A Farming System Analysis of Improved Cassava Technology

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The success of the modern rice and wheat varieties was achieved by the recognition of the yield advantage of the dwarf-gene under conditions where soil fertility and water were non-limiting. International agricultural research on rice and wheat had strictly production objectives, was oriented toward irrigated areas where there was maximal control over the plant environment, and was based on selection for particular plant characteristics on the research station. Early IRRI and CIMMYT research was patterned on a one-way flow of information from the research station to the farm.

The second generation of rice and wheat research and the succession of international agricultural research centers has recognized that the information flow between research station and farm needs to be in both directions in order to ensure that new agricultural technology will be effective. IRRI, itself, demonstrated that the adoption of new rice varieties was highly region specific and even in those regions were new varieties predominated, there was a large and quite variable gap between farm yields and research station yields (IRRI 1978). Both adoption and productivity were being constrained by factors not represented on the research station. For the newer IARC's these farm-level constraints would be more critical as

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research is almost wholly directed at rainfed areas, where water is to a large degree not subject to management, and fertilization therefore much riskier. Moreover, agricultural research began to focus on the maximization of adoption across a wide and variable target area as a principal objective, rather than concentrating on high yields in specific regions. Ensuring maximum adoption requires a much more systematic tailoring of technology to particular farm conditions.

On-farm testing within a whole farm context has become a primary means of establishing this information link between the research station and the farm. This paper will describe in some detail the role of on-farm testing in the development of new cassava technology at CIAT.

On Farm Testing of CIAT Cassava Technology

Cassava technology research strategy: The principal objective of the CIAT cassava program is to increase productivity of cassava cultivation in its target area, Latin America and Asia. The strategy to accomplish this objective follows from two basic observations:

(1) that the comparative advantage of cassava on both economic and physiological grounds is in more marginal agricultural zones and

(2) that the principal producers of cassava are relatively small-scale producers.

The technology development strategy thereby focused on increasing yields with the minimal requirements of purchased inputs. This strategy recognized the limited resource position of the predominate farmer population and that the marginal agricultural zones would have minimal infrastructure, making purchased inputs expensive if not unavailable. This strategy implied that the development of cultural practices would not be heavily dependent on purchased inputs, i.e. would be low cost. The breeding strategy defined as its main objective the improvement of the genetic yield potential of the crop. This was sought through improvement in plant efficiency in the production of economic yield, i.e. roots. Harvest index became the principal selection criterion in the breeding program (Kawano 1978).

Technology evaluation system: Research experimentation in the CIAT cassava program is carried out in the main research station and three principal sub-stations. Both varieties and cultural practices emerge from testing in these four sites. Varieties in conjunction with the recommended minimum input package are then put into the regional trial net work for multi-environment evaluation. From this process varieties and associated technological components emerge for testing in the farm trials (see the research process schematic in Figure 1). The on-farm testing provides a final determination of whether maximum yields at the research station translate into economic optimality at the farm level and the extent to which recommendations developed at one or a few station sites can be generalized to farm conditions at many sites.

Not only do the farm trials provide an ecnomic assessment of improved technology but they also provide a final check on the breeding program. Because funding agencies for international centers must justify donations with observable benefits, implicit pressures are put on commodity programs to produce new varieties quickly. Given this time pressure and the expected lower probability of success as the number of selection characterisitcs increase, breeders usually identify limited objectives in their crossing and selection program. Thus, breeding programs at IARC's concentrate on those plant characteristics that breeders objectively estimate will most contribute to increased productivity. The resulting program focus is either upon resistances to principal pathogens or plant characteristics that improve the genetic yield potential. The farm trials provide a partial check on whether these breeding objectives are consistent with the requirement of the farming system. It is obviously important that the form trials are undertaken in a wide variety of eco-systems and farm systems into which the new technology is expected to move. Where characteristics are identified that are lacking in the varieties in their adaptation to particular farm conditions, then a decision is necessary on whether the national or the international institution should be responsible for these modifications. The modifications could be minor such as improved input use, or a major modification of the selection criteria in breeding could be required for some eco-systems.

The role of the cassava farm trials thus revolves around three principal objectives: 1) to assess the productivity of new cassava technology under actual farm level conditions relative to yields under current practices; (2) to understand the structure of cassava farming systems as a potential means for diagnosing further requirements or refinements in the technology; and (3) to simulate the potential farm-level impact of the release of new cassava technology, especially by assessing potential adoption constraints and income increase. The farm trials focus on maximizing the information flow from representative cassava farming systems into the research process and in so doing provide the means of evaluating current technology, diagnosing potential constraints on either productivity or adoption, and assessing potential economic impact.

