1	3.1	4
Apl. fungicides	0.0	0	0.1	0	0.0	0	0.1	0	0.0	0	0.1	0
Apl. herbicides	0.0	0	0.1	0	0.0	0	0.1	0	0.0	0	0.1	0
Weedings	46.1	45	58.1	68	43.4	52	38.3	59	51.3	57	47.6	56
Pruning	0.0	0	0.5	1	0.3	0	0.1	0	0.1	0	0.2	0
Harvesting	6.8	6	3.4	4	8.2	10	7.5	11	9.2	10	6.6	8
TOTAL	105.8	100	84.8	100	82.2	100	66.1	100	91.5	100	86.4	100

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.) (1977), op. cit., p. H-12

FIGURE 4. ESTIMATED LABOR USE IN THE PRODUCTION OF CASSAVA PER HECTARE (MEN DAYS/HECTARE) (%) TOTAL LABOR PERCENTAGE USED IN THE ACTIVITIES.

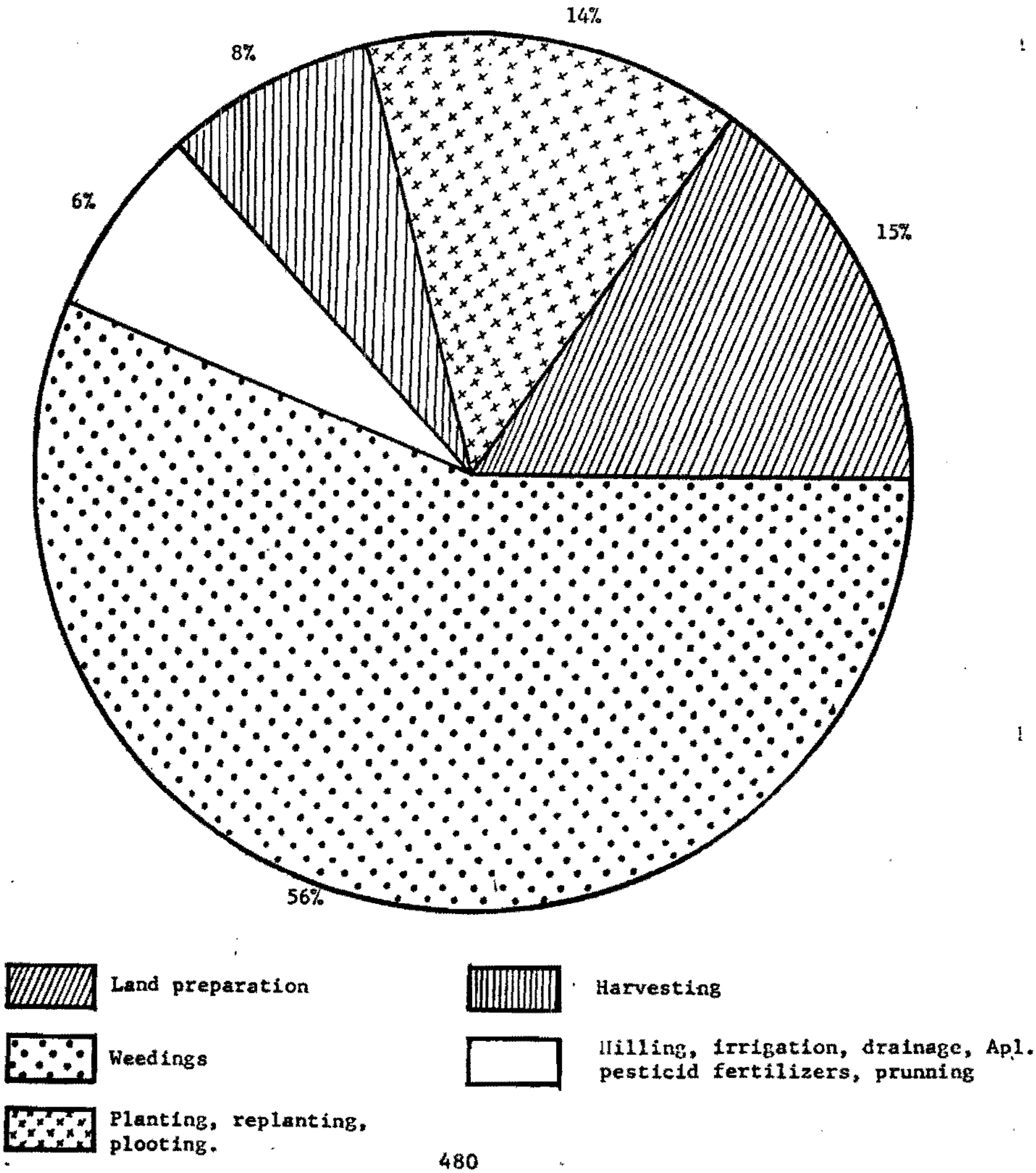


FIGURE 5. LABOR USE DISTRIBUTION FOR TOTAL ZONES (MEN-DAYS/HA) DURING ONE SEASON AVERAGE 1973 - 75

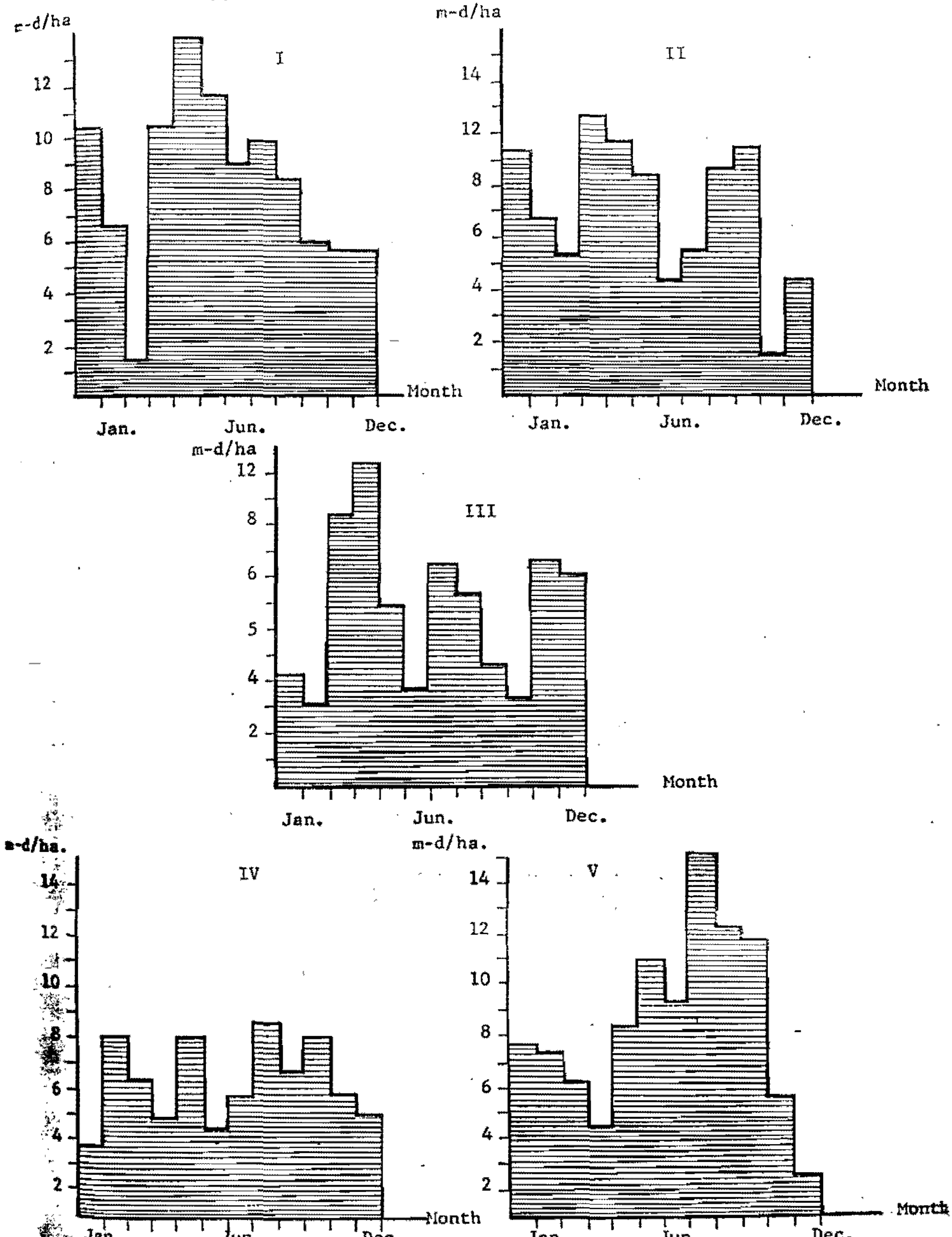


TABLE 15. AVERAGE VARIABLES PRODUCTION ACTIVITIES COSTS OF CASSAVA PER HECTARE

Activities	ZONE I		ZONE II		ZONE III		ZONE IV		ZONE V		TOTAL	
	$/ha	%	$/ha	%	$/ha	%	$/ha	%	$/ha	%	$/ha	%
Land clearing	38.3	1	0	0	37.4	1	37.1	1	383.7	11	82.9	2
Land preparation	862.6	28	1183.5	24	571.1	14	769.4	19	596.8	16	815.0	20
Ploting	65.2	2	86.9	2	63.2	2	20.9	0	11.7	0	52.8	1
Planting	197.4	7	393.8	8	538.4	14	479.5	12	293.2	8	382.6	10
Replanting	37.7	1	42.4	1	27.6	1	62.4	2	95.7	3	50.5	1
Hilling	2.1	0	68.4	1	0	0	5.5	0	0	0	17.0	1
Irrigation	0	0	0	0	0	0	0	0	100.9	3	15.7	0
Drainages	6.4	0	16.7	0	1.0	0	32.8	1	27.7	1	16.0	1
Ap. Fertilizers	33.3	1	49.8	1	21.8	1	23.9	1	27.2	1	31.9	1
Ap. Fungicides	0	0	2.7	0	0	0	1.4	0	0	0	1.0	0
Ap. Insecticides	140.4	5	66.2	1	156.2	4	159.4	4	34.4	1	114.1	3
Ap. Herbicides	0	0	9.2	0	0	0	1.9	0	0	0	2.4	0
Weedings	1202.0	39	2333.5	47	1991.0	50	1812.2	44	1524.9	43	1791.2	45
Pruning	0	0	20.5	0	14.0	0	0	0	2.0	0	7.9	0
Harvesting	177.2	6	136.3	3	381.8	10	358.1	8	271.5	8	260.3	7
TOTAL	2762.6	90	4409.9	88	3803.0	97	3764.5	92	3369.6	95	3641.3	92

Sourcw: R. O. Díaz and Per-Pinstrup-Andersen (eds.) (1977), <u>op. cit.</u>, p. I-11

TABLE 16. AVERAGE VARIABLES PRODUCTION INPUTS COSTS OF CASSAVA PER HECTARE

Inputs	ZONE I		ZONE II		ZONE III		ZONE IV		ZONE V		TOTAL	
	$/ha	%	$/ha	%	$/ha	%	$/ha	%	$/ha	%	$/ha	%
Seed	117.7	4	196.3	4	69.4	1	121.3	3	128.0	4	127.7	3
Fertilizers	74.7	2	315.2	6	11.0	0	94.6	2	25.5	1	112.0	3
Insecticides	113.1	4	73.6	2	70.9	2	109.9	3	20.0	0	80.3	2
Fungicides	0	0	0.7	0	0	0	1.0	0	0.0	0	0.3	0
Herbicides	0	0	23.1	0	0	0	4.6	0	0	0	6.1	0
TOTAL INPUTS	305.5	10	608.9	12	151.3	3	331.4	8	173.5	5	326.4	8
TOTAL VARIABLE COST*	3068.1	100	5018.8	100	3954.3	100	4095.9	100	3543.1	100	3967.7	100

*/ Activities (Table 15) plus inputs.

Source: R. O. Díaz and Per-Pinstrup-Andersen (eds) (1977), op.cit., ps. I-6, I-7, I-8, I-9, I-10, I-11.

TABLE 17. AVERAGE TOTAL PRODUCTION COSTS OF CASSAVA PER HECTARE AND PER TON IN EACH ZONE.

	ZONE I		ZONE II		ZONE III		ZONE IV		ZONE V		TOTAL	
	$/ha	$/ton	$/ha	$/ton	$/ha	$/ton	$/ha	$/ton	$/ha	$/ton	$/ha	$/ton
Average variable costs	3068	694	5019	397	3954	1318	4096	661	3543	957	3968	640
Administration			199	16	0	0	83	13	6	2	62	10
Technical assistant	8	2	9	1	1	0	0	0	3	1	4	1
Surveillance	39	9	263	21	97	32	8	1	44	12	96	15
Pack	52	12	126	10	55	18	344	55	33	9	123	20
Interest (12% of variable cost)	368	84	602	48	474	158	491	79	425	115	476	77
Total cost excluding land rent	3535	803	6218	494	4581	1527	5022	810	4054	1096	4729	763
Land rent (10% of land value)	278	63	4511	358	321	107	540	87	423	114	1318	212
TOTAL COST	3813	866	10733	852	4902	1634	5562	897	4477	1210	6047	975

Source: R. O. Díaz and Per Pinstrup-Andersen (eds) (1977), op. cit., ps. I-14, I-15, I-16.

FIGURE 6.

ESTIMATED VARIABLE PRODUCTION COST PER HECTARE OF CASSAVA (%)

TOTAL COST PERCENTAGE USED IN THE ACTIVITIES

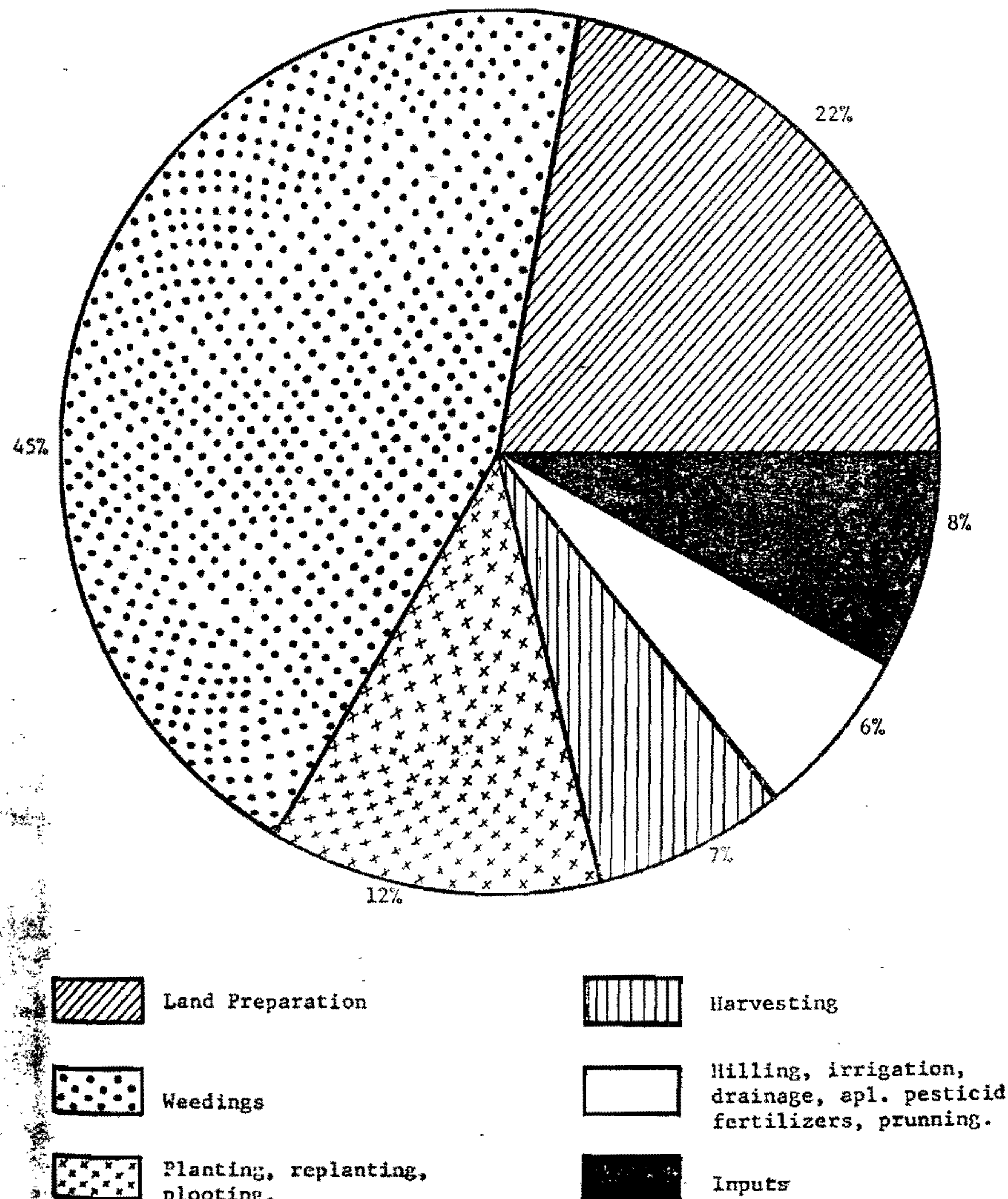


TABLE 18. LAND RETRIBUTION AVAILABLE FOR OWNER, RENTS AND SHARECROPPERS, AND NET RETURNS, GIVEN AS PERCENTAGE OF LAND AND PRODUCTION VALUE. AVERAGE BY ZONE.

	ZONE I		ZONE II		ZONE III		ZONE IV		ZONE V		TOTAL	
	$/ha	$/ton	$/ha	$/ton	$/ha	$/ton	$/ha	$/ton	$/ha	$/ton	$/ha	$/ton
Value of land	2776		45153		3208		5400		4227		13185	
Value of production	5859	1331	25685	2038	5946	1982	7982	1287	4016	1029	10485	1691
Net return and land retribution	2324	528	19467	1545	1365	455	2959	476	-37		5755	923
Percentage of land value	83.1		43.1		42.5		54.6		0		43.6	
Percentage of production value	39.1		75.8		23.0		37.0		0		54.9	

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.)(1977), <u>op. cit.,</u> p. I-18

TABLE 19.. TOTAL PRODUCTION COSTS OF CASSAVA AND NET RETURNS PER HECTARE AND TON FOR SHARECROPPER IN EACH ZONE. AVERAGE BY ZONE.

Activity	ZONE I		ZONE II		ZONE III		ZONE IV		ZONE V		TOTAL	
	$/ha	$/ton	$/ha	$/ton	$/ha	$/ton	$/ha	$/ton	$/ha	$/ton	$/ha	$/ton
Average variable cost	3548	591	6224	546	3909	1447	4463	647	3940	788	4526	730
Administration	0	0	34	3	0	0	0	0	0	0	8	1
Technical assistance	0	0	6	0	1	0	0	0	0	0	2	0
Surveillance	0	0	231	20	45	17	18	3	75	15	77	12
Pack	4	1	188	16	78	29	446	65	0	0	177	29
Land rent	3799	633	11841	1039	2718	1007	5684	823	2996	599	5664	914
Interest (12% of variable cost)	425	71	749	65	469	174	535	77	473	95	543	87
Total Cost	7776	1296	19273	1691	7220	2674	11146	1615	7484	1497	10997	1773
Value of production	8927	1488	24385	2139	4985	1846	9940	1440	5392	1078	11767	1898
Net returns	1151	192	5112	448	-2235	-828	-1206	-175	-2092	-419	770	125

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.) (1977), op. cit., p. I-20

TABLE 20. AVERAGE OF CASSAVA FOR TOTAL ZONES. AVERAGE BY FARM SIZE. (COL. $/TON.).

	Average	Low	High	Tipical Desviation
ZONE I :				
Small	1380	330	2880	570
Medium	1260	400	2400	490
Large	1390	1000	2270	380
Total	1320	330	2880	500
ZONE II :				
Small	2110	1000	3810	870
Medium	1760	760	4760	990
Large	2060	960	3920	760
Total	2000	760	4760	830
ZONA III :				
Small	2110	1340	3520	690
Medium	2230	1080	3200	680
Large	1720	780	3360	700
Total	1980	780	3520	720
ZONE IV :				
Small	1360	830	2100	510
Medium	1230	540	3180	580
Large	1070	380	2170	510
Total	1150	380	3180	530
ZONE V: :				
Small	1060	750	2000	290
Medium	1090	1000	2000	300
Large	1070	860	1200	120
Total	1070	750	2000	260
TOTAL :				
Small	1590	330	3810	740
Medium	1470	400	4760	730
Large	1550	380	3920	750
Total	1540	330	4760	740

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.) (1977), op. cit., I-4

TABLE 21. PERCENTAGE DISTRIBUTION OF CASSAVA PRODUCERS ACCORDING TO ORIGINAL AND DESTINATION OF CASSAVA. AVERAGE BY FARM SIZE.

DESCRIPTION	ZONES: I	II	III	IV	V
PLACE OF SALE					
Ground[1/]	41.0	76.5	0	27.3	0
Farm [2/]	27.9	9.4	52.5	1.8	88.6
Local Market Place	19.6	1.6	39.6	7.3	9.1
Principal Market Place	8.2	12.5	3.4	60.0	0
DESTINATION					
Selling for :					
Human Consumption	45.9	100.0	94.9	96.4	75.0
Animal Consumption	0	0	0	0	0
Processing	50.8	0	0	0	22.7
No selling	3.3	0	5.1	3.6	2.3

1/ Before harvest ("selling")

2/ Harvested

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.) (1977), op. cit., p. K-3

TABLE 22. PERCENTAGE DISTRIBUTION OF FARMS ACCORDING TO THE CLASS AND TYPE OF TRANSPORTATION FOR TOTAL ZONES.

	I	II	III	IV	V	TOTAL
CLASS						
Owned	3	0	7	0	5	2
Rented	25	14	36	67	5	30
None	72	86	57	33	90	68
TYPE						
Mechanical	5	14	22	65	10	23
Animal	23	0	20	2	0	9

Source: R. O. Díaz and Per Pinstrup-Andersen (eds.) (1977), op. cit., p. K-6

The average price paid to the farmers was of $1540/ton. The price at zones II and III was almost double the price at zone V. Price at these zones may have been favoured by the access to big markets. There were no large differences between small and large farmers as to the price of cassava but wide variations were noticeable in the same zones (Table 20).

Marketing and transport of cassava for industrial processing and starch plants was produced only at zone I, with traditional technology and at zone V, with advanced technology.

One third of the farmers sold their cassava "in situ" i.e. before harvesting (Table 21). With this system price is defined by farmer and buyer before harvesting the crop. The cost of harvesting is paid by the buyer who sometimes supplies the bags. The main reasons why farmers deal this way are: a) he believes profits are higher b) he avoids marketing problems c) he eliminates the risk associated with a yield smaller than expected and d) need of cash before harvest time.

Most of the visited farmers had no transportation available (Table 22). There were regions where more that one fifth of the farmers used animal transportation.

Cassava production is generally found at places isolated from consumer centers. This situation makes the marketing of the product more difficult forcing the farmers to sell in their farms. These that utilize this transportation and carry their product to the market are forced to sell at the prices imposed by the wholesaler which may have a very wide profit margin .

SUMMARY AND CONCLUSIONS

The need for usefull information about the cassava crop in order to make decisions according to research priorities and to develop a methodology that can be utilized by institutions or persons from other countries interested, motivated the International Center for Tropical Agriculture (CIAT), to initiate a study on cassava covering the following aspects: (1) description of the production processes, (2) identification of factors associated with low yields, (3) estimate production costs and other economic indexes.

A group of cassava farmers distributed in five different regions, were visited during different stages of the cassava growing cycle in order to obtain information on all activities of: (1) production and planting systems (2) type of soils based on samples taken at each one of the visited farms (3) direct observation of insects, diseases, weeds and water problems (4) estimation of inputs used and production costs for each one of the studied zones.

At the farms surveyed most of the production activities are

performed with hand labor. Around 40 percent of the farmers planted cassava intercropped with other crops, maize being the most important.

Weed control is one of the most important activities in the cassava production process. The majority of the soils are acid and loam textured. Diseases caused by Cercospora spp were the most important at almost all plantations under 1200 m of altitude and phoma leaf spot was the main disease causing yield losses at more than 1200 m over sea level. Insects were found at all regions surveyed, of which thrips was the most frequent. Gallmidge, mites, white fly, fruit fly, tingids, horn worm and leaf cutter ants where the most important. Broad leaf weeds were the most frequent at all zones. Ferns were some of the most common weeds.

Machinery was used for land preparation and very little for other labors. Insecticides, especially for leaf cutter ant control were the most common chemical input. The size of seed increased as altitude over sea level decreased.

Average yields from the survey were less than 7 ton/ha. A wide variation was observed from 0 to more than 40 ton/ha. In spite of this, use of labor for cassava production averaged at 86 man-days per hectare.

The variable production costs was estimated at \$4000/ha and \$640/ton and the total cost at \$6000/ha and \$1000/ton of cassava produced. The highest value of production was of \$25000/ha and the lowest was \$4000/ha. The proportion of family labor used by the farmers for the cassava production process was of 42.4, 19.9, 67.4, 48, 52, 45.1 percent for zones I, II, III, IV, V and farmers total costs respectively.

The average price paid to the cassava farmers was of \$1540/ton cassava for processing and starch obtained was sold only at two zones. One third of the farmers sold their cassava before harvesting and the majority had no transportation available.

It is important to note that this type of information is indispensable for the research workers in charge of establishing simple unexpensive technologies which could be adopted to different ecosystems and cultural levels.

AGRICULTURAL ADMINISTRATION :

HOW TO APPLY THE ECONOMIC THEORY 1/

J.N. Efferson

" Very often economists, eager to show the world how much they know about their proffesion, have made of economics, the science of common sense, very difficult to understand. By the use of unusefull words, endless phrases and innumerable, confusing and complicated graphs, they have made economics as the most obscure of the foreign lenguages, and even more difficult to understand and to apply to agricultural administration local problems. As a result, farmers have made little use of the economic theory in their daily decision making activities. They need specific facts, not abstract theories.

They really need basic facts pertinent to the matter on which they must decisions, as much as they need economic theory which is world wide accumulated experience to evaluate and interpretate these facts. Without both factors arriving to correct conclusions is impossible. "

1/ Agricultura de las Américas Año 25, Nov. 7, 1976 pp. 94

ECONOMIC ANALYSIS OF EXPERIMENTAL RESULTS 1/

Per Pinstrup-Andersen

1. Nature and usefullness of Economic Analysis

The main purpose of economic analysis of experimental results is to help establishing recommendations to farmers on the use of resources and production technology. Economic analysis look for the economic optimum based on experimental data. It is of little use for the farmer that the application of 500 kg. of Urea will increase yields per hectare. The same way it is of little use to know that one weeding per week during the first seven months of growth will result in larger production. The farmers' objective normally is not to maximize yield but to maximize net income. So, the farmer is interested in an economic optimum and not a physical maximum. Agro-biological experiments should be complemented with economic analysis so that experimental results may have relevance among the farmers.

2. Necessary data

The type of data necessary depends on the specific analysis to be performed. It is essential then, to decide if an economic analysis is to be made and to especific what analysis it will be before commencing the experiment. If these considerations are not included in the planning of the experiment, it is probable that later on the analysis cannot be done due to lack of data.

It is common for an agriculture research worker to perform his experiment, tabulate the data and then ask for an economic analysis without consulting the economist but after the experiment is finished. It is like estimating the efficiency of an animal diet after a period of time without information on the quantities of feed consumed. In most cases it is impossible.

Generally, the data necessary for economic analysis, besides experimental results, consists of amounts and prices of inputs used, prices of the produce and impact over other resources. However, information especifications varie from one experiment to another.

1/ CIAT, Internal Publication. August, 1974.

3. Estimation of economical optimum

Estimation of economical optimum is based in the fact that an activity whose cost is inferior to the value of the result of the activity increases net income.

If the cost of applying 100 kg of fertilizers is $50.oo and the value of the increase in production is $60.oo the farmer would increase net income by the use of fertilizers.

If the value of the increment is only $40.oo it would be best not to use fertilizers. But, exactly how much fertilizer should be used. It may be used to the point where the cost of each aditional unit of fertilizer equals the value of the increment in production. In economic terms, we can say, where the marginal cost (MC, of the fertilizer input) is equal to the value of the marginal product (VMP, cassava production).

Figure 1, shows a hypothetical example of the estimation of the optimum amounts of fertilizer use. While the maximum yield is of 13.000 kg/ha corresponding to the use of 600 kg of fertilizer per hectare, the economical optimum corresponds to the use of 383 kg of fertilizers per hectare. The curve presented in figure 1 is called "Production Function". The production function shows the input-product relationship for a certain input-in this case fertilizer keeping other inputs at a constant level.

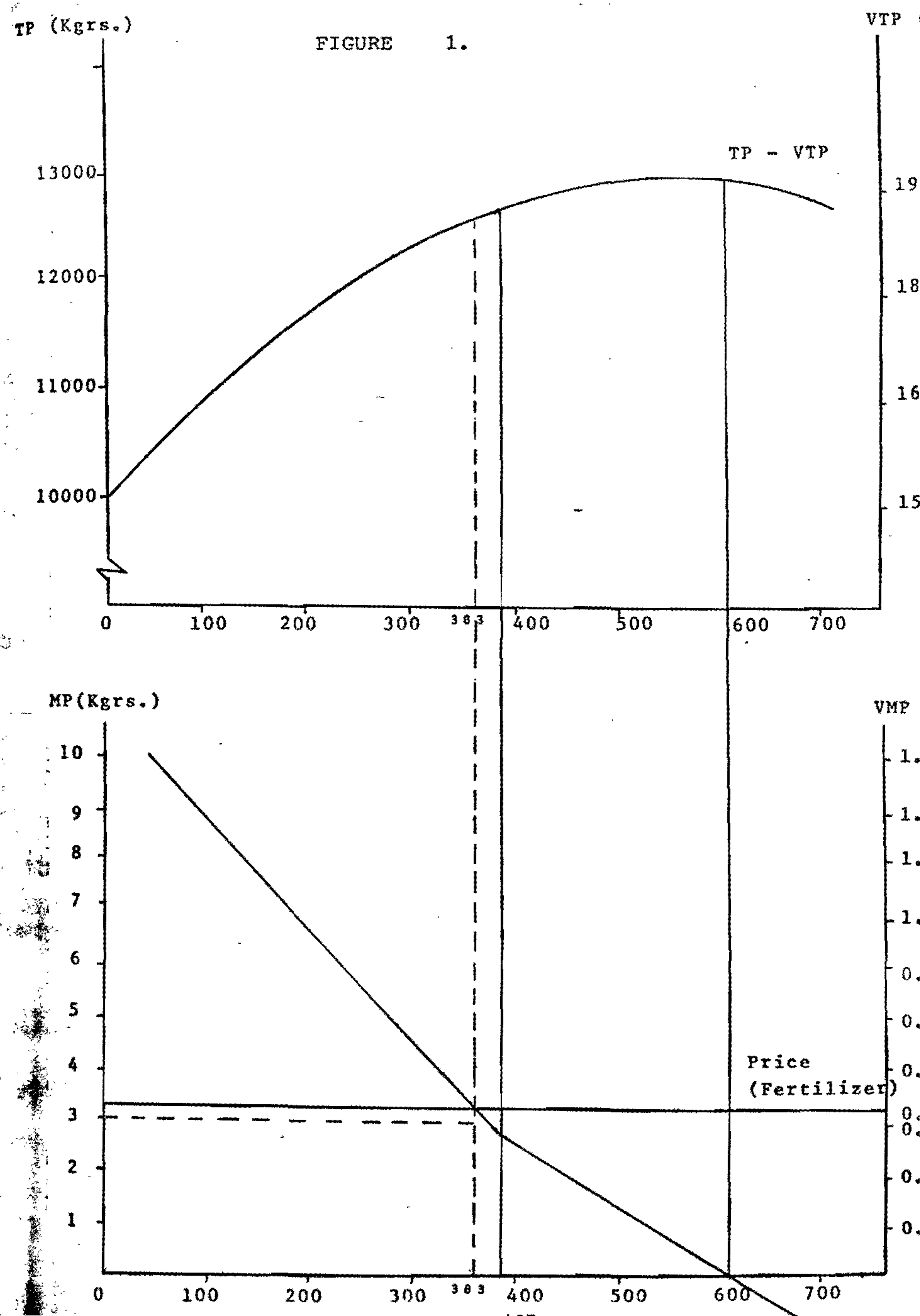
Transformation of experimental results into a continuous function like in the case of fertilizer use is not always possible. For example, a comparative analysis of net profits from using three different types of herbicide. In cases like this budget methods are used estimating the cost and benefit of each one of the three possibilities.

4. The role of risk and uncertainty

The response to fertilization shown in table 1, expressed as a production function in figure 1, refers to an experiment already completed (hypothetical data). If the same experiment could be repeated under exactly the same conditions the response would be the same. However, certain factors exist which cannot be controlled or predicted that can influence the response to fertilization. These factors are related mainly to environmental conditions, i.e. rains, droughts, winds, insect or disease attacks and price variations for the product or the inputs. The presence of these factors cause risk and uncertainty in the agricultural enterprise. Because of these reasons, the farmer must decide about the amounts to use for each input based on experimental results and on the probabilities of the different degrees of the uncontrollable factors.

The application of experimental results without consideration of

FIGURE 1.



TP (Kgrs.)
VTP
TP - VTP
13000
12000
11000
10000
19
18
16
15
0
100
200
300
383
400
500
600
700
MP(Kgrs.)
VMP
10
9
8
7
6
5
4
3
2
1
Price
(Fertilizer)
0
100
200
300
383
400
500
600
700

TABLE 1. HYPHOTHETICAL RESULTS OF A FERTILIZERS EXPERIMENT.

Land	Fertilizer	Production	Average Production	Marginal Production	Price (Fertilizer)[1]	Price Production	V.M.P.
(Ha)	----------	----------	(Kgs) ----------	----------	($/Kgs)	($/Ton.)	($)
1	0	10.000			0.50	150	
				10			1.50
1	100	11.000	110.0		0.50	150	
				8			1.20
1	200	11.800	59.0		0.50	150	
				6			0.90
1	300	12.400	41.3		0.50	150	
				4			0.60
1	400	12.800	32.0		0.50	150	
				2			0.30
1	500	13.000	26.0		0.50	150	
				1			0.15
1	600	13.100	21.8		0.50	150	
				-1			-0.15
1	700	13.000	18.5		0.50	150	

1/ Assuming that other production cost are independent of the nitrogen level.

risk and uncertainty may be cause of severe failrues. For example, in Puebla, Mexico, it was found that optimum Nitrogen levels varied from 0 to 200 kg/ha in 1968 and 1969, and the precipitation regime was blamed as the main cause for this variation. Flor and Pinstrup-Andersen[2/] present additional considerations on the importance of risk and uncertainty and methods for estimating the economical optimum under such conditions.

5. Implications to the farmer and to the agricultural sector

A single farmer normally produces a very small portion of the total production sold in a certain market. Also, the use of a certain input is only a small proportion of the total sold. An increase in production or an increase in the use of an input in one or few farms, will not cause changes in prices of inputs or product. However, when a large proportion of farmers increase their production or use of inputs, prices tend to change. So, if estimates of the benefit to the farmer brought by a new technology are calculated based on fixed prices results would not be valid if a great portion of the farmers adopt the new technology. Instead of utilizing fixed prices for product and inputs, the calculations should include and estimation of the expected variation in prices due to an increase in production and or use of inputs.

Excercises on this matter and other cases of economical optimum estimation using different phases of cassava production are explained further.

2/ Carlos Flor M., and Per Pinstrup-Andersen "Some economical models for risk and incertainty situation The case of Nitrogen" Paper presented at the 2 Colloquium on Soils, Palmira, Aug 29- Sept 3, 1971.

APPLICATED EXERCISES ON ECONOMICAL ANALYSIS

Rafael Orlando Díaz D.

In the previous section on the economical analysis of experimental results, it was defined that the objective of the farmer is not only to obtain high yields but to obtain high net incomes. The point that defines the maximum income situation to the farmer is obtained by calculating the economical optimum for the enterprise.

Estimation of economical optimum is based on the fact that the farmer's net income is increased by an activity whose is lower that the result of the activity.

To apply economical analysis to experimental results some usefull concepts must be kept in mind.

The expression "Production Function" is applied to the physical relationships between the resources of a company and the amount of goods and services produced per unit time, without considering prices. It can be expressed mathematically by $Y= (F(X_1, X_2.....X_n)$. The amount of resources by X_1, X_2, to X_n. The equation must be read as(the amount produced "Y" per unit time, is a function of (or depends of) the amounts of resources X_1, $X_2....X_n$ used by the company per unit time. [1]

Table 1 presents production relationships without considering prices and value of production relationships considering price of input and product. A graphic representation of a production function without considering prices is given in figure 1. Figure 2 represents relationships for value of production.

Figure 3 shows production costs commonly used in the elaboration of budgets obtained based on a linear production function.

Mathematical relationships for average costs are given in Table 2.

---

1 A more detailed explanation about functions and how they are obtained mathematically is given in Bishop, C.E. and W.D Toussaint. Introduction to Agrcultural Economic Analysis. John Wiley and Sons, Inc. 1958.

Given this definitions, some exercises using hypothetical cases of some biological experiments and the criterion used to perform the economical analysis of results, are described below.

Case No. 1

Estimation of optimum Nitrogen levels for cassava. Variables will be: (1) price of Nitrogen input (2) price of cassava product and (3) price of input and product.

Costs of applying Nitrogen, weedings and harvests vary with variations in the Nitrogen level applied and the production levels obtained.

Case No. 2

Estimation of optimum plant population. The number of plants per hectare vary and thus, the yields vary also. As a consequence the cost of seed, planting and harvest will vary. Other costs are assumed constant.

Case No. 3

Optimum number and time for weeding of cassava. This example is the case of a comparative analysis of the net profit resulting from ussing four different alternatives based on results of simple budgets, estimating the cost and benefit of each one of the alternatives.

Case No. 4

Optimum time of harvest. Variables are time of harvesting, so, the yields vary too. Because it is probable that the cassava harvested decreases in its quality, this depends on the type of market, the price per ton of cassava must be varied. The alternative cost of the land is considered. The cost of harvesting also varies.

TABLE 1. RELATIONSHIP OF THE PRODUCTION

iF : X_i = Quantity of the input

Y_i = Quantity of the product

Average Product.

$AP = Y_i / X_i$: The ratio of the total product (TP) to the quantity of input used in producing that amount of product.

Marginal Product.

$MP = \Delta Y_i / \Delta X_i$: The addition to product resulting from the addition of one unit of the input.

Relationship of the value of the Production.

iF : P_{xi} = Price of the input

P_y = Price of the product

Value of the total Product.

$$VTP = P_y \cdot Y$$

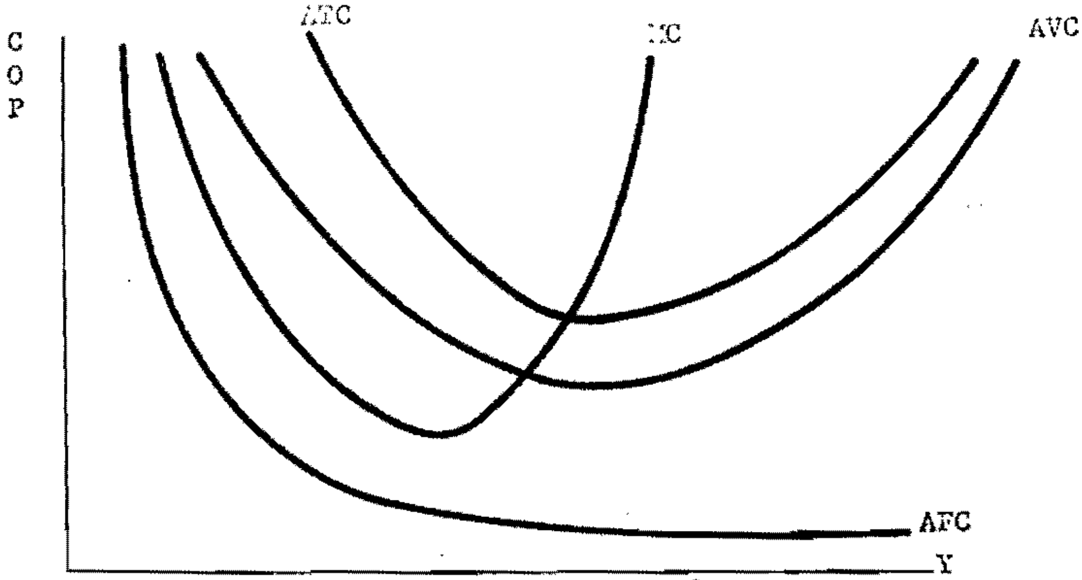
Value of the average Product.

$$VAP = (P_y)\ (Y_i/X_i) = P_y \cdot AP$$

Value of the Marginal Product.