Site and farm selection: Given the large research target area of international centers and the potentially wide variability in cassava farming systems, representativity becomes a principal problem in site selection. Obviously farm trials are not compatible with random sampling from the population of cassava farmers, even if that population was known. Rather site selection must take place on the basis of constructs known to influence enterprise choice within farming systems. Hypotheses can be formed around these constructs which would weight selection to particular ranges of variability in these factors. Duckham and Masefield (1970) identify five factors that potentially limit or influence the choice of crop or animal activities within a farming system: (1) agro-climatic factors and associated biological limitations, (2) the internal resource position of the farm, principally available land, labor, and capital, (3) external economic constraints, especially input and output market prices and the organization and structure of output markets, (4) infrastructural features, such as land tenure, extension, services, and communication systems, and (5) farmer goals.

Choice of cassava as a principal cropping activity is hypothesized to be influenced by three principal factors:

a. agro-climatic conditions: cassava as a species is adapted to a wide range of climatic and edaphic factors; however, its comparative advantage vis-a-vis other crops is its yielding ability under greater agricultural stress conditions. Low profitability, high prive variance, the need to market rapidly after harvest plus this comparative advantage in unfavorable conditions help to explain the concentration of cassava production in more marginal zones.

b. farmer resource availability: in marginal agricultural zones relative land/labor ratios heavily influence the choice between cropping activities and grazing activities. Since cassava is relatively labor intensive and labor markets are usually not well developed in marginal areas, cassava is principally found on farms where this ratio is low, i.e. on small scale farms.

c. output market conditions: since cassava is highly perishable after harvest and transport is costly in comparison to the value of the crop, the distance from the market will heavily influence output price; as well, since cassava markets are independent of one another (because of transport costs) and market size is usually small, marketing risk due to seasonal market gluts is high; marketed cassava thus tends to come from farmers having few other alternatives, i.e. small-scale farmers in more marginal agricultural zones.

Farm trial sites were chosen on the basis of variation in these three factors but were weighted toward small-scale farmers and more marginal agricultural zones. The sites were selected to include as much diversity in the output markets as possible. Since cassava is more flexible than most crops in optimal harvest period but more perishable after harvest, variation in output markets was important to assess the interaction between market demand and timing of planting and harvest and the associated use of land, labor, and capital. The following section will describe the farming system for the trial site in the principal Colombian production zone, the Caribbean coastal plain.

A Cassava Farming System:
A Colombian Example

The market: The Carribbean coastal plain of Colombia makes up a seven state area. The area contains 3.7 million people, about a third of which reside in urban areas (DANE, 1976). The area, produces 46% of the cassava production of Colombia, a volume estimated at approximately 910 thousand tons (OPSA, 1979). This is the major cassava producing zone in Colombia.

Markets for cassava are all located within the zone and are all for fresh cassava. These include two large urban areas, totaling about a million people, and a single large-scale starch processing plant. High transport costs to other major Colombian cities and the high risk of loss in transport preclude the servicing of other markets. Since arbitrage[1/] between marketing regions is prevented and the low value by weight cassava markets are isolated from each other; hence consumer prices are dependent only on supply-demand conditions on the coast. This market isolation is typical of fresh cassava markets. Market prices in the coast tend to be lower than in most other major urban markets in Colombia.

The perishability and bulkiness of cassava put particular restrictions on the structure of marketing channels and particular demands on the role of middlemen. Middlemen must manage daily supplies to ensure that they are sufficient to meet demand yet not more than demand, since this would risk substantial losses. Wholesalers, especially, either must have an adequate estimate of daily demand and a means of controlling supplies or must rely on highly variable prices to move daily arrivals. Since market

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[1/] one of the basic concepts of marketing is that products can move between markets, when the price differences are greater than the transportation costs. Cassava's perishability after harvesting makes this arbitrage move difficult.

supplies in one day are not linked to the next days, supplies by a storage mechanism, daily price variation would be expected to be random and highly variable.