$VMP = (MP)\ (P_y)$ = The value of product per unit of input at any particular level of input.

TABLE 2. AVERAGE COST



Average Fixed Cost.

$$AFC = TFC/Y = (P_{x2}X_2 + P_{x3}X_3 + \ldots\ldots + P_{xn}.\ X_n)\ /Y$$

Average Variable Cost.

$$AVC = TVC/Y = P_{x1}X_1\ /Y = (P_{x1})\ Y/X_1 = P_{x1}\ /\ AP$$

AP = Average Product.

Marginal Cost.

$$MC = \partial TC/\partial Y = (TVC + TFC)\ /\partial Y$$

$$= \partial(P_{x1}X_1 + \sum_{i=2}^{n} P_{xi}X_i)\ /\partial Y$$

$$= P_{xi}.\ \partial X_i/\partial Y + 0 = (P_{xi})\ \partial Y/\partial xi$$

$$= P_{xi}\ /MP\ X_i$$

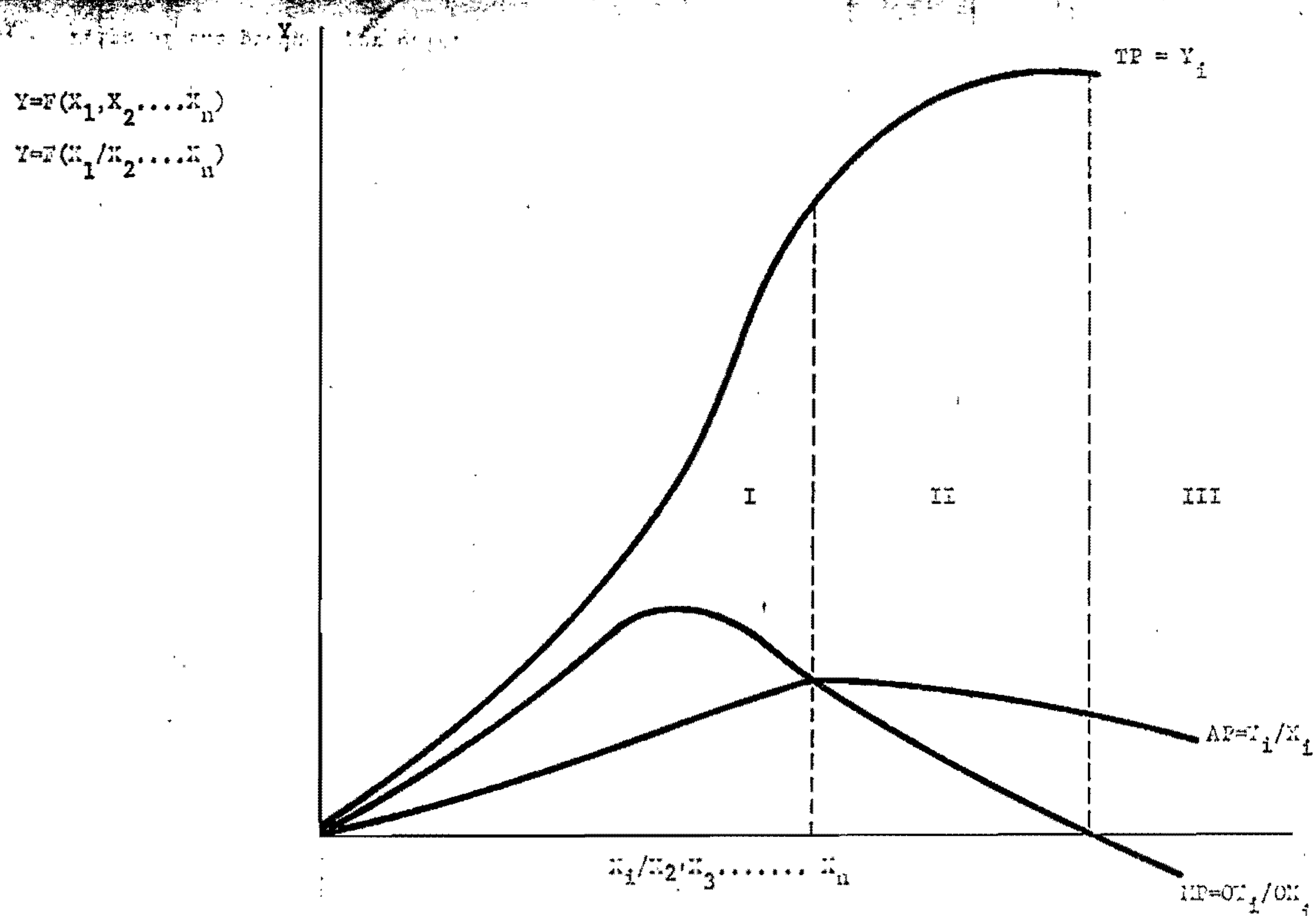
MP = Marginal Product

Average Total Cost

$$ATC = TC/Y = (AVC + TFC)\ /Y = (P_{x1}X_1/Y) + (TFC/Y)$$

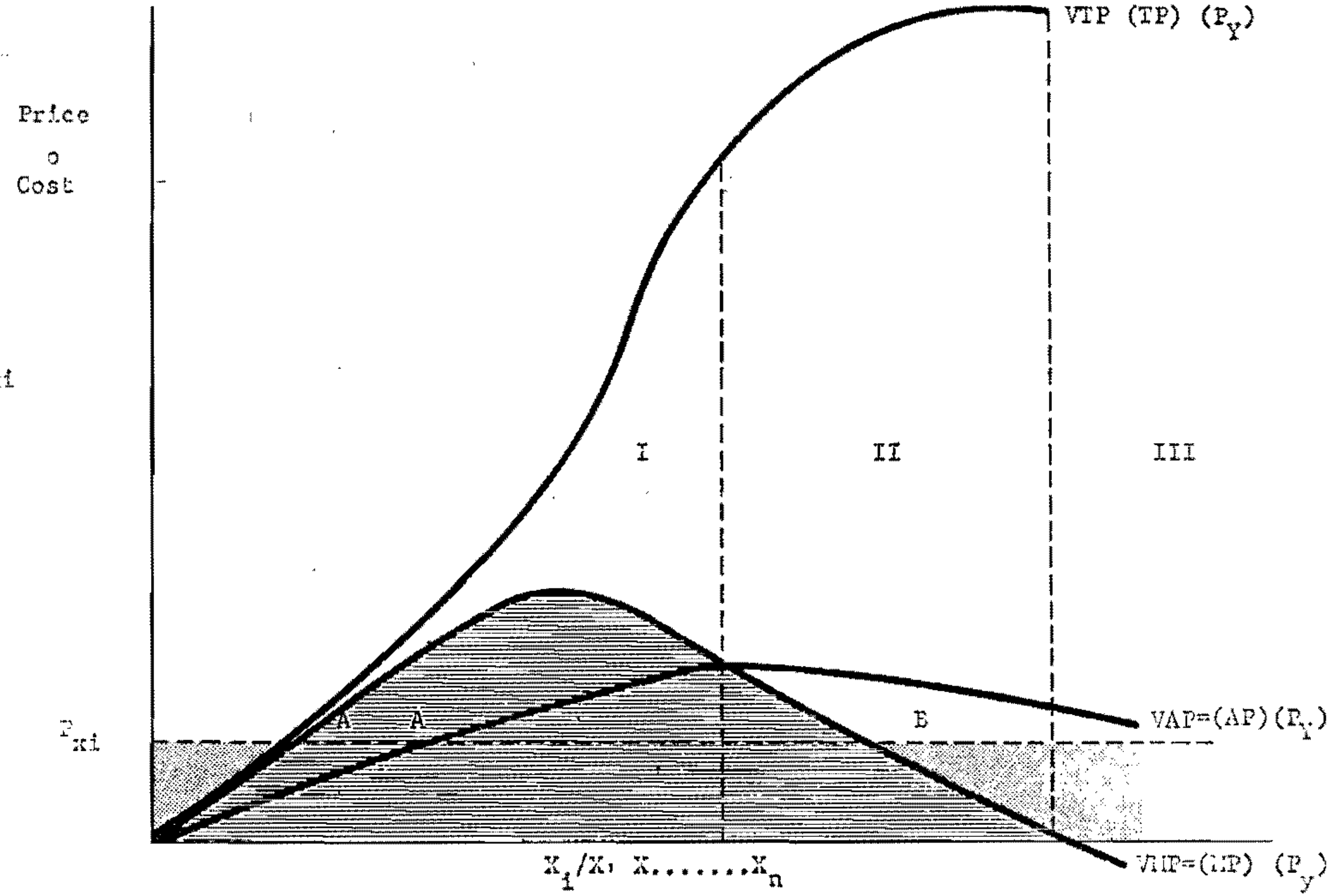
$$= AVC + TFC$$

FIGURE 1. PRODUCTION FUNCTION



TP	=	The way in wich the quantity of a particular product depends upon the quantities of particular inputs used.
AP	=	The ratio of the total product (TP) to the quantity of input used in producing that amount of product.
MP	=	The addition to product resulting from the addition of one unit of the input.

FIGURE 2. RELATIONSHIP OF THE VALUE OF THE PRODUCTION.



$A'\ :\ P_{xi} = VAP$

$(Y_i/X_i)\ (P_Y) = P_{xi}$

$\therefore\ Y.P_Y = X_i.\ P_{xi}$

$B\ :\ P_{xi} = VMP$

$(MP)(P_Y) = P_{xi}$

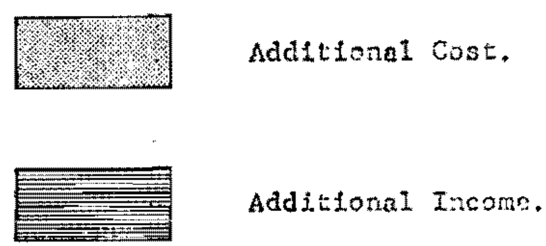
$MP = P_{xi}/P_Y$

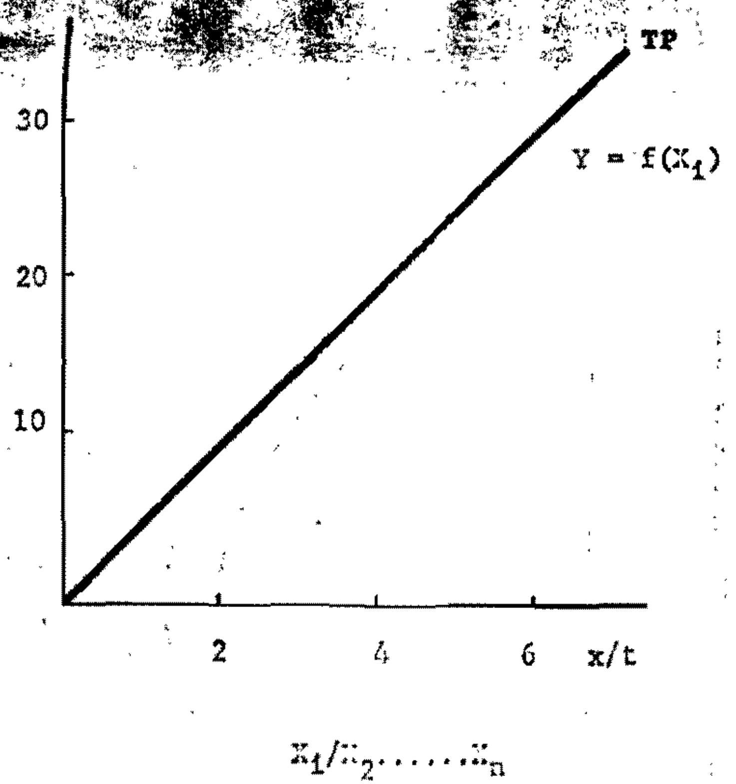
$VAP = (Y_i/X_i)\ (P_Y)$

$VMP = (Y_i/X_i)\ (P_Y)$

P_{xi} = Price of the variable input

P_{yi} = Price of the product per unit.





TP = Total Product.

TVC = Total Variable Cost.

TFC = Total Fixed Cost.

TC = Total Cost.

FIGURE 3. PRODUCTION COSTS.

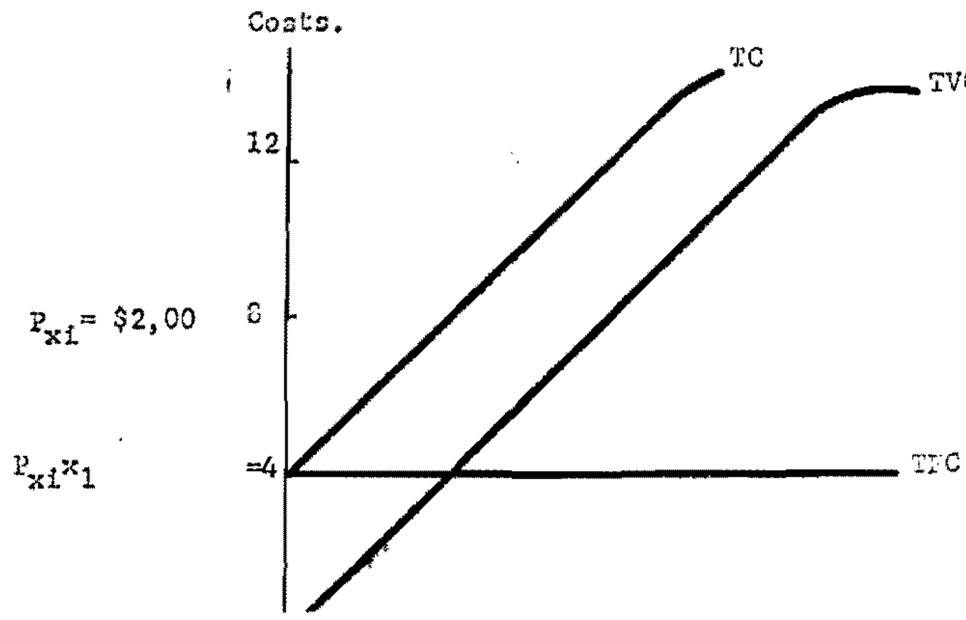
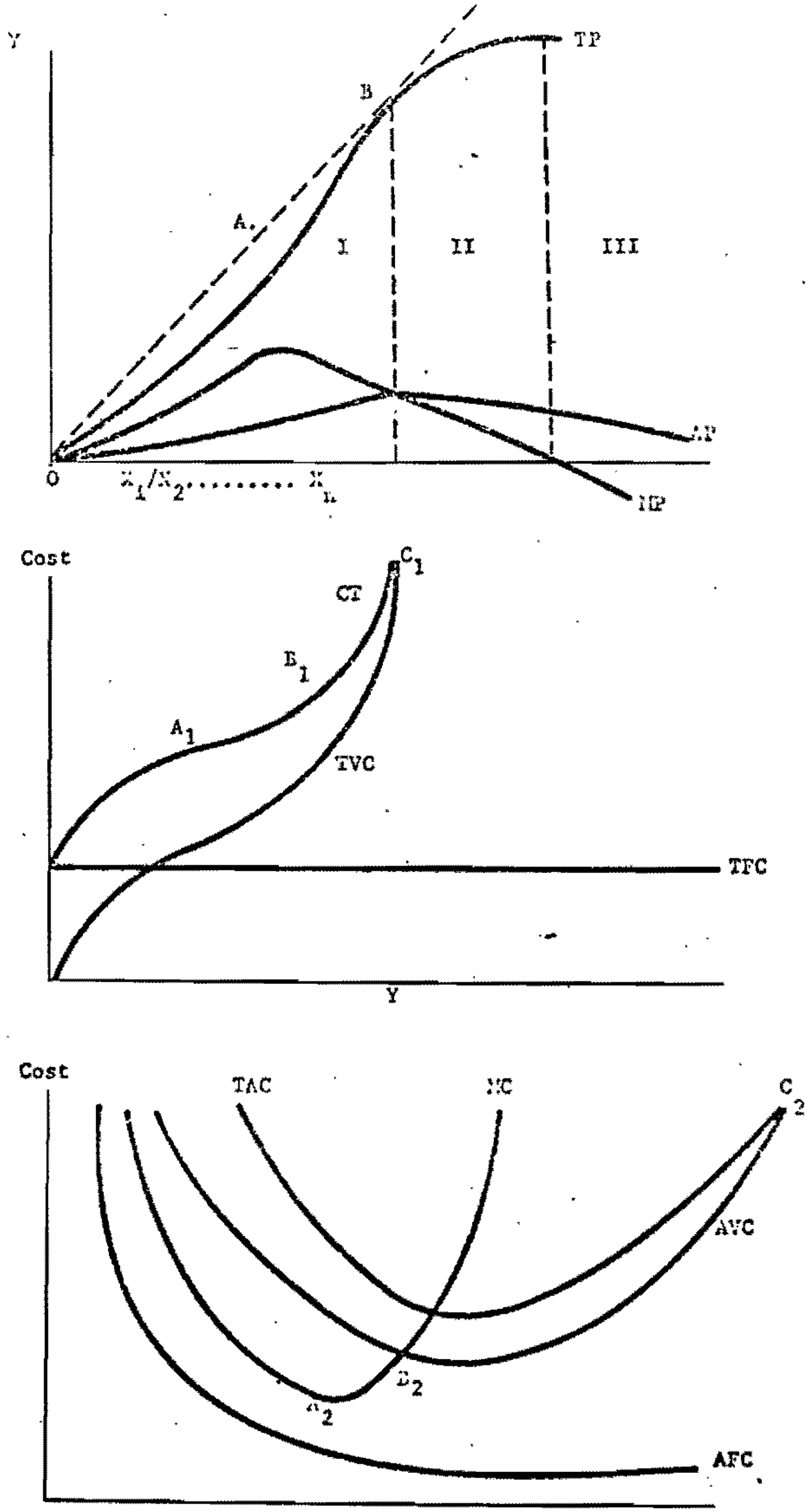


FIGURE 4. RELATIONSHIP BETWEEN COSTS AND PRODUCTION.



CASE NO. 1. ESTIMATION OF OPTIMUM NITROGEN LEVELS FOR CASSAVA.

Nitrogen	Production	Aplication Cost	Price N/Kgr.	Weeding Cost	Harvesting Cost	Others Costs	MP	(1) VMP	(1) MC	(2) VMC	(2) MC	(3) VMP	(3) MC
(Kg/ha)		($/ha)						($)					
0	5,000	0	0.4	200	100	100	20	2	0.80	2.0	0.70	1.6	0.80
50	6,000	10	0.4	200	110	100	20	2	0.22	2.0	0.12	1.6	0.22
100	7,000	11	0.4	180	120	100	15	1.5	0.26	1.5	0.16	1.2	0.26
200	8,500	12	0.4	150	135	100	10	1.0	0.30	1.0	0.20	0.8	0.30
300	9,500	12	0.4	130	145	100	5	0.5	0.36	0.5	0.26	0.4	0.36
400	10,000	13	0.4	120	150	100	2	0.2	0.40	0.2	0.30	0.16	0.40
500	10,200	13	0.4	120	150	100	0	0.0	0.41	0.0	0.31	0.0	0.41
600	10,200	14	0.4	120	150	100							

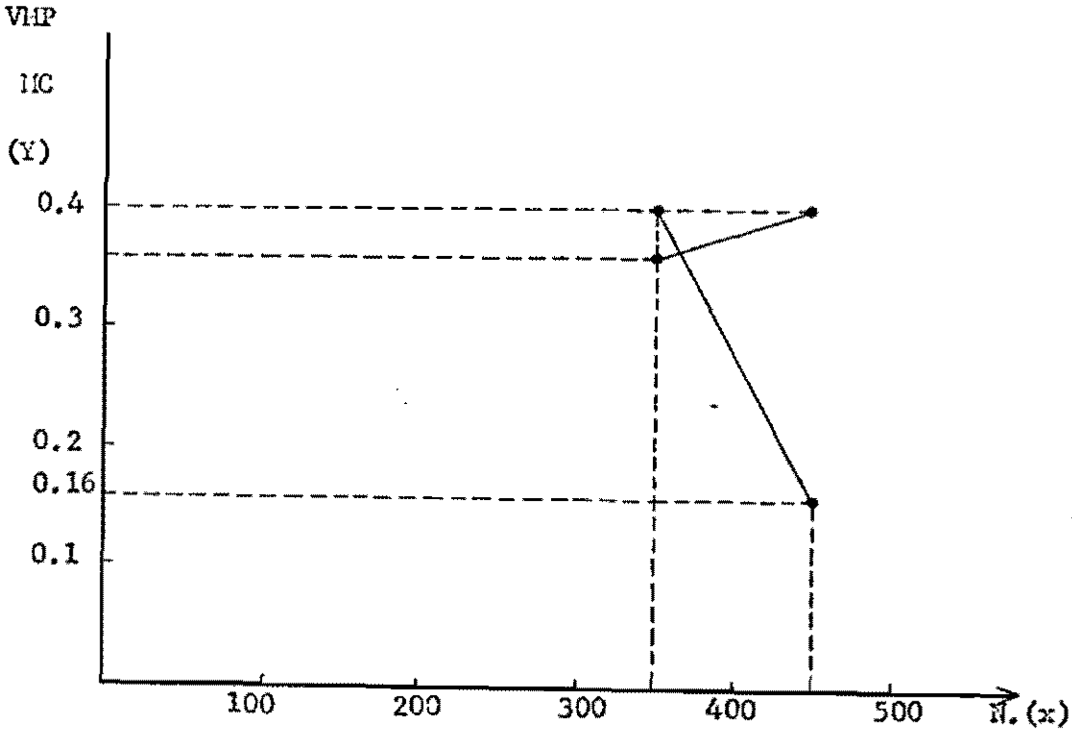
(1) Price of the Nitrogen : $400/ton. = $0.4 kgs.
Price of the Cassava $100/ton. = $0.1 kgs.
Optimum Nitrogen Level = 391 kgs/ha.

(2) Price of the Nitrogen : $300/ton. = $0.3/kgs.
Price of the Cassava : $100/ton. = $0.1/kgs.
Optimum Nitrogen Level = 420.6 kgs/ha.

(3) Price of the Nitrogen : $400/ton. = $0.4 kgs.
Price of the Cassava : $ 80/ton. = $0.08/kgr.
Optimum Nitrogen Level = 364 Kgr./ha.

CASE NO. 1 (EXERCISE 3). ESTIMATION OF OPTIMUM NITROGEN LEVELS FOR CASSAVA

Nitrogen	VMP	MFC	
250	0.4	0.36	P_y = \$0.08/Kgrs.
	>	<	
350	0.16	0.40	P_x = \$0.004/Kgrs.



(X_1, Y_1)	(350, 0.5)	(350, 0.26)
(X_2, Y_2)	(450, 0.2)	(450, 0.30)

$(Y_2 - Y_1) / (X_2 - X_1) = m$

$m\ (VMP) = (0.16 - 0.4) / (450 - 350) = \frac{0.24}{100} = -0.0024$

$m\ (MC) = (0.40 - 0.36) / (450 - 350) = \frac{0.04}{100} = 0.0004$

$Y = a + mx$

$0.4 - 0.024X = 0.36 + 0.0004X$

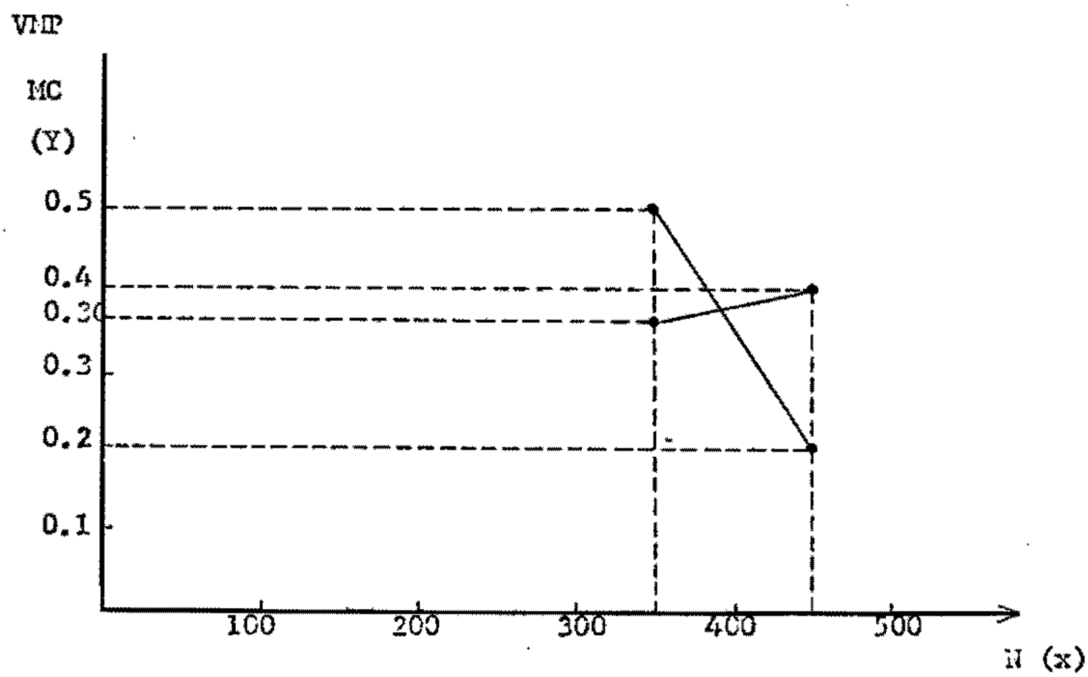
$0.04 = 0.0028\ X$

$X = 14.28$

X Cut = 350 + 14.28 = 364.3 Kgrs./Ha.

CASE NO. 1 (EXERCISE 1). ESTIMATION OF OPTIMUM NITROGEN LEVELS FOR CASSAVA.

Nitrogen Kgs/ha.	VMP	MC	
350	0.5	0.36	P_y = \$ 0.01/Kgs.
	>	<	P_x = \$ 0.04/Kgs.
450	0.2	0.40	



(X_1 , X_1)	(350, 0.5)	(350, 0.36)
(X_2 , Y_2)	(450, 0.2)	(450, 0.40)

$$(Y_2 - Y_1) \ / \ (X_2 - X_1) = m$$

$$m\ (VMP) = (0.2 - 0.5) \ / \ (450 - 350) = - \frac{0.3}{100} = - 0.003$$

$$m\ (MC) = (0.40 - 0.36) \ / \ (450 - 350) = \frac{0.04}{100} = 0.0004$$

$$Y = a + mx$$
$$0.05 - 0.003X = 0.36 + 0.0004X$$

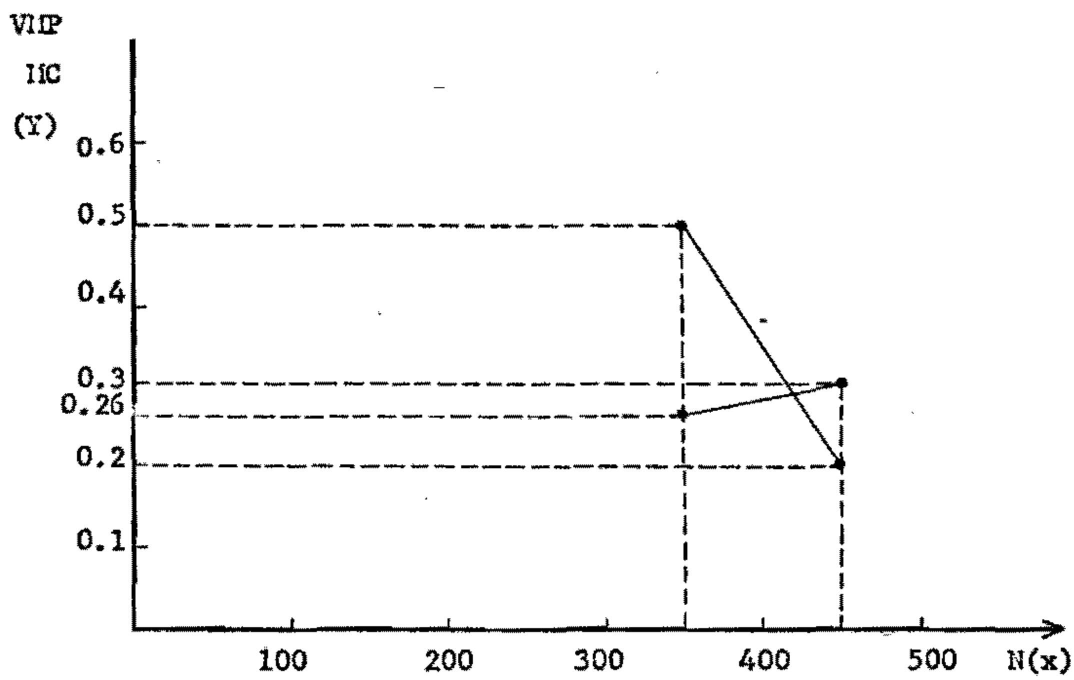
$$0.14 = 0.0034X$$

$$X = 41.17$$

$$X\ Cut = 350 + 41.17 = 391.17 \text{ Kgrs./ha.}$$

CASE No. 1 (EXERCISE 2). ESTIMATION OF OPTIMUM NITROGEN LEVELS FOR CASSAVA.

Nitrogen	VMP	MFC		
350	0.5	0.26	Py	= \$0.1/Kgrs.
	>	<	Px	= \$0.3/Kgrs.
450	0.2	0.30		



(X_1, Y_1)	(350, 0.5)	(350, 0.26)
(X_2, Y_2)	(450, 0.2)	(450, 0.30)

$$(Y_2 - Y_1) / (X_2 - X_1) = m$$

$$m\,(VMP) = (0.2 - 0.5) / (450 - 350) = -\frac{0.3}{100} = -0.003$$

$$m\,(MC) = (0.30 - 0.26) / (450 - 350) = \frac{0.04}{100} = 0.0004$$

$$Y = a + mx$$

$$0.5 - 0.003X = 0.26 + 0.0004X$$

$$0.24 = 0.0034X$$

$$X = 70.59$$

$$X \text{ Cut} = 350 + 70.59 = 420.6 \text{ Kgrs/ha.}$$

CASE NO. 2. ESTIMATION OF OPTIMUM PLANT POPULATION (HYPOTHETICAL DATA)

Benefits	Plants /ha.	Production (Kg/ha.)	Seed Cost	Planting Cost	Weeding Cost	Harvesting Cost	Others Costs	MP	VMP	MC
			($/ha.)							
50	5,000	6,000	100	50	200	100	100			
								0.8	0.08	0.023
320	10,000	10,000	200	70	170	150	100			
								0.6	0.06	0.026
495	15,000	13,000	300	80	160	180	100			
								0.4	0.04	0.024
575	20,000	15,000	400	90	160	190	100			
								0.2	0.02	0.024
565	25,000	16,000	500	100	160	200	100			
								-0.6	-0.06	0.022
190	30,000	13,000	600	110	160	200	100			

Price of the seed : $ 20/Thousands stakes. $ 0.02/stake

Price of the Cassava : $100/ton. $0.1/Kgr.

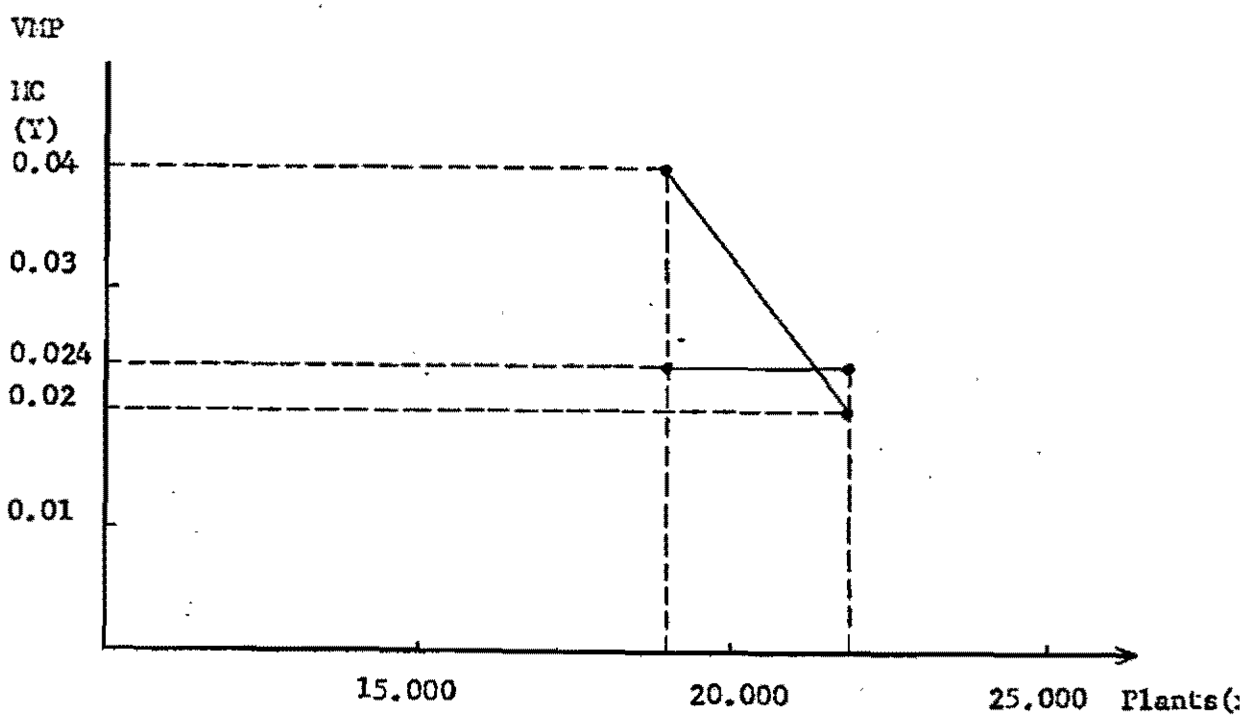
The optimum plant population per hectare is : **21.500 plants/ha.**

CASE NO. 2. OPTIMUM PLANT POPULATION

Plants/ha.	VMP	MC
15750	0.04	0.024
	>	=
22500	0.02	0.024

P_y = \$0.1 /Kgrs.

P_x = \$0.02/Stake



(X_1 , Y_1)	(15750, 0.04)	(15750, 0.024)
(X_2 , Y_2)	(22500, 0.02)	(22500, 0.024)

$(Y_2 - Y_1) \quad (X_2 - X_1) = m$

$m \text{ (VMP)} = (0.02 - 0.04) \; / \; (22500 - 15750) = - \frac{0.02}{3750} = 0.0000296$

$m \text{ (MC)} = (0.024 - 0.024) \; / \; (22500 - 15750) = \frac{0}{6750} = 0$

$Y = a + mx$

$0.04 - 0.00000296X = 0.024 + 0X$

$0.016 = 0.00000296X$

$X = 5405.40$

$X \text{ Cut} = 15750 + 5333.33$

$= 21155.40$ Plants/Ha.

CASE NO. 3. OPTIMUM NUMBER AND TIME FOR WEEDING OF CASSAVA (HYPOTHETICAL DATA)

Number of Weedings	Age of the crop	Production	Men-day/ha for weeding	Harvesting Cost	Others Costs.	Total Cost	Value of the total Product	Benefit
	(Days)	(Kg/ha.)		($/ha)				
1	30	5,000	15	95	200	340	500	160
1	60	6,000	23	100	200	369	600	231
1	90	3,000	35	70	200	375	300	-75
2	30/60	10,000	30	150	200	440	1,000	560
2	60/90	11,000	38	160	200	474	1,100	626
3	30/60/90	12,000	45	170	200	505	1,200	695
4	30/60/90/120	12,400	60	170	200	550	1,240	690

Cost of the man-day : $ 3.00

Price of the Cassava : $100/ton. $0.1/Kgr.

Number and time for weeding : 3, to the 30, 60, 90, days respectively.

CASE NO. 4. OPTIMUM TIME OF HARVEST (HYPOTHETICAL DATA)

Age for Harvesting	Production	Price of the Cassava	Harvesting Cost	Others Costs.	MP	VMP	CM
(Months)	(Kg/ha.)	($/ton)	--------($/ha)	--------			
12	10,000	100	150	300	750	75	30
14	11,500	100	170	300	550	55	27.5
16	12,600	100	185	300	300	30	25
18	13,200	100	195	300	200	20	22.5
20	13,600	100	200	300	150	15	20
22	13,900	80	200	300	100	10	20
24	14,100	80	200	300			

Alternative cost of the land : $ 20/month

Price of the Cassava : $100/ton.

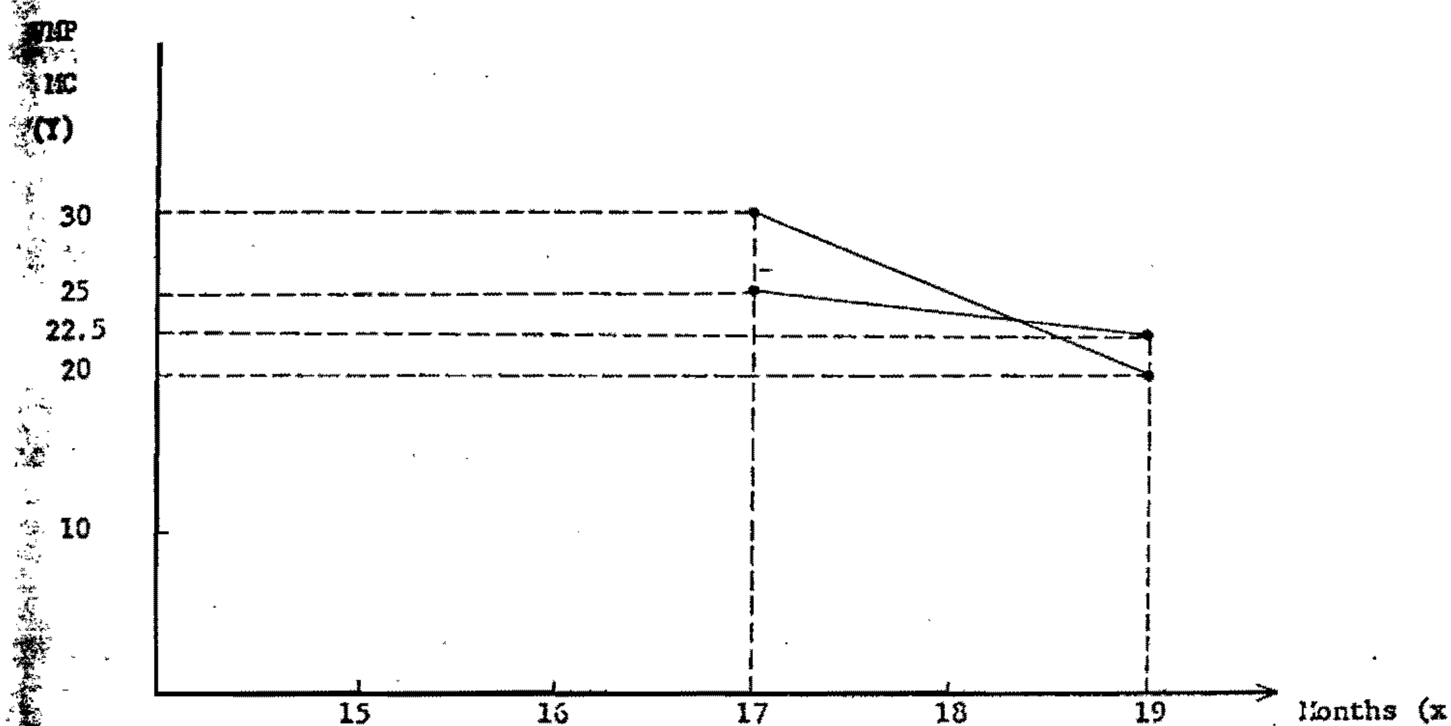
Optimum time of harvest **18.33** months

CASE NO. 4. OPTIMUM TIME OF HARVEST.