However, not only are daily cassava prices relatively stable but seasonal variation is minimal (see Figure 2). Lack of high seasonal price variability thus implies some supply regulation either through staggered plantings or storage in the ground delayed harvesting. This is reflected in the difference in price variability between cassava and potatoes in Figure 2. How then is daily market demand coordinated with farming system decisions?. First, the farmer is usually preclued from selling his own supplies on the wholesaler market, due partly on the requirement for volume sales and partly to the high risk that the wholesaler will not buy on a particular day, i.e. the possibility of daily market gluts exists. The farmer, therefore, must rely on transport intermediaries and the volume and timing of his harvest are restricted by access to the intermediary. The farmer usually markets his cassava by selling an urharvested lot to an intermediary. When the intermediary has made marketing arrangements with the wholesaler, be then schedules the harvest of various lots. The farmer, however, can have little control over the timing of the harvest. The risk and management required in the marketing channels combined with the high transport costs result in a very high marketing margin (Table 1), which result in higher prices on a colorie basis than the other major staple, rice. This high relative price further restricts the potential.

A base price in the coastal zone is provided by the industrial market. The starch factory buys cassava at an extreme discount compared to the industrial fresh market price, usually about a 40 to 50% discount. The factory is a residual buyer of cassava, which is of poor quality or cannot be sold on a particular day on the fresh market. That is, it provides a sure market for farmers who need to harvest their crop, either for ready capital on to release the land for other uses.

The paper now turns to analyzing how this market structure interacts with agro-climatic conditions and farmer resource availability to determine farmer demand for new cassava technology.

The farming system: As is true in most of Latin America, farm size, and therefore relative land/labor ratios, is a determining factor in the choice of activities. This relationship is seen in the data on land use and farm size in Magdalena state, where the study was varried out (see Table 2). As farm size increases land shifts increasingly into the more extensive production activity, cattle grazing. At smaller farm sizes farmers are forced into intensive use of their land, i.e. crop activities. Where agro-climatic conditions are marginal, cassava emerges as the principal cropping activity superseding rice and maize.

In the farm trial site agricultural stress produced by environmental factors can be considered to be moderate to severe for most crops. Nevertheless, these agroclimatic conditions are probably representative for cassava. Soils in the zone are sandy with as much as 80% sand content. Soil fertility is low in terms of organic matter, phosphorous, and potassium and well below critical levels for maximum cassava production in both phosphorous and potassium (see Table 3). Moreover, cation exchange capacity at between 0.3 and 1.6 is extremely low.

Farmers in the zone distinguish between two types of soil, called red and white soils, with the red recognized to be superior. As shown in

Table 3, the structure of the two soil types is basically the same and the fertility is only marginally better for the red soils. Cation exchange capacity for the white soils, however, is significantly lower than the red soils.

Annual rainfall averages approximately 1400 mm, with a coefficient of variation of 25%. The rainfall distribution (see Figure 3), is divided into a 7 to 8 month rainy season (April to November) and a 4 to 5 month dry season (December to March). As shown by the confidence limits rainfall of over 100 mm/month is assurred in two periods, May to June and August to October. For cassava this defines a critical planning season in the May to June period, allowing the plant the full advantage of the rainy season. Extending the planting past June or July makes yield dependent on the rain in the next rainy season.

High average temperatures of 28°C, the very low water retention capacity of the soil, and poorly distributed and variable rainfall results in substantial water stress, which cannot be avoided by a crop such as cassava with a long growing season. Soil and water stress conditions such as exist in the region severely limit the choice of cropping alternatives and entail a high management component in planning the cropping activities, so that the effects of stress are minimized.

Land use patterns for the farmers in the sample are dominated by cassava (see Table 4). It is principally sown in association with maize and to a lesser extent with the relatively more drought resistant crops, sesame and cowpeas. Sesame is the only other crop that really competes for land with cassava.

Even though land/labor ratios among the small-scale farmers in the sample are relatively low, labor availability can be limiting at critical periods in the cropping year, especially since the rainfall distribution defines planting dates. As shown in Table 5 and Figure 4, the rainfall distribution heavily influences labor needs, which tend to be concentrated in teh May-August period, i.e. during the principal planting season and the period during the first two weedings. This labor bottleneck is aggravated if the farmer prepares his land by hand. Thus, most farmers pay for tractor hire services to prepare their land, unless they just do not have the working capital. The farmer does have the option of pushing his planting date into August or September but at the risk of a substantial reduction in yield and a much longer plant development period.

Production practices are conditioned by these environmental factors and resource constraints. Farmers attempt to plant in the April-June period. This ensures that the cassava plant has access to as much as eight months of rainfall. The cassava crop with the present variety matures within eight months when planted in this season. The farmer can be in harvesting in December and has four months till the start of the next planting season. If the farmer leaves the crop till after the start of the next rains, i.e. till July or August of the succeeding year, yields will increase and farmers will as well be in the period of seasonally high prices. However, by doing this farmers give up the opportunity of planting at the beginning of the ~~rains in the~~ second year. Where land is not a constraining factor, this is not a problem. Where land is constraining, farmers must plant in the August-September period, when risk of crop losses are greater, yields tend to be less, and the crop needs 11 to 12 months to mature.

The farmer in his attempts to maximize income is required to juggle planting dates and harvest times in relation to his farm size and his labor availability. Moreover, he is further restricted by his access to the market, in that he cannot sell to intermediaries when be woul always like to and therefore cannot plan his harvest with any degree of certainty. This fact is demonstrated in Table 6, which shows harvest time and market destination for the sample of eight farmers. Harvest is relatively well distributed through a twelve month period, highlighting both the storability of standing cassava and the regulation of market supplies. There are costs to the farmer in this harvest delay in his not being able to plant with the rains. This is indicated by the fact farmers will sell to the industrial market in the May-June period at a market price discount in order to be able to clear their land for planting.

What then is the relationship between the structure of the farming system, the organization of the marketing system and the requirements for new technology? Yield increasing technology is obviously necessary in this system to increase incomes given the limited land resources of the farmers. However, the market structure puts further restrictions on the characteristics of the technology, which are particularly associated with varietal requirements. Early maturity is essential in the system, in order to reduce marketing risk and take advantage of surplus labor for harvest in the slack season. Varieties as well must be capable of being stored in the ground for long periods with little risk of yield loss on loss of quality. Resistance to root rot pathogens is important. Quality maintenance, particularly low fiber content and high starch content, becomes important in order to ensure high selling prices. Particularly, quality cannot decline to an extent that it is not marketable, a factor which will be discussed in the next section. These requirements thereby provide the necessary background for evaluating the agronomic trials with new technology.

Agronomic Field Trials

Apart from determining the structural components of the cassava farm system, the farm trials also attempt to determine the potential yields of cassava with new technology, to evaluate the introduction of new technology within a whole farm context, and to assess the implications that these results have for the research program. The objective evaluation of productivity of new technology vis-a-vis farmer traditional technology precedes, and is a necessary datum for, the analysis of the farmer's subjective evaluation of the technology and his decision as to whether or not to adopt. The trials test those components of a potential technology package that appear to be consistent with the needs of the farmin system under study. Moreover, where the farmer can individually adopt various components from the total package, the package is broken down into factorial trials to evaluate the yield effect of each component. The farm trials evaluate varieties and cultural practices as a final check on the research design process.

Whereas the breeding section has identified plant efficiency as the principal objective, the cultural practices section has identified suboptimal plant populations, especially due to low germination rates, and weed control as the principal constraint on productivity. Also, where soil fertility is below the recognized critical levels, fertilizer application is recommended. the farm trials test a combination of cultural practices involving stake selection, stake treatment, stake planting position; plant population, fertilizer, and improved varieties. The selection of the different technology components depends on a preliminary soil and cropping system evaluation of the region. At the same time agro-climatic and farm yield data are collected on the individual farms for use in the diagnostic and simulation phases of the testing.

Productivity of traditional technology: Farmers in the region use relatively low plant populations of approximately 6250 per hectare. This population does not vary between monuculture and intercropping system. Planting material is of an appropriate length and is planted vertically. However, stakes are not selected for disease and insect problems and are stored without protection for as much as two months. Replanting is considerable. No fertilizer is used, although where farm size in large enough there is a rotation of cassava with guinea grass, the fallow lasting from 1.5 to 3.0 years. After fallow, cassava in usually planted consecutively for 3 to 4 years.

For the farm sample yields under this technology averaged 7.1 tons per hectare and the standard deviation between farmer lots was 2.7 tons (coefficient of variation = .38). For a crop with surch rustic characteristic, yield variance was quite large. Factors potentially influencing yield were incorporated into a regression equation, the results of which are presented in Table 8. Soil color, crop rotation, and to a lesser extent the amount of labor used in weeding made a substantial impact on yield level. Surprisingly, intercropping and the time of planting had no apparent effect on yield levels [2].