Age (Months)	VMP	MC
17	30	25
	>	>
19	20	22.5

P_y = \$ 0.1/Kgrs.

P_x = \$ 20/Month.



(X_1, Y_1)	(17, 30)	(17, 25)
(X_2, Y_2)	(19, 20)	(19, 22.5)

$(Y_2 - Y_1) / (X_2 - X_1) = m$

$m\ (VMP) = (20 - 30) / (19 - 17) = \frac{10}{2} = 5$

$m\ (MC) = (22.5 - 25) / (19 - 17) = - \frac{2.5}{2} = 1.25$

$$Y = a + mx$$
$$30 - 5X = 25 - 1.25X$$
$$X = 1.33$$
$$X\ Cut = 17 + 41.33 = 18.33\ Months$$

CHARACTERISTICS OF THE WORLD'S CASSAVA PRODUCTION WITH EMPHASIS ON LATIN AMERICA*

R. O. Díaz D.

Prologue

This report analyzes in brief form the relative importance of cassava production in relation to other agricultural products in cassava producing countries (CPC) and particularly as related to those products with which CIAT is presently working.

On the basis of historical series, the production, area, and yield of cassava are analyzed, especially for the Latin American countries, with the object of evaluating their impact on the price of the product and on the income of the producers in cases where new technology being developed generates increases in crop yield.

Information supplied by Dr. Julián Buitrago from the Swine Program, CIAT, was considered in the preparation of this report. He is thanked for his colaboration.

Introduction

The cassava producing countries of the world (1) are also responsible for 93% of the world's production of coffee and bananas and for about 80% and 70% of the world's production of sugar cane and beans, respectively (Table 1). These same countries' production of wheat is inferior to Russia's production (83.9 million tons) and superior to the production of the United States and Canada (62 million tons).

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(1) In Africa the following countries: Burundi, Central African Republic, Republic of Congo, Togo, Comoro Islands, Gabon, Ghana, Angola, Madagascar, Cameroons, Liberia, Equatorial Guinea, Ivory Coast, Nigeria, Uganda, Guinea, Ruanda-Urundi, Kenya, Niger, Senegal, Sierra Leone, Zambia, Malawi, Mali, Gambia, Chad, Somalia, Upper Volta, Benin (Nigeria) Zaire, and Sudan.

Asia includes: Thailand, Indonesia, Malaysia Sabah (No. Borneo), North Vietnam, Timor Islands, West Malaysia, South Vietnam, The Philippines, India, Laos Burma, Cambodia, China, Sarawak, Sri Lanka.

Oceania includes: Tonga, Figi, Trust Territory of the Pacific Islands, New Caldonia, Papua, and New Guinea.

Latin America includes: Brazil, Colombia, Paraguay, Ecuador, Venezuela, Cuba, Haiti, Perú, Argentina, Dominican Republic, Bolivia, Honduras, Jamaica, Panama, Nicaragua, Guatemala, Costa Rica, El Salvador, Puerto Rico and French Guiana.

* Internal Document of the Cassava Program, May 1977. Preliminar

The production of maize in the cassava producing countries is very inferior to that of the United States (118.5 million tons) and the production of potatoes is very similar to that of Poland (48.5 million tons).

In production of sorghum, the cassava producing countries do not reach twice the production of the United States, the main world supplier (16 million tons), but in soybean the production of the cassava growing countries is very inferior to that of the United States, 33.1 million (56% of the world's production). In relation to meat, the United States produces 10.7 million tons while the cassava producing countries only 9 million tons.

It can be concluded that the main source of animal and vegetable protein are not produced by the cassava producing countries, but rather in developed countries. Furthermore, cassava and rice, with the exception of sugar cane, are the main sources of energy in all these countries.

In relation to CIAT's commodities, (cassava, beans, maize, rice) the area planted to cassava in 1974, was equivalent to only 2% of the plowable agricultural surface of all the cassava producing countries; for beans it was 3%, maize 8%, and rice 18% (FAO 1975).

In the cassava producing countries in Latin America, the area planted to cassava is equivalent to 2.4% of the total plowable agricultural surface, to beans 5%, maize 18% and rice 6%.

Comparing the world's production of these crops, in 1974 (Table 1) in terms of dry matter volumes (2), the following yields were attained: 286 million tons of rice, 246 million tons of maize, 36 million tons of cassava, and finally, 11 million tons of beans (3). In spite of the fact that cassava has a high composition of water, the total dry matter volume produced was three times superior to the dry matter volume of beans produced in the world.

AREA AND PRODUCTION

World production of cassava in 1974 was estimated at 103 million metric tons. During the period from 1964 to 1974, production increased 2.9 percent annually (Table 3). Area planted in 1974 was 11 million has, representing an annual increase of 2.14 percent from 1964 (Table 4). Average yield per hectare was 9.3 tons in 1974 and the rate of yield increase from 1964 was of 0.8 percent (Table 5). An increase in both production and area planted is evident, as is a slight increase in yield.

Asia and Latin America accounted for 29% each of the world production of cassava, and Africa produced 42% (Table 3). Area harvested was as follows: Africa 51%, Asia 26%, Latin America 23% (Table 4).

(2) Based on the following humidity indexes for each product: cassava 65%, beans and maize 13% and rice 11%.

(3) Estimated rom Table 1.

FIGURE 1. Production zones and area planted to cassava (1,000 hectares) in Latin American producing countries, 1974.

Sources: Production zones: personal communication from scientists in CIAT's Cassava Program.

Planted area: FAO, 1975. Anuario de Producción, Vol. 29.

This reflects a very low average yield for Africa, 7.6 ton/ha in comparison with 10.4 ton/ha for Asia and 11.7 ton/ha for Latin America (Table 5) (4).

The average yield in Asia, Oceania and Lain America is above the average world yield, while that of Africa is slightly below.

Compared with the rest of the producing continents of the world, few problems arise in Africa caused by the presence of insects or diseases (Lozano and Booth 1974), in spite of the fact that mosaic, a viral disease has been reported to be exclusive to Africa (Terry 1974). Thus, the main cause for low yields in Africa are due to the lack of adequate cultural practices for cassava farming.

Brazil attained one fourth of the world production of cassava, followed in importance by Indonesia, Nigeria and Zaire with one tenth each. In latin America only two more countries, Colombia and Paraguay, produced at least 1% of the total cassava harvested (Table 6).

Latin America produced 30 million tons, with an annual growth rate for the last 10 years of 1.1 percent. The distribution of this production was Brazil 83%, Colombia and Paraguay 4% each, and Ecuador and Peru 1% each (Table 3).

A slightly decreasing rate in cassava production is evident in countries such as French Guyana, Paraguay, Panama, Venezuela, Puerto Rico and Argentina (Table 3). There is no information available to explain this trend.

Cassava is grown under traditional systems, primarily in farms no larger than 1 ha, associated or mixed mainly with maize (Table 7). In some countries of Asia and Africa it has been cultivated as a secondary crop, in the shade of coconut or african palm plantations. This practice has decreased in the last years. In Latin America it is common to intercrop cassava with semestral crops.

In the majority of the Latin American countries (Figure 1) such as Ecuador (Varón 1975), Venezuela (Arias 1975), Paraguay (Belloti 1977) and Guatemala (Funegalli 1975), cassava is planted in small plots along with other crops of short vegetative period. In Perú (Rosas 1975) cassava is planted alone in family farms on small plots or occasionally intercroped with maize or plantain.

The following conclusions can be stated in relation to area planted and world production of cassava: (1) the largest area planted is found in Africa with slightly low yields resulting from traditional and rudimentary production techniques, and (2) the majority of cassava production is done in plots no larger than 1 ha, established mixed or intercroped with other semestral crops, primarily maize.

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(4) Yields estimated based on the relation between production (tons) and area (has).

Annual Production per Capita

Per capita production of cassava in cassava producing countries was ten times larger than the per capita production of beans, slightly superior to that of maize and a little less than half that of rice (Table 8).

Compared with other agricultural crops grown in the cassava producing countries, cassava per capita production was slightly superior to that of wheat and potatoes and close to four times larger if compared with sorghum and soybean.

The African continent had the highest per capita production of cassava, but, along with Asia and Oceania, the smallest per capita production of meat (Table 8). Asia was estimated to have the highest per capita production of rice - 138 kgr person/year. This comparison is relevant in that it points out Asia as having an advantageous position in relation to the availability of protein sources - rice has 8% digestible protein and cassava only 1% (Gutierrez and Buitrago 1974).

The production of cassava decreased in the last ten years at a rate slightly inferior to the rate of population growth in the cassava producing countries (1.5% vs. 2.3%), resulting in a decreasing annual growth of production per capita (Tables 9 and 10).

In comparing the cassava producing countries (Table 11), Burundi, the Central African Republic and Congo show the largest per capita production of cassava, followed by Paraguay. Important in Latin America were also Brazil, Ecuador, French Guyana and Colombia (5).

The situation with cassava is similar to that of all agricultural crops produced in the tropics, where the population grows at a slightly higher rate than the production of any of these crops.

AVAILABILITY

Apparent Availability of Calories

Presently the most important use for cassava is human consumption. It has been estimated that 56% of the world's production is destinated to human consumption (Nestel 1974).

Given its low level of protein content, cassava is only used as a source of energy either for human consumption or for the elaboration of concentrates.

Compared with wheat, maize and rice (Table 12), cassava presents the least apparent availability of digestible calories. In the cassava

(5) These figure were computed dividing the production figures in Table 1 by the population data in Table 6.

producing countries, the apparent per capita availability of calories in cassava was 153, inferior to that of rice and maize (1121 and 366) and superior to that of beans, barley, sorghum and banana (33, 90, 110 and 40).

Cassava participated only with 5% of the digestible caloric requirements in the cassava producing countries. In Africa, Oceania and Latin America the caloric requirements supplied by cassava are close to 16% and in Asia it is very low, only 2% (Table 13). In only three Latin American countries did cassava participate above 8% of the digestible caloric daily requirement per person; Paraguay 55%, Brazil 30%, and Ecuador 8%.

At the continental level it has been observed that Africa presented the largest per capita production of cassava and the lowest per capita production of meat and rice. This inverse relation has not been very marked in Latin American countries (Table 14). As the participation of cassava as a source of calories increases in these countries, the availability of animal or vegetable protein sources does not present any tendency.

Animal Feed

Available information indicates that cassava for animal feed is concentrated in the European Common Market (Phillips 1974). If cassava prices, as compared to other grains, are favorable, good perspectives exist for the future, especially in those countries with deficiency of energy sources.

Presently more than 90% of Thailand's production of cassava is consummed in Europe, practically monopolizing the European Common Market demand (Boonsue and Sinthuprama 1975). Thailand first exported its cassava in chips (6); lately they are exporting it in pellets.

Indonesia, another large producer of tuberous in the world, has not been able to cope the world demand for cassava, and cassava products primarily because of the fluctuations in the domestic consumption levels of this product. In Malaysia, another asiatic country, high production costs have difficulted the exporting of cassava derivatives, but the internal demand for animal feed has shown a fast growth rate (Firman Manurung 1974). In Latin America only Brazil has exported 2% of its cassava production in the form of flower, starch "tapioca", and chips (Phillips 1974).

Nestel (1974) indicates that the actual potential of cassava in the animal feed industry seems to lie in these same producing countries, especially in those where the pressure of the demand creates an increase in the price of those products used in the manufacture of concentrates, and where a market for meat quality is being developed.

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(6) Denominated "raspas" in Portuguese and "tajadas" in Spanish.

Nestel's theory coincides with the situation presented by some Latin American countries such as Panama, Costa Rica, Colombia, and Venezuela, where dehydrating plants have been installed for producing flower from cassava pellets. In the State of Monagas, Venezuela, a recently established 360 ton/day plant for the production of cassava pellets is dedicated primarily to supplying the local market with raw materials for the animal industry (Agroindustrial 1977).

The goals of the recent cassava flower industry in Latin America coincide with the doubts raised by various experts in animal nutrition (Buitrago et al 1975) in relation to the potential in cassava and its derivatives as a source of energy for animal feed. The demand for grains, seeds, oleaginous, and other energy and protein sources for the preparation of concentrate feed in Latin America will increase notoriously. Thus, the competition for products for animal feed is becoming more critical.

The potential of cassava as a source of energy is being recognized in some Latin American countries. Rosas (1975) shows that in Peru the demand for fresh cassava has undergone a slight increase in the last years; to the point that every significant increase of the area cultivated is subject to the establishment of flower or starch producing industries. In Guatemala (Fumagalli 1975) there are potential areas for increasing the production of cassava but not for industrial purposes as in this country currect production satisfies the domestic demand for human consumption and the needs of the small industry.

Starch Industry

The relative importance of the different kinds of starch varies from region to region (Phillips 1974). Starch from maize is more important in the United States and Canada, from potatoes in Europe, from sweet potatoes and rice in Japan and the Far East. The best markets for cassava starch are found in Japan, the United States and Canada, but in these countries cassava has contributed less than 10% of the total starch used.

Cassava starch is preferred as raw material for numerous products, e.g. for sizing in the linen and glue industries. Starch can be obtained from maize, potatoes, sweet potatoes, rice, sorghum, waxi maize, West-Indian sago, and cassava. Sago cannot be grown in the tropics as it has a long vegetative period, 8 to 10 years. Potatoes grow in temperate zones and along with rice, are a basic element in the diet. Another basic element in the diet of tropical countries is maize, which is presently processed economically to produce starch.

The feasibility of commercially producing starch from cassava is uncertain, nevertheless, it is important to bear in mind projections estimated by Phillips for the total cassava starch demand until 1970 and the decade following, showing an annual growth rate fluctuating from 2 to 16%.

In Latin America only Brazil on a big scale and Colombia on a small scale produce cassava starch with low impurity content. In this continenc the production of starch from cassava has been in the hands of small industries with rudimentary technology.

IMPLICATIONS

As of today, three different markets have been identified for the farming of cassava, according to the investigations carried out by Phillips (1974): starch and animal feed industries, discussed in general in this report, and human consumption where the situation is slightly different.

Taking Colombia as an example, where 95% of the cassava produced is used for human consumption and the rest goes to the industrial sector, primarily for starch (Diaz and Pinstrup-Andersen 1977), the following has been observed: The area planted to cassava has varied year after year (Table 15), with an increasing tendency during the last 20 years (7) (Figure 2). The average annual increase in production was estimated to be 28,080 tons (8); however, yield has been almost constant with a slight annual increase of only 60 Kg/ha (9). That is to say, the gradual increases presented in cassava production are primarily due to growths in cultivated area.

In relation to prices (Table 16), for the last 18 years, the currect price has increased annualy by $70.34 per ton (10) and, at constant prices, the annual increase has been approximately $1 per ton (12). No creditable data is available on cassava prices in more recent years but it is known that they have risen at a very high rate, primarily due to adverse climatic conditions present in the latter years in all agricultural areas in Colombia.

Since (1) the increase in cassava production is a result primarily of an increase in area planted, (2) actual prices have been practically constant throughout the period (Figure 3), and (3) the majority of cassava produced is used directly for human consumption, it can be assumed that both supply from the farmers and demand for human consumption has increased proportionally with population growth. But besides population growth, increase in income per capita has also influenced cassava consumers demand (13).

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(7) Area equation (Y) = 95.47 + 2.99x, R= 0.83
(8) Production equation (Y) = 560.75 +23.03x, R = 0.76
(9) Yield equation (Y) = 5.98 + 0.06x, R = 0.46
(10) Current price equation (Y) = -60.65 70.34x, R= 0.94
(11) Prices deflated by the price index of the Central Bank.
(12) Constant price equation (Y) = 67.15 + 1.37x, R= 0.60
(13) Total demand growth rate is equal to the population growth rate, plus the elasticity in demand for the product multiplied by the growth rate of income per capita.

According to empirical estimates available (Pinstrup Andersen, Per et al 1976), the increase in consumer's income should not have a major impact on demand for cassava since it is primarily consumed by persons of low income (14). In other words, people consume more cassava as their income increases, but only to a certain point. From then on this product behaves as an "inferior good".

Assuming that the population in Latin America will increase at a rate of 2.5% in the next decade and that the per-capita income will increase at a rate of 2% (Sanders and Alvarez 1977), cassava production can increase at a rate of 2.7% without affecting prices. The annual cassava production rate of growth for Latin America in the last decade was 1.23%.

An increase in the production of cassava above 3% would be sufficient to cause a decrease in prices occasioning a reduction in net profits of the producing sector thus diminishing the stimulus to future production.

A solution would be to reduce cassava prices to levels competitive with those of other products, primarily of the starch and flower markets. Thus, a competitive price level would be attained, maintaining acceptable profits for the producers if cassava yields could be increased through simple and inexpensive technology. For the case of Mexico where cassava shows a very low popular consumption, the solution suggested has been to increase the area planted to cassava for industrial purpose, especially for concentrates.

Besides being an energetic supplement in animal concentrates, cassava may be a potential substrate in the production of protein from a fungus (Nestel 1974). By means of this bilogical process the level of protein in cassava could be increased up to 35% (15).

The economic feasibility of producing alcohol from cassava is being studied in Brazil. This is a very important aspect in terms of the present worldwide energetic crisis.

Recent studies show that bread or bread-type products can be elaborated with formulas containing cassava flower or starch as the basic ingredient, replacing wheat flower (Knight 1974). In countries such as Paraguay and Brazil there are laws obliging bread producers

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(14) The elasticity income for cassava demand in Cali, Colombia has been estimated at 0.1185 (Pinstrup Andersen, P.N. de Londoño and E. Hoover 1976). The impact of increasing food supply on human nutrition. Implication for commodities priorities in agricultural research and policy. American Journal of Agricultural Economics, 58(2), May 1976, p. 131-142.

(15) See Gomez, G.G. for more detailed information on this process.

to use a percentage of cassava flower in making bread. In Colombia there are advanced studies on the use of cassava flower in the elaboration of bread and noodles; however the problem here is the scarcity of the product with consequent favorable prices for the fresh root.

CONCLUSIONS

According to information available it seems that the best perspective for developing the industry of concentrates is the use of cassava as an energy source for the domestic market. This implies (1) producing countries must think more in satisfying the domestic market than in exporting concentrates, given good comparative prices, and (2) reduce cassava prices to levels competitive with the prices of other substitute products.

Finally, and in spite of the fact that the market for exported starch is very uncertain, this line is very interesting and must be studied closely in producing countries as the sub-products of this process are very useful in the concentrate industry.

FIGURE 2. — TRENDS IN CASSAVA PRODUCTION, AREA AND YIELD
1955 - 1975

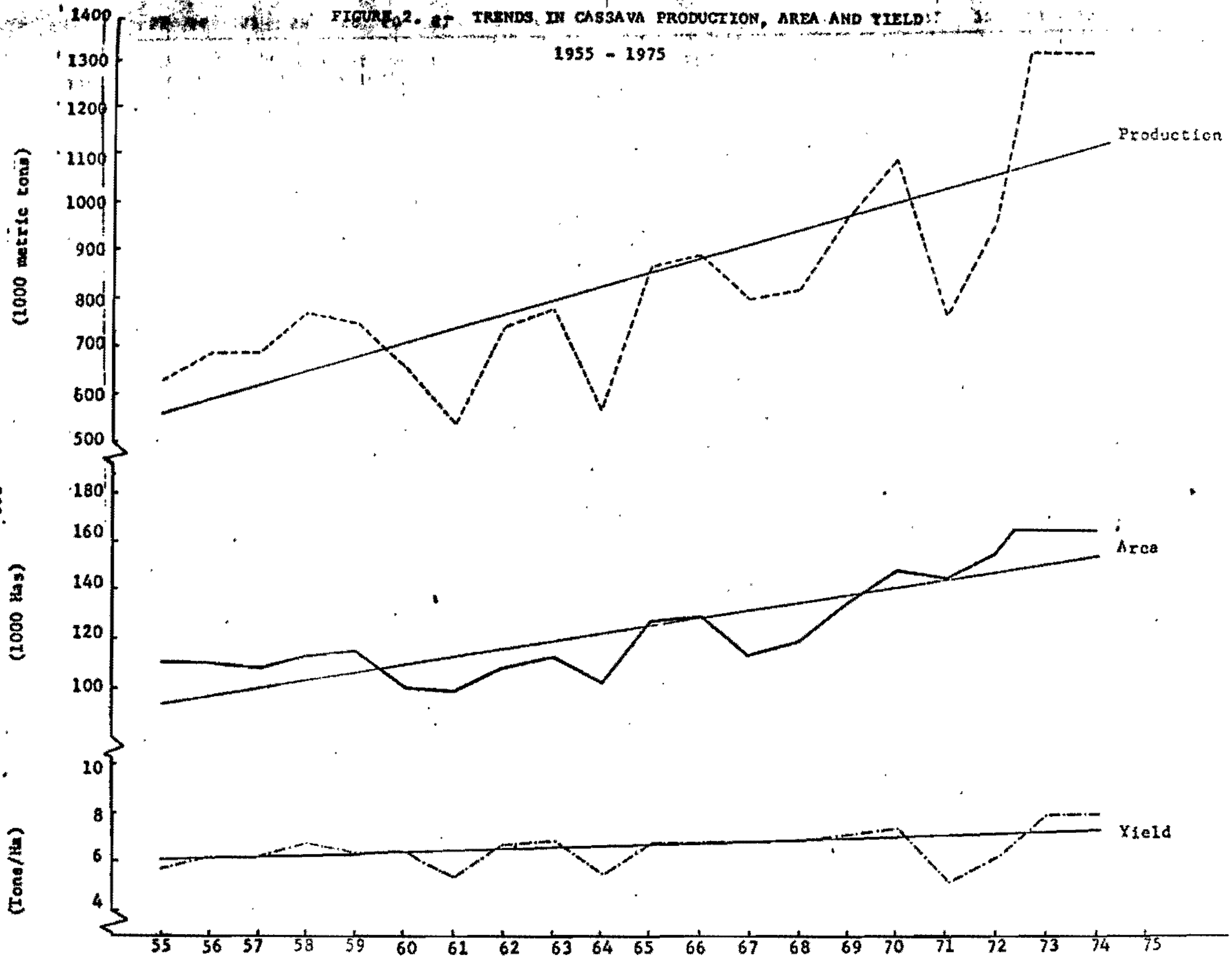

FIGURE 3. TRENDS IN CASSAVA PRICES

1955 - 1974

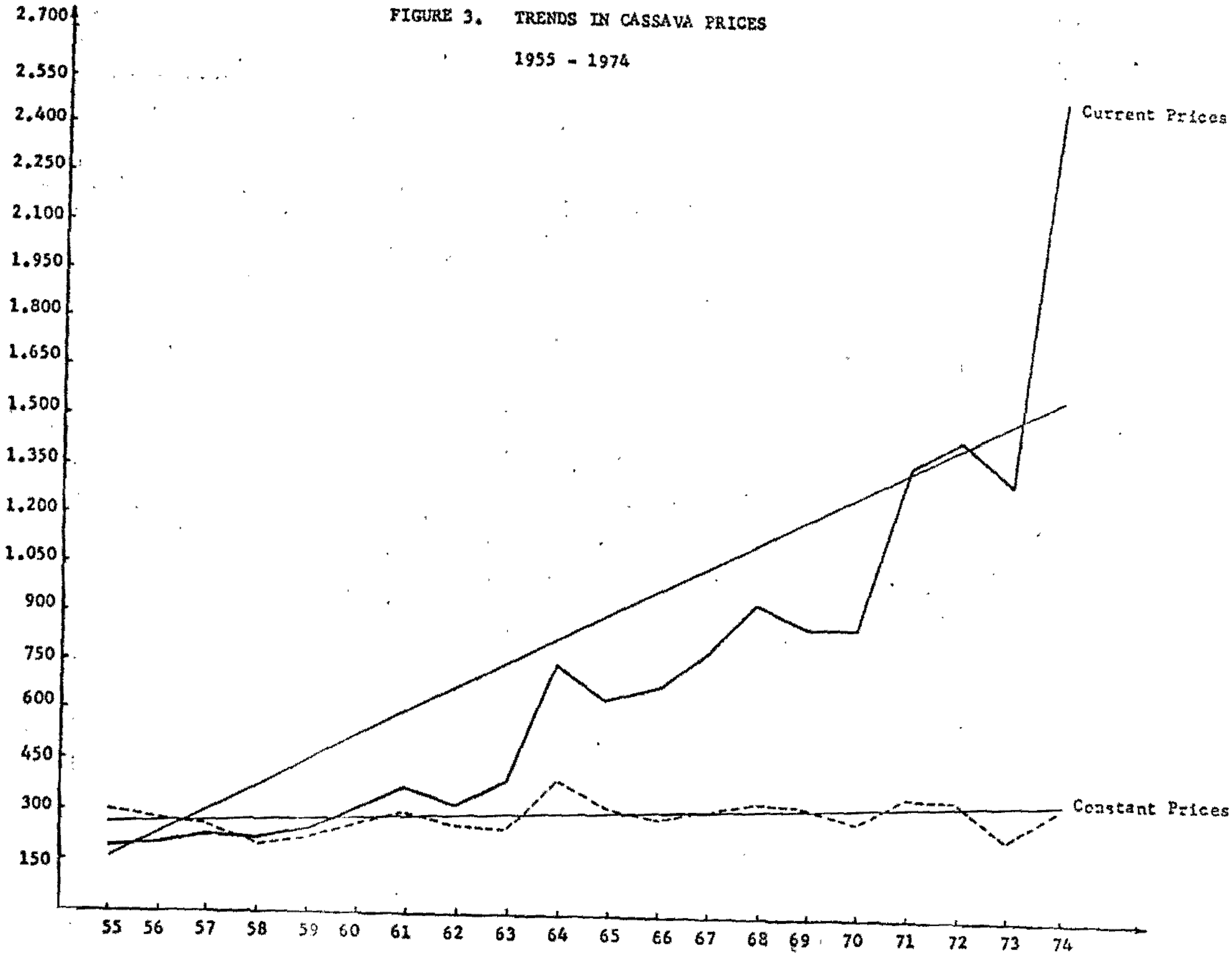

Table 1. Annual production of some important agricultural crops in the cassava producing countries. (Millions of tons) 1974.

Region	Wheat	Barley	Dry Beans	Maize	Rice	Sugar Cane	Potatoes	Cassava	Cotton (Fiber)	Sorghum	Soy-bean	Coffee	Bananas	Meat
A.L. a/	9.2	0.9	2.9	31.9	10.8	250.0	8.5	29.7	4.0	7.6	8.7	2.9	18.7	5.8
AS. b/	58.8	22.9	5.0	45.7	242.2	236.8	43.2	29.6	10.4	10.5	12.7	0.3	9.5	2.0
AF. c/	0.5	0.02	1.0	9.3	4.7	16.1	1.2	43.7	1.9	8.1	0.1	1.1	4.7	1.2
OC. d/	h/	h/	h/	0.005	0.02	2.6	0.004	0.2	h/	0.004	h/	0.04	0.9	0.009
TCPC. e/	68.5	23.8	9.0	86.9	257.7	505.5	52.9	103.0	16.3	26.2	21.5	4.5	33.8	9.1
TW. f/	360.0	171.0	12.6	294.3	321.0	655.7	296.2	103.0	39.8	50.3	56.9	4.8	36.4	42.3
% g/	19.0	13.9	71.2	29.5	80.3	77.1	17.8	100.0	41.0	52.0	37.7	92.7	92.9	21.4

a/ L. A. Latin America

b/ AS. Asia

c/ AF Africa

d/ OC Oceania

e/ TCPC Total Cassava Producing Countries

f/ TW Total world

g/ % Percentage of the Cassava Producing Countries in relation to the world total.

h/ Data is not available.

SOURCE: FAO 1975 : Production Yearbook Vd. 28-1

Table 2. Annual production of some important agricultural crops in the cassava producing countries and other countries of the world. (Millions of tons) 1974.

Product	1st country Name	Mill. Tons	2nd country Name	Mill. Tons	3rd country Name	Mill. Tons	Total World Mill. Tons
Wheat	U.S.S.R.	83.9	United States	48.3	China	37.0	359.9
Barley	U.S.S.R.	54.2	China	20.5	France	9.9	170.9
Dry Beans	India	2.5	Brazil	2.2	China	2.0	12.5
Maize	United States	118.5	South Africa	11.2	Brazil	17.3	294.3
Rice	China	115.3	India	60.4	Indonesia	22.8	321.0
Sugar Cane	India	140.9	Brazil	96.4	Cuba	56.0	655.9
Potatoes	U.S.S.R.	81.0	Poland	48.5	China	38.0	296.1
Cassava	Brazil	24.7	Nigeria	10.0	Indonesia	13.8	102.9
Cotton Cake	U.S.S.R.	8.4	United States	6.6	China	6.4	39.8
Sorghum	United States	16.0	India	10.2	Argentina	6.1	50.3
Soybean	United States	33.1	China	11.8	Brazil	7.8	58.8
Coffee Pulp	Brazil	1.6	Colombia	4.6	Ivory Coast	2.6	4.8
Bananas	Brazil	7.0	Ecuador	3.4	India	3.2	36.4
Meat	United States	10.7	U.S.S.R.	6.4	Argentina	2.2	42.2

SOURCE: FAO 1975, Production Yearbook. Vol. 28-1

Table 3. Cassava production (thousands of metric tons) in Latin American countries total in Africa, Asia, Oceania, Latin America and World Total 1964 - 1974

Country	1964	1974
Brazil	24356	24715
Colombia	700	1320
Paraguay	1449	1109
Peru	497	485
Ecuador	189	424
Argentina	240	299
Venezuela	312	293
Bolivia	150	270
Cuba	200	234
Dominican Republic	153	205
Haiti	120	144
Honduras	16	44
Panama	45	40
Nicaragua	12	18
El Salvador	8	15
Jamaica	8	15
Costa Rica	7	10
Guatemala	3	7
Puerto Rico	6	5
French Guiana	6	4
TOTAL		
Africa	20727	43473
Asia	18978	29638
Oceania	113	217
Latin America	28502	29656
Total CPC **	68320	102984

* Excluding Barbados, Trinidad & Tobago, Guadeloupe, Martinique, Surinam and Guiana, as there is no information available for some periods.

** Total Cassava Producing Countries.

SOURCE: FAO 1975. Production Yearbook, Vol. 29.

Table 4. Area planted to cassava (thousands of hectares) in Latin American countri
total for Africa, Asia, Oceania, Latin America and World total 1964 - 197

Country	1964	1974
Brazil	1716	1989
Colombia	125	165
Paraguay	103	80
Ecuador	24	49
Venezuela	25	40
Peru	50	38
Cuba	30	35
Haiti	30	34
Argentina	21	23
Bolivia	9	21
Dominican Republic	15	20
Honduras	5	6
Panama	6	5
Nicaragua	3	4
Guatemala	1	3
Jamaica	3	2
Costa Rica	3	2
El Salvador	1	1
Puerto Rico	2	1
French Guiana	1	1
TOTAL		
Africa	3461	5636
Asia	2228	2853
Oceania	10	20
Latin America	2174	2519
Total CPC**	7873	11028

* Excluding Surinam, Barbados, Guadeloupe, Martinique, Trinidad & Tobago, and Guiana, as there is no information available for some periods.

** Total Cassava Producing Countries.

SOURCE: See Table 1.

Table 5. Average cassava yield (tons/ha) in Latin American countries, total for Africa, Asia, Oceania, Latin America and World Total 1964 - 1974*

Country	1964	1974
El Salvador	8.0	15.0
Paraguay	14.1	13.9
Argentina	11.4	13.0
Bolivia	16.6	12.9
Peru	9.9	12.8
Brazil	14.2	12.4
Dominican Republic	10.2	10.2
Ecuador	7.8	8.6
Panama	7.5	8.0
Colombia	5.6	8.0
Jamaica	2.6	7.5
Venezuela	12.0	7.3
Honduras	3.2	7.3
Cuba	6.6	6.7
Costa Rica	2.3	5.0
Puerto Rico	3.0	5.0
Nicaragua	4.0	4.5
Haiti	4.0	4.2
French Guiana	6.0	4.0
Guatemala	3.0	2.3
<u>Total</u>		
Africa	5.9	7.7
Asia	8.5	10.4
Oceania	11.3	10.4
Latin America	13.1	11.7
Total Cassava Producing Countries	8.7	9.3

* Excluding Surinam, Barbados, Guadeloupe, Martinique, Trinidad & Tobago, and Guiana, as there is no information available for some periods.

** Total Cassava Producing Countries.

Average yield estimated on the basis of area and production data supplied by FAO, 1975, Production Yearbook, Vol. 29.

Table 6. Countries showing cassava production (thousands of metric tons) equivalen to at least one percent of the world production, 1974

Country	Production	Percentage of World Production
Brazil (Latin America)	24715	24
Indonesia (Asia)	13775	11
Nigeria (Africa)	10000	10
Zaire (Africa)	8879	9
India (Asia)	6421	6
Thailand (Asia)	6240	6
Burundi (Africa)	4000	4
Tanzania (Africa)	3500	3
Mozambique (Africa)	2400	2
Ghana (Africa)	1770	2
Angola (Africa)	1640	2
Madagascar (Africa)	1378	1
Colombia (Latin America)	1320	1
Paraguay (Latin America)	1109	1
Central African Republic (Africa)	1100	1
Sudan (Africa)	1100	1
Uganda (Africa)	1100	1
Total CPC*	**102984**	**100**

*** Total cassava producing countries.**

SOURCE: FAO Production Yearbook, Vol. 29.

Table 7. Farming systems in some of the countries having a production of cassava of at least one percent of the total world production, 1974

Country	Type of Farming
Brazil (a) (Latin America)	1. Monoculture. Commercial planting for industrial use. 2. Culture intercropped with maize, sorghum, beans in the majority of family farms in the northeast.
Nigeria (b) (Africa)	1. Monoculture. 2. Cultures of African Palm and cassava (cassava becomes a weed).
Indonesia (c) (Asia)	1. Monoculture. Commercial planting. 2. Intercropped. 58% of growers, primarily with maize (one half), legumes or annual crops or other crops.
India (d) (Asia)	1. Monoculture.- Commercial planting. 2. Cassava is intercropped, the majority is produced by small farmers. 3. A small proportion is planted in the shade of coconut palm.
Thailand (e)	1. Monoculture. Primarily commercial. 2. Intercropped with young plantations of rubber, primarily in the south.
Ghana (b) (Africa)	1. Monoculture. 2. The majority in parcels of cassava and maize.
Colombia (f) (Latin America)	1. Monoculture. 68% of the area planted. 2. Cassava, maize, 13% of the are planted. 3. Cassava, beans, plantains, coffee and sesame, 19% of area planted.
Paraguay (g) (Latin America)	1. Most of the farmers in the country plant cassava in small parcels along with other crops.
Uganda (b) (Africa)	1. Monoculture. Small scale. 2. The majority of cassava is intercropped.
Cameroons (b) (Africa)	1. Monoculture. Small scale. 2. The majority of cassava is intercropped.
Togo (b) (Africa)	1. The majority planted in small parcels along with legumes, maize, rice, sorghum.
Peru (h) (Latin America)	1. The majority are small family farms with small cassava parcels. 2. Occasionaly cassava is intercropped with maize or plantains.
Philippines (i) (Asia)	1. The majority of cassava is intercropped with coconut palm or maize.

Table 7. (continued)

a/ Toro, J.C. 1977. Personal communication, CIAT, Colombia.

b/ Terry, E.R. and R. MacIntyre (ed). The International Exchange and testing of cassava Germ Plasm. Proceedings of an interdisciplinary workshop held at IITA, Ibadam, Nigeria, 17-21. November 1971. 1971. IDRC 063e. Ottawa, 59 p.

c/ Poespodarsono, S. A. Winarno and P. Wijoyo. 1976. Survey on Mukibat cassava in East Java In: Nugroho, 11 (ed) Brawijaya University, Malang, Indonesia. IDRC. Ottawa, p. 3.

d/ Home, A. 1974. Tapioca. A case study of India with particular reference to Kerala. In: Phillips, T.P. Cassava utilization and potential markets. IDRC. 020e. Ottawa, Canada, 107-125 p.

e/ Boonsue, B. and S. Sinthuprama 1975. Thailand In: Nestel B. and R. MacIntyre. International Exchange and Testing of cassava Germ Plasm. Proceedings of an interdisciplinary workshop held at CIAT, Palmira, Colombia, 4-6 February 1975. IDRC. 049e. p. 26-28.

f/ Díaz, R. O. y P. Pinstrup-Andersen, 1974. Descripción agroeconómica del proceso de cultivar yuca en Colombia. CIAT, Palmira, Colombia (in press).

g/ Belloti, A. 1977. Personal communication, CIAT, Colombia.

h/ Rosas, J.C. 1975. Perú. In: Nestel B., and R. MacIntyre (ed). International Exchange and Testing of cassava Germ Plasm. Proceedings of an interdisciplinary workshop held at CIAT, Palmira, Colombia, 4-6 February 1975. IDRC. 049e. p. 15-16.

i/ Carpena, A.L. and D.P. Baldos 1975. Phillipines. In: Nestel, B. and R. MacIntyre (ed). International Exchange and Testing of cassava Germ Plasm. Proceedings of an interdisciplinary workshop held at CIAT, Palmira, Colombia, 4-6 February 1975. IDRC. 049e. p. 23-24.

Table 8. Annual per capita production of some important agricultural crops in the cassava producing countries of the world, 1974*.

Region	Wheat	Barley	Dry Beans	Maize	Rice	Sugar Cane	Potatoes	Cassava	Cotton (Fiber)	Sorghum	Soy-bean	Coffee	Bananas	Mea
LA. a/	38.39	3.58	11.86	132.63	44.67	1039.21	35.41	123.27	16.57	31.74	36.25	12.22	77.85	24.
AS. b/	33.61	13.07	2.88	26.12	138.45	135.35	24.67	16.94	5.96	5.98	7.23	0.19	5.41	1.
AF. c/	1.97	0.10	4.19	37.45	18.93	64.81	4.75	174.79	7.50	32.40	0.29	4.59	17.57	4.
OC. d/	f/	f/	f/	1.41	6.48	730.22	1.13	61.11	f/	1.13	f/	11.16	246.97	2.
TCPC. e/	30.56	10.59	4.00	38.76	114.93	225.44	23.58	45.92	7.27	11.67	9.57	1.98	14.92	4.

(a) A.L. Latin America

(b) AS. Asia

(c) AF. Africa

(d) OC. Oceania

(e) TCPC. Total Cassava Producing Countries

(f) Non-available data.

* Index estimated on the basis of production and population data.

Table 9. Population (thousands of persons) in cassava producing countries in Latin America, total for Africa, Asia, Oceania, Latin America and World total 1964 - 1974. *

Country	1964	1974
Brazil	80216	106659
Colombia	18086	25088
Argentina	21869	25051
Peru	11124	14887
Venezuela	8818	11862
Cuba	7646	9285
Ecuador	4929	6867
Guatemala	4475	5952
Bolivia	4148	5275
Dominican Republic	3588	4951
Haiti	3888	4483
El Salvador	2857	3983
Honduras	2141	2933
Puerto Rico	2580	2868
Paraguay	1965	2572
Nicaragua	1653	2243
Jamaica	1742	1999
Costa Rica	1445	1940
Panama	1223	1631
French Guiana	39	58
Total		
Africa	192481	248709
Asia	1418673	1749642
Oceania	2795	3551
Latin America	184432	240587
Total Cassava Producing Countries	1798381	2242489

*Excluding Barbados, Trinidad & Tobago, Guiana, Surinam, Martinique, Guadeloupe, as there is no information available for some periods.