Differences between farms in management (or differences in restrictions on whether farmers could rotate their land or use more labor) and soil quality appeared to greatly influence cassava yields under traditional technology. This yield variance between farms occurred in a region that was otherwise homogenous. The question arises as to the extent that recommendations about new technology can be generated without taking these sources of variation into account.

Productivity of improved technology: The agronomic trials tested four technology components, increased plant population (10,000 per hec-

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[2] The explanation of crop yield variance in farmers fields is a difficult enterprise, given the multitude of potential sources of variation and the difficulty in measuring them. The relatively low significance of the regression coefficients reflect this difficulty. However, given the very limited number of observations, the results are never the less surprisingly good, in that the signs of the coefficients are in the theorectically expected direction. With more data as the trials continue, the estimates will be expected to improve.

tare), stake selection and treatment, fertilizer, and varieties. Plant population and stake selection and treatment were tested as one component in the first set of trials. The fertilizer treatment was 500 Kg of 10-20-20. Varieties tested included the local variety, Secundina, and two CIAT selections, M Col 22, a non-vigorous, efficient plant type, and CMC 40, a medium vigorous variety. The two CIAT varieties were varietal selections from the CIAT germplasm bank that exhibited wide adaptability in four years of testing in the CIAT regional trials. CMC 40 had maintained high yields in multi-environment testing (see Table 13) while M Col 22 had maintained high quality, especially starch content. The first hybrid varieties had just been put into regional trial evaluation and were not yet ready on-farm testing. The trials were planted in the main planting season in May and harvested before the start of the rains in April.

The results of the agronomic trials are presented in Table 9 and the statistical tests in Table 10. The following conclusions were drawn from the data:

a) There was a large increase in the yield of the local variety using the two recommended agronomic practices, rising from 7.1 to 12.1 tons per hectare. This magnitude of response of the local variety to good management was unexpected.

b) There was no statistically significant response to fertilizer for the varieties tested except in the case of M Col 22, the non-vigorous variety. This is somewhat unexpected given the low fertility status of the soil.

c) There was no significant difference between yield of the CIAT selections and the local variety.

d) There was a very significant difference between starch content of the local variety and the CIAT varieties.

e) Interestingly, starch content of the more vigorous varieties, Secundina and CMC 40, declined with fertilization but in the case of the non-vigorous variety M Col 22, increased. These differences, however, were not significant.

Yield variance between farms remained surprisingly high, even under relatively controlled experimental conditions. Ideally it would be valuable to explain this variance, but this was impossible with the limited number of farmers in the first series of trials. However, some indication of the potential value of explaining interfarm variation can be seen in Table 11, in which the yield data are broken out by soil type. Although the number of observations in some cells were not sufficient to test for significance, the results do support the estimates of the regression analysis, showing a yield difference due to soil type. The soil analysis showed no variation in the structure of the two soils and only marginal differences in fertility status; yet the yield differences are striking, especially for the CIAT selections. Obviously cassava responds to small differences in soil nutrient status when it is so close to the critical limits. The white soil produced much lower yields, except in the case of Secundina, which appeared to be better adapted. The response to fertilizer on the white soil was large. The effect of fertilizer on starch content were again negative for Secundina and CMC 40 and positive for M Col 22 but starch content was consistently lower for all three varieties on the lower fertility white soils. There thus appears to be a differential effect on starch content between natural fertility status of the soil and fertilizers. Not unexpectedly, farmers prefer to plant their white soils with sesame.

On a purely agronomic basis two principal conclusions can be drawn from the trials. First, the response of the local variety to recommended cultural practices resulted in a 70% yield increase. Given that cultural practices are usually highly location specific, the potential wide applicability of these practices is encouraging. On the other land, in areas where environmental stress is not so severe, the yield response might not be as high. Second, variation across farms in yields and starch content was found to be substantial. This certainly included differences in soil type and probably as well includes differences in pathogen incidence and differences due to the effect of following. The design of technology packages for a region must take into account sources of variation as well as mean yield evaluations. Although not represented here, this should include an estimation of temporal as well as spatial variation[3/].