SOURCE: FAO 1975. Production Yearbook, Vol. 29

Table 10. Annual per capita production of cassava (kilograms) in Latin America countries, total for Africa, Asia, Oceania, Latin America and total for cassava producing countries, 1964 - 1974. *

Country	1964	1974
Paraguay	737.40	431.18
Brazil	303.63	231.72
French Guiana	153.85	68.97
Ecuador	38.34	61.74
Colombia	38.70	52.61
Bolivia	36.16	51.18
Dominican Republic	42.64	41.41
Peru	44.68	32.58
Haiti	30.86	32.12
Cuba	26.16	25.20
Venezuela	35.38	24.70
Panama	36.79	24.52
Honduras	7.47	15.00
Argentina	10.97	11.94
Nicaragua	7.26	8.02
Jamaica	4.59	7.50
Costa Rica	4.84	5.15
El Salvador	2.80	3.77
Puerto Rico	2.33	1.74
Guatemala	0.67	1.18
TOTAL		
Africa	107.68	174.79
Asia	13.38	16.94
Oceania	40.43	61.11
Latin America	154.54	123.27
Total CPC **	37.99	45.92

* Excluding Barbados, Guiana, Guadeloupe, Martinique, Surinam, and Trinidad & Tobago, as no information is available for certain periods.

** Total cassava producing countries

Index estimated on the basis of production data (Table 2) and population data (Table 8).

Table 11. Annual per capita production of cassava (kilograms) for those countries having an index greater than the world per capita production, 1974*.

Countries	Production per capita	Production Index per capita
Burundi (Africa)	1009.51	2198.41
Central African Republic (Africa)	627.85	1367.27
Republic of Congo (Africa)	462.65	1007.51
Paraguay (Latin America)	431.18	938.98
Zaire (Africa)	371.72	809.49
Togo (Africa)	343.09	747.15
Comoro Islands (Africa)	335.57	730.77
Gabon (Africa)	326.30	710.58
Mozambique (Africa)	265.81	578.85
Tonga (Oceania)	265.31	577.77
Angola (Africa)	264.35	575.68
Benin (Africa)	240.72	524.22
Tanzania (Africa)	233.80	509.15
Brazil (Latin America)	231.72	504.60
Madagascar (Africa)	177.01	385.47
Nigeria (Africa)	163.35	355.73
Figi (Oceania)	157.24	342.42
Liberia (Africa)	155.97	339.66
Thailand (Asia)	153.19	333.60
Equatorial Guinea (Africa)	150.82	328.44
Ivory Coast (Africa)	131.27	285.87
Camerrons (Africa)	127.43	277.50
Indonesia (Asia)	103.93	226.33
Uganda (Africa)	99.84	217.42
Guinea (Africa)	97.47	212.26
Ruanda (Africa)	88.08	191.81
French Guiana (Latin America)	68.97	150.20
Sudan (Africa)	62.11	135.26
Ecuador (Latin America)	61.74	134.45
Kenya (Africa)	58.51	127.42
Sarawak (Asia)	55.12	120.03
Pacific Islands (Oceania)	52.63	114.61
Colombia (Latin America)	52.61	114.57
Sri Lanka (Asia)	51.76	112.72
Bolivia (Latin America)	51.18	111.45
Total Cassava Producing Countries	45.92	100

* Index estimated on the basis of production and population statistics in: FAO 1975, Production Yearbook, Vol. 29.

Table 12. Apparent daily per capita availability of calories of some agricultural products important in the cassava producing countries, 1974*.

Region	Wheat	Barley	Dry Beans	Maize	Rice	Potatoes	Cassava	Sorghum	Soy-bean	Bananas	Availability of total Kilocalories	% (g)
	(3290)	(3122)	(3020)	(3460)	(3570)	(800)	(1220)	(3450)	(4500)	(1000)		
LA. a/	342.34	30.28	98.13	1243.99	432.31	76.80	407.91	296.89	442.11	211.04	3601.80	100
AS. b/	302.50	111.62	23.83	247.22	1352.39	54.01	56.55	56.52	89.14	14.82	2308.60	88.79
AF. c/	17.76	0.86	34.50	353.68	184.47	10.37	582.09	305.11	3.58	47.97	1540.39	59.25
OC. d/	h/	h/	h/	12.89	60.93	2.37	196.60	10.21	h/	666.19	949.19	36.51
TCPC. e/	274.74	90.41	33.01	366.48	1121.08	51.53	153.12	110.02	117.62	40.79	2358.80	90.72

(a) L.A. Latin America

(b) AS. Asia

(c) AF. Africa

(d) OC. Oceania

(e) TCPC Total cassava producing countries.

(f) The figures within the parentheses are equivalent to the average kilocalories in one kilogram of edible material of each product.

(g) Percentage availability of needs considering 2,600 kilocalories as the average caloric requirement per capita per day.

(h) Information not available.

* Figures estimated by multiplying the per capita production data in Table 7 by the factors shown in parentheses and dividing this result by 365 days per year.

Table 13. Apparent daily per capita availability of calories from cassava in Latin American countries, total for Africa, Asia, Oceania, Latin America and World Total, 1974*.

Countries	Apparent Daily per capita Availability of Calories (a)	Percentage of the Caloric Requirements (b)
Paraguay	1441.20	55
Brazil	774.52	30
French Guiana	230.53	9
Ecuador	206.36	8
Colombia	175.85	7
Bolivia	171.07	7
Dominican Republic	138.41	5
Haiti	107.36	4
Peru	108.90	4
Venezuela	82.56	3
Cuba	84.23	3
Panama	81.96	3
Honduras	50.14	2
Argentina	39.91	2
Nicaragua	26.81	1
Jamaica	25.07	1
Costa Rica	17.21	1
El Salvador	12.60	0
Puerto Rico	5.82	0
Guatemala	3.94	0
TOTAL		
Africa	372.48	14
Asia	44.92	2
Oceania	33.63	1
Latin America	412.03	16
Total Cassva Producing Countries	120.50	5

* Excluding Barbados, Guiana, Guadaloupe, Martinique, Trinidad & Tobago, and Surinam, as there is no information available for certain periods.

(a) 1 Kgr of fresh cassava is equivalent to 1.2 digestible megacalories, IN: Maner, J. H., J. Buitrago, R. Portela and I. Jimenez, 1972. La Yuca en la Alimentación de Cerdos. ICA. CIAT (in press) p. 3.

(b) 2.6 megacalories as an average of the daily per capita caloric requirements, In: National Livestock and Meat Board, 1965. Lessons on meat. Chicago, Illinois, p. 27.

Table 14. Relation between apparent daily per capita availability of proteins in grams and the apparent daily per capita availability of calories from cassava in Latin America.

Countries	Apparent Daily Per Capita Availability of Proteins (grs) (a)	Index (b)	Apparent Daily Per Capita Availability of Calories (c)	Index (d)
Argentina	95	144.40	39.91	10.04
Paraguay	70	106.90	1441.20	362.43
Nicaragua	69	104.88	26.81	6.74
Brazil	67	101.84	774.52	194.77
Jamaica	67	101.84	25.07	6.30
Costa Rica	63	95.76	17.21	4.33
Cuba	63	95.76	84.23	21.18
Panama	62	94.24	81.96	20.61
Venezuela	62	94.24	82.56	76.00
Peru	62	94.24	108.90	27.39
Guatemala	58	88.16	3.94	0.99
Honduras	53	80.53	50.14	12.61
El Salvador	51	77.52	12.60	3.17
Colombia	50	76.00	175.85	44.22
Dominican Republic	50	76.00	138.41	34.81
Bolivia	47	71.44	171.07	43.02
Ecuador	43	65.36	206.36	51.89
Haiti	39	59.28	107.36	27.00

(a) U.S.D., ERS. F.D.C.D. Working Paper, Agriculture in the Americas. Statistical Data, April 1976.

(b) (Average for Latin America 66 gr.) = 100

(c) The same data in Table 9.

(d) (Average for Latin America 397.65 kilocalories) = 100

Table 15. Area planted to cassava, production and yield in Colombia 1955 - 1974

Years	A R E A		PRODUCTION		YIELD	
	(1,000) Has	Index*	(1,000) Metric tons	Index	Tons/Ha	Index
1955	111	98.2	633	82.4	5.7	83.[illegible]
1956	110	97.3	682	88.8	6.2	91.[illegible]
1957	109	96.5	687	89.4	6.3	92.[illegible]
1958	113	100.0	768	100.0	6.8	100.[illegible]
1959	115	101.8	748	97.4	6.5	95.[illegible]
1960	100	88.5	650	84.6	6.5	95.[illegible]
1961	98	86.7	539	70.2	5.5	80.[illegible]
1962	108	95.6	734	95.6	6.8	100.[illegible]
1963	112	99.1	773	100.7	6.9	101.[illegible]
1964	102	90.3	561	73.0	5.5	80.[illegible]
1965	127	112.4	864	112.5	6.8	100.[illegible]
1966	129	114.2	890	115.9	6.9	101.[illegible]
1967	115	101.8	794	103.4	6.9	101.[illegible]
1968	118	104.4	814	106.0	6.9	101.[illegible]
1969	134	118.6	965	125.6	7.2	105.[illegible]
1970	148	131.0	1095	142.6	7.4	108.[illegible]
1971	145	128.3	754	98.2	5.2	76.[illegible]
1972	155	137.2	961	125.1	6.2	91.[illegible]
1973	165	146.0	1320	171.8	8.0	117.[illegible]
1974	165	146.0	1320	171.8	8.0	117.[illegible]

* Index: 1958 = 100

SOURCE: DANE. Bol. Mensual de Estadística. Area and Yield. No. 276, July, 1974. Area, Yield and Production, 1973 and 1974. Ministry of Agriculture Agricultural Programs.

Table 16. Cassava prices in Colombia, 1955 - 1972

Years	CURRENT PRICES		CONSTANT PRICES	
	Pesos/Ton (1)	Index 1958 = 100	Pesos/Ton (2)	Index 1958 = 100
1955	193	96.5	84.5	152.5
1956	198	99.0	80.0	144.4
1957	215	107.5	69.9	126.2
1958	200	100.0	55.4	100.0
1959	250	125.0	63.2	114.1
1960	303	151.5	73.0	131.8
1961	378	189.0	86.1	155.4
1962	338	169.0	75.0	135.4
1963	398	199.0	69.9	126.2
1964	755	377.5	112.9	203.8
1965	658	329.0	90.9	164.1
1966	691	345.5	80.9	146.0
1967	795	397.5	87.6	158.1
1968	955	477.5	98.5	177.8
1969	891	445.5	86.6	156.3
1970	891	445.5	79.7	143.9
1971	1361	680.5	109.1	196.9
1972	1467	733.5	101.2	182.7

(1) Boletin Mensual de Estadística. No. 227, August 1974.

(2) Current prices deflated by the price index at wholesale levels reported by the Central Bank.

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COMMUNICATION TECHNIQUES

Fritz Kramer, M.D.

1. THE COMMUNICATION PROCESS

Communication is the process by which messages get transferred from a source to a receiver.

To communicate effectively, we must be familiar with the communication process and all the factors involved. Knowing about communication helps us to better master our problem solving tasks, be they of a professional or personal nature.

The communication process may be looked at in terms of five elements. They are: Source / Message / Channel / Receiver / Effects.

1.1. Source

A source is the initiator of the message. It may be an individual, a group of individuals, or an institution or organization.

There are several things which will determine how a source will operate in the communication process. These include the communication skills (the source's ability to think, write, speak, draw). They also include his attitudes toward his audience, toward the subject he is communicating about, toward himself, or toward any factor pertinent to the situation. Knowledge of the subject, the audience, the situation, and other background factors also influences the way the source will operate in the communication situation. So will his social background (his education, his friends, his salary, his social status), and finally, the cultural context in which the source lives.

1.2 Message

The message is the stimulus transmitted from the source to the receiver. It is the idea that is communicated. In encoding a message, the source must consider several subfactors: First, of course, the content has to be selected. Second, the source must organize the content such that it is acceptable for a given audience. That is to say, the source must select a proper treatment of the content. And third, the code has to be chosen. Generally, we think of code in terms of the natural languages, (Spanish, English, Swahili, Chinese, etc.). However, there are other codes, such as gestures, music, art, and so on. In all cases, we need to look on the code in terms of the effectiveness with which we can reach a given audience. If the source makes a poor choice in either content, treatment, or code, the message will likely be ineffective.

We should remember that the message itself is simply a complex of stimuli without any inherent meaning. Messages do not mean by themselves, Messages mean only to people. Or, to say the same thing differently, meanings are in people, not in messages. The message is assigned meaning only when it is translated (or decoded) by the receiver.

1.3 Channel

A channel is the means by which a message gets from a source to a receiver. Channels connect the source and receiver, enabling them to communicate. There are several ways of classifying channels. Here, we will examine two of these: First, a channel may either be a mass media channel or an interpersonal channel. Mass media channels are those that involve a mass medium, such as television, newspapers, magazines, films, radio, etc. These channels make it possible for a source to reach a large number of receivers. Interpersonal channels are those that involve a face-to-face exchange between a source and receiver. In general, it is the case that mass media channels are highly effective in informing receivers of things that are happening. However, they are not effective in actually influencing people's behavior. Here, interpersonal channels are much more relevant.

A second way of classifying channels is on the basis of the physical senses they affect. For example, a drawing affects sight, a tape recording affects hearing, a fist in the face affects touch, and the fumes of gasoline affect smell.

Generally, it has been found that at any given moment, a receiver can pay attention to only one sense. However, it also holds true that the more sense channels we use to get a message across, the more effective our message.

1.4 Receiver

The receiver is the recipient of the source's message the decoder of the message stimuli. The receiver is perhaps the most important single element in the communication process. Yet, we often overlook him. Sources become message-oriented; they get so concerned with their topic and expressing it comprehensively that they do not encode their messages in terms that the receiver can understand.

All of the factors that determine how a source operates equally apply to the receiver. Communication skills may be thought of as how well a receiver can hear, read, or use his senses. Attitudes relate to how a receiver thinks of the source, of himself, of the message. His knowledge about the topic may be greater or lesser than the source's knowledge. His social background or even his culture may be different in many ways from that of the source. Each of the above subfactors will affect the receiver's understanding of the message.

1.5 Effects

The effects of communication are the changes in receiver behavior that result from decoding the message. Let us realize that the primary purpose of communication is to bring about certain changes or effects in the receiver.

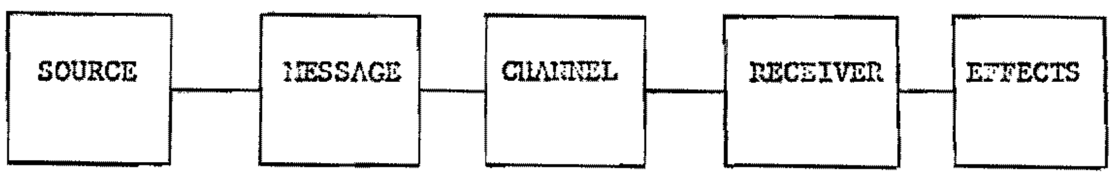
There are three basic types of communication effects:

a) Changes in the receiver's knowledge;
b) Changes in the receiver's attitudes;
c) Changes in the receiver's overt behavior

Quite often, these three changes occur in sequence: that is, the receiver first gains knowledge of an idea, practice, or tool. Then, he evaluates the innovation against his needs. If he feels that it is "better," he has formed a favorable attitude toward the innovation. Finally, he actually incorporates the innovation in his behavior; that is, he overtly changes his behavior.

We now have discussed the five basic ingredients of the communication process. Up to this point, our model of the communication process looks like this

FIG. 1



As it now stands, the model seems to imply that there is but a one-way flow of messages. Our own experience in communicating tells us this is not really what happens. Think for a moment about talking with someone. After speaking for a few minutes, you will start to encode your message differently if your receiver responds with smiles and affirmative nods as opposed to the case where your receiver starts to frown, or even show his fist. If you don't alter your message encoding, you will be a very ineffective communicator.

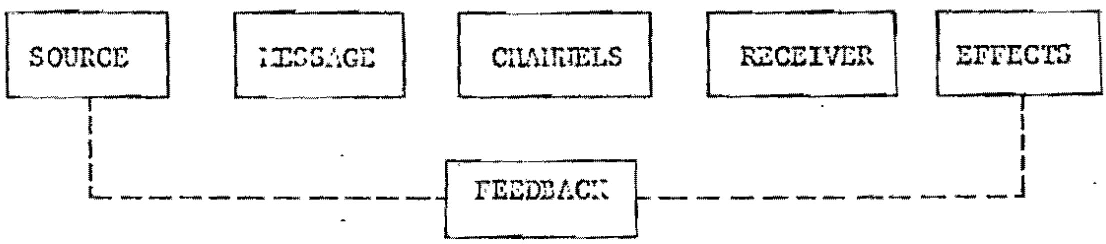
When the receiver responds to the source's message, he generates messages back to the source. The source and the receiver are now interacting. This all-important link is known as feedback.

1.6. Feedback

Feedback can be thought of as response by the receiver to the source's message, which the source may perceive and use to modify his further messages. Basically, there are two kinds of feedback: positive and negative. Positive feedback confirms to the source that the intended effect was achieved. Negative feedback informs the source that the intended receiver effect was not achieved. In general, the more feedback-oriented we are in communicating, the greater our potential for being effective.

Let us now present the final communication model that presents all five elements plus the all-important factor of feedback.

FIG. 2



2. THE COMMUNICATION PROCESS FROM THE RECEIVER'S PERSPECTIVE

Communication is a means to and end. The end, as we have seen, is to change the behavior of our receivers. Before we can change the behavior or our receivers, however, we must know more about the process by which a receiver changes his behavior.

From psychology, we know that the process works something as follows:

First, our receiver must want something.

Second, he must become aware of the existence of something that may satisfy his wants.

Third, our receiver must make a decision to incorporate the new idea in his behavior pattern.

Fourth, he must actually incorporate the idea.

Fifth, he must be rewarded. That his, our receiver must feel that his behavior change has indeed resulted in a satisfaction of his wants.

3. THE COMMUNICATION PROCESS FROM THE SENDER'S PERSPECTIVE

The above discussion demonstrates to us that in order to change behavior, we must repeat the communication process several times. In the early stages of our communication endeavors, our intention is to create a need, then to introduce a solution, then to get the solution adopted, and finally, to reward the receiver for having adopted the solution.

Next, we will see if there are any guidelines we can follow at each of the different phases of leading our receiver to a certain behavior change:

Phase 1: <u>To point out a need</u>

Here, the intended purpose is to have our receiver acknowledge that there is a need to improve his situation in a given respect. In order to achieve this end, the source must point out a basic <u>inconsistency</u> between the values the receiver holds and what he is actually doing. (A value is a desired endstate of the receiver, as, for example " a good life ", " prosperity," social esteem," etc.)

Phase 2: <u>To provide knowledge of an alternative</u>

In this phase, the purpose is to simply introduce the receiver to a new idea, practice, or tool. Here, we are not so much interested in providing knowledge as to <u>how</u> the innovation works. All we want is to make the receiver aware of the innovation's existence. Quite often, mass media can do an excellent job here. Mass media can easily reach large audiences at low cost.

Phase 3: <u>To relate alternative to the problem context of receiver</u>

The purpose of this communication phase is to get the receiver to make a commitment or decision to use the alternative. It is probably the most critical phase in our work. We must be successful in convincing the receiver that the incorporation of this innovation would resolve the conflict that was pointed out in phase 1. Research shows that one of the most critical factors that will determine our success is the degree to which we have <u>credibility</u>. Credibility is the extent to which we, the source, are considered trustworthy, authoritative, and dynamic. As our credibility increases, our success in our efforts to convince the receiver of the desirability of the innovation will increase.

Phase 4: <u>Incorporating the Innovation into the Receiver's Environment</u>

Even though our receiver may have made a decision to use the new idea, he may not know <u>how</u> to use it. Here is where the task of training comes in. We, the source, must clearly identify the training objectives which the receiver must be able to master; then, we must provide him with the necessary instruction; following instruction, we must give the receiver an opportunity to practice what we have told him, and finally, we must evaluate the receiver's behavior to see if he indeed can master the kind of objectives that we had identified.

Phase 5: <u>To Reward the Receiver</u>

We must keep in mind that a receiver will maintain a change in his behavior only as long as he is being rewarded for engaging in it. During the fifth phase of communication, our concern must be with pointing out to our receiver that his new way of doing things is indeed an improvement over what he has been doing in the past. Of course, quite often this kind of " relevation " is obvious to the receiver all by himself. However, we may do well to make it an explicit effort to reinforce our receiver in his new behavior. Of course, the most convincing way of doing this is by demonstrating to our client the reduced gap between his values and what he is actually doing.

4. THE PLANNING OF COMMUNICATION STRATEGIES

As we have seen, communication is a goal-oriented activity. To reach our goals with as little resources as possible, we must proceed in a systematic manner. Just as is the case with any systematic endeavor, we must pass through the following phases: (1) Problem Definition; (2) Development of Solution; (3) Implementation of Solution; and (4) Evaluation.

4.1. Problem Definition

Before considering routes and kinds of vehicles to use, we must know where we are going. That is, we must know what the problem is. To get an answer to this question, we must have information about the following topics:

4.1.1. What is the Need to be Met ?

To identify the need to be met, we must make a simple comparison between what is (the status quo) and what we would like it to be (ideal state). In other words, we must find out where our receiver is with regard to a certain problem, and where we would like him to be. To answer the former question, we must identify where our client is in terms of the behavior change process. For example, if our goal is to have our clients use fertilizer we have to ask ourselves: are our clients already recognizing a need for change? Do they have knowledge of the fertilizer package we are interested in? Have they already formed an attitude toward this package? Or are they already using it? Once we know where our clients are in using an innovation, we can then specify where we want them to be next. The problem, then, is how we must communicate in order to get our receivers from where they are to where we want them to be.

4.1.2. What is the Situation of the Receiver

The success of our communication efforts is dependent on our knowing our receivers. Before planning any communication strategy, we must carefully consider our receiver's total situation. What are their communication skills? What are some of their values that they are holding? Who are their friends and what is their influence over our clients? What is their social status? What are some of the attitudes that may have a bearing on our communication attempts? What media are our clients exposed to? What kinds of resources do they have available? The answer to such questions may help us to identify potential obstacles or potential facilitating factors that may help us.

4.1.3. What Resources are Available?

Next, we must make a complete inventory of the kinds of resources that are available to us. For example, we must know how much time we have to prepare ourselves, how much money is available, what skills we have as communicators, what services we can draw on, what the manpower is that we can count on, to what extent we have access and control over our receivers, what communication media are available, etc.

4.1.4. Statement of Objectives

Once we have a good idea of what the need is that we must meet, what the characteristics are of our clients, and what resources we have available to us, we must clearly state what our objectives are. The statement of objectives is an important step, but it is frequently by-passed or given minimal thought. Often objectives are stated too generally, such as " I want farmers to use fertilizer." To have more specific guidelines for all our future activities, we must specify:

(a) who is our target audience? Which farmers are we specifically concerned about?
(b) what do we want our target audience to be able to do after being exposed to our communication that they could not do before it? Remember that expected behavior changes are of three types:

(ba) change in knowledge. Here, the target audience lacks information about a certain topic. The purpose of communication is to ensure that the audience obtain and master this information.

(bb) Change in attitude. Here, our audience has a neutral or even negative attitude toward the idea or object that we are interested in. The purpose of our communication is to create a positive feeling toward the object.

(bc) Change in skills. Even though our audience may know of an innovation and be convinced that it is of value to them, they may not have the skills to use this information. In this case the purpose of our communication is to ensure that our clients wills be given the know-how knowledge and that they will acquire the skills to use it.

(c) how are we going to measure whether or not our audience has changed their behavior according to our intentions ?

4.2. Selection of Presentation Strategy

Whereas the objective tells us WHAT is to be accomplished, the presentation strategy informs us HOW the objective is to be accomplished. The how should take into account what media will be used, what content will be presented, and how this content is to be organized.

4.2.1. Selection of Media

The selection of media depends on the objective as well as on the availability of media. Consider the great variety of media that are potentially available: field days, lectures, demonstrations, exhibits, radio, pamphlets, films, etc., or any combination of these. Seldom is it the case that one single medium is sufficient to carry the entire message for a given objective. Rather, it is usually advisable to use and interrelate a variety of media.

4.2.2. Selection of Content

Again, the objective provides the basis for the selection of information. Always keep in mind that only information is included which is necessary to achieve the objective. Never include content that is not directly relevant to the objective!!

4.2.3. Selection of Organization

After the information to be presented has been collected, the first step in organizing it is to prepare a content outline. An outline requires arrangement of the information in a systematic order. It allows for a quick check of extraneous material or omissions of essential information, and for the evaluation of the information included against the stated objectives.

After preparing a content outline, the information needs to be organized in a more detailed fashion. This elaborated content outline we call a treatment. The treatment for a flip chart or a leaflet is a rough sketch of the final layout which shows the location of the visual and verbal elements. From the treatment it is but a short step to the final presentation.

4.3. Execution of the Communication Event

The execution of the event requires careful attention to details. A planning checklist is helpful. For example, if you are planning a field day, the following points may have to be considered:

- Transportation of farmers to and from experimental plots.
- Information to farmers about departure time and place.
- Experimental plots ready for visits.
- Plan for dividing farmers into small groups at experimental plots.
- Training demostrators to host each small group.
- Procedures for rotating small groups.
- Large group meeting place available for question and answer period.
- Leaflets for distribution at end of day.

4.4. Evaluation

In evaluating a communication attempt, it is useful to distinguish between two different kinds of evaluation:

formative evaluation and
summative evaluation.

4.4.1. Formative evaluation

Refers to the review of our activities before and during our communication event. For example, during the planning of an event we may ask ourselves such evaluation questions as:

- Is the idea to be communicated important, useful, valid?
- Will our receiver understand the message?
- Will he consider the message relevant?
- Will he be able to do what the message asks ?
- Is the message accurately prepared?
- Is there anything about the message that might offend?

And for the actual execution of the event we may ask ourselves:

- Was the presentation timely?
- Was it clear?
- Did it permit audience feedback?

4.4.2. Summative evaluation

On the other hand, refers to the actual measuring of our objectives. That is, we are asking ourselves the question:

"Now that our audience has been exposed to the presentation, have they actually changed their behavior as we had specified it in our objective?"

Thus, you can see that formative evaluation helps us to maximize the chances that our presentation will be successful. Summative evaluation informs us whether we have actually been successful or not.

5. TEAM WORK

More often than not, a given change task is beyond the means of just one individual. Whenever a whole group is acting as a source, this group must be highly organized and coordinated in order to achieve the change goals.

5.1. Group Structure

The way we organize a group has definitive effects of how the group functions.

Essentially, there are two ways we can organize a group. There is vertical structure, in which the leader appears at the top and individuals of lesser rank appear further down the list. There may be several levels at which some individuals will have equal rank but different roles. Such a structure is common to military organizations.

On the other hand, there is horizontal structure. This type of structure implies that everyone has equal rank but different roles and tasks. A group with a horizontal structure will democratically select a leader. Leadership of a group with horizontal structure will change from time depending on the type of task the group is working on.

5.2. Group Objectives

Groups may devote their time to two different objectives. First, a group has a certain mission to fulfill. For example, if the goal is to change the behavior of a certain target audience, the group has to define the problem, design a solution, implement the solution, and finally, evaluate it. We may call this the task-orientation of the group.

However, in order to function as a group, the members of the group have to devote some time to the pure maintenance of the group itself. This includes taking care of the personal problems a group member may experience, or to resolve inter-group problems as they may occur. This, we may refer to as the <u>people orientation</u> of the group.

Now, it appears obvious that a group that is organized around a vertical structure is much more effective in its task-orientation. Authority is delegated. Everyone knows his responsibility. All the resources are grouped around a single goal: to get the job done. However, it has been found that groups with a vertical structure have considerable personnel problems. The members of the group feel that they are just one part in a machine - a part that could easily be replaced. Members also tend to feel that their talents are not fully utilized, and that they have to behave in a rather mechanical way.

On the other hand, a group with a horizontal structure is somewhat less task oriented, at the expense of being more concerned about the maintenance of the group.

Since every group member has about equal rank, communication within the group is much more extensive, and decisions come about more slowly. However, group members feel happier in this structure, and they feel that their talents are fully utilized.

5.3. Group Leadership

Group leadership is of extreme importance in any group. Any leader may be placed on a autocracy-democracy continuum. The authoritarian leader is a true supervisor. He decides what each member of the group is going to do, and how he is going to do it. The authoritarian leader seldom consults group members for their ideas, and he tends to make decisions in isolation.

On the other hand, a more democratic leader believes that leadership is the property of the group. He sees himself more as a coordinator of the group, rather than as a decision-maker for the group. A democratic leader will actually tend to follow the group, rather than lead it. Whereas the authoritarian leader expects his subordinates to execute his orders, the democratic leader expects his fellow group members to participate and contribute in any important matter that may confront the group.

It is to be expected that a vertically structured group with its heavy emphasis on task-orientation is much more conducive to an authoritarian leader. On the other hand, a horizontally organized group with its orientation toward group members is much more likely to produce a democratic leader.

In organizing ourselves to undertake a major communication task, we must carefully weigh our options. Given the nature of the task ahead of us, to what extent should we plan for a vertical or horizontal structure; how much time and effort can we expand on maintaining our group (people orientation), and what kind of leadership do we want to encourage?

Whatever arrangements we come up with, we must assure that the following things will happen:

1. Define mission and role. Every member in our group must know what our basic commitments and goals are. These commitments and goals are likely to be set by ourselves, as well as by those whom we serve.

2. Define Roles and responsibilities. Every one group member needs to know what he is to do and the kinds of things he is responsible for.

3. Limit internal conflict. However it is done, conflict between group members or between sub-groups must be kept at a minimum. Whereas some degree of competition can be very helpful, open conflict will jeopardize our long-range policies, our mission, our special capabilities, and our identity.

6. ORAL COMMUNICATION

On any given day, you are delivering many, many messages. Most or them are probably brief; the great majority of them informal; many of them vital to your moment-to-moment existence.

Some of these messages will be prepared, that is thought about in advance; but most of them will be on the spur of the moment. But they are all messages and most of them will be oral.

Below, we will analyze in more detail the steps you should take in preparing and presenting an oral message. Although some of these steps apply mainly to situations that call for a planned, carefully prepared message, most of them apply to the daily, informal messages that make up the bulk of our communication.

6.1. Steps in communicating orally

Below we will present a list of steps that one may go through in preparing an oral communication. This list is intended to be workable for the beginning speaker, and the order of the steps is probably the most surtable order for him or her. As he attains the freedom that comes with experience and success, the communicator will learn to vary the order of preparation and the degree of emphasis on the steps.

6.1.1. Decide the why and what of your message.

Why are you communicating and what will you make known? These questions must dominate your thinking once you feel the urge to open your mouth.

Any further preparation depends upon the answers to the questions:
- "Why am I communicating ?"
- "What do I want to do with my audience ?"

In preparing your communication, you should determine your specific purpose for speaking. State what you want your listeners to do or believe, or understand. This is your purpose sentence, and you should refer to it throughout the preparation of your message so that you never loose track of why you are speaking.

After you have chosen your topic, try to anticipate your listeners probable reaction. Will they be interested or bored, receptive or hostile, apathetic? If it seems unlikely that your subject will receive some kind of positive reaction, now is the time to change it.

6.1.2. Adapt the speech to the audience that you are addressing

First, learn of the purpose of the meeting. If the subject has been assigned, limit remarks to a particular aspect that fits the occasion and the audience. If the audience is coming to hear you speak, prepare your message with this in mind. If the meeting is more a round table discussion, or a committee meeting, prepare your message with an eye to contributing what you can to the meeting's intent.

Learn as much as you can about the people you will communicate with. It may be helpful to know in advance the sex and age groups of the listeners, their occupations and life styles, their cultural inclinations, and views on current controversial issues. These things help reveal the personalities, attitudes, beliefs, and behaviors of your listeners and they will assist you in deciding what kinds of languages and ideas you'll need to use to get your messages across most effectively.

6.1.3. Construct a basic, abbreviated plan for your message

Here, you must think of a basic plan of what you intend to say, and the order of your main points. Divide your speech into two, three, or four main headings. Most listeners cannot remember more than four basic points.

6.1.4. Collect Material for your message

The materials of speaking can be classified into three kinds.
a) personal proof. Personal proof is used to raise or maintain

our credibility with our listeners. Try to show to your listeners that you are interested in them, that you know your subject, that you really want to share your ideas with them.

b) Materials of development. This kind of material is to carry the sense of our message. Your listener will not understand your message unless you back up your statements with evidence and reasoning. You must make clear to them points they may not readily understand.

c) Materials of experience. This type of material is used to help your listeners associate your experience with their experience. Help your listeners associate your experience with their experience. Help your listeners to associate with your talk as much as possible.

As you gather materials, consider how much you know about your subject and how much more you need to know to accomplish your speaking purpose.

6.1.5. Organize Your Message

Normally, the most useful plan is one that has four parts: the purpose sentence, the introduction, the body of the message, and the conclusion. The sequence is important. First prepare your purpose sentence, then prepare the body, then the conclusion, and finally, the introduction. (Since the introduction presents the message, you cannot logically prepare it until you know what the message is all about).

6.1.6. Deliver the Message

There are two aspects of effective delivery: Voice, and Non-verbal behavior.

6.1.6.1. Voice

Rate of Speech : Variety is needed. Rate must fit the mood of the material. Use pauses to let ideas sink in.

Pitch : The good speaking voice has range and flexibility of pitch. Use pitch to enhance your message.

Force and Loudness: Note the physical conditions of the place in which you will communicate and adjust your voice accordingly. Also, try to use the voice as a tool for emphasis.

Articulation: Try to clearly articulate your words. Don't mumble, mutter, or run words together.

6.1.6.2. Non-verbal Behavior

In delivering a speech, make your body work for you. Consider the following points:

Posture: During your presentation, use a relaxed posture, but do not slump. Be comfortable without being sloppy. At no time should your posture draw attention away from what you are saying.

Gestures: Use gestures to reinforce your ideas. Gestures may be used to describe the size, shape, or motion of an object. Or you may use common gestures of the head, shoulder, arms, and hands to support a verbal point.

Movement of the body as a whole : A step forward usually communicates the idea that the point you are making is more important. A step backward invites the audience to relax, or to think about a point. Also, to invite more informality you may walk around while you are talking. And try to use body movements as a means to indicate transition between thoughts.

6.1.6.3. Stage Fright

Almost everyone is nervous before a formal setting. Even in improptu situations, you may find that your hands are shaking a little, the room is suddenly too warm, and you are at a loss for words. To effectively deal with these symptoms, try the following:

Relax: There are ways to relax, and they can be learned. Two of the simplest are: (1) Take a few deep, long breaths just before you rise to face your listeners. (2) Take your time in getting ready to speak. Take a moment to get set to speak. No one is in a hurry.

Do not attempt to memorize your speech : Nothing promotes stage fright so quickly as trying to memorize a speech.

Channel nervous energy into body movements and gestures. Walk around; use the chalkboard; demonstrate objects; even arrange your notes.

6.1.7. Evaluate Your Message

We most often communicate for a purpose, and whatever the purpose is, it is more likely to be achieved if we can receive and accurately interpret feedback from our message. Experienced speakers recognize what every beginning speaker and every communicator should come to know: that only through evaluation can one learn to improve his speaking. Make an effort to evaluate listener reactions while you are speaking. This will allow you to improve your message while you are communicating it.

Make a deliberate attempt to evaluate the effects of your speech after delivering it. The question you want to answer is: has the audience changed in the direction that you wanted it to change ? Answer to this question may be obtained through a discussion session after the speech. Or you may want to use some questionnaires. Or you may use any other form of observation measurement that will inform you of the degree to which you have been successful. Finally, never avoid criticism and evaluation, take it in good grace, and then evaluate the evaluation. Do not be depressed when the criticism reveals your faults. Use it to become a better communicator.

7. MEDIA OF COMMUNICATION

Earlier, we introduced the communication model:

SOURCE MESSAGE CHANNEL RECEIVER EFFECT

We will now concern ourselves more with the <u>channels</u> or <u>media</u> that are available to us. Of course, the messages we want to send accross a given channel must be prepared such that they will be compatible with the channel. After all, if we are using radio, for example, the entire message must be in the forms of sound (speech, music, sound effects). Thus, as we introduce any one medium, we will also discuss how the message may be prepared to fit that particular medium.

In presenting the media, we will use the following breakdown: First, we will discuss non-projected media, followed by projected media, and finally we will discuss tape recording.

7.1. Non - Projected Media

7.1.1. Presentation Boards

There are several different types of presentation boards that can be used to supplement a lecture or demonstration. These include bulletin boards, chalkboards and flannel boards. Base the selection of a presentation board on the audience, the goals, the content being presented, and available materials.

7.1.1.1. Bulletin Board

A bulletin board can be plywood, the wall of a building, a blanket stretched tautly between two trees, heavy corrugated cardboard, or wire screening. In using bulletin boards, consider the following:

<u>Utilization</u> :
- choose a location where the board will be seen;
- keep the board neat and clean; remove old materials promptly;

- use a variety of techniques to attract attention. In addition to pictures and drawings, try displaying real objects. A few stalks of rice, a syringe, or a specimen will add appeal and credibility to displays on agriculture.
- use a variety of lettering techniques. Letters can be cut out of paper, cloth, cardboard, or wood.
- involve the audience. Displays can ask questions that relate to the needs of the audience. Handout leaflets can be a part of a display.

Suggested Applications:

- to announce upcoming events;
- to remind your clients to weed their crops, use a specific variety, etc.
- to display photographs of local activities;
- to demonstrate comparisons;
- to display pictures of projects in other places that are of local interest;
- to provide supplementary information.

Evaluation Questions: Always try to get some measure of the effectiveness of a bulletin board. There are many questions that can be asked:

- what percentage of people passing the board are looking at it?
- what could have been done to attract more attention?
- was the lettering legible ?
- was the message easily understood?

7.1.1.2. Chalk Board :

The best-known and most easily-used presentation board is the chalkboard. Chalkboard presentations can be improved by following a few guidelines:

Utilization:
- always plan carefully;
- make writing and illustrations neat and ligible;
- don't stand in front of material that the audience should see;
- don't put too much on the board;
- be sure that the audience can see;
- use color for emphasis.

Suggested Applications:

- to summarize key words of an oral presentation;

- to list the steps in a process;
- to list ideas suggested by the audience;
- to develop a concept point by point;
- to present new words or terms.

Evaluation:
- was all material on the board neat, legible, and easily understood ?
- how could the presentation have been improved ?
- was the chalkboard the most appropriate medium to use ?

7.1.1.3. Flannel Boards:

The flannel board can be useful in conjunction with an oral presentation. Items can be placed on the board progressively to tell the story or to keep the audience aware of the main points in a talk. A flannel board is easily constructed:
1. Cut a piece of plywood or heavy cardboard to the appropriate size (for 100 persons, 100 centimeters by 100 centimeters is about right.
2. Stretch a piece of rough-surfaced cloth, such as flannel or burlap, over the board and tighten it securely in place.
A wide variety of materials will adhere readily to such a board. These include:
- Cloth cutouts;
- Pieces of yarn or string;
- Cardboard strips with a piece of rough cloth or coarse sandpaper.

Utilization:
- Lean the flannel board back slightly when in use;
- Avoid windy locations;
- Carefully plan the steps of representation. Rehearse the presentation in advance.
- Stand beside the board; not in front of it;
- Consider legibility;
- Leave items on the board only as long as they are needed.
- Avoid excessive handling. It distracts the audience.

Applications:
- To illustrate a process as it is being explained;
- To develop charts.

Evaluation:
- Was the flannel board relevant ?
- Was the material organized logically ?
- Were all the words on the board legible ?
- Did the board help meet the objectives ?

7.1.2. Charts and Posters

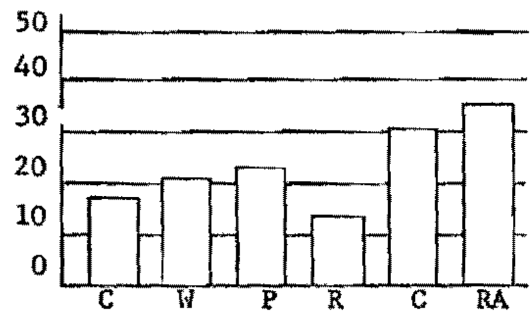
7.1.2.1. Charts:

Pictorial and graphic charts are among the most useful visual materials. Presented during discussion, they can clarify difficult concepts and emphasize important points.

7.1.2.1.1. Bar Charts:

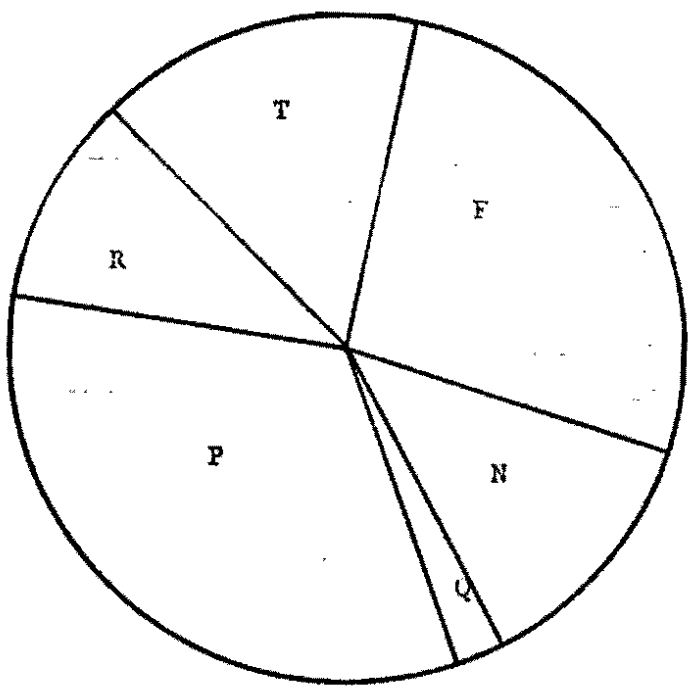
Indicate relative quantities by a series of vertical or horizontal bars and are good for showing changes over a period of time.

The bars should not crowd the edges and the space between bars should be about half the width of a bar. Shading or coloring bars will add emphasis. Charts should be used on only sophisticated audiences.



7.1.2.1.2. Pie Charts:

Show the relationship between a whole and its parts, such as the relationship between single crop and total crop production, or between various budget categories and total budget. To maintain clarity, slice the pie into no more than six or seven pieces. Add

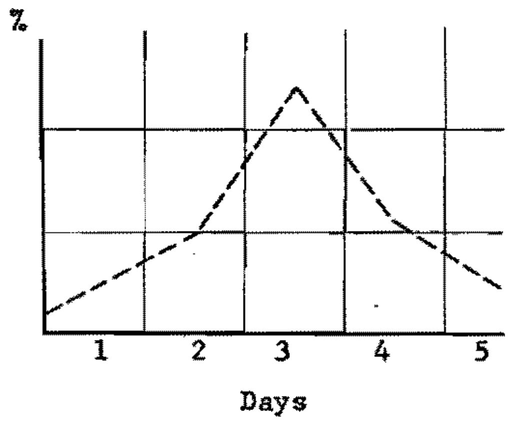


emphasis and separate different items by using colors.

7.1.2.1.3. Line Charts:

Show trends by using a line that indicates a relationship between two factors such as growth and time.

Several bits of data can be handled on one chart by using solid lines, dashed lines, and dotted lines. Colored lines can also be used. However, too much information can be confusing. So keep the chart simple.

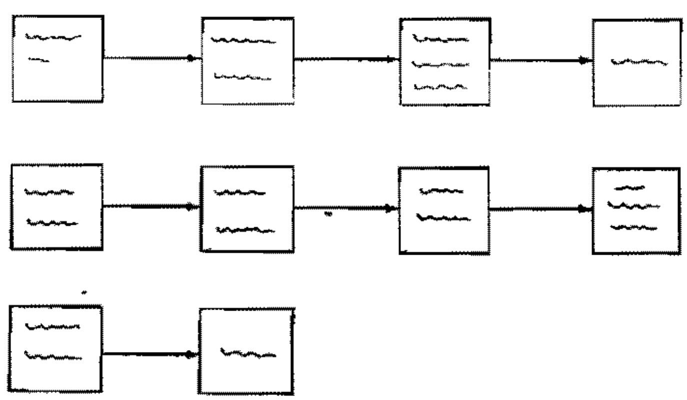


7.1.2.1.4. Flow Charts:

Combine boxes or drawing with lines and captions to show sequences or processes such as life cycles or administrative structures.

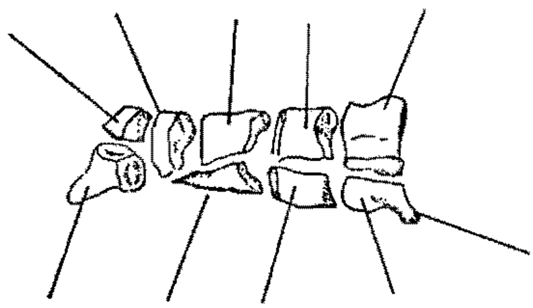
Such charts can form the structure for an entire talk, supplemented by charts explaining each step in the basic flow chart.

Avoid complicated diagrams that will confuse the audience.



7.1.2.1.5. Illustrative Charts:

Are pictures or diagrams that may or may not be accompanied by verbal descriptions. Complicated charts can be displayed on a wall or bulletin board so they can be studied at leisure. If charts are to be used with a class or large audience, keep the illustrations simple and the lettering large enough to be easily read at a distance.



7.1.2.1.6. Flip Charts:

Are simply a series of charts bound together at the top. They are used primarily to present a step-by-step sequence such as the steps in planting, in weaning calfs, or the steps in marketing one's crops.

Use plain paper for pages to make a pad which can be used in much the same way as a chalk board. Make drawings on the paper with crayons, chalk, felt pens, or charcoal.

Flip charts have the advantage of allowing the user to return to previous drawings by flipping back a few pages.

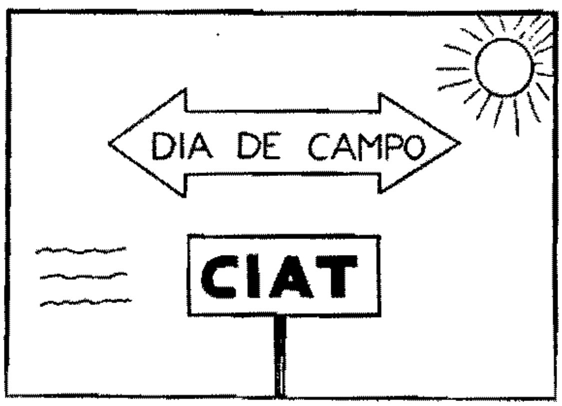
Evaluation Questions for Charts:

- Did the chart attract attention ?
- Was the content appropriate to the audience and the objectives ?
- Was the content organized in a logical, easy to understand sequence ?
- Did the chart help meet the objectives ?

7.1.2.2. Posters:

Posters are small signs that represent one idea simply and concisely. Posters can be used to announce coming events or to remind the audience of an earlier presentation. When planning posters, keep these ideas in mind:

- Keep it simple. A poster is intended to remind, not to convey a large amount of information.
- Begin designing a poster by making several small sketches. Then, have members of the audience pick the one they feel will be most effective.
- Place posters in conspicuous places. They must be readily seen by the intended audience.
- The message of the poster must be immediately apparent.
  If only a few posters are to be made, do them by hand.
  For larger quantities, use stencils, silk screen, or off-set printing.



Suggested Applications:

- To announce a campaign or a coming event;
- To remind an audience of an idea or concept.

Evaluation:

- Did the poster attract attention ?
- How could it have been more eye-catching ?
- Was the poster's message clear to viewers ?
- Were there enough posters to get across the message ?

7.1.3. Leaflets and Pamphlets

These easily-produced materials can be invaluable for communicating with many different groups. The important thing is to make the leaflet or booklet attractive and meaningful to the audience.

Utilization: There are a number of points to follow when planning and producing effective written materials.

- Plan carefully. Know the audience and write for that specific group. Know the goals and select and organize material appropriate to these goals.
- Attract and hold the attention of the reader. People are attracted to a leaflet or booklet by three things:
  1. The Cover. It must attract attention, and its message should be immediately apparent.
  2. Size and style of type and illustrations, and layout on printed page. A simple type face is most legible. For leaflets, a type size of 14 points is ideal. Most printers can suggest type choices and layout as well as assist with other production problems.
  3. The writing. Consider the audience, their needs and interests, as well as their reading level. If the content is written humorously, be sure it is humor the audience will appreciate.

Be specific and accurate. All facts should be correct and up-to-date. Consider various production possibilities. Each method of duplicating and printing has advantages and disadvantages, depending on the quantity of leaflets needed, the kind of type and illustrations being reproduced, the quality desired, and the budget available. Spirit duplication (Hectograph) is useful when fewer than 100 copies are needed and professional printing quality is not essential. Mimeograph is useful for 100 to 1000 copies. If high quality is important, if photographs are to be included, or if large quantities are needed, offset or letterpress printing must be employed.

- Consider distribution problems. How will the audience get copies of the leaflet or pamphlet ?

Suggested Applications: Seldom is it the case that a pamphlet or leaflet is effective all by itself. This type of publication should be considered in order to augment a meeting, a personal visit, a training session, a radio program, etc.

Evaluation Questions:
- Is the leaflet or booklet appropriate to the needs, interests, and literary level of the audience ?
- Is the writing interesting to the audience?
- Is the material organized in such a way that it can be followed and understood ?
- Were the production and distribution methods appropriate ?
- Does the cover attract attention ?
- Do the illustrations contribute to the message ?
- Is the content factually correct ?

7.2. Media that require projection

Because a bright light stands out in darkened surroundings, projected materials often capture the exclusive attention of an audience. Because of their appeal, properly produced materials may promote acceptance of new ideas or practices that are presented by slides, filmstrips and motion pictures, or by projecting photographs or drawings with opaque or overhead projectors.

7.2.1. Slides

A single slide or carefully planned slide sequence, accompanied by narration, can be one of the most useful projected materials. Before making slides, check the kind of slide projector available. The most common slide is called the 2 by 2. This refers to the slide amount and actually includes a number or different imagen sizes. The four most common are shown below:

Handmade slides: There are many occasions when a title slide or a slide with a simple illustration or perhaps a few words is needed. There are:

- Scratch the image with a sharp object on a piece of black and white film that has been exposed and developed.
- Use felt-point pens on clear photographic film, acetate, or plastic sheeting.
- If a thermal or heat copier (e.g. Thermofax) is available, it can be used to make high quality slides.

Handmade slides can be made the size of super slides or any other shape and size that will fit in a 2 by 2 mount. Also, handmade slides are ideal for use with larger projectors such as a 3.1/4 by 4 lantern slide projector. Slide mounts can be purchased or made from thin cardboard.

Photographic Slides: Many inexpensive cameras are available which will make good quality color slides. When planning such slides, consider the following:

- Choose a camera and accessories that will meet your needs. A camera in the range of 3000 to 4000 pesos can be used for most outdoor photography including distances as close as 60 centimeters. Generally, single lens reflex cameras are best as all-round cameras. They are excellent for copying and close-up photography. However, these cameras cost in the neighborhood of 6000 pesos. Before buying any camera, consult a qualified dealer for information about the kind of equipment to meet the need.

- Learn to use the camera properly.

- Choose the right film. A wide variety of color films are available. Some are designed for indoor use, some for outdoors, and some for pure lighting conditions or " high speed " photography. Choice of film depends on the job to be done, availability, and personal preference. Technical facilities and expertise are needed to process color film, so the selection of a color film should also be based on the availability of good, reliable, commercial processing within the country or on a reliable mailing service.

- Strive for good technical quality. Be careful about focus, correct exposure, lighting within picture, and composition.

Suggested Applications: You may use slides to

- Show comparisons of demonstration pilots;
- To teach a step-by-step process;
- To supplement a commercial filmstrip with locally made pictures;

- To support any verbal presentation with parallel pictures.
- To record the activities of a field day or any other agricultural event as a guide for planning later such events.

Evaluation Questions:

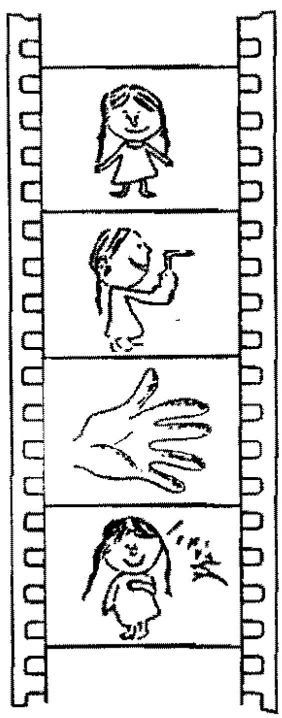
- Were the slides carefully planned ?
- Could they have been organized in a more effective way ?
- Could the audience understand each photograph or drawing ?
- Did the slides help meet the objectives ?

7.2.2. Filmstrips

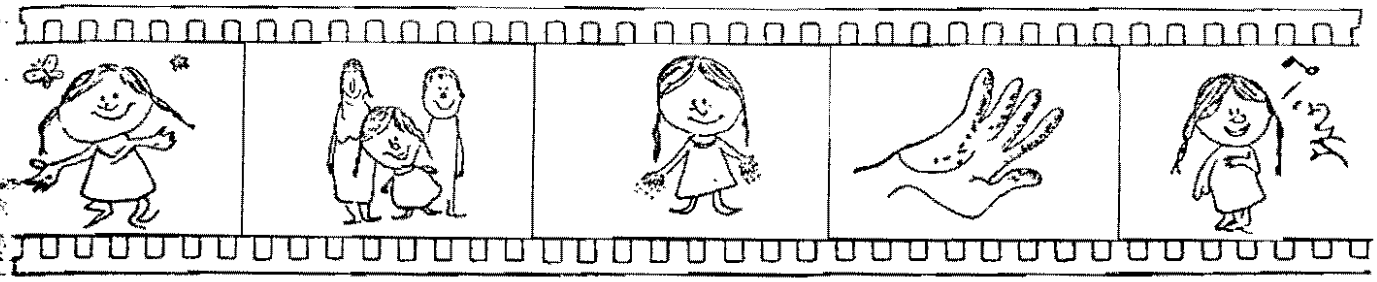
A filmstrip is a series of pictures on one continuous piece of film. Although filmstrips lose the flexibility of slide sets, they do have some real advantages. Filmstrips can be carefully sequenced and the sequence will remain unchanged no matter who uses the strip. Filmstrips are compact, and one small can will hold the equivalent of several dozen slides.

Most commercial filmstrips are made with a single frame camera. However, double frame filmstrips can be made by using a double frame camera, whichever is used depends on the kind of camera and projection equipment available.

Single frame filmstrip:



Double frame filmstrip:



Utilization: To make filmstrips, keep the following in mind:

- Plan carefully. The individual frames cannot easily be rearranged after the shooting, so plan the sequence of pictures carefully and then follow the plan exactly.
- Consider a variety of production techniques. A filmstrip can be made by shooting a series of live action scenes or by shooting a series of still photographs. Titles can be interspersed by taking pictures of titles written on a chalkboard or cutout letters on a flannel board or other suitable background.

Suggested Applications:

Filmstrips covering basic processes can be carefully planned and produced so they will be appropriate to large segments of the population. With printed guides about using them, these filmstrips can be distributed to extension workers, teachers, etc. Such materials can increase the effectiveness of their communication. If recording facilities are available, a filmstrip can be accompanied by a tape narration.

7.2.3. Motion Pictures

Motion pictures compell attention in almost any circumstance. However, motion picture projectors are expensive to purchase and generally are not readily available. However, if a projector is available, films can often be obtained from agencies or the United States and other Nations as well as Ministries of Agriculture, Education, Health and information. These will usually be 16mm. films.

In recent years there has been increased use of 8mm films. A new format called " super 8 " has come into the market and is being widely used for short, single, single concept films or film loops.

For anyone interested in making films, several publications explain the fundamentals of planning a film story. Camera operation is also discussed in a number of publications. But, in general, quality film making is the domain of professionals.

Utilization: Keep these ideas in mind when choosing and using film:

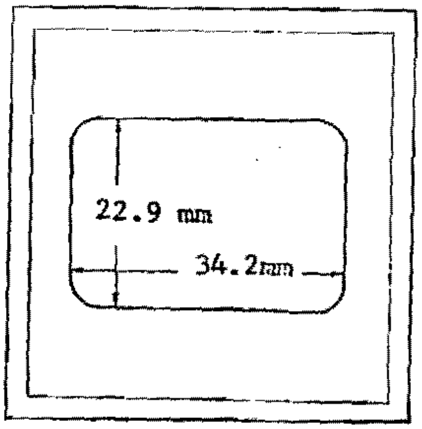
- Consider your audience when choosing a film.
- Preview the film in advance.
- Introduce the film. Before showing a film tell the viewers what the film is about and what they should look for.
- Use proper projection practices. Follow instructions. Always set up in advance. Keep a spare projection bulb and a spare exciter lamp on hand and know how to change them.
- Discuss the film. Discussion, after a film, may be the most important part of the presentation.
- Re-show all or part of the film. Re-showing allows the audience to grasp more fully the concepts presented.
- Combine the film showing with other media. Bulletin boards, posters, or pamphlets can be used to announce film showings. A presentation board can be used to list important points when introducing a film or when reviewing it after a showing.

Suggested Applications:

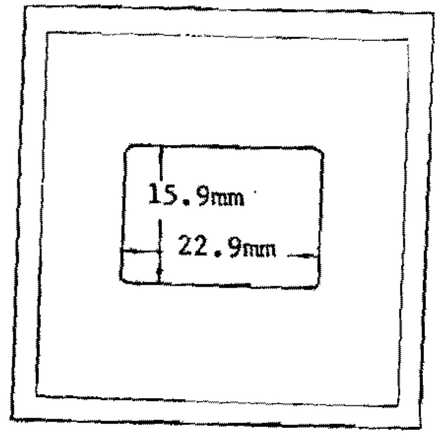
- To show processes where movement is of particular importance.
- To demonstrate a process to a large group.
- To entertain an audience. Films can be followed by a slide show, a short talk, or some other presentation relating to an agricultural problem.
- To attract and focus the attention of a large group on a major campaign or project.

Evaluation Questions:

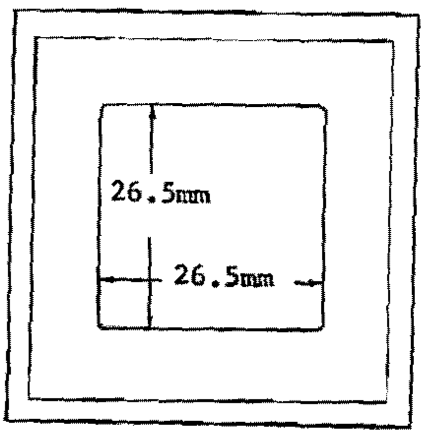
- Was the film content and style of presentation suitable for the audience..?
- Would the same ideas have been presented with equal effect by simpler means?
- Was the projection adequate..?
- Would additional discussion before or after the film have helped the audience understand the ideas being



135-35 mm



135-Half frame



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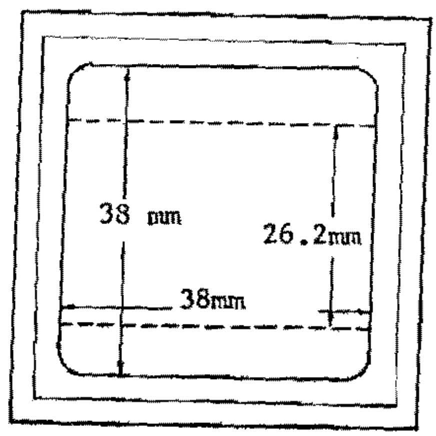
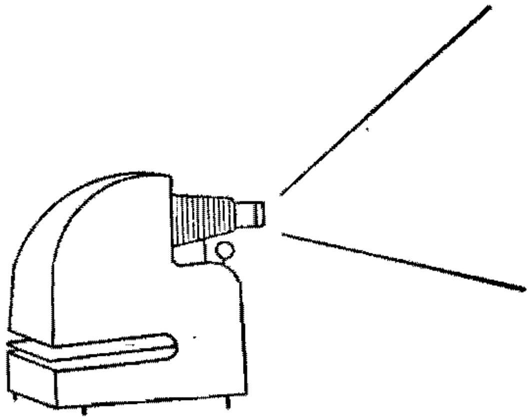


127-Supor-Slide (38x38 mm)
828 -(26.2x38mm)

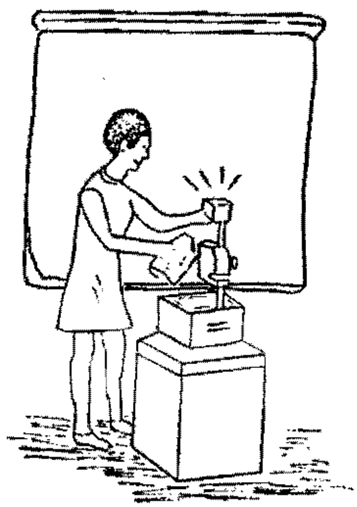
presented..?

7.2.4. Opaque Projection



Opaque projectors are available for projecting materials such as maps, photographs, book pages, or even three-dimensional objects. This is often quicker, more convenient, and safer than handing the materials around the room. The disadvantage is that most opaque projectors are large and cumbersome. Opaque projectors require a dark room because they have a low light output compared with projectors which show transparencies.

7.2.5. Overhead Projection



Overhead projectors are used to project large transparencies as well as some opaque and translucent materials. With an overhead projector the image is projected on the screen behind the person doing the presentation. The large transparency size coupled with an efficient ilumination and lens system provides a large, bright image on the screen that does not necessitate darkening the room.

There are several techniques for making overhead transparencies, hand-drawn transparencies are the most useful when resources are limited. They can be made on cellophane, clear acetate, or old photographic film that has been cleared in a strong chlorine household bleach. Old X-ray film are often available from hospitals and they are ideal.

Lettering or drawing can be done with waxed pencils, india ink, and some felt-point pens.

When making and using overhead materials, consider these factors:

- Keep it simple. Use one basic idea in each transparency and avoid unnecessary visual elements.
- Use legible lettering.
- Use imaginative design.
- Use good projection techniques. Line up the projector and focus in advance.

Overhead transparencies can be used to help present a variety of concepts in many subject areas. Evaluation of effectiveness should be based on their contribution to meeting the instructional objectives.

7.3. Recording

Tape recordings are inexpensive, durable, easy to transport or to mail. Also, tapes can be erased and used over and over again. Recorders are available in a variety of types, sizes, and prices. Until recently, most recorders used 1/4 inch tape on a reel, but recorders that use 1/8 inch tape in cassette are becoming increasingly popular. Reel-to-reel recorders are advantageous when high quality is needed or when a considerable amount of editing is required. Cassette recorders are particularly useful when portability and ease of operation are important. Both types are available for operation on batteries or external power sources. Choice should be based primarily on the intended use. The instruction booklets that come with each machine provide step-by-step details of operation.

Utilization:

Microphone choice and use. Tape recorders come with a microphone that is electroincally matched to the particular type of recorder.

In general, when recording one voice, place the microphone 20 to 30 centimeters from the person at about the level of his or her mouth. When recording the voice of several persons, try to place the microphone near the center of the group in the middle of a table. When a microphone is set on a table, put a folded cloth under it to avoid vibrations. Do not run a microphone cord parallel to an A.C. power cord. Cross the cords at right angles to avoid hum. Avoid handling the microphone during a recording to reduce noise.

<u>Acoustic treatment</u>. Recording quality can be improved by making a temporary blanket boot or by placing the microphone in a corner with a blanket or other soft material behind it. This reduces reverberations and helps cut down background noises.

<u>Recording Level</u>. Follow the instructions that come with the recorder to determine the proper settings. Setting the recording level too high will result in distorted sound. Setting it too low will emphasize background noise.

<u>Tape splicing</u>. Sooner or later a tape breaks, but it can easily be spliced together. Use tape-splicing tape, not ordinary cellophane tape, and follow these three steps:

1.) Hold the ends of the tape together with a slight overlap and cut both pieces at the same time at an angle of about 60 degrees.

2.) Join the two ends together, uncoated side up (shiny side) and cover the joint with a piece of splicing tape.

3.) Trim off the excess splicing tape alongside the edges of the recording tape.

<u>Tape editing</u>. This is a selective cutting and splicing operation used to remove unwanted portions or to rearrange parts of a recording. The exact point for editing can be located by moving the tape back and forth by hand across the recording head and marking the point with waxed pencil.

<u>Recording from record players or radios</u>. Whenever possible, connect the recorder directly to the speaker terminals. The placing of the microphone in front of the speaker results in poor quality sound transfers.

<u>Suggested Applications</u>:

- To record interviews for later play back over a local radio station.
- To record comments of local person to accompany a slide show, silent film, flip chart, etc. For

example, recordings of comments made at a fertilizer demonstration site could be used with slides of the treated and untreated plots.
- To record the verbal presentation that goes along with a set of slides or filmstrip.

Evaluation Questions:

- Were different voices easily identified..?
- Would different microphone placement or acoustical treatment have improved the recording quality..?
- Would editing have helped to remove extraneous noise or unnecessary details..?
- Could editing have helped organize the content in a more logical manner..?
- Did the tape really help do a better job of communicating..?

USE OF STATISTICS AND EXPERIMENTAL DESIGN IN CASSAVA RESEARCH

Gastón Mendoza *
María Cristina Amézquita *

GENERAL INTRODUCTION TO STATISTICS AND EXPERIMENTAL DESIGN

1.1. Introduction

I would like to start this first conference by giving you an out look on the biometrics Unit at CIAT and on the reasons for our existence within an agricultural research centre. We will define the Scientific Method, as an integral of the different steps followed by a research worker, from the critical observation of a phenomenon to the inference of conclusions. This will lead us to a better understanding of the relationship between the question on the investigators' mind and the experimental design he must use to prove his hypothesis. Finally, we will discuss why statistics are used in research and we will introduce some basic concepts and terminology.

The second and third conferences will cover the designs most used in agricultural experimentation. The fourth conference will end the theoretical part of the course with an overview on regression, correlation and surface response techniques.

The topic for the last conference will be the use of statistics in regional trials, conducted by the CIAT cassava Agronomy Program in 1975.

1.2. The role of the CIAT Biometrics Unit

The Biometric Unit is a central service group which assists in the planning, design, analisis and interpretation of the results related to the different experiments conducted by CIAT programs.

These services are financed by funds from the unit itself and are supplied to the research and training program at no cost.

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* Biometrics Unit, CIAT.

The functions of the Biometrics Unit are:

1. Statistical assistance in the planning, design, analysis and interpretation of the experiments.

2. Handling of large volumes of information (socio-economic and agricultural surveys, germplasm banks, creation and maintenance of data files).

3. Development of cooperative research projects with other programs.

4. Evaluation of technology (study of the impact of new varieties, cultural practices, etc. developed by CIAT).

5. Research on the implementation of new statistical tecniques.

6. Trainning of professionals in the field of statistics.

1.3. The Scientific Method:

Scientific method is the set of logical steps followed by a research worker in arriving to an inference starting from the critical observation of a phenomenon. We can say that scientific method is the use of logic and objectiveness for the better understanding of a phenomenon. Its essential characteristic is that starting from a critical observation one can arrive to a hypothesis which may be experimentally proved. We can describe the process followed by the scientific method thus:

1. Observation of the Phenomenon: The phenomenon is observed in a critical way but without leading us to any conclusions. For instance, in a cassava field planted with only one variety, some areas can be observed where plants are stunted while in other areas the plants are healthy.

2. Problem definition: This observation of the phenomenon leads to the definition of a problem whose solution must be the goal of the researcher.

3. Establishment of the hypotheses: The investigator can develop many hypotheses on the possible causes of the observed phenomenon. The important thing is to formulate hypotheses relevant to the problem and experimentally verifiable. In other words, the operational significance to-wards solving the problem, must be kept in mind. Continuing with our example, a reasonable hypothesis could be: Ho: Nitrogen deficiency in the soil causes lack of vigor in the plant.

4. Planning of the experiment: Once the hypothesis has been established, the following step is to proof or disproof it objectively by means of an experiment. By it, the researcher tries to control all factors except those whose effect he wishes to measure. However, some factors exist which are impossible to control, for example, weather variables. The uncontrolled factors constitute the "experimental error". Before choosing an appropriate experimental design, the treatments to be

tried must be especified, the experimental material must be selected, it must be decided what type of population the results will be applied to, and the desired accuracy. If hypothesis Ho from our previous example was to be proved, one way of checking it objectively would be to test different levels of nitrogen and observe the performance of the plant keeping other factors constant (other minerals in the soil, water, etc.).

5. Choosing the experimental design: The experimental design indicates the manner in which the experimental units[1/] must be groupped and how the treatments must be assigned to the experimental units. When selecting an experimental design, simplicity and precision must be coupled. The highest precision is obtained with a design which minimizes the variation not under experimenters' control, i.e, the variance of the experimental error. Further, the type of design to use depends on the hypotheses that are to be proven simultaneously. The higher the number of hypotheses, the more refined the design will be. A good experimental design provides the desired information with a minimum of efforts and resources. Once the experimental design is chosen, the forms for data colection and the analysis procedures are designed.

6. Conducting the experiment. The experiment must be conducted following strictly the experimental design and the planned statistical and cultural controls. Generally speaking, basic recommendations for a good handling of agricultural experiments are: uniformity in the application of water, in the planting density and in the application of insecticides, fungicides and herbicides, as long as these are not the studied factors.

7. Analysis and interpretation of results. The analysis of results produced by an experiment has the objective of proving by statistical means, the hypotheses established by the researcher.

8. Written report. This report must summarize every aspect of interest about the experiment, from motivation to interpretation of results. It is important to include all the unpredicted situations which ocurred, during the experiment.

1.4. Utility of statistics in research

There are two types of experiment: Deterministic and aleatory. A deterministic experiment is one whose result is, for all practical purposes, exact. For example, a physical experiment. An aleatory experiment is one whose result cannot be predicted because it is subject to variations not under control of the researcher, such are biological experiments. As a consequence, the verification of a theory by aleatory

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1/ Experimental unit is the minimum unit of experimental material to which a treatment is applied. For example, in field experiments experimental units are usually plots and not individual plants.

experiments cannot be absolute. The worker can only conclude that the observations are compatible or not with the theory, within the limits of error to which observations are submitted.

The role of statistics is to supply means which allow a distinction between situations where the observed differences among different "treatments" are relatively small and attributable to chance, and situations where such differences are relatively large and are better explained by effects different from the "treatments"; in both cases the conclusions arrived at have a known reliability.

1.5. Basic concepts and terminology:

Sample and Population. A sample is a collection of individuals or observations belonging to a bigger collection called population or universe from which we need information. If the selection of individuals is done randomly the sample is called a random sample.

Random variable. Is one whose value cannot be predicted but depends on chance.

Frequency distribution. It is the table of frequencies obtained by grouping the data in exclusive and exhaustive classes. Its graphic representation is called a histogram of frequencies. For the case of a continuous variable, if the class interval is reduced indefinetely, its distribution function is obtained. Example 1: Distribution of the odd digits in each one of 200 random samples of 10 digits. If X= number of odd digits in a sample of 10, the (observed) frequency distribution could have been:

X	0	1	2	3	4	5	6	7	8	9	10
Observed frequency	2	2	8	25	39	45	35	25	14	4	1

and the corresponding frequency graph is shown in figure (a). Variable has for theoretical distribution the so-called binomial distribution where $p=1/2$ and $n=10$[1/] and it is possible to demonstrate that $\Pr(X=x)=\binom{10}{x}(1/2)^{10}$, so that the theoretical frequency distribution (adjusted to whole digits) is:

	0	1	2	3	4	5	6	7	8	9	10
Theoretical frequency 200 Pr(X=x)	0	2	9	23	41	50	41	23	9	2	0

1/ Generally, if $X \sim Bin(n,p)$, then $\Pr(X=x) = \binom{n}{x} p^x(1-p)^{n-x}$,

$0 < x < n$; were $\binom{n}{x} = \frac{n!}{(n-x)!x!}$

Example 2: Normal distribution with mean $\mu = 5$ and variance $\sigma^2 = 2.5$. It is an approximation of the previous theoretical distribution with the same central tendency and equal "dispersion" around the mean (variance). Figure (b) shows the corresponding graph.

Normal distribution: Two "parameters" characterize a normal distribution: μ (mean) and σ^2 (variance; σ = standard deviation). If X is distributed following a normal distribution with mean μ and variance σ^2 we can write $X \sim N(\mu, \sigma^2)$. The normal distribution has many uses in statistics for practical and theoretical reasons; very manageable and extensively tabulated; many random variables follow approximately a normal distribution or may be reduced to normal by proper transformations; the distribution of sample means from any population tends to be normal as the sample size increases.

Some properties of the normal distribution are presented next:

1. Probability density function:

$$f_X(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-(x-\mu)^2/\sigma^2} \qquad -\infty < x < \infty$$

2. Cumulative distribution function.

$$F_X(x) = \Pr(X \le x) = \int_{-\infty}^{x} f_X(x)\,dx$$

= area under the curve $f_X(x)$ from $-\infty$

3. The following property is valid for all random variables

$$\int_{-\infty}^{\infty} f_X(x)\,dx = 1$$

4. Parameters μ and σ^2 are estimated from a sample of size by the following statistics,

$$\hat{\mu} = \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad \hat{\sigma}^2 = S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$$

5. If $X \sim N(\mu, \sigma^2)$ and σ^2 is known, then

$\Pr(\mu - \sigma < X < \mu + \sigma) = .68$

$\Pr(\mu - 1.96\sigma < X < \mu + 1.96\sigma) = .95$

$(X-\mu)/\sigma \sim N(0,1)$

$\bar{x} \sim N(\mu, \sigma^2/n)$ and $\dfrac{\bar{x}-\mu}{\sigma/\sqrt{n}} \sim N(0,1)$

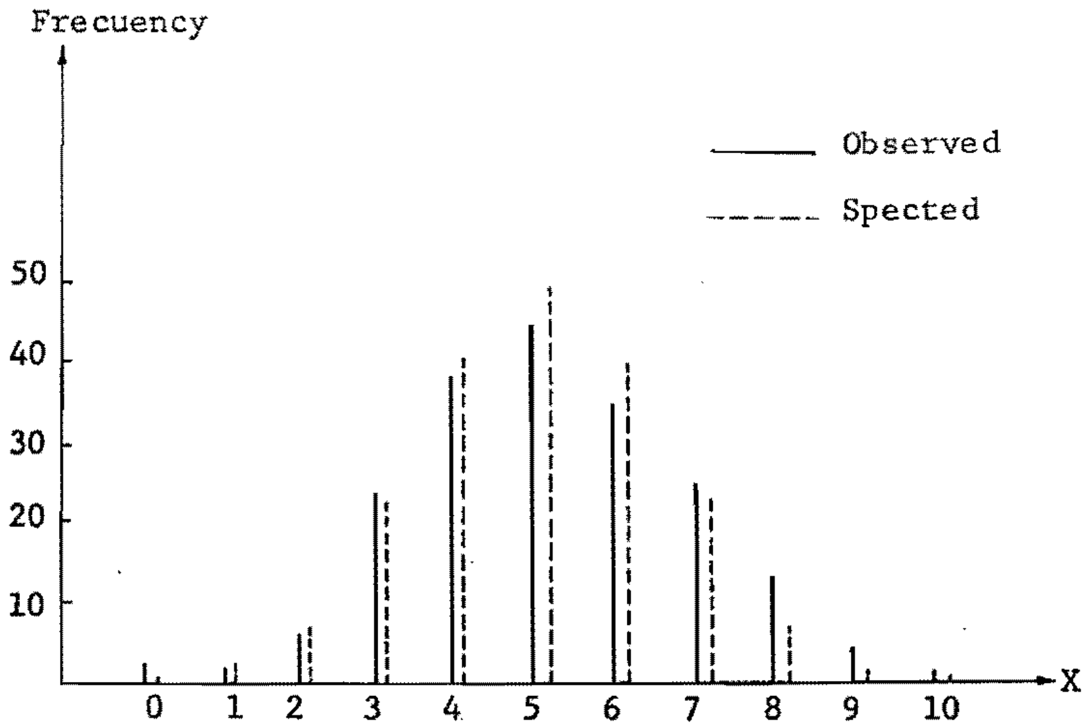


Fig.(a): Frecuency distribution of the number of odd digits in each of 200 samples of size 10.

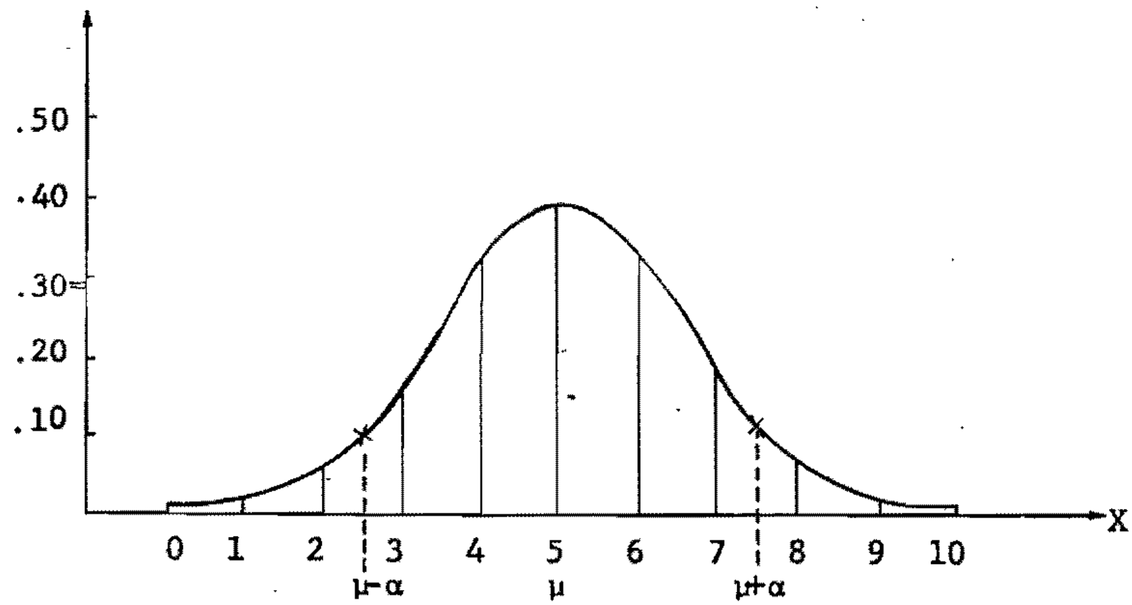


Fig. (b): Graph of the density function of a normal distribution with mean $\mu=5$ and variance $\alpha^2=25$.

6. If $X \sim N(\mu, \sigma^2)$ but σ^2 is unknown, then $(\bar{x}-\mu)\sqrt{n}/S$ follows a similar distribution to N(0,1) called t-distribution with (n-1) degrees of freedom.

Test of hypothesis

Null hypothesis (Ho): It is the one currently accepted as true and is rejected only if the experimental evidence against it is "large".

Alternative hypothesis (H_1): It is the one that would be "proven" when the null hypothesis is rejected.

Example 1: Two-tailed test. Ho: $\mu_1 = \mu_2$ Vs. H_1: $\mu_1 \neq \mu_2$

Example 2: One-tailed test Ho: $\mu_1 \leq \mu_2$ Vs. H_1: $\mu_1 > \mu_2$

Type I error: It is the error committed when a true null hypothesis is rejected.

Type 2 error: It is the error committed when a false alternative hypothesis is accepted.

The classic procedures for hypothesis testing minimize the probabilities of a type II error, (called, operating characteristic of the test), for a predetermined level of probability of type I error (called, level of significance) and of sample size.

Level of significance: α =Pr (rejecting Ho|Ho is true)

Level of confidence: 1- α =Pr (accepting Ho|Ho is true).

THE MOST COMMON DESIGNS USED IN CASSAVA EXPERIMENTATION

2.1. What is the experimental design?

By experimental design we understand a set of rules which indicates how to assign the treatments to the experimental units. A good design allows valid comparisons between treatments and the control of the main source of variation that field experiments present: soil heterogeneity. A good design must include three important aspects: random application of treatments to the experimental units, a proper number of replications and a maximum control of the experimental error.

2.2. Choosing the design:

The best type of design for a given experiment depends on the magnitude of the soil heterogeneity in the experimental area, on the type and number of treatments to be tested and on the degree of precision desired.

2.3. The most used designs in cassava research:

The most commonly used designs in cassava field experiments are:

- Completely randomized design (for one or several factors).
- Complete randomized block design (for one or several factors).
- Split-plot designs.
- Systematic designs.

We will describe briefly how and when to use each one of these designs. We present a summary of the necessary calculations for the statistical analysis and some examples to illustrate its use.

2.4. Completely randomized design.

- Used when the experimental units are homogeneous, as in laboratory experiments.
- Any number of treatments can be tested (either levels of a factor or combination of levels of several factors).
- The treatments are applied to experimental units randomly.
- Any number of repetitions are possible.

Example: Three different ways of cassava stake planting are to be compared: horizontal, vertical and inclined planting. The soil area available for the trial is perfectly homogeneous. Since we wish to compare three treatments, we must divide the area in 3,6,9,12,15, etc. plots (experimental units) depending on the maximum number of repetitions possible, 1,2,3,4,5, etc. respectively. If, for example, the available area is restricted so that the maximum possible replications are 2, the area will be divided in 6 equal experimental units and each treatment will be applied to two of them, randomly. The following illustration shows one possible layout of the treatments in the field. The tested variable would be yield per plot, measured as fresh weight of roots in Kg.

Rep I	HS	IS	VS
Rep II	VS	HS	IS

HS = Horizontal stake planting

VS = Vertical stake planting

IS = Inclined stake planting

Field layout of a completely randomized design with three treatments and two replications.

2.4.1. Analysis of variance:

Mathematical model

$$Y_{ij} = \mu + \tau_i + e_{ij} \qquad i = 1,2,\ldots\ldots,t \quad j = 1,2,\ldots\ldots,r$$

- e_{ij} — Experimental error in cell (i, j)
- τ_i — Effect of treatment i
- μ — Grand mean
- Y_{ij} — Variable under study observed in plot j where treatment i was applied.

Assumptions: $e_{ij} \sim NID(0,\sigma^2)$; $\sum_{i=1}^{t} \tau_i = 0$

If $\overline{Y}_{..} = (\sum_{i=1}^{t} \sum_{j=1}^{r} Y_{ij})/(rt)$,

$$\overline{Y}_{i.} = (\sum_{j=1}^{r} Y_{ij})/r$$

then $\bar{Y}_{..}$ is an estimator of μ,

$\bar{y}_{i.}$ is an estimator of $\mu+\tau_i$

Besides, the sum of squares of the deviations with respect to $\bar{Y}_{..}$, denominated total sum of squares corrected for the mean, can be splitted in the following manner:

$$\sum\sum(Y_{ij}-\bar{Y}_{..})^2=\sum\sum(\bar{Y}_{i.}-\bar{Y}_{..})^2 + \sum\sum(Y_{ij}-\bar{Y}_{i.})^2$$

The first sum in the right hand side is an indicator of the differences among treatment means, and the second is an indicator of the variability of the observations with respect to the corresponding treatment mean. For such reasons they are called treatment summ of squares and error sum of squares, respectively. To make these two indicators comparable, the so-called degrees of freedom are introduced. The quotient of a sum of squares by its corresponding number of degrees of freedom is called mean square of such effect. The degrees of freedom associated with TSS, TRSS and ESS are, respectively, rt-1, t-1 and (r-1)t.

Let's consider the null hypothesis Ho: $\tau_i=0, i=1,\ldots,t$, Vs. the alternative hypothesis H_1: $\tau_i\neq 0$ for at least one i.

If hypothesis Ho is true, that is, there are no differences among treatment means, then TRMS and EMS tend to be similar and as a consequence the ratio TRMS/EMS tends to be approximately one. If, by the contrary, H_1 is true, then TRMS tends to be higher than EMS and as a consequence the ratio TRMS/EMS tends to be higher than one. Therefore, values of TRMS/EMS close to one support Ho and higher values support H_1. It is interesting to point that EMS is an estimate of the variance σ^2, which exists due to aleatory factors out of the control the researcher. Still remains to decide how "big" TRMS/EMS must be to be able to conclude, with certain reliability, that the observed differences among treatment means are due to real differences between treatments and not to chance. For this it is necessary to choose the confidence level $1-\alpha$ and make use of the fact that under Ho the ratio TRMS/EMS follows a distribution called as the F distribution with t-1 and (r-1)t degrees of freedom. Summaryzing, hypothesis Ho is rejected at the α level of significance if, and only if,

$$\text{Observed } F = \frac{TRMS}{EMS} > F_{t-1,(r-1)t}(\alpha) = \alpha - \text{Upper percentil of the } F_{t-1,(n-1)t} \text{ distribution}$$

All the above procedure may be condensed in the so-called ANOVA table.

Source of Variation	d.of f.	s.s.	m.s.	Observed F
Treatment	t - 1	$\frac{1}{r}\sum Y_{i.}^2 - \frac{1}{rt} Y_{..}^2$	TRMS	$\frac{TRMS}{EMS}$
Error	t(r-1)	TSS-TRSS	EMS	
Total (corrected for tr-1 global mean)	tr-1	$\sum\sum Y_{ij}^2 - \frac{1}{rt} Y_{..}^2$		

The formulae for sum of squares given above are appropriate for the use of desk calculators. $Y_{i.}$ is $\sum_j Y_{ij}$ e $Y_{..}$ is $\sum_{ij}\sum Y_{ij}$.

2.4.1. Numerical example:

The yield of t = 5 cassava varieties is to be compared. By previous experience we know that the soil is homogeneous. Further 30 plots are available. Then we can use r = 6 repetitions for each variety (it must be remembered that the number of repetitions is usually determined by the precision desired and not by the area available). The next step is to assign the varieties to the plots in a completely random way. Suppose the following were the observed yields in Kg per plot:

Variety							$Y_{i.}$	$\bar{Y}_i$
1	88	129	117	312	220	99	965	161
2	235	263	216	156	244	233	1347	224
3	412	225	218	463	156	226	1700	283
4	284	484	164	445	388	436	2201	367
5	674	332	595	498	571	366	3036	506

$Y_{..} = 9249$ $\bar{Y}_{..} = 308.3$

Some calculations to obtain the ANOVA table are:

$TRSS = (965^2 + 1347^2 + 1700^2 + 2201^2 + 3036^2)/\ 6 - 9249^2/30 = 431421$

$TSS = 88^2 + 129^2 + \ldots + 571^2 + 366^2 - 9249^2/30 = 716036$

The ANOVA table is:

Source of Variation	d. of f.	S.S.	M.S.	F Observ.	$F_{4,25}(.01)$
Varieties	4	431421	107855.3	9.474	4.17
Error	25	284615	11384.6		
Total	29	716036			

Since F observed > $F_{4,25}(.01)$, at α = .01 we must reject the null hypothesis that all varieties have equal yields. If we had decided to use α = .05, the critical value would have been $F_{4,25}(.05)$ = 2.78 which is also smaller than the observed F, so we would have concluded that at α = .05, the null hypothesis was rejected. It is the researcher's decision which significance level to use. Levels .01 and .05 are only guides which give, respectively, 1 and 5 opportunities in 100 of rejecting the null hypothesis when in fact it is true. In this case the minimum significance level at which the null hypothesis is still rejected is approximately 0.0001.

THE MOST COMMONLY USED DESIGNS IN CASSAVA EXPERIMENTATION (Cont.)

3.1. Randomized complete block design:

- It is used when the experimental material is not homogeneous and a classification in subgroups more or less homogeneous is possible. For example, if the field shows a known gradient in only one direction, it is possible to split it in "blocks" as homogeneous as possible. This gradient can be a fertility, acidity or slope gradient in a definite direction.

- Each block must contain all the treatments. The number of treatments must be relatively small (less than 12 according to Kempthorne; when the number of treatments is higher it is advisable to use Lattice designs). The treatments may correspond to different levels of a factor or to a combination of levels of several factors.

- The treatments are randomly assigned to experimental units from one block. A different randomization is done for each block.

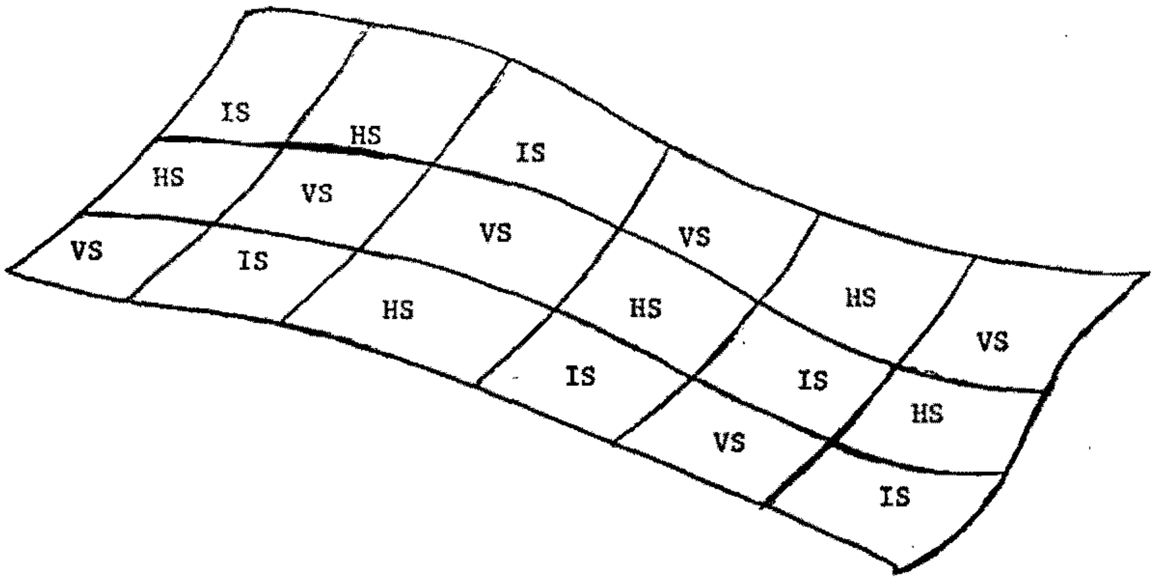
- It allows any number of replications.

- In order for this design to be more efficient than the completely randomized design, it is required that the variation among blocks be as high as possible, while the variation within the blocks is minimum. Further, for the tests significance to be valid the interaction treatment x block must be zero.

Example: Following the previous example, let's assume that three ways of planting the stake are to be compared, but the field available is not homogeneous; presenting a marked slope, with drainage problems at the lower portion. In this case, it is best to split the field into "blocks": HIGH, MEDIUM, and LOW, for example, and test the three stake planting methods in each block, allocating them randomly on the plots. The physical shape of the field, with 2 replications may be seen next:

ALLOCATION OF TREATMENTS ON THE FIELD
IN A RANDOMIZED COMPLETE BLOCK DESIGN
WITH THREE TREATMENTS AND THREE BLOCKS

High Zone (Block 1)	Medium Zone (Block 2)	Low Zone (Block 3)



HS = stake planted horizontally

VS = stake planted vertically

IS = stake planted inclined.

3.1.1. Analysis of Variance:
Mathematical model:

$$Y_{ij} = \mu + \tau_i + \beta_j + e_{ij} \qquad i = 1,2,\ldots,t \quad j = 1,2,\ldots,b$$

- e_{ij} — experimental error in (i,j)
- β_j — effect of block J
- τ_i — effect of treatment i
- μ — grand mean
- Y_{ij} — observed response in cell (i,j).

Assumptions: $e_{ij} \sim NID(0,\sigma^2)$; $\sum_{i=1}^{t}\tau_i = 0 = \sum_{j=1}^{b}\beta_j$

If $\bar{Y}_{..} = (\sum_{i=1}^{t}\sum_{j=1}^{b} Y_{ij})/(bt)$,

$\bar{Y}_{i.} = (\sum_{j=1}^{b} Y_{ij})/b$, $\qquad \bar{Y}_{.j} = (\sum_{i=1}^{t} Y_{ij})/t$, Then $\bar{Y}$ is an estimator of μ

$\bar{Y}$ is an estimator of $\mu + \tau_i$

$\bar{Y}$ is an estimator of $\mu + \beta_j$

The total sum of squares corrected by the mean may be splitted thus:

$$\sum\sum(Y_{ij}-\bar{Y}_{..})^2=\sum\sum(\bar{Y}_{i.}-\bar{Y}_{..})^2+\sum\sum(\bar{Y}_{.j}-\bar{Y})^2+\sum\sum(Y_{ij}-\bar{Y}_{i.}-\bar{Y}_{.j}+\bar{Y}_{..})^2$$

The sums of squares of the right hand side are called S.S. due to treatments, S.S. due to blocks and error S.S. respectively. The degrees of freedom associated with TSS, TRSS, BSS and ESS are bt-1, t-1, b-1, and (b-1) (t-1), respectively. Like in the case of completely randomized design, the quotient of a S.S. by the corresponding number of d. of f. is called mean square. Likewise, EMS is an estimator of σ^2. However, the σ^2 of the randomized complete block model is not the same as that of the randomized completely design. In fact, if blocking is effective then σ^2 blocks $<<\sigma^2$ randomized completely. This is precisely the objective of blocking; to increase the precision of comparisons by excluding from the variability of the randomized completely design, that due to differences among blocks.

For the randomized complete block design it is possible to test <u>independently</u> the following pairs of hypothesis:

Ho: $\tau i = 0 \quad i = 1,\ldots,t,$ Vs

(I)

H_1: $\tau_i \neq 0$ for at least one i, and

Ho: $\beta_j = 0 \quad j = 1,\ldots,b.$ Vs

(II)

H_1: $\beta_j \neq 0$ for at least one j.

For similar reasons to those mentioned in the case of completely randomized design the decision rules for the hypothesis written above are:

(i) Reject the hypothesis $\tau_i = 0$, $i = 1,\ldots, t$ at the significance level α, sss $\frac{TRMS}{EMS} > F_{t-1,(b-1)(t-1)}(\alpha)$

(ii) Reject the hypothesis $\beta_j = 0$, $j = 1,\ldots, b$, at the significance level α, sss $\frac{BLMS}{EMS} > F_{b-1,(b-1)(t-1)}(\alpha)$

The ANOVA table is:

Source of Variation	d. of f.	s.s.	m.s.	Observed F
Treatments	t - 1	$\frac{1}{b}\sum_i Y_{i.}^2 - \frac{1}{bt} Y_{..}^2$	TRMS	TRMS/EMS
Blocks	b - 1	$\frac{1}{t}\sum_j Y_{.j}^2 - \frac{1}{bt} Y_{..}^2$	BLMS	BMS/EMS
Error	(t-1)(b-1)	SCT-SCTR-SCBL	EMS	
Total	tb - 1	$\sum\sum Y_{ij}^2 - \frac{1}{bt} Y_{..}^2$		

3.1.2. Numerical example:

Suppose we wish to compare the yields of t = 5 cassava varieties but the field is not homogeneous. Also, suppose it is possible to group the 30 available plots in b = 6 blocks of 5 plots each, so that the plots in one block are more or less equally fertile. The next step is to assign the varieties to the plots in each block, in a random way. Suppose that the yields obtained, in kg per plot were:

				REP.				
Variety	I	II	III	IV	V	VI	Y_i	$\bar{Y}_i$
1	88	129	117	312	220	99	965	161
2	235	263	216	156	244	233	1347	224
3	412	225	218	463	156	236	1700	283
4	284	484	164	445	388	436	2201	367
5	674	332	595	498	571	366	3036	506
$Y_{.j}$	1693	1433	1310	1874	1579	1360	$Y_{..}$ = 9249	$\bar{Y}_{..}$ 308.3
$\bar{Y}_{.j}$	338.6	286.6	262.0	374.8	315.8	272.0		

$TRSS = (965^2 + 1347^2 + 1700^2 + 2201^2 + 3036^2)/6 - 9249^2/30 = 431421.8$

$BLSS = (1693^2 + 1433^2 + 1310^2 + 1874^2 + 1579^2 + 1360^2)/5 - 9249^2/30 = 46644.3$

$TSS = 88^2 + 129^2 + \ldots + 571^2 + 366^2 - 9249^2/30 = 716036.3$

$ESS = 716036.3 - 431421.8 - 46644.3 = 237970.2$

The ANOVA table is:

Source of variation	d. of f.	s.s.	m.s.	$F_{Observed}$
Varieties	4	431421.8	107855.5	9.065
Blocks	5	46644.3	9328.9	0.784
Error	20	237970.2	11898.5	
Total	29	716036.2		

If $\alpha = .01$ the null hypothesis (I) is rejected since $9.065 > 4.43 = F_{4,20}(.01)$; however, null hypothesis (II) is accepted since $0.784 \not> 4.10 = F_{5,20}(.01)$. It is clear then that in this case blocking was not effective (P=.0002 >.0001).

3.2. Split-plot designs

- They are used when because of the nature of the levels of a factor, large experimental units are needed, while levels of other factors may be assigned to smaller units. For example, experiments where factor "irrigation" is to be measured it is advisable to separate the plots receiving certain levels of irrigation. Fertilizer and insecticide experiments present a similar case.

- The split-plot design is used when two factors are measured, one of which requires large units and the other may be assigned to smaller units. The levels of the first factor are assigned randomly to the main plots next, the levels of the second factor are assigned randomly to the sub-plots of each main plot. Each main plot will have as many sub-plots as there are levels of the second factor. Comparisons between levels of the first factor are less precise than those between levels of the second factor and those between interactions of first and second factors. At least two replications are necessary to make these comparisons.

- The split-split-plot design is used when three factors are to be studied and one of them requires large units while the other two can be assigned to smaller units. The levels of the first factor are assigned randomly to the main plots. The levels of the second factor are assigned randomly to the sub-plots of each main plot and the levels of the third factor are assigned randomly to the sub-sub-plots of each sub-plot. Each main plot contains as many sub-plots as there are levels of the second factor, similarly, each sub-plot contains as many sub-sub-plots as there are levels of the third factor. The comparisons between levels of the first factor are the less accurate; comparisons between levels of the second factor and interactions of first and second factor, have intermediate precision; finally, comparisons between levels of the third factor and its interactions, are the most precise. As in the case of the split-plot design, at least two replications are needed in order to make valid comparisons.

3.2.1. Numerical example;

Split-split-plots: The effect of thrips on the yield of four varieties of cassava is to be analyzed, with and without insecticide sprayings, with and without irrigation.

Factor A: Irrigation (2 levels): with irrigation (a_1)

without irrigation (a_o)

Factor B: Insecticide (2 levels): with insecticide (b_1)

without insecticide (b_o)

Factor C: Variety (4 levels): Variety 1
Variety 2
Variety 3
Variety 4

In order to keep the irrigated plots separate from the non-irrigated ones, the area was divided into two main plots and the two levels of the "irrigation" factor were assigned to them randomly. Each main plot was divided into two sub-plots to which the two levels of the factor "insecticide" were assigned randomly. Finally, each sub-plot was divided into four sub-sub-plots to which the four varieties were assigned randomly. Two replications were used. The following illustration shows the final layout.

REPLICATION I

Main plot 1 (with irrigation: a_1)

b_1 With insecticide	b_o Without insect.
V_2 (8)	V_1 (4)
V_4 (5)	V_3 (6)
V_1 (6)	V_2 (6)
V_3 (7)	V_4 (3)

Main plot 2 (without irrigation: a_o)

b_1 With insecticide	b_o Without insect.
V_2 (5)	V_3 (6)
V_4 (3)	V_1 (3)
V_3 (5)	V_2 (5)
V_1 (3)	V_4 (2)

REPLICATION II

Main plot 1
(without irrigation: a_o)

b_o Without insect.		b_1 with insecticide	
V_2	(6)	V_3	(6)
V_1	(4)	V_2	(4)
V_3	(5)	V_1	(5)
V_4	(4)	V_4	(4)

Main plot 2
(with irrigation: a_1)

b_1 With insecticide		b_o without insect.	
V_3	(7)	V_1	(4)
V_1	(6)	V_3	(8)
V_4	(4)	V_2	(4)
V_2	(7)	V_4	(5)

Numbers in brackets are yields in kgs.

The following tables are needed for the calculation of the ANOVA sums of squares:

AxB:

(6+3+5+2) + (6+4+5+4)

	b_o	b_1	
a_o	35	35	70
a_1	40	50	90
	75	85	160 = Y...

AxC:

	V_1	V_2	V_3	V_4	
a_o	15	20	22	13	70
a_1	20	25	28	17	90
	35	45	50	30	160

BxC:

	V_1	V_2	V_3	V_4	
b_o	15	21	25	14	75
b_1	20	24	25	16	85
	35	45	50	30	160

AxBxC:

a_o

	V_1	V_2	V_3	V_4	
b_o	7 (3+4)	11	11	6	35
b_1	8	9	11	7	35
	15	20	22	13	70

a_1

	V_1	V_2	V_3	V_4	
b_o	8	10	14	8	40
b_1	12	15 (8+7)	14	9	50
	20	25	28	17	90

Ax Rep:

	I	II	
a_o	32	38	70
a_1	45	45	90
	77	83	160

Bx Rep:

	I	II	
b_o	35	40	75
b_1	42	43	85
	77	83	160

AxBxRep: I

6+3+5+2

	b_o	b_1	
a_o	16	16	32
a_1	19	26	45
	35	42	77

II

	b_o	b_1	
a_o	19	19	38
a_1	21	24	45
	40	43	83

The correction term is:

$$TC = \frac{Y_{...}^2}{\text{Total number of plots}} = \frac{160^2}{2X(2X2X4)} = 800$$

$SST = 8^2 + 5^2 + ... + 4^2 + 5^2 - TC = 70.000$

$SS\ Rep = (77^2 + 83^2)/16 - TC = 1.125$

$SSA = (70^2 + 90^2)/16 - TC = 12.500$

$SSB = (75^2 + 85^2)/16 - TC = 3.125$

$SSAB = (35^2 + 35^2 + 40^2 + 50^2)/8 - SSA - SSB - TC = 3.125$

$SSC = (35^2 + 45^2 + 50^2 + 30^2)/8 - TC = 31.25$

$SSAC = (15^2 + 20^2 + 22^2 + 13^2 + 20^2 + 25^2 + 28^2 + 17^2)/4 - SSA - SSC - TC = 0.250$

$SSBC = (15^2 + 21^2 + 25^2 + 14^2 + 20^2 + 24^2 + 25^2 + 16^2)/4 - SSB - SSC - TC = 1.625$

$SSABC = (7^2 + 11^2 + ... + 14^2 + 9^2)/2 - SSA - SSB - SSC - SSAB - SSAC - SSBC - TC = 4.125$

$SS(AxRep) = (32^2 + 38^2 + 45^2 + 45^2)/8 - SSA - SSRep - TC = 1.125 = \text{Error (a)}$

$SS(BxRep) = (35^2 + 40^2 + 42^2 + 43^2)/8 - SSB - SSRep - TC = 0.5$

$SS(AxBxRep) = (16^2 + 16^2 + 19^2 + 26^2 + 19^2 + 19^2 + 21^2 + 24^2)/4 - SSA - SSB - SSRep - SSAB - SS(AxRep) - SS(BxRep) - TC = 0.5$

Error (b) = SS(BxRep) = SS(AxBxRep) = 1.000

Source of variation	d. of f.	s.s.	m.s	F Observated
Replication	r-1 = 1	1.125	1.125	1.00
Irrigation =A	a-1 = 1	12.500	12.500	11.11
Error (a)	(r-1)(a-1) = 1	1.125	1.125	
Insecticide =B	b-1 = 1	3.125	3.125	6.25
AxB	(a-1)(b-1) = 1	3.125	3.125	6.25
Error (b)	a(b-1)(r-1) = 2	1.000	0.500	
Variety = C	c-1 = 3	31.500	10.417	11.63
AxC	(a-1)(c-1) = 3	0.250	0.083	0.09
BxC	(b-1)(c-1) = 3	1.625	0.542	0.61
AxBxC	(a-1)(b-1)(c-1)= 3	4.125	1.375	1.54
Error (c)	a b(c-1) =12	10.750 1/	0.896	
Total	abcr - 1 = 31	70.000		

- The effects of replication and irrigation are tested with the Error (a):

$\frac{MSRep}{MS\ Error\ (a)} = 1.00 \not> 161 = F_{1,1}(0.05)$ We accept the hypothesis of of no effect due to replications (P=.5).

$\frac{CMA}{CMError\ (a)} = 11.11 \not> 161 = F_{1,1}(0.05)$ We accept the hypothesis of no effect due to irrigation (P= .1885).

- The effects due to insecticides and insecticide x irrigations are tested with the error (b):

$\frac{MSB}{MSError\ (b)} = 6.25 \not> 18.51 = F_{1,2}(.05)$ The hypothesis of no effects due to insecticide is accepted (P= .1296)

$\frac{MSAB}{MSError(b)} = 6.25 \not> 18.51 = F_{1,2}(.05)$ The hypothesis of no interactions AxB is accepted (P= .1296)

The varietal effects and their interactions are tested with Error (c):

$\frac{MSC}{MSError(c)} = 11.63 > 3.49 = F_{3,12}(.05)$ The hypothesis of no effects due to varieties is rejected (P=0.0007).

1/ Error (c) is obtained by substraction.

Finally, low F values for AxC, BxC and AxBxC lead to acceptance of the hypotheses related to those interactions.

3.2.2. Analysis of variance for a split-plot design

Source of variation	d. of f.	s.s.
Replication (Rep)	r-1	$(R_1^2+\ldots+R_r^2)/(ab)-TC$
Main plot (A)	a-1	$(A_0^2+\ldots+A_a^2-1)/(rb)-TC$
Error (a) = RepxA	(r-1)(a-1)	$(A_0R_1^2+A_0R_2^2+\ldots+A_{a-1}R_r^2)/b-$ SCRep-SCA-TC
Sub-plot (B)	b-1	$(B_0^2+\ldots+B_{b-1}^2)/(rb)-TC$
AxB	(a-1)(b-1)	$(\overline{A_0B_0}^2+A_0B_1^2+\ldots+\overline{A_{a-1}B_{b-1}}^2)/r$ SCA-SCB-TC
Error (b) = RepxB+RepxAxB	a(r-1)(b-1)	By difference
Total	abr-1	$\sum\sum\sum Y_{ijk}^2 - TC$

Where:

Rk = total for replication k, k= 1,2...,r.

A_i = Total for the i^{th} level of factor A, i = 0,1,...., a-1.

B_j = Total for the j^{th} level of factor B, j = 0,1...b-1

$\overline{AiBj}$ = Total for the combination (a_i, b_j), i =0,1,...a-1; j=0,1,...b-1

AiRk = Total for the combination (a_i, r_k), i =0,1,..,a-1; k=1,2,...r

TC = Y^2.../(abr) = correction term

(i) The hypothesis that the means of all levels of factor A are equal, is rejected iff MSA/MSError(a) $> F_{a-1,(r-1)(a-1)}(\alpha)$

(ii) The hypothesis that all levels of factor B are equal, is rejected iff MSB/MSError (b) $> F_{b-1,a(r-1)(b-1)}(\alpha)$

(iii) The hypothesis that the means of all slots (ai,bj) are equal is rejected iff MSAB/MSError (b) $> F_{(a-1)(b-1),a(r-1(b-1)}(\alpha)$

3.2.3. Numerical example Split-plot

In an experiment conducted at the University of Wisconsin the yields of four lots of oats were compared (a=4), for three chemical seed treatments and one control (b=4). The seed lots were assigned randomly to the main plots within each replication.

The seed treatments were assigned at random to the sub-plots within each main plot. Yields, in bushels per acre are given in the following table:

Seed lot	Replication	Control (a_0)	Ceresan M (a_1)	Panogen (a_2)	Agrox (a_3)	Totals
		Treatment (B)				
Vicland (1)	1	42.9	53.8	49.5	44.4	190.6
	2	41.6	58.5	53.8	41.8	195.7
	3	28.9	43.9	40.7	28.3	141.8
	4	30.8	46.3	39.4	34.7	151.2
Totals		144.2	202.5	183.4	149.2	679.3
Vicland (2)	1	53.3	57.6	59.8	64.1	234.8
	2	69.6	69.6	65.8	57.4	262.4
	3	45.4	42.4	41.4	44.1	173.3
	4	35.1	51.9	45.4	51.6	184.0
Totals		203.4	221.5	212.4	217.2	854.5
Clinton	1	62.3	63.4	64.5	63.6	253.8
	2	58.5	50.4	46.1	56.1	211.1
	3	44.6	45.0	62.6	52.7	204.9
	4	50.3	46.7	50.3	51.8	199.1
Totals		215.7	205.5	223.5	224.2	868.9
Branch	1	75.4	70.3	68.8	71.6	286.1
	2	65.6	67.3	65.3	69.4	267.6
	3	54.0	57.6	45.6	56.6	213.8
	4	52.7	58.5	51.0	47.4	209.6
Totals		247.7	253.7	230.7	245.0	977.1
Treatment totals		811.0	883.2	850.0	835.6	3,379.8

Replication	Totals
1	965.3
2	936.8
3	733.8
4	743.9

Source of variation	d. of f.	s.s.	M.S.	F Obs.	F (.01) table
Rep.	3	2842.87	947.623	13.79**	6.99
Seed Lot (A)	3	2848.02	949.340	13.82**	6.99
Error (a) = Rep.*Lot	9	618.29	68.699		
Treat (B)	3	170.54	56.847	2.80	4.40
Lot * Treat	9	586.47	65.163	3.21**	2.99
Error (b)	36	731.20	20.311		
Total	63	7,797.39			

4.0. Regression and correlation:

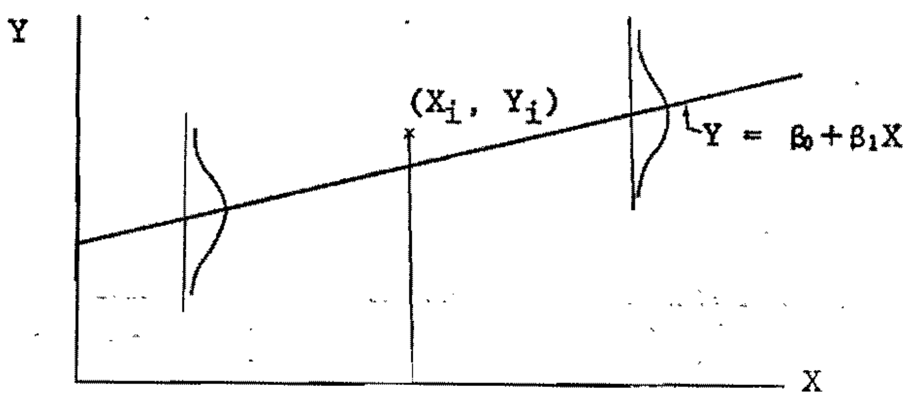
Regression and correlation are statistical techniques which serve to analyze the relationship between k "independent" continuous variables, $X_1, \ldots, X_k$ and one dependent variable Y, starting from n sets of data of de form $(X_1, \ldots, X_k; Y)$,which correspond to one experimental unit. X's are expected to be statistically independent but may be structurally dependent in the sense that response function for a factor depends on the levels of the other factors.

4.1. Simple linear Regression:

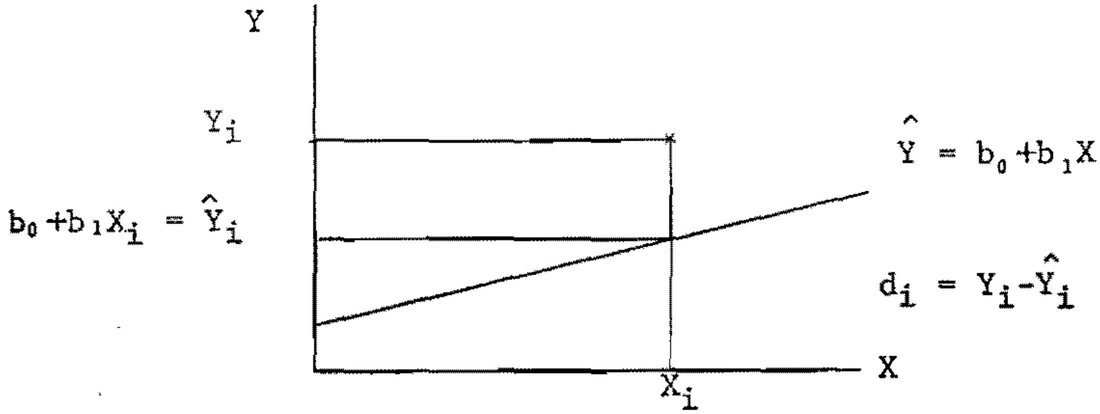
It is the simplest type of regression where the functional relationship between X and Y is assumed linear according to the model:

$$Y_i = \beta_0 + \beta_1 X_i + e_i, \; e_i \sim NID(0, \sigma^2).$$

The objective is the estimation of parameters β_0 and β_1 , from n observed pairs (X_i, Y_i).



The criteria used to determine estimators of β_0 and β_1 is to minimize the sum of squares of the observed deviations with respect to the regresion line fitted to the data. This fitting method is called least squares.



$$b_0 = \bar{Y} - b_1\bar{X}$$

$$b_1 = \frac{\sum(X_i-\bar{X})(Y_i-\bar{Y})}{\sum(X_i-\bar{X})^2}$$

$$\text{Var}\ (b_0) = \sigma^2\left[\frac{\sum X_i^2}{n\sum(X_i-\bar{X})^2}\right]$$

$$\text{Var}\ (b_1) = \frac{\sigma^2}{\sum(X_i-\bar{X})^2}$$

$$\text{Var}\ (\hat{Y}_i) = \sigma^2\left[\frac{1}{n} + \frac{(X_i-\bar{X})^2}{\sum(X_i-\bar{X})^2}\right]$$

$$\text{Var}\ (b_0+b_1X_*) = \sigma^2\left[1+\frac{1}{n}+\frac{(X_*-\bar{X})^2}{\sum(X_i-\bar{X})^2}\right]$$

X^* Indicates a non-existent level in the data used to fit the regression line.

ANOVA TABLE

Source of variation	d. of f.	S. S.	M.S.
Reduction due to regression	1	$b_1\{\sum X_iY_i-(\sum X_i)(\sum Y_i)$	MSR
Deviation from regression	n-2	by difference	MSE
Corrected total	n-1	$\sum Y_i^2 - (\sum Y_i)^2/n$	

MSE is an estimator of σ^2

The test of the null hypothesis $H_0 : \beta_1 = 0$ Vs.

$H_1 : \beta_1 \neq 0$ at α level

is done following the decision rule:

Reject H_0 sss $\frac{MSR}{MSE} > F_{1,n-2}(\alpha)$

where $F_{1,n-2}(\alpha)$ is the α -upper percentile of the F distribution with 1 and (n-2) degrees of freedom.

Coefficient of determination R^2

$R^2 = \frac{SCR}{SCT}$ = proportion of total variation explained by the linear regression of Y on X.

Values for R^2 close to 0 indicate a poor fit; values close to 1 indicate a good fit.

Linear correlation coefficient between X and Y:

$r_{xy} = \pm\sqrt{R^2}$,where the sign for xy is the same as the sign for b_1

$$= \sqrt{\frac{\sum(X_i-\bar{X})^2}{\sum(Y_i-\bar{Y})^2}}\, b_1 = \frac{S_x}{S_y}\, b_1$$

In general, $-1 \leq r_{xy} \leq 1$.

Values of $|r_{xy}|$ close to zero indicate a poor linear correlation between X and Y while values of $|r_{xy}|$ close to one indicate a high linear correlation between X and Y.

r_{xy} measures the degree of linear association between X and Y; on the other hand, b_1 (both X and Y considered as random) measures the predictable changes in Y when X is increased one unit.

4.2. Multiple linear regression:

When we have more than one independent variable, the model is:

$$Y_\mu = \beta_0 + \beta_1 X_{1\mu} + \beta_2 X_{2\mu} + \ldots + \beta_k X_{k\mu} + e_\mu, \quad e_\mu \sim NID(0, \sigma^2)$$

The estimated equation is

$$\hat{Y} = b_0 + b_1 X_1 + \ldots + b_k X_k$$

where b_0 , b_1 , . . . , b_k are estimated by the least squares method and may be obtained from a computer using any of various available multiple regression programs. Also, the summary ANOVA table can be obtained from the computer and is as follows:

Source of variation	d. of f.	S. S.	M. S.
R	k	SSR	MSR
E	n-k-1	SSE	MSE
T	n-1	SST	

As in the case of simple regression MSE is an estimator of σ^2 and

$H_0: \beta_k = 0 \;\forall k$ Vs.

$H_1: \beta_k \neq 0$ for some k

is tested with the decision rule:

Reject H_0 iff $\frac{MSR}{MSE} > F_{k,n-1-k}(\alpha)$

where $F_{k,n-1-k}(\alpha)$ is the α-upper percentile of the F distribution with k and (n-1-k) degrees of freedom.
The coefficient of determination, R^2 = SSR/SST, has the same interpretation anymore.

4.3. Uses of regression analysis:

1. Predict Y for given X values

2. Examine the effects of X's an Y (when there is a cause effect relationship between X and Y)

3. Determine the shape of the regression curve (polinomial regression and non-linear regression)

4. Adjust Y for uncontrollable effects quantified by X's (ANCOVA)

Example of simple linear regression

Observed data for rainfall (x) and yield of wheat (Y) in an area during 10 years

X (mm)	Y (Kgr./ha)
230	2600
210	2500
280	2900
270	2700
230	2700
280	3200
270	3300
220	2800
260	3000
250	3300

4.4. Systematic designs:

Experimental designs can be divided into two groups: aleatory and systematic. The designs we have studied so far are aleatory and are characterized because the assigning of treatments to experimental units is randornized.

On the other hand, in systematic designs, the assignation of treatments to experimental units is done in a systematic or ordered manner.
The objective of this type of designs is to allow the researcher the observation of a continuous response to the treatment. For example, if the response of a bean variety to nitrogen is being studied, and experiment can be designed consisting of different doses of Nitrogen to the soil in an increasing way and the yield of the plants receiving each treatment would be measured.

Before modern experimental design was developped, that is before Fisher introducted aleatory principles in the assigning of treatments to the experimental units, a systematic assignment of the treatment in each replication seemed natural. One of the most common types of systematic arrangement is that in which the assignment of treatments is exactly the same in any of the replications, as shown in the graph.

Replication 1				Replication 2				Replication 3			
A	B	C	D	A	B	C	D	A	B	C	D

Many other systematic designs have been developed, however, they all present relatively the same disadvantages respect to aleatory designs:

1. The detected differences between tratments can contain a systematic error due to the correlation between adyacent plots.

2. They are not efficient when the experimental area is heterogeneous because they will not allow a valid estimation of the variance.

The advantages are:

1. Simplicity

2. They allow an ordering of the treatments. For example, the variety may be ordered according to maturity, fertilizers according to their efficiency, etc.

3. The response to the treatment can be observed continuously.

As an example of systematic designs, we will mention the ones used for cassava experimentation at CIAT:

1. Response surfaces.

2. Fan design.

3. Paralell row design.

4.4.1. Response surface:

When one or more factors are to be studied - $x_1, x_2, x_3, \ldots, x_n$ which respresent continuous variables like weather, amounts of nitrogen, temperature, etc, it is natural to think in the yields, or response Y as a function of the levels of these factors. At is:

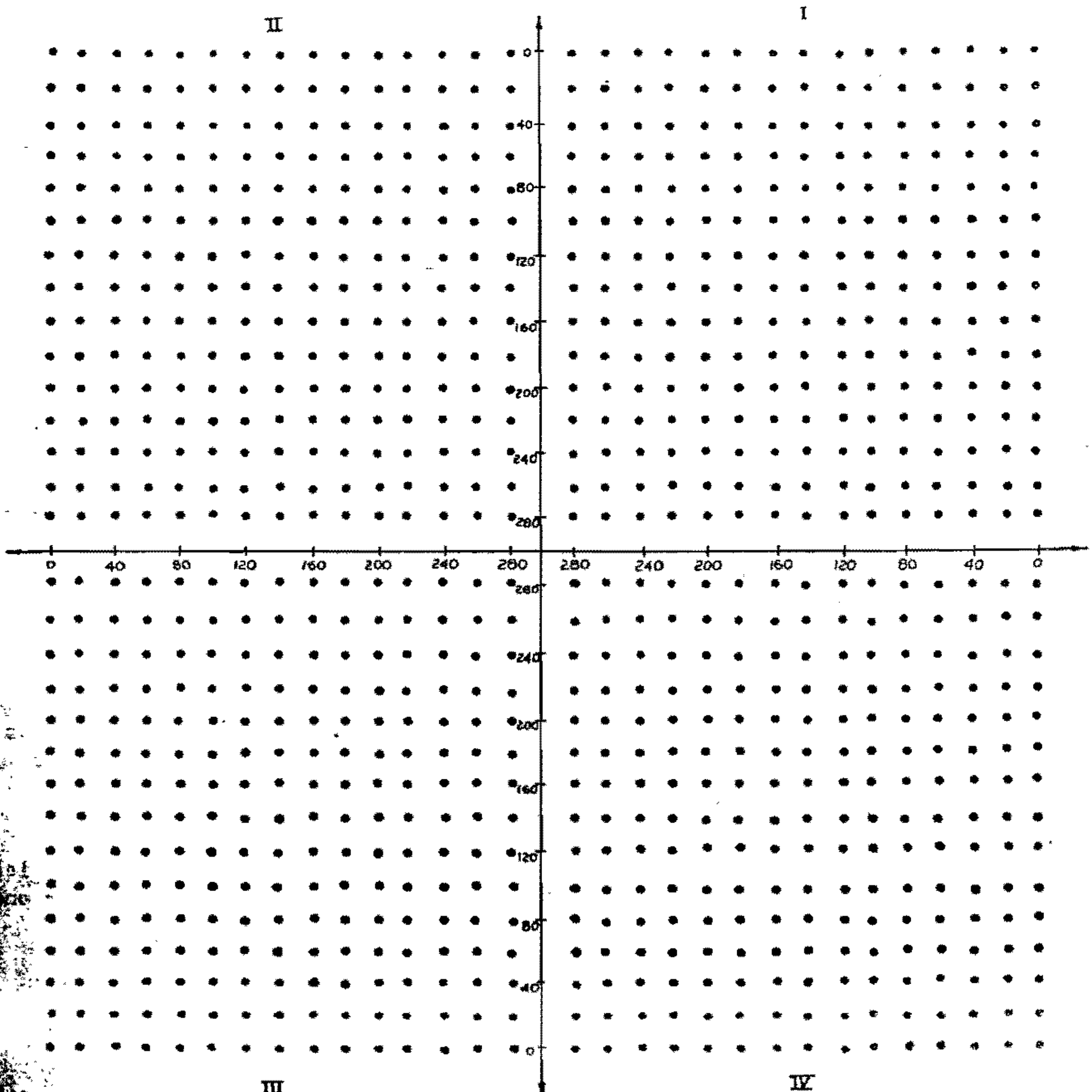
$$y = f(x_1, x_2, x_3, \ldots, x_n) + \varepsilon$$

Where ε represents the experimental error

Function f is called "response surface". The knowledge of f gives a complete summary of the experimental results and allows the prediction of the response for a combination of values of factors X_i.

Example: "Effect of N and K on the yield of the cassava plant". The effect of 16 nitrogen levels: 0,20,40,60,80,....,300 gr/-plant and 16 levels of potash: 0,20,40,60,....,300 gr/plant on the yield (as fresh weight of roots) of a cassava variety is to be measured. The observation are made on individual plants.
Plants were spaced 80 cms and levels of N and K were applied as shown in the graph, is such a way that each plant received a certain combination of N x K. Each quadrant corresponds to one replication. The number of treatments per replication, equal to the number of plants, is 16x16 = 256.

N x K SYSTEMATIC DESIGN FOR CASSAVA IN 4 REPLICATIONS



Each quadrant represents a complete replication of the design with 256 plants per replication. Each dot is one individual plant which receives one of the 256 N x K combinations.

The response of cassava to N and K may be expressed by the following response surface.

$$Y_{ij} = a_0 + a_1N_i + a_2K_j + a_3K_j + a_4N_i^2 + a_5K_i^2 + \varepsilon_{ij}$$

- ε_{ij} — Experimental error
- $a_5K_i^2$ — Quadratic effect of K
- $a_4N_i^2$ — Quadratic effect of N
- a_3K_j — Interaction effect
- a_2K_j — Linear effect of K
- a_1N_i — Linear effect of N
- a_0 — Average effect
- Y_{ij} — Yield of the plant with i^{th} level of N and j^{th} level of K

which mesures the linear as well as the quadratic effect of N and K and the interaction N x K and corresponds to what is called a quadratic regression model.

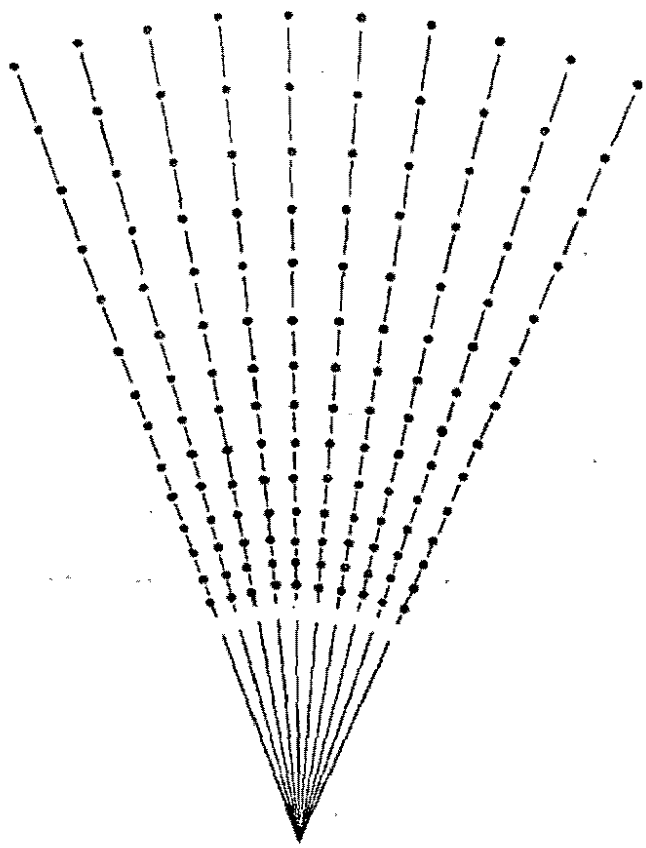
4.4.2. Parallel Row and Fan Designs 1/

These two designs are basically used to measure the yield of different varieties over a wide range of plant densities. The number of plants per unit area varies systematically from one to another, but the pattern for plant arrangement remains constant. Any range of plant densities can be tested.

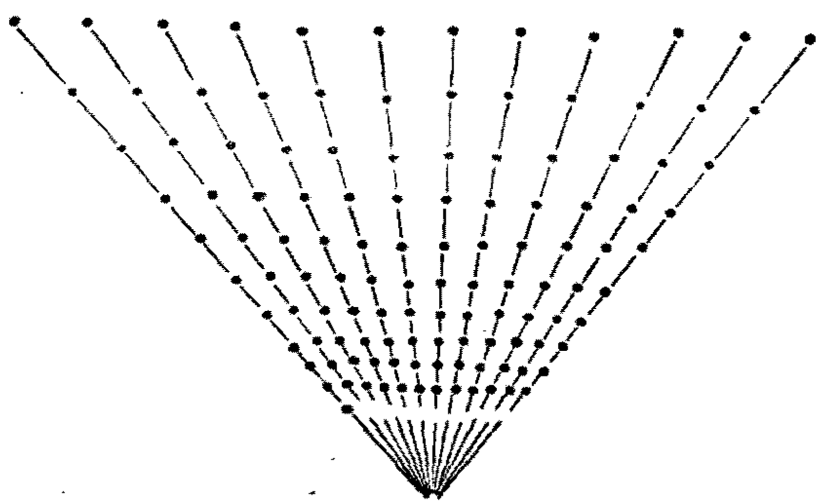
In the following graphs the arrangement of the plants in the field, with the fan and parallel row designs, respectively, is shown, for one variety.

1/ Bleasdale, J.K.A. "Systematic designs for spacing experiments. "Experimental Agriculture". August 12, 1966

ARRANGEMENT OF PLANTS IN A FAN DESIGN TO TEST 14 PLANT POPULATION



ARRANGEMENT OF PLANTS IN A PARALLEL ROW DESIGN TO TEST 10 PLANT POPULATIONS



In the fan design, plants are arranged in rows irradiating from a central point of origin, in such a way that the distance between plants along a radius is approximately equal to the distance between radii, in that point.
Each arc corresponds to a different plant density. When more than one variety is to be tested, this arrangement is duplicated in another section of the circle, keeping "border rows" between two adyacent varieties or an adequate spacing along the lateral radius.

To test or measure the yield response to different plant densities, a function may by fitted.

$$R_{ij} = f\ (D_j)$$

D_j: J^{th} level of plant density

R_{ij}: Yield of i^{th} plant planted with j^{th} density

which may or may not be linear, and thus find which density causes maximum yields.

In the parallel row design, each row corresponds to a different plant density level, the humber of plants per row is kept constant, but the distnace between rows varies systematically.

The analysis is similar to the one used for fan designs.

LIFE CYCLE SWINE FEEDING SYSTEMS WITH CASSAVA

Guillermo G. Gómez

Cassava, cultivated throughout the tropical countries for its high energic value, is normally used in different forms, as a food for more than 200 million people. The area planted to cassava in the world has increased approximately 30 percent during the period from 1961-65 to 1974 (FAO, 1974). About one-third of the world total is produced in Latin America above all in Brazil, which is by far the first cassava-producing country.

Although most of the cassava roots are presently used as human food, the perspectives for cassava as an animal feed have been stimulated by the agricultural policy changes of the European Economic Community (EEC), which made feasible the use of alternative energy feedstuffs, such as imported cassava, to replace high-priced cereals in composite feeds, notably for swine (Coursey and Halliday, 1974; Phillips, 1974).

As a result of active research on genetic selection and the development of more efficient cultivation methods and production practices, the improvement of cassava yields seems to be relatively easy to obtain under practical field conditions, as evidenced by experimental regional trials (CIAT, 1975, 1976). Alternative uses of cassava for the industrial starch and the animal feed markets would thus become economically feasible.

Extensive experimental evidence has been obtained on the use of cassava roots as an animal feed, and least-cost feed rations with varying prices of cassava and other feed ingredients have been estimated for different animal species by several EEC importers of cassava (Phillips, 1974). Most of the experimental data on swine feeding has been obtained with growing-finishing pigs, from weaning to marketing weights; but limited information is available on the reproductive periods and the life cycle swine feeding systems. The purpose of this paper is to review and report on experimental information regarding the use of cassava roots, especially in the form of fresh cassava and cassava meal or flour, throughout the life cycle of the pigs.

Effect of cyanogenic glucosides in cassava feeding programs

Cassava varieties are normally classified as sweet or bitter according to their cyanide content. Most of the hydrocyanic acid (HCN) or cyanide (CN) is found in the form of a cyanogenic glucoside known as linamarin. The concentration of linamarin, as evidenced by the cyanide liberated, is substantially higher in the peel of the roots than in the pulp (de Bruijn, 1973; Wood, 1965). Linamarin releases HCN on treatment with dilute acids; naturally however, the release of HCN is due to the action of the enzyme linamarase, usually present in the tissues - notably in the peel - of the roots. The contact of the enzyme with the substrate linamarin normally occurs when the tissues are damaged mechanically either by crushing or by destruction of the cellular structure of the plant or tissues.

Pigs do not readily consume fresh bitter cassava roots, and therefore, their growth is retarded. When a protein supplement was supplied ad libitum along with chopped, fresh bitter cassava roots, the pigs consumed an excess of the supplement to compensate for the limited consumption of the bitter cassava roots. On the other hand, fresh sweet cassava roots are readily consumed by growing pigs and their growth is acceptable, either when fed separately or thoroughly mixed with a protein supplement (Table 1) (Gómez et al. , 1976).

Because of the physical contact of linamarase and linamarin when cassava roots are chopped to be dried, most of the HCN is released; thus meal prepared from bitter cassava roots has a relatively low HCN content (100-150 ppm on a dry matter basis). A composite diet including high levels (approx. 73 percent) of bitter cassava meal was consumed slightly less by growing pigs than a diet based on similar levels of sweet cassava meal (Table 2) (Gómez et al., 1976), but the difference in consumption was not as great as that observed with the fresh roots. These data suggest that drying the roots greatly reduces the problem of limited consumption of fresh bitter roots by the growing pigs.

Limited information is available on the effect of cyanogenic glucosides present in bitter cassava varieties when fed during the reproductive periods. Fresh sweet cassava plus a 40 percent protein supplement containing 0, 250 and 500 ppm of added cyanide (as potassium cyanide) throughout the gestation period had no deleterious effect on the reproductive performance of gestating gilts at farrowing; nor was any carry-over effect observed in the subsequent lactation performance (Tewe, 1975). During lactation all gilts were fed a control diet based on common maize and soybean meal. An enlargement of the thyroid glands was observed in fetuses at the end of gestation of gilts fed diets containing high cyanide levels (Tewe, 1975); however, those gilts that received high levels of cyanide during the gestation period performed similarly at weaning time. Apparently the placental barrier plays a significant role in preventing the growing fetuses from toxic effects. Experimental information (Ekpechi, 1967 1973; Ermans et al., 1969; Van Der Velden et al., 1973) has been published in which a goitrogenic character is attributed to cassava, especially in areas where dietary iodine is limited. A working hypothesis has been proposed (Ermans et al., 1973) to explain the goitrogenic character of cassava, as a consequence of the increased thiocyanate concentration in the blood. Fortunately, since most of the cassava cultivars grown in Latin America are sweet, no major problems are encountered in feeding fresh, ensiled or dried cassava to animals, especially pigs.

Use of fresh sweet cassava roots in swine feeding programs

Fresh cassava roots and cassava meal are the forms in which cassava is most commonly used for swine feeding. Ensiled roots are also acceptable to pigs and could be a form of preserving them in highly humid environments such as those found in the lowland tropics. Experimental information to be reported on the use of fresh cassava in the different periods of the life cycle of the pig has been obtained through collaborative research between the Centro Internacional de Agricultura Tropical (CIAT) and the Instituto Colombiano Agropecuario (ICA) in Colombia.

Fresh cassava was fed ad libitum, either separately from the protein supplement or throughly mixed with it, and fed in quantities calculated to supply the minimal daily requirements of the growing pigs. The control diet was fed in automatic feeders, and all experimental animals were kept in confinement on cement-floored corrals. The results of this experiment are presented in Table 3 (Buitrago, 1964). Body weight gain was similar for the animals fed the control diet and those fed fresh cassava roots and the protein supplement ad libitum. The animals fed fresh cassava mixed with controlled quantities of the protein supplement, consumed less cassava and protein supplement; consequently, the average daily gain was lower than that of the other two experimental groups. On the other hand, the effect of restricting both cassava and the protein supplement according to the appetite and needs of the animals resulted in a better feed efficiency (kg of feed consumed/kg of body weight gain).

The amount of fresh cassava required per animal to reach marketing weight (95-100 kg) was approximately 390-400 kg of fresh chopped roots. The basic difference in feed intake was the amount of protein supplement saved when it was mixed with chopped fresh cassava; however, the extra labor required to do the mixing could reduce the advantages of this method. The consumption of fresh cassava by growing-finishing pigs varies according to the protein content of the supplement. The daily intake of cassava was greater when the protein supplement (fed free choice) supplied higher protein levels and the intake of the supplement decreased. An overall tendency to overconsume protein throughout the growing-finishing periods was observed as the protein content of the supplement increased (Table 4) (Job, 1975).

Fresh sweet cassava is readily consumed by gestating gilts or sows when an adequate supplement provides a good source of protein, minerals and vitamins. The results of an experiment to evaluate the use of fresh cassava for gestating gilts are shown in Table 5. All gilts were fed a control diet (maize-soybean meal) throughout the lactation period. Gestating gilts fed fresh cassava and kept in confinement gained more body weight during gestation than those fed fresh cassava but kept on pasture lots and than the gilts fed the control diet. The number of baby pigs farrowed and weaned by the gilts fed cassava in confinement was, however, less than that of the other two experimental groups.

Lactating sows fed a diet based on fresh chopped cassava mixed with a 40 percent protein supplement consumed on the average 6.5 kg of fresh cassava and 1.2 kg of protein supplement per day (Table 6). The litter performance for the cassava-fed sows was inferior with respect to the number of weaned pigs than the control diet-fed sows; the average weight of weaned pigs was higher for the cassava-fed sows; but total litter weight was similar for both experimental groups.

Results obtained during the different periods of the swine life-cycle suggest that fresh cassava roots are an excellent source of energy for growing-finishing pigs when properly supplemented with protein, minerals and vitamins. Handling of feeding programs based on fresh cassava is an important aspect to be considered. Self-feeding systems based on the separated, ad libitum consumption of fresh chopped cassava roots and protein supplement leads to an excess intake of the supplement resulting in a daily protein uptake significantly higher than the recommended requirement. A controlled supply of chopped cassava mixed with a protein supplement would restrict the excess protein consumed to normal levels, but the additional labor must be taken into account.

During the reproductive periods of gestation and lactation, a controlled individual feeding system is the most advisable under all circumstances. Unfortunately there is no information available on the use of fresh cassava during the consecutive gestation and lactation periods. It is assumed that no major differences would be encountered when a feeding system were based on the continuous use of fresh cassava; however, more experimental information is needed, especially with regard to the lactation period.

Life-cycle swine feeding program based on sweet cassava meal

Because of the handling difficulties normally encountered when fresh cassava roots are used for swine feeding, the most convenient and practical way, wherever possible, is to dry the chopped fresh roots in order to grind them into a meal or flour that can be easily incorporated and mixed in composite diets. Cassava meal is an excellent energy source of good nutritive value due to its highly digestible carbohydrates (70-75%), mainly starch; but since its protein content is extremely low, it requires a great deal of supplementary protein to balance the diets. In all experimental work at CIAT, cassava meal has been obtained from sweet cassava cultivars, mostly of the variety Llanera. The roots are chopped, sun dried on cement floors and then ground into a meal texture.

A life cycle swine feeding program was outlined, in which the level of crude protein of the experimental diets followed the recommendation of the National Research Council (NRC, 1973) (Table 7).

A feeding program was based on cassava meal and simultaneously compared to a control feeding program based on common maize. For both programs, soybean meal was used as the protein source to balance the experimental diets (Gómez et al., 1976a). The experimental work was aimed to study the long-term effects of feeding high levels of cassava meal on the reproductive performance of gilts.

Experimental animals were grouped according to their initial body weight and litter history into two groups of 16 weaned female pigs each. Selected gilts initiated the feeding program, either on cassava meal or common maize, when they weighed approximately 20 kg and were fed the experimental diets throughout their growing (20-50 kg), finishing (50-90 kg), pre-gestation (90-120 kg), gestation and lactation periods. Methionine was not added to any of the experimental diets (Table 8) (Gómez et al., 1976a). Boars used to breed the experimental gilts were fed a standard common maize-soybean meal diet. Experimental diets were supplied in automatic feeders during the growing, finishing and lactation periods. Individual, daily controlled feeding was undertaken during the pre-gestation (2.0 kg/diet/gilt) and gestation (1.8 kg/diet/gilt) periods. In all phases or periods of the experiment, water was available to the animals at all times.

Results obtained during the growing-finishing periods are shown in Table 9. The average daily gain obtained by the growing gilts fed the cassava meal-based diet was significantly lower ($P<0.05$) than that of the gilts fed the control diet but similar to gains previously reported when fresh cassava or cassava meal-based diets were fed to groups of females and castrated males (Maner, 1972). Reproductive performance of the two experimental groups is summarized in Table 10. In general, gilts in the cassava meal feeding program gained less body weight (37.5 vs 48.3 kg) during gestation than gilts in the common maize feeding program; however, gilts on cassava meal diets continued gaining body weight (+13.5 kg) throughout their lactation period whereas the gilts on common maize diets lost weight (-6.7 kg) during the same period. Consequently the overall change in body weight of the gilts in the cassava meal feeding program was significantly higher ($P<0.05$) than that of the gilts in the common maize feeding program (41.1 vs 26.3 kg, respectively). The number and weight of the live-born baby pigs were similar ($P>0.05$) for both experimental groups, although a trend of fewer and lighter baby pigs per litter was observed for the gilts in the cassava meal feeding program. At 21 days of age and thereafter, the number of suckling pigs per litter was significantly inferior ($P<0.05$), by approximately 3 pigs per litter, for the lactating gilts in the cassava feeding program. The average body growth of the suckling pigs in both experimental groups was similar, as evidenced by practically the same average weight at weaning time (15.87 vs. 15.70 kg). However, because of the larger number of weaned pigs per litter, the common maize feeding program produced heavier litters than the cassava meal feeding program (145.4 vs. 103.6 kg). A similar trend of raising fewer suckling pigs throughout the lactation period was previously reported in feeding fresh cassava or cassava meal during either the gestation or lactation periods (Maner, 1972).

The reasons or factors involved in the lower reproductive performance of the gilts in the cassava meal feeding program are not clear. The slightly lower body weight, although within the normal range, of the gilts fed the cassava meal-based diet at breeding could have had an adverse effect on the number of embryos which would subsequently affect the number of live-born pigs. From the production point of view, however, the most striking difference was significantly lower number of weaned pigs in the cassava feeding program. Whether these results are a consequence of a carry-over effect from the gestation period or are due to the gain in body weight during lactation - or to both - need further experimental evidence.

The absence of methionine supplementation does not appear to be responsible for the lower reproductive performance of gilts in the cassava meal feeding program. The results of recent experimental work in which cassava meal-soybean meal-based diets were fed throughout the gestation and lactation periods, with and without methionine, showed that gilts fed the cassava meal diets performed similarly, irrespective of the methionine supplementation, at least for the first gestation and lactation periods (Table 11) (Gómez and Santos, unpublished results). The experimental period was initiated at breeding when gilts exhibited similar body weights, and individual controlled feeding (1.8 kg diet/gilt/day) was followed throughout the gestation period. On the average, all animals of the experimental groups lost weight during lactation, as compared to the weight gain exhibited during lactation in the previously mentioned experiments (Gómez et al., 1976a).

The use of methionine supplementation is recommended when high levels of cassava are mixed in composite diets with plant protein sources, such as soybean meal. Apparently, methionine supplementation serves the double purpose of improving the protein quality of the diets and of supplying a readily available source of labile sulfur for cyanide detoxication (Maner and Gómez, 1973). In the case of experimental information obtained with rats, methionine supplementation in cassava meal diets normally produces significant improvement because the protein source used is casein, which is known to be deficient in this amino acid. In addition, for this type of biological evaluation with laboratory animals, suboptimal levels of dietary protein are commonly employed, making a response to methionine supplementation feasible. The effect of methionine supplementation would depend basically on the protein quality of the feedstuff used as the protein source.

Data on intake of the experimental diets and the basic ingredients recorded from the life cycle swine feeding program based on cassava meal are presented in Table 12. Overall total intake of experimental diets and for individual periods were similar for both groups. The most important difference was the amount of soybean meal required for the cassava meal feeding program as compared to the maize-based feeding program. Considering only the growing and finishing periods, the total relative amounts of cassava meal and soybean meal required per animal to reach marketing weight are 87 and 193 percent, respectively, of the amounts of common maize and soybean meal required to obtain similar performance with pigs in the common maize feeding program. Almost twice as much soybean meal is required for the growing-finishing periods of feeding programs based on cassava.

Feed intake during the reproductive periods (pregestation, gestation and lactation, as well as the baby pig starter feeding) was also similar for both feeding programs. The cassava meal-based feeding program required 87 and 159 percent of cassava meal and soybean meal, respectively, as compared to the amounts of common maize and soybean meal required in the feeding programs based on common maize. However, because of the lower experimental results obtained at weaning time with the cassava meal-based feeding program, the amount of diet required to produce a weaned pig was 45 percent higher (119.0 vs. 82.1 kg diet/weaned pig) for this feeding system as compared with the common maize feeding system. These data support the theoretical concept that the economic feasibility of using cassava as a substitute for other energy sources would depend on the relative price of cassava, as well as the price of the protein supplement needed to balance a cassava-based diet (Phillips, 1974).

SUMMARY

Sweet cassava roots are an excellent source of energy for swine feeding if properly supplemented with protein, vitamins and minerals. Fresh bitter cassava roots are not readily consumed by pigs due to their high linamarin content. Chopped fresh cassava could be fed to pigs throughout their life cycle, separately or mixed with a protein supplement. A tendency to over-consume the protein supplement and therefore to waste the excess protein was observed in all experiments where fresh cassava and supplement were fed ad libitum and separately.

A life cycle swine feeding program based on the use of high levels of cassava meal (60-70%) was tested at CIAT and compared with a conventional common maize feeding program. Soybean meal was the protein source used for all diets. Gilts in the cassava meal feeding program grew more slowly during pregestation and gestation, as compared to the gilts in the control program. However, gilts fed the cassava diets gained weight during lactation, whereas the gilts from the maize feeding program lost weight during the same period.

Litter performance at weaning was significantly inferior for the gilts fed the cassava meal diets; and since feed consumption was similar for both experimental groups, the amount of diet required to produce a weaned pig in the cassava feeding program was significantly higher than in the common maize feeding program. Recent experimental information suggests that methionine supplementation is not the factor responsible for the lower reproductive performance obtained in the cassava meal feeding program.

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Table 1. Comparison of intake and performance of finishing pigs fed either sweet or bitter fresh cassava and a protein supplement (P.S.) free choice or controlled.

Parameter	Sweet cassava +		Bitter cassava +	
	P.S. Ad. lib.	P.S. controlled	P.S. Ad. lib.	P.S. controlled
Avg daily gain (kg)	0.66	0.77	0.56	-0.08
Daily intake cassava (kg)	2.99	3.40	0.99	0.93
Daily protein intake (kg)	0.81	0.82	1.21	0.22
Total feed intake (kg)*	1.98	2.01	1.60	0.58
Feed/gain	2.99	2.61	2.86	Neg.
Protein in diet (%)	14.1	13.3	23.5	13.3

* Express to contain 10 percent moisture

Table 2. Effect of sweet and bitter cassava meal as the major carbohydrate source in diets for growing pigs.

Parameter	Cassava meal	
	Sweet	Bitter*
Initial weight (kg)	39.8	39.3
Final weight (kg)	57.1	54.9
Avg daily gain (kg)	0.62	0.56
Avg daily feed (kg)	1.77	1.35
Feed/gain	2.86	2.43

* Estimated to contain 150-200 mg HCN/kg of fresh cassava

Table 3. Performance of growing-finishing pigs fed fresh sweet cassava and a protein supplement (43%) free choice.

Parameter *	Control diet	Fresh cassava +P.S.	Fresh cassava Mixed with P.S.
Avg daily gain (kg)	0.84	0.83	0.79
Avg final body wt (kg)	100.4	99.5	95.6
<u>Avg daily feed intake (kg)</u>			
Fresh cassava	-	4.05	3.89
Protein supplement	-	1.17	0.73
Total feed intake **	2.89	2.80	2.30
Feed/gain	3.43	3.36	2.90

* Mean of five pigs per group; avg initial weight, 17.8 kg; 98-day trial
** Approximately 10 percent moisture content

Table 4. Performance of growing-finishing pigs fed fresh sweet cassava and 20, 30 or 40 percent protein supplement free choice

Parameter *	Control diet	Cassava + 20% P.S.	Cassava + 30% P.S.	Cassava + 40% P.S.
Daily gain (kg)	0.63	0.70	0.67	0.65
<u>Daily feed intake (kg)</u>				
fresh cassava	-	1.78	2.74	3.32
Protein supplement	-	1.39	1.00	0.75
Total feed intake **	2.08	2.08	2.07	2.04
Feed/gain	3.30	2.97	3.09	3.14
Protein in diet (%)	14.3	14.6	16.6	17.3

* Mean of five individually fed pigs per treatment; avg initial weight, 21.1 kg; avg final weight, 86.1 kg; 98-day trial

** Approximately 10 percent moisture content

Table 5. Performance of gestating sows fed diet based on fresh cassava and a protein supplement (40%)

Parameter	Control diet *	Fresh cassava + P. S.	
		Pasture **	Confinement ***
No. sows bred	10	10	10
No. sows farrowed	9	7	7
<u>Weight of sows (kg)</u>			
Breeding	165.8	163.6	152.8
Farrowing	185.7	188.5	190.5
Gestation wt gain	19.9	24.9	37.7
Lactation wt gain	13.2	7.7	8.4
<u>Progeny at farrowing</u>			
No. pigs/litter	10.4	10.0	7.7
Litter wt (kg)	13.3	11.2	9.1
Individual wt (kg)	1.28	1.12	1.18
<u>Progeny at weaning (35 days)</u>			
No. pigs/litter	8.3	7.3	6.9
Individual wt (kg)	6.94	6.05	6.49

* 1 kg/sow/day

** 1.7 kg fresh cassava + 0.4 kg P.S./sow/day

*** 3.1 kg fresh cassava + 0.62 kg P.S./sow/day

Table 6. Performance of lactating sows fed fresh cassava and a protein supplement (40%)

Parameter	Control diet	Fresh cassava + 40% P.S.
No. of sows	13	16
Postfarrowing sow wt (kg)	179.3	158.3
Sow wt gain 35 days (kg)	11.0	7.6
Daily feed intake (kg)		
Fresh cassava	-	6.5
Control diet or P.S.	4.8	1.2
Data at farrowing		
No. pigs/litter	10.8	9.3
Individual wt (kg)	1.18	1.36
Data at weaning (35 days)		
No. pigs/litter	9.0	7.6
Avg wt/pig (kg)	6.03	7.63
Total litter wt (kg)	54.3	58.0

Table 7. Crude protein content of experimental diets in life cycle swine feeding programs based on cassava meal or common maize and soybean meal as the source of protein

Life cycle period	Crude protein in diet (%)
Growing, 20-50 kg	16
Finishing, 50-90 kg	13
Pregestation, 90-120 kg	13
Gestation	16
Lactation	16
Baby pigs, starter feed (10-56 days)	18

Table 9. Experimental results of the growing-finishing periods of gilts * in life cycle swine feeding programs based on common maize or cassava meal

Parameter	Common maize	Cassava meal
No. gilts	15	16
Avg daily gain (kg)	0.77	0.71
Avg daily feed intake (kg)	2.38	2.30
Feed/gain	3.09	3.24

* Avg initial and final weights: 21.4 and 89.5 kg, respectively

Table 8. Composition (%) of experimental diets in life cycle swine feeding programs based on cassava meal or common maize

Ingredient	Growing		Finishing and pregestation		Gestation and lactation		Starter diet baby pigs	
	Maize	Cassava meal	Maize	Cassava meal	Maize	Cassava meal	Maize	Cassava meal
Common maize	79.5	-	87.9	-	76.4	-	62.5	-
Cassava meal	-	69.0	-	75.9	-	67.0	-	50.6
Soybean meal	15.8	26.2	7.3	19.3	18.8	28.2	22.7	34.6
Sugar	-	-	-	-	-	-	10.0	10.0
Minerals and vitamins *	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8

* All diets contained (%) the following: bone meal, 4.0; minerals premix, 0.5 and vitamins premix, 0.3.

Table 10. Experimental results of the gestation and lactation periods in life cycle swine feeding program based on cassava meal or common maize

Parameter	Common maize	Cassava meal
No. gilts farrowed	10	14
<u>Changes in body weight of gilts (kg)</u>		
Weight at breeding	127.6	118.5
Weight at 110 days gestation	175.6	156.0
Total gestation gain	48.3	37.5
Postfarrowing wt	160.6	146.1
Net gestation gain	33.1	27.6
Weaning wt	153.9	159.6
Change in body weight lactation	-6.7	+13.5
Change in body weight gestation-lactation	+26.3	+41.1
<u>Data at farrowing</u>		
No. live-born pigs	10.0	8.4
Avg weight/pig (kg)	1.09	0.97
<u>Data at weaning (56 days)</u>		
No. weaned pigs	9.4	6.6
Avg weight/pig (kg)	15.87	15.70
Total litter wt (kg)	145.4	103.6

Table 11. Effect of methionine supplementation in cassava meal-based diets for gestating-lactating gilts *

Parameter	Common maize	Cassava meal + Soybean meal 0.0% methionine	Cassava meal + Soybean meal 0.3% methionine
No. gilts farrowed	14	10	10
Body weight of gilts (kg)			
At breeding	117.0	121.2	120.1
Total gain, gestation	56.9	49.1	47.6
Weight loss, lactation	17.3	13.8	15.3
Total gain, gestation-lactation	39.6	35.3	32.3
Data at farrowing			
No. pigs/litter	8.5	9.1	9.4
Avg pig wt (kg)	1.09	1.06	1.07
Data at weaning (56 days)			
No. pigs/litter	7.1	8.2	8.0
Avg pig wt (kg)	16.74	16.15	16.54
Total litter wt (kg)	117.02	128.50	131.95

* Gómez, G. and J. Santos, unpublished results

Table 12. Intake (kg) of experimental diets and basic ingredients in life cycle swine feeding programs based on cassava meal or common maize

Experimental period	Common maize diets			Cassava meal diets		
	Diet	Maize	Soybean meal	Diet	Cassava meal	Soybean meal
Growing	77.9	59.5	14.7	91.9	63.6	23.9
Finishing	137.9	121.2	10.1	124.0	94.1	23.9
Subtotals	215.8	180.7	24.8	215.9	157.7	47.8
Pregestation	230.6	202.7	16.8	217.2	164.9	41.9
Gestation	209.9	160.4	39.5	211.0	146.0	54.9
Lactation	265.5	202.8	49.9	292.5	196.0	82.8
Baby pig/starter	79.6	49.8	18.1	51.1	25.9	17.7
Subtotals	785.6	615.7	124.3	771.8	532.8	197.3
Total	1001.4	796.4	149.1	987.7	690.5	245.1

PILOT PLANT FOR SINGLE-CELL PROTEIN PRODUCTION

J. Santos N. and G. Gómez

Root crops including cassava (*Manihot esculenta* Crantz) are commonly grown throughout the tropics for food and contribute a considerable proportion of the total caloric intake of the human population (FAO, 1973). Cassava has become the staple food of more than 200 million people throughout the tropics (Coursey and Haynes, 1970).

The prospects for increasing cassava production in tropical areas are very promising, not only as a consequence of an increase in the area planted to cassava but notably as a result of improved technology, which suggests that drastic improvements in crop yield could be readily obtained by appropiate genetic selection and cultural practices (CIAT, 1975, 1976).

Because pigs are efficient converters of the high energy content of cassava roots, the greatest possible increase in cassava utilization as an animal feed is most likely to occur in swine feeding. Extensive experimental information is available on the use of cassava roots in swine feeding, and some contributions to this knowledge have been made during the last few years at the Centro International de Agricultura Tropical (CIAT) in Cali, Colombia. Part of the work on the use of cassava in swine feeding has been done in collaboration with the Instituto Colombiano Agropecuario (ICA).

The most important factor for determining the use of cassava as an animal feed is its price in relation to alternate energy sources and its dependence on the price of supplementary protein sources (Phillips, 1974). Because of its low protein content as compared with cereals, any substitution of cassava (fresh, ensiled or dried) for cereals in mixed feeds would be accompanied by an increased requirement of supplementary protein. Experimental data indicate that a life-cycle feeding program for swine based on the use of cassava meal or flour requires approximately 60 to 65 percent more protein supplement (soybean meal) than a similar feeding program based on common maize (Gómez et al., 1976). Therefore, the potential of cassava as an animal feed in the tropics will depend to a great extent on the availability of conventional protein or on the development of new protein sources.

Conventional protein sources such as fish meal and soybean meal while are being used increasingly for human nutrition, are becoming so high in price that their use in swine feeding will be restricted in the future. Other protein sources such as cottonseed meal are of limited use because of their toxic nature. In addition, in many cassava-producing areas it is difficult to grow other crops (i.e., soybeans) that will provide the protein required to balance the animal feeding programs adequately. The need to find alternate nonconventional feed proteins is becoming increasingly important. Research relating to the use of cassava as an animal feed or as a substrate for microbial protein production is clearly justifiable.

The process for converting cassava into microbial protein is an attractive area of research for those cassava-producing areas where animal production - notably swine - could be significantly increased. The production of microbial protein from cassava would substantially upgrade the value of the feed and result in a nutritious product.

The existence of both a Cassava Program and a Swine Production Unit at CIAT makes it especially advantageous to undertake a project for the production of a fungal protein on a pilot plant scale. CIAT has completed the construction of this pilot plant in order to study the different aspects involved in the production of fungal protein using cassava as a substrate. This work is being done in cooperation with the University of Guelph under the auspices of the International Development Research Centre of Canada. The purpose of this paper is to report on some of the preliminary results and experiences.

THE PILOT PLANT PROCESS

The pilot plant at CIAT was built during 1975 and began operating by early 1976. The following equipment has already been installed: a washer, a rasper, two self-aspirating fermentors (the starter and main fermentors with working capacities of 200 and 3000 liters, respectively) and a roller-press harvester. The first two machines, built in Colombia, are normally used in the starch factories found around the Cauca Valley. The two fermentors and the biomass harvester were designed and built at the University of Guelph. The characteristics of the fermentors have been described elsewhere (Azi et al., 1975). Equipment layout and a picture of the pilot plant are shown in figures 1 and 2. A single-cell protein (SCP) laboratory has also been allocated and equipped in a local adjacent to the pilot plant. A Microferm, 10-liter bench-scale fermentor,* designed for batch fermentations and continuous culture of microorganisms, was installed in the SCP laboratory. In addition, accessory facilities consisting of racks and wooden trays for sun and air drying of the biomass are located in an area adjacent to the pilot plant.

* New Brunswick Scientific Co., New Brunswick, New Jersey

A detailed description of the basic aspects of the process was given by Reade and Gregory (1975). The process was designed to operate with a minimum of instrumentation. The parameters for monitoring culture growth are temperature, pH and dissolved oxygen. Although these parameters would not necessarily be required in practical production units, they facilitate research in that they confirm experimental information obtained on a laboratory scale at the University of Guelph. Both fermentors were provided with side openings for the insertion of instrument probes, which are controlled by means of a master switch box. The composition and preparation of the medium for the laboratory process, 200 and 3000 liter fermentors are basically the same as previously described (Reade and Gregory, 1975).

The pilot plant process starts with either fresh cassava roots or cassava meal or flour. When fresh roots are used, they are washed to remove the soil and sand clinging to the outside. Next, the whole roots including the peel are rasped to break open the cell walls in order to facilitate the suspension of the starch granules in the fermentation medium. The rasped cassava is then transferred to the fermentor, which is half filled with water previously heated to about 70°C by the passage of steam through a heat exchanger; in the case of the large (main) fermentor, a hoist and bucket arrangement is used to lift the rasped cassava. The high temperature of 70°C needs to be maintained for about 10 minutes in order to gelatinize the starch and to prevent the development of fungistatic activity in the mash (Reade and Gregory, 1975; Gregory et al., 1976). More water is added to the tank to bring the fermentor almost to its full operating volume, as well as to lower the temperature of the fermentation medium to about 46-47°C. The remaining ingredients necessary to complete the adequate nutrient supply for optimal growth of the microorganism are urea and monopotassium phosphate, which are added to the medium while stirring. Sulfuric acid (9 N) is then used to bring the initial pH of the medium to 3.5. The fermentor is now ready for inoculation of the microorganism. Fermentation is usually completed within 20 hours; temperature is maintained throughout the fermentation period by means of a temperature controller, which actuates a solenoid-controlled water valve to regulate the flow of cooling water at ambient temperature. At the end of the fermentation period, the biomass is harvested and can be fed fresh or sun/air dried to be subsequently incorporated into composite diets for animal feeding. The flow diagram for these steps is shown in Figure 3.

Standardization of the process was done with the 200-liter fermentor using either fresh cassava roots or cassava meal. Because people working in the pilot plant might be allergic to or infected by spores from revertants of the asporogenous *Aspergillus fumigatus* I-21A or by hyphal fragments (Sidransky, 1975), special safety precautions have been taken so preliminary observations, as well as the work under way are being obtained with the 200-liter fermentor. Use of the 3000-liter fermentor awaits more defined safety precautions, from a microbiological aspect (Gregory, this monograph), as well as from experimental results at CIAT's pilot plant.

<u>Preliminary results on SCP production from cassava at CIT's pilot plant</u>

The microorganism used is *Aspergillus fumigatus* I-21A (ATCC 32722) (Reade and Gregory, 1975). This fungus is an asporogenous mutant; therefore, the problem of aspergillosis (inhalation of spores) is practically eliminated or significantly reduced. Although a biomass harvester is now installed in the pilot plant, the information presented herein was obtained without the use of this machine; the harvesting of the final biomass was performed by emptying the contents of fermentation tank into burlap saks and squeezing most of the water content of the biomass, first manually and then with a wine press to obtain a partially dried product, which is placed on wooden-framed trays for furtherly drying by exposure to sun rays and air.

Average data from fermentations with the 200-liter tank, using either fresh chopped cassava roots or cassava meal or flour as the usbstrates, are shown in Table 1. The amount of either fresh roots or cassava meal used in each fermentation was determined by the content of total carbohydrates of the substrate so as to obtain an initial carbohydrate concentration of the fermentation medium of approximately 4 percent (w/v). The yield of the dried biomass obtained was similar for both substrates when expressed on a dry matter basis. The crude protein content of the final dried, product was about 28 percent, which is lower than that reported for laborabory results (Reade and Gregory, 1975), Gregory et al., 1976). The biomass, when water is partially extracted with a wine press, was dried easily when exposed to sun and air; the material became dark and hard when dried in an oven.

A biological evaluation with growing rats was performed to ascertain the nutritive quality of the total or crude protein content of the dried biomass resulting from fermentations with either fresh roots or cassava meal as substrates. Since this fungal protein has been reported (Gregory et al., 1977) to be deficient in sulfur-containing amino acids - notably in methionine - the effect of the addition of this amino acid was also studied. Table 2 presents the experimental results obtained with growing rats. Total weight gains over a 28-day-experimental period were very poor for the diets based on the unsupplemented biomass; methionine supplementation significantly improved the protein quality of the fungal protein, resulting in body weight gains similar to those obtained with casein and superior to the soybean meal protein. PERs (protein efficiency ratio: g body gain/g protein consumed) were adjusted so that standard casein was used as a reference with a value of 2.5; methionine-supplemented microbial protein exhibited adjusted PER values similar to those for casein.

Because of the biohazard for the personnel working at the pilot plant, with regard to the possible infection by aspergillosis derived either from inhalation of revertants producing spores or from hyphal fragments (Sydransky, 1975) carried in the aerosols formed at harvesting (Gregory, this monograph), special safety precautions were taken to reduce risks to a minimum. For these reasons and until completely safe conditions can be assured for the personnel, the fermentation will be carried out in the 200-liter fermentor. There are several aspects that need to be studied with the starter fermentor before progress can be obtained to the extent of using the 3000-liter fermentor. However, despite the present uncertainties, especially as regards safety aspects, the process seems to be very promising for practical application in cassava-producing areas to solve partially the increasing demand for protein supplements for cassava feeding programs, notably for swine.

SUMMARY

A process for microbial protein production, using cassava as the energy substrate, was developed and tested at a laboratory scale at the University of Guelph. The microorganism used is the fungus Aspergillus fumigatus I-21A an asporogenous mutant that can grow under very selective conditions of temperature (45°C) and pH (3.5). A pilot plant has been built at the Centro Internacional de Agricultural Tropical (CIAT) in order to test the technology developed at a laboratory scale and to produce sufficient quantity of biomass for practical evaluation in animal feeding, notably in swine. Preliminary results obtained at the pilot plant are reported, suggesting a potentiality of the process once complete safe operational procedures could be established. Results of a feeding trial with fungal biomass obtained at the pilot plant indicate that the product has a good nutritive quality, if methionine is adequately supplemented.

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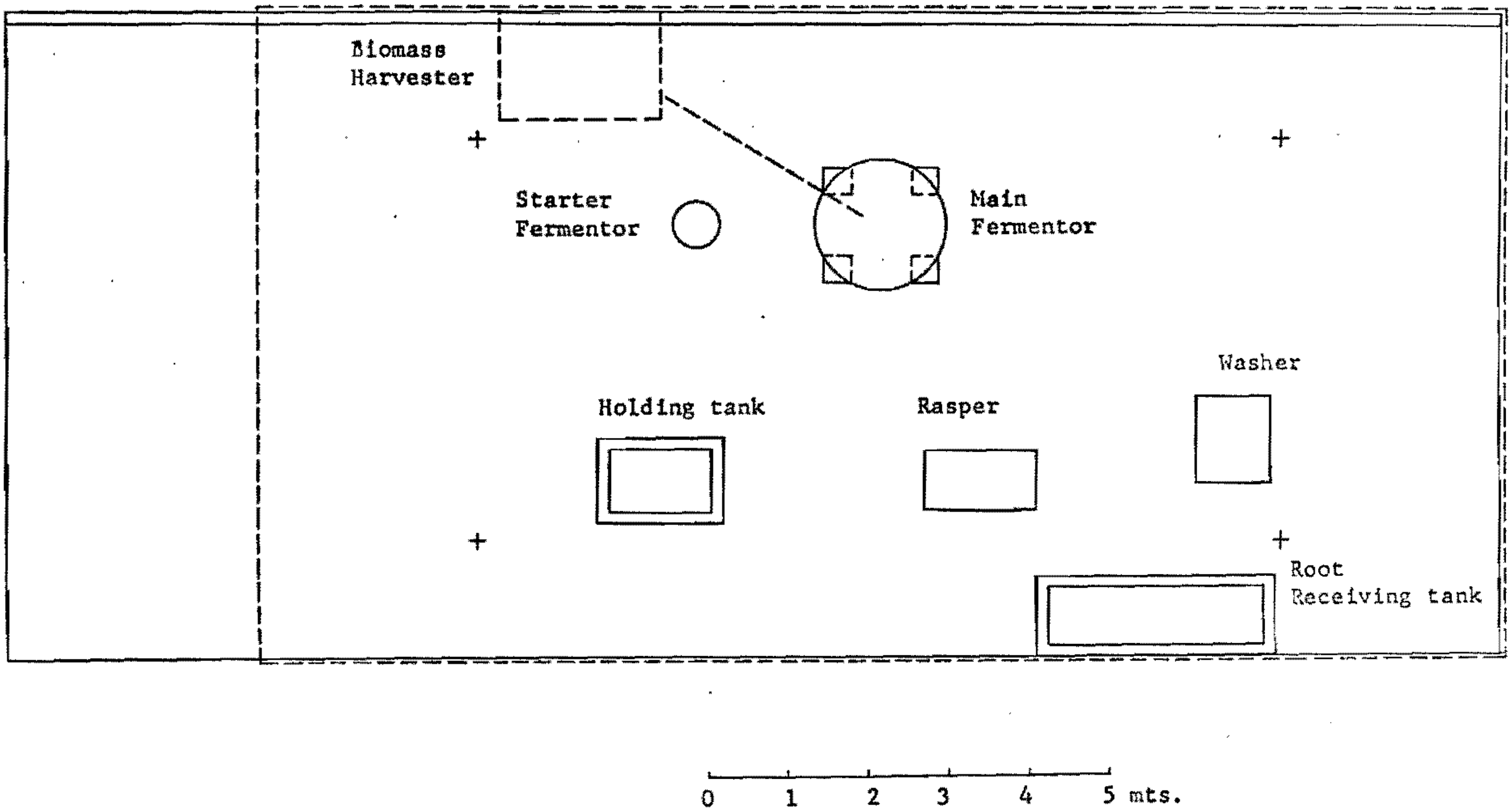
Figure 1

LAYOUT OF THE PILOT PLANT FOR SCP - PRODUCTION FROM CASSAVA



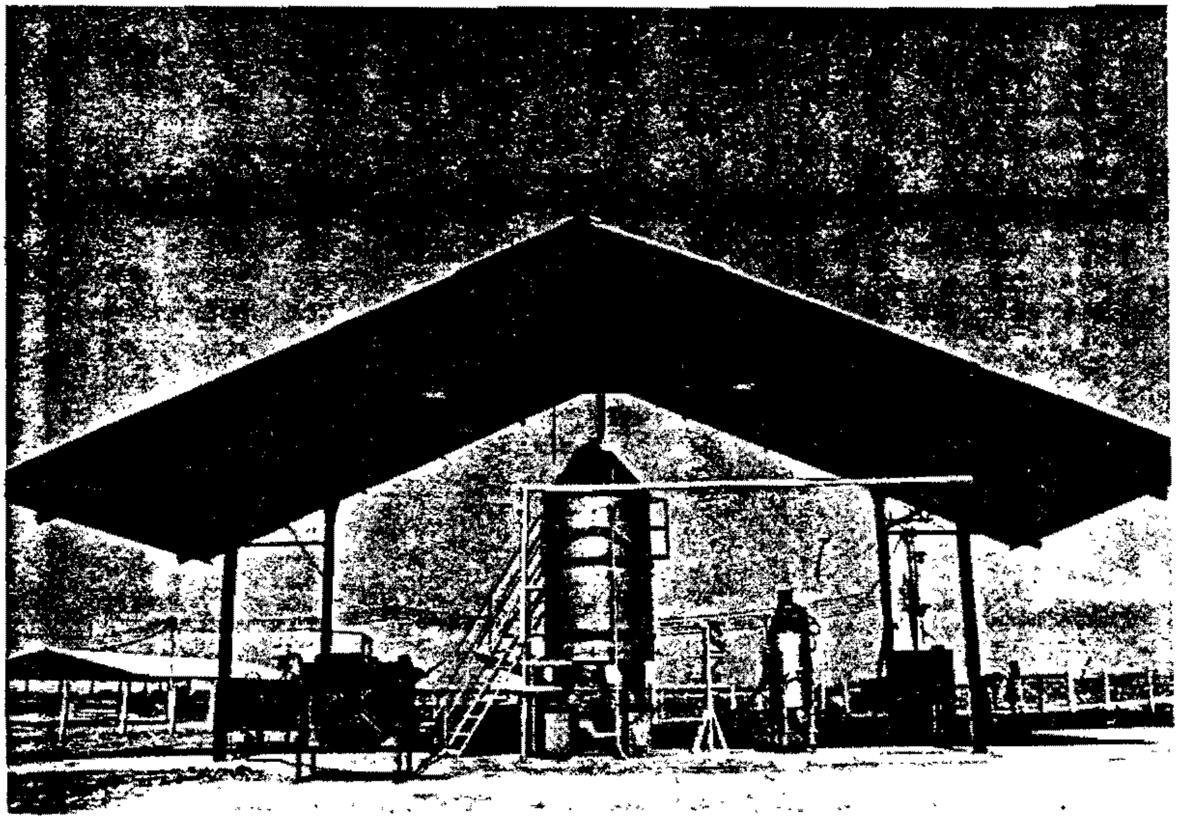


Fig. 2. View of the pilot plant in the CIAT Swine Unit for producing Microbial protein utilizing cassava roots as the energy substrate.

Table 1. Results of fungal protein (*Aspergillus fumigatus* I-21A) production in a 200-liter fermentor using fresh roots or cassava meal as substrates

FRESH CASSAVA ROOTS *	
Amount of cassava mash (kg)	25.3
Amount of sun-dried biomass obtained (kg)	4.4
Product yield (g/liter)	22.2
Yield: weight of dried biomass in relation to	
fresh cassava (%)	16.9
Cassava, dry matter basis (%)	48.5
Crude protein content in dried biomass (%)	28.6
CASSAVA MEAL **	
Amount of cassava meal (kg)	11.5
Amount of sun-dried biomass obtained (kg)	5.4
Product yield (g/liter)	27.0
Yield: weight of dried biomass to cassava meal (%)	47.0
Crude protein content in dried biomass	28.2

* Mean of ten fermentations

** Mean of five fermentations

Table 2. Effect of methionine supplementation on the protein quality of fungal biomass grown on a cassava medium and fed to rats *

Parameter **	Control Casein	Soybean Meal	Biomass produced on: Fresh cassava + 0.3% methionine	Fresh cassava without methionine	Cassava meal + 0.3% methionine	Cassava meal without methionine
Total feed intake, (g)	302.6^{a}	308.8^{a}	296.0^{a}	195.6^{b}	323.7^{a}	198.8^{b}
Total weight gain, (g)	78.2^{a}	68.2^{b}	74.8^{a}	24.2^{c}	85.0^{a}	29.7^{c}
Feed/gain	3.9^{c}	4.5^{c}	4.0^{c}	8.5^{a}	3.8^{c}	6.9^{b}
Absolute PER	2.6	2.3	2.5	1.2	2.6	1.5
Adjusted PER ***	2.5^{a}	2.2^{b}	2.5^{a}	1.2^{c}	2.5^{a}	1.5^{c}

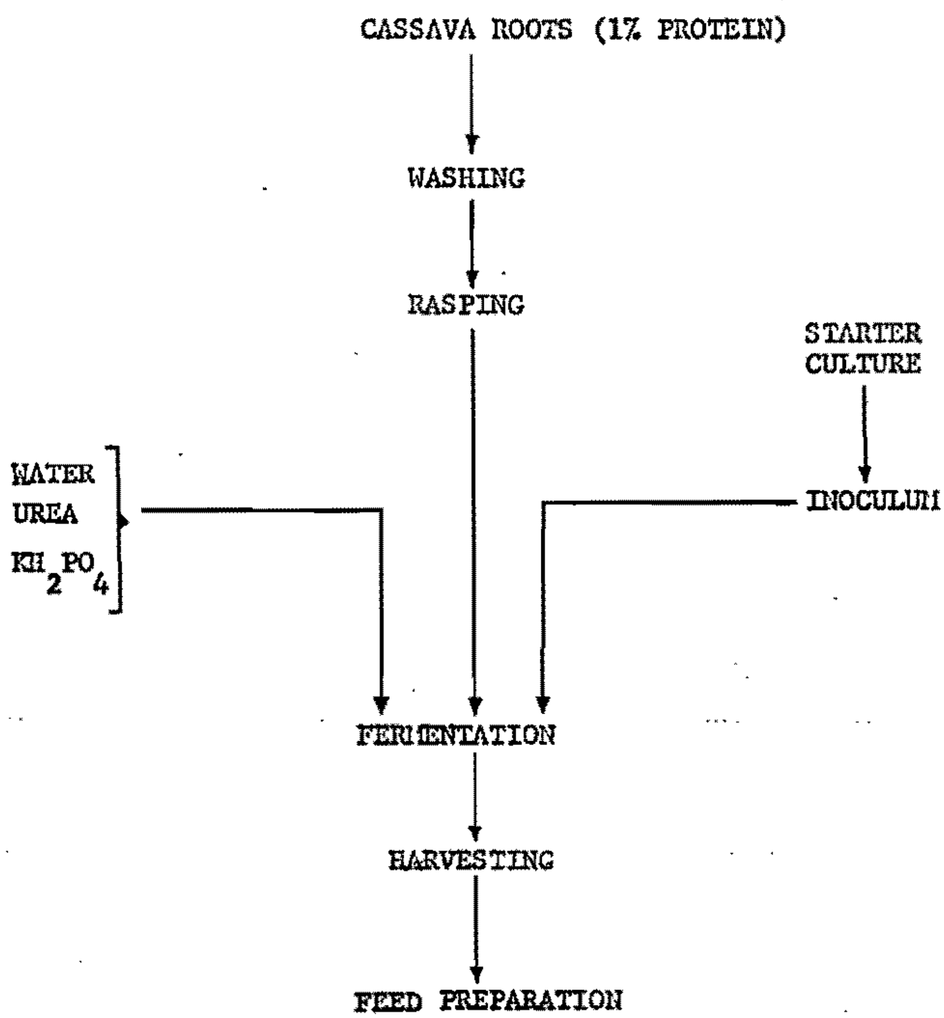
* Average results from 10 male rats per group; 28-day experimental period; avg initial wt 41.2 ± 2.1 g

** Values with a common superscript are not sugnificantly different.

*** Values adjusted to make the PER for standard casein 2.5

Figure 3.

CASSAVA-SCP FERMENTATION FLOW DIAGRAM



THE UTILIZATION OF CASSAVA FORAGE IN RUMINANT FEEDING [1]

C. Patrick Moore *

Introduction

The plant botanically described as Manihot esculenta Crantz is known around the world by many different names such as cassava, tapioca, manioc, maniok, mandioca, aipi, and yuca. Plants of the genus Manihot occur naturally only in tropical America, where about 100 different species are known (Rogers and Fleming, 1973). Cassava was used in South America as a food plant by the native Amerindians long before Columbus discovered the New World and was probably transported by the Spanish and Portuguese to Africa and Asia as early as the 16th Century. Its diffusion within the Continent of Africa has come about most rapidly during the 20th Century (Coursey and Halliday, 1974.).

In terms of production, cassava ranks among the top 10 food crops in the world and appears to be increasing in importance. In 1972 the world production was estimated at 105 millon tons of fresh roots, produced from a land area of 11 million hectares (Table 1). Considering the fact that cassava ranks among the top ten food crops in the world, it has received relatively little attention from the research scientist. The scientific cassava documentation Center located at CIAT in Cali, Colombia, estimated that no more than 4,000 scientific and popular articles exist about cassava.

TABLE 1. WORLD DISTRIBUTION OF CASSAVA PRODUCTION

Major Areas	Area 000 Acres	Production 000 Tons Fresh roots
Africa	5,996	42,220
Zaire	810	10,500
Nigeria	960	9,570
Tanzania	800	6,000

1 Paper presented at International Seminary on Tropical Livestock production, In Acapulco, Mexico; March 8 to 12, 1976.

* Animal Science Training Coordinator. Centro Internacional de Agricultura Tropical, CIAT. Cali, Colombia.

Major Areas	Area 000 Acres	Production 000 Tons Fresh roots
South America	2,549	36,168
Brazil	2,100	31,000
Paraguay	125	1,850
Colombia	160	1,600
Asia	2,331	22,188
Indonesia	1,350	10,099
India	355	5,939
Thailand	225	3,867
Central America and Caribbean	110	713
Oceania	11	128
Total World Production:	10,998	105,417

Source : FAO Production Yearbook, 1972

Of those 4,000 articles, probably no more than 5 percent are related to the use of cassava in animal feeding and the major part of those related to the use of the root as an energy source with only a few papers dealing with the use of the leaves and stems as a principal source of protein.

The object of this paper is to bring together information that has been published about the utilization of cassava forage (leaves, stems and stalks) in the feeding of livestock with particular emphasis on ruminants.

Nutritive Value of Cassava Forage

It should be pointed out that most of the existing data on cassava forage has been taken from plants which were planted for root production and not specifically for forage production.

Reports from Perú (Galiano, 1955); Colombia (Obregón, 1968); Nigeria (Oyenuga, 1955); Brazil (Gramacho, 1973) and the United States (Ramos-Ledón and Popenoe, 1970) generally agree on the chemical composition of the aerial part of the plant when harvested at approximately one year of age (Table 2).

TABLE 2. AN APPROXIMATE ANALYSIS OF CASSAVA FORAGE HARVESTED AT ROOT MATURITY

Analysis	D.M.	Protein	Fat	CH_2O	Fiber	Ash
Cassava forage	25.0	16.0	7.5	45	14.5	12.0

The data presented in Table 2 should be taken as a general guide since climate, soil type, age of harvest, fertilization and sampling procedure may affect the resulting chemical analysis of the plant. It has also been reported that the forage has a significant amount of calcium (.88percent CaO); phosphorus (1.0 percent P_2O_5) and carotene (208,000 I.U./lb) which are also important nutrients provided by cassava forage.

The leaves of the cassava plant have the highest proportion of protein. Ramos-Ledón and Popenoe (1970), reported an average of 25.5 percent leaf protein in plants grown in southern Florida, while Rogers (1959) reported a range of from 20.6 percent to 36.1 percent leaf protein in different cultivars of cassava found in various parts of Jamaica. The Florida work also showed the percentage of protein in the stems to be considerably lower (5.6 percent) and that a withdrawal of nitrogen from the leaves occurs after the formation of seeds, and root enlargement.

Data collected at CIAT (Moore and Cock) from plants cultivated only for forage production and harvested every 90 days gives a better idea of the chemical composicion of the plant at an age when the entire plant is edible (Table 3).

TABLE 3. CHEMICAL COMPOSITION OF 90-DAY-OLD CASSAVA PLANT*

Parts of Plant	% of total plant	D.M.	Nitrogen	Prot. (Nx 6.25)	Ether extrac.	Crude Fiber	Ash
Leaves (%)	52	29.0	4.38	28.0	15.3	9.0	8.1
Stems (%)	15	18.0	1.65	11.3	14.3	21.9	8.5
Stalk (%)	33	15.7	1.76	11.0	13.0	25.2	7.8

* Unpublished data - CIAT

It can be seen from Table 3 that the leaf portion of the plant contains more than twice the amount of protein (N x 6.25) than the stem or stalk and makes up slightly more than one-half of the total dry matter of the plant at 90 days. The protein and nonprotein fractions of the plant have not been determined to date; however, data published by Oyenuga (1955) suggest that the nitrogen present in the leafy portion may be as much as 90% true protein. Unpublished data of Cock and Echeverry are of the same order. This, however, should not be a major consideration in feeding the plant to ruminants since they are able to utilize nonprotein nitrogen as well.

Essentially no work has been done on the selection of cassava plants for forage production or nutrient content. Genetic selection and agronomic practices to increase dry matter production and protein content is an obvious area for future studies.

Agronomic Aspects of Cassava

While no agronomic practices have been developed for cassava as a forage plant, certain comments can be made which apply in general to the plant.

Muller et al (1974) states that cassava grows best in a sandy soil with optimum growing temperature of 27°C. When the temperature drops to 15°C, growth stops; at 8 to 10°C the plant dies. The optimum rainfall is 700 to 1000 mm and large amounts of sunshine are required. He further states that a 50 ton yield of roots per hectare makes a heavy demand on the land; will remove from the soil approximately 120 kg P_2O_5 , 450 kg K_2O and 250 kg CaO. No mention is made of nitrogen depletion; however, leaf production alone would suggest that 400 to 600 kg of nitrogen would be removed from the soil per ha/yr. All cassava forage production data to date has been in association with root production. Either the leaves have been harvested several times during the life cycle of the plant or harvested at the time the roots are harvested.

Work done by Conceicao et al (1973) shows that certain varieties are better forage producers than others and suggests that a negative correlation may exist between root production and forage producing ability (Table 4).

A reduction in root growth would be expected when the branches are harvested three times (every 4 months) during the year. No comparison is made as to the root production of these varieties (Table 4) if no branches were harvested: however, Ahmad (1973) harvested 7.3 tons of leaves (dry weight) during the year (every 10 weeks) from one hectare which reduced the production of roots to almost one half of the normal. Preliminary results at CIAT (Cock, Pers. Comm.), without intensive variety selection, indicates that up to 20 tons of forage dry matter per hectare can be harvested in one year. This was

TABLE 4. PRODUCTION OF CASSAVA TOPS AND ROOTS FOR THE YEARS 1969-72

	Average Production (Ton/ha) *			
	Tops	Relative production	Roots	Relative production
Platina	46.79	157	12.52	100
Graveto	37.06	125	20.99	168
Salangor Preta	33.03	111	25.39	203
Mamao	32.29	109	20.77	166
Cigona	30.76	103	21.39	171
Sutinga	29.73	100	18.60	149
Average	34.73			

* Fresh weight

accomplished by increasing the plant population from 10,000 plants/ha (normal population for root production) to 111,000 plants/ha. The entire plant was harvested every 90 days, which is equal to 4 cuttings per year. This production level is approximately twice that reported by other workers harvesting the cassava forage in conjunction with the roots. Since the original plantings are still in production (1 1/2 years) no measure has been made of root production.

In similar trials at CIAT, using small plots with 30 x 30 cm spacing, a yield of over 30 t/ha of dry matter was obtained in 11 months in four harvests ; in three harvests, yields dropped to slightly more than 25 t/ha. When spacing was increased to 60 x 60 cm, the yield was further reduced to 16 t/ha. It should be noted that these yields were obtained on intensively managed small plots on a fertile soil. Considering that the information available to date shows that harvesting leaves from the cassava plant when planted as a root crop will greatly reduce the root production; it appears that separate planting (for roots or for forage) would produce more total dry matter per hectare. If certain varieties are better producers of forage and others better producers of roots, varietal selection will be very important.

Toxity Problems in Cassava

It is well known by the scientists working on cassava that the forage and roots contain cyanogenetic glycosides which are readily split by enzymes naturally present in the plant to form free hydrogen cyanide (HCN). These are normally detoxified in the body with the resulting formation of thiocynates, which can be found in the blood and urine. This cyanide formation has been associated with disturbing thyroid function, and the depletion of the suphur-containing amino acids (Coursey and Halliday, 1974).

It has not been made clear whether or not the HCN normally occurring in cassava production produces a toxic effect in domestic animals or whether the HCN present is merely tying up some nutrient which could be added to the diet to overcome the deficiency.

It has been reported (Ross and Enriquez, 1969) that cassava leaf meal (554 ppm of HCN) in excess of 10 percent of the ration will retard growth in baby chicks and is inferior to similar levels of alfalfa meal. In those studies, methionine was suggested as the first limiting factor in the cassava meal and was probably caused by an increased demand for the sulphur-containing amino acids used in the detoxification process of the cyanide. A look at the amino acid profile of cassava leaves and stems (Table 5) shows methionine and cystine (sulphur-containing amino acids) to be low in relation to most other amino acids. This explains why methionine could be limiting if the amounts naturally present are tied up in the detoxification of HCN.

If the HCN content in cassava is proven to be a serious problem in livestock, Obregón (1968) and Galiano (1955) have shown that most if not all, of the HCN can be removed by sun drying before it is fed to livestock.

Further evidence that methionine is limiting in cassava based diets fed to monogastrics has been shown by Eggum (1970), Hutangalung (1972) and Maner (1972), who improved the quality and digestibility of the dietary protein by adding methionine to the diet.

To further verify that the toxic factor in cassava forage caused no physiological problems in ruminants, Moore and Cock (unpublished data), fed fresh cassava forage alone to four two year old steers for two months with no visual disorder. Blood thyocinates levels in the fresh cassava fed steers (3.9 mg/%) were three times greater than steers (1.28 mg/%) grazing pará (Brachiaria mutica) pasture. In a separate trial, pure diets of fresh cassava forage were fed to a small group of sheep in confinement with no visual adverse effects. Hill (1973) also reported that feeding either cassava forage or roots had no adverse effects in cattle or sheep.

Feeding Value of Cassava Forage

The limited research work that has gone into determining the chemical composition and protein quality of cassava forage has been largely restricted to the leaf, as a protein source for humans.

TABLE 5. PROTEIN VALUE OF DEHYDRATED AERIAL PART OF CASSAVA PLANT AND SOME TROPICAL GRASSES, COMPARED WITH SOYBEAN MEAL (ON A DRY BASIS)

Constituents	Cassava *Manihot utilissima* Leaves	Cassava *Manihot utilissima* Leaves+Stems	Napier grass *Pennisetum Purpureum*	Gatton panic *Panicum maximum*	SBMO Solvent extracted
Crude protein (%)	27.0	20.3	12.6	11.9	45.7
	----------	----------	g/16g nitrogen	----------	----------
Amino acids					
Arginine	5.21	3.89	6.10	5.64	7.41
Cystine	1.18	0.98	0.51	-	1.52
Glycine	4.92	5.10	5.85	5.00	5.23
Histidine	2.47	2.32	2.54	2.82	2.39
Isoleucine	4.12	4.40	4.32	3.45	5.45
Leucine	10.09	8.75	8.64	7.55	6.97
Lysine	7.11	5.89	6.02	4.82	6.32
Methionine	1.45	1.83	1.86	1.36	1.52
Phenylalanine	3.87	4.37	5.42	5.82	4.79
Threonine	4.70	5.70	4.41	4.73	4.14
Tryptophan	1.09	1.24	-	-	1.30
Tyrosine	3.97	4.12	3.73	3.18	3.27
Valine	6.18	8.43	6.27	5.18	5.23

Source : Draft feeding standard, Republic of Singapore, 1972.

The nutritive value of the leaves is recognized as they constitute part of the human diet in parts of Africa. Efforts have been made to extract the protein from the leaves; however, the process is very sophisticated and relatively expensive.

Factors such as a long growing season, low dry matter production and irregular harvesting are probably some of the reasons why only a few research papers exist on the utilization of cassava forage in ruminant feeding. In addition, the most common systems for beef and milk production in the tropics do not presently lend themselves to the feeding of cut forages.

However, as the demand for high quality protein (meat and milk) increases along with the increased demand for alluvial lands for cereal grains, the cattleman will have to look for ways of intensifying his operation. One way will be to grow cultivated tropical forage crops such as elephant grass, sugar cane, corn, sorghum, etc. to be combined with legumes, oil seed meals and nonprotein nitrogen as sources of supplemental protein.

In many tropical countries, beef-type animals are being used as dual-purpose animals to produce both meat and milk, since no dairy type cow has been developed which can thrive in the tropical environment. The cyclic production of these animals, which is well known by everyone working in the tropics, is largely related to the rainfall pattern and thus the pasture feed supply of the zone. Cows tend to conceive a month or so after the rains begin which means they give birth at the beginning of the dry season. If they must nurse a calf and are milked during the dry season, when both quantity and quality of forage are low, they will suffer a great physiological shock due to undernutrition. The result is low milk yields, and a weak cow that goes into an anestrous period lasting for several months or until she can build back body tissues. This will take her well beyond the normal breeding season and thus result in a calf produced approximately every two years.

This ohenomenon can be avoided (assuming climatic changes are not greatly affecting reproduction) by developing pastures which will grow and provide adquate nutrients during the dry season, or by growing cultivated forage crops during the rainy season and preserving them for the dry season. Several alternative solutions have been presented (Preston 1975) as to how cultivated forages and other by-products can be utilized to eliminate weight losses and increase reproductive efficiency. Preston also points out that while ruminants can utilize a rather high level of nonprotein nitrogen they still require a dietary source of performed protein.

Cassava forage has a great potential as a protein source. Echandi (1952) in Costa Rica showed that cassava forage meal was almost as good as alfalfa meal. Grazing milk cows receiving cassava meal gave 90 to 96% as much milk as those receiving equal amounts of alfalfa meal. Since the alfalfa meal was imported, it became the more expensive supplement even though it produced slightly more milk per kilogram fed.

To evaluate the effects of feeding fresh cassava forage on growing animals, a trial was designed (Moore and Cock, unpublished data) to feed 250 kg steers in corrals on either: (A) elephant grass alone; (B) 75 percent elephant grass + 25 percent cassava forage; or (C) 50 percent elephant grass + 50 percent cassava forage. Both groups B and

C gained 30 percent faster than group A. Group B (25 percent cassava forage) gained 4 percent faster than group C (50 percent cassava forage) suggesting that the protein level in ration B was nearly adequate and that energy became limiting in ration C (Table 6).

TABLE 6. ELEPHANT GRASS AS A GROWING-FINISHING RATION SUPPLEMENTED WITH CASSAVA FORAGE

	Diet		
Parameters	A Eleph.grass alone	B 75% eleph.grass 25% cassava forage	C 50% eleph. grass 50% cassava forage
Initial weight (kg)	265.5	276.3	270.0
Final weight (kg)	342.5	392.7	379.0
A D G (g)	306.0	461.0	445.0
Dry matter consumed (kg/da)	5.4	6.3	6.1
Crude protein (%)	6.0	9.7	13.0
Feed efficiency	17.6	13.7	13.7

The animals on elephant grass alone ate 22 percent more feed (17.6 kg per kg of live weight gain) than did either group B or C (13.7 : 1). The inefficient conversion of feed to gain appeared to be related to the low protein content of the elephant grass.

As a follow-up to that experiment another trial was designed to compare cassava forage to other sources of protein, i.e. fresh Desmodium distortum and cottonseed meal (CSM). In this trial, mature sugar cane was used as the major source of energy. The cane was allowed to reach maturity (12 to 14 months of age) before cutting, which corresponds to the age that it is harvested in the Cauca Valley of Colombia for sugar production.

Desmodium distortum was selected as another source of protein because of its high protein content (23 percent) and because of its growth style which lends itself to easy harvesting. One problem associated with Desmodium distortum is that it is an annual species and while 3 to 4 cuttings (intervals of 60 days) can be obtained, total dry matter production declines with each subsequent cutting (Paladines, Pers. Comm.).

All three forage species were offered fresh daily and in separate feeders, ad libitum, to determine individual consumption of each. The CSM was fed once daily on top of the sugar cane. Each animal was kept in individual pens.

The animals in treatment I (cane and CSM) gained 7 percent faster (659 g/da) than treatment II (622 g/da) and 11 percent faster than animals in treatment III (584 g/da) (Table 7).

The average daily dry matter consumption was essentially the same for all treatments (5.3, 5.2, 5.2, respectively) whereas the efficiency of converting feed to live weight gain was more varied. The steers receiving CSM were 5 percent more efficient than those receiving cassava and 11 percent more efficient than those receiving Desmodium distortum. It is very noticeable that the percentage difference between treatments in average daily gain was similar to that found between differences in feed efficiency.

However, when efficiency of gain is related to the amount of protein consumed, the relationships change. Since two protein sources were fed as fresh forage (ad libitum) and one was fed as a dry concentrate,there was a large difference in daily protein intake due to the difference in moisture and protein content. The protein (N x 6.25) consumed per day by those animals on CSM was roughly double that consumed by the other two groups. This suggests that approximately 1.4 kg of protein was consumed per kg of live weight gain in group I while only 0.7 kg of protein was consumed per kilogram of live weight gain in group II and III.

TABLE 7. PERFORMANCE OF GRADE ZEBU STEERS FED CHOPPED SUGAR CANE PLUS THREE SOURCES OF PLANT PROTEIN

Parameters	Treatments * I	II	III
	Sugar cane plus 1.8 kg CSM	Sugar cane and cassava	Cassava and D. distortum
No. animals	8	8	8
Initial weight (kg)	229.5	241.4	241.0
Final weight (kg)	303.3	311.1	306.4
Days on trial	112.0	112.0	112.0
Average daily gain (kg)	.659	.622	.584
Feed efficiency	8.0	8.4	9.0
Avg. daily dry matter consumption (kg)	5.3	5.2	5.2

* All forages where fed ad libitum.

A possible explanation for this difference in protein utilization would be that group I was fed an excessive amount of protein which was inefficiently utilized or that the forage protein sources provided other nutrients not present in the cane plus CSM diet. Minerals should not be a consideration since all animals were offered a complete mineral mix free choice; however, the relatively high content of fat especially in the cassava forage may have had a positive effect on live weight gain and feed efficiency.

The steers in group II ate 20 percent less cassava forage (1.52 kg/da) than those receiving Desmodium distortum forage (1.94 kg/da), but they ate 11 percent more cane per head/da. The lower intake of cassava could represent a palability problem with the cassava due to its bitter taste caused by the HCN content. However, the data suggest the HCN content of the cassava did not affect the average daily gain, nor feed efficiency of these steers consuming diets with 30 percent of the total as cassava forage.

Economic Implications of Cassava Forage Production

Since the cassava plant has never been looked at as a major source of protein for livestock feeding, no data exists relative to production cost. However, it would appear reasonable to use figures published by Díaz, Andersen and Estrada (1974) on the cost of producing cassava roots in Colombia as a base line estimate for producing cassava forage (Table 8).

Thirty percent was added to the US dollar cost for increased seed and harvest cost due to an increase in the plant population per hectare plus 4 harvests during the year to give a more realistic estimate of the production cost of one hectare of cassava forage (US$ 428.09/ha).

TABLE 8. ESTIMATED AVERAGE TOTAL COST OF CASSAVA PRODUCTION IN COLOMBIA

Inputs	Col. Pesos/ha.	US$ / ha. *
Average variable cost	2,390	119.50
Land rent	1,800	90.00
Transportation cost	720	36.00
Interest on working capital	576	28.80
Other costs	1,100	55.00
Total cost	6,586	329.30

* Exchange rate 20: 1

Preliminary results (Cock, Pers. Comm.) have shown that the production of over 20 metric tons of dry matter is possible from one hectare of good land (capable of producing 50 tons of roots). Using the previously mentioned production cost figures (US$428.00/ha); one kg of dry matter would cost slightly more than US 02 ¢. One kg of protein (N x 6.25) would then cost (US .02 x 20 percent protein) US. 10 ¢. Table 9). As a comparison, one kg of cottonseed meal (48 percent protein) in Colombia presently costs US.15 ¢ which is equal to US .31 ¢ per kg of protein. One kg of urea, which is said to be cheapest source of protein (262 percent protein equivalent) in Colombia, presently costs US .24 ¢; equal to US .09 ¢ per kg of protein equivalent, or one cent less than the cost of one kg protein from cassava forage.

TABLE 9. COSTS OF SEVERAL SOURCES OF PROTEIN IN COLOMBIA

	Per kg dry matter	Per kg protein
Cottonseed meal	US$ .15	US$ .31
Cassava forage	.02	.10
Urea	–	.09

Using the present cost of producing sugar cane in the Cauca Valley of Colombia (US$ 625/ha) with a production of 50 tons of dry matter (whole plant) per hectare, the cost of one kg of dry matter would be US .012. The daily production cost of the cassava/sugar cane diet in this experiment would then be (1.52 kg cassava x US.02 = US. 03) + (3.70 kg sugar cane x US. 012 = US.04) = US.07 or 1.3 cents per kg of feed consumed. Taking the present market price of fat steers in Colombia of US .48 per kg live weight and an average daily gain of .62 kg, the feed production cost per kg of gain (US 11 ¢) would represent only 23 percent the value of one kg of gain, whereas the CSM/sugar cane diet cost, per kg of gain (US 40 ¢), was equal to 83 percent of the value of one kg of gain in this experiment. (Table 10). It should be stressed that the protein content in ration was probably higher than necessary and attributed to the higher cost of the ration. Also, the forage production figures presented in this paper are from the Cauca Valley of Colombia and would be nearer a maximum possible than an average for the tropics. However, there should be little doubt that cassava forage can play a very important role in ruminant feeding in the tropics, whether it be used as part of a fattening ration or in a dry season supplement program for the breeding or milking herd.

TABLE 10. COSTS OF PRODUCTION

	Dry matter ha	Cost/ ha US$	Cost/ kg	Daily consumption kg	Daily cost US$
Sugar cane	50 ton	625.00	.01	3.70	.04
Cassava forage	20 ton	428.00	.02	1.52	.03
				Total	.07

Average daily gain	.62 kg
Live weight value	US$ .48 kg
Value of daily gain	US$ .30

SUMMARY

The nutritive value of cassava as a forage is little known and even less utilized in its native tropical regions of the world. This paper shows that cassava forage is a good source of protein for ruminants and competes well with other sources of plant protein as measured by animal performance. The dry matter production per ha/yr (20 ton) is very high relative to other tropical plants high in protein, which makes it attractive as a forage plant. A population of 111,000 plants/ha and a harvesting interval 90 days gave the highest yields.

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