Profitability and Technology Recommendations: The first stage in providing a simple evaluation of a new technological package is its profitability. If it is profitable, then it can then be entered into a more systematic evaluation of adoption constraints through an analysis of the interaction between resource restrictions, plant characteristics, etc. and the characteristics of the technology package. This profitability assessment is summarized in Table 12, which shows that in this first pass at defining a technological package for such conditions as describe the

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[3/] During the analysis of this first set of trials, it became obvious that the number of farms in the sample was critical to a statistically sound analysis of the interesting question of yield variation. Observations will be added through successive planting seasons so as to assess both spatial and temporal variability. Obviously the number of farms will as well have to be increased in each set of trials.

trial site the two agronomic practices in conjunction with the local variety were highly profitable, principally because they entailed a minimal increase in either cash expenses or labor utilization.

However the profit calculations for the different varieties depended heavily on expected output price, i.e. on whether the variety could enter the fresh market as opposed to only entering the industrial market. On the this point a connection must be drawn between market structure and varietal quality. Given the role of the wholesaler in regulating daily supplies, the relative stability of prices, the high risk of monetary loss of over-supply and the limited market in relation to production, the wholesaler is not interested in trading cassava of inferior quality. Daily price discounts for quality differences are difficult in such limited markets and virtually impossible to pass through the market chain. Producing high quality cassava assures farmers, access to market. Without high quality fresh market access is barred. Farmers were asked whether the CIAT varieties had sufficient quality for sale to the fresh market. Although HCN content was sufficiently low, they all related that starch content was far too low for sales on the fresh market. These differences in starch content were confirmed by quantitative measurement, as shown in Table 9. Defining what is a minimum standard is difficult with the limited observations, but 30% appears to be a good first "guestimate".

Thus, although the trials validated the yield and economic advantage of the cultural practices, they raised questions about the difficulty of making fertilizer recommendations in non-acid but low fertility soils. The results also placed certain minimum characteristics on variety performance in order to ensure economic optimality.

Variety Inferences: The CIAT selections tested in the farm trials were two of the five most widely adapted cultivars from the CIAT germplasm bank, which were selected in four years of regional trials (see Table 13), including four years of testing in the farm trial region (Media Luna). Hybrids are only now in their second year of evaluation in the regional trials and will enter the farm trials in the next series of trials. Before entry of hybrids into the farm trials, the question arises as to what these first set of farm trials have said about variety evaluation that was not identifiable by the regional trials.

The regional trials selected varieties on the basis of yield performance. A principal objective is to identify cultivars with wide adaptability, i.e. high yielding ability across sites. For an international center this is a response to the need to service a wide target area. As shown in Table 13, widely adapted varieties, at least for conditions below 1500 m. altitude, can be identified. However, for farmers, and to a lesser extent for national research institutions, there is little demand for wide adaptability, unless wide-adaptability and yield stability are highly correlated- for rice there is evidence the suggest that this is not the case (IRRI 197). Rather farmers will be interested in adaptation to stress factors specific to their farm system. The farm trials raised two issued. First, the characteristic of wide-adaptability as identified in regional trial evaluations was not sufficient to out-yield traditional varieties. The question arises why this result at the farm level should differ from the regional trial evaluation. Second, while yield may be a sufficient characteristic for final variety evaluation in the regional trials, market value is the principal selection characteristic at the farm level and this depends on other characteristics which consumers will pay for.

In terms of yielding ability, the widely-adapted selections in the farm trials did not perform as well as the regional trials would have suggested, while the local variety responded very markedly to good management. The under performance of the selections is explicable. The farm trials were able to capture the potential inter-farm variability, which was found to be large, i.e. the full range of yield constraining factors for which local varieties are selected. The varienties in the farm trials were put under multiple stresses difficult to capture in regional trials. Besides the stressful climatic conditions, farm trials capture the much lower fertility status of soils on small-scale farms that have been continuously cropped as well as the variation in soil type. Moreover, the trials expose the variety to a higher probability of pathogen attack characteristic of the region. Testing in a number of farms exponses the varieties to the full range of yield-constraining factors for which the local variety has been selected. It is impossible that the regional trials will capture all these factors at one site or across sites. Under this particular set of farm-level conditions, there was no statistically significant difference in yields between the local and widely-adapted varieties. These results do not resolve the issue of wide adaptability versus local adaptability but rather help to further focus research and evaluation methodology.

The second issue raised by the farm trials has been that while the yield levels between local and selected varieties were similar, quality characteristics, particularly as embodied in starch content, were not the same. Markets are small enought, wholesaler risk so high, and alternative supplies usually so plenifuI that inferior quality cassava will not be traded [4/]. Also given that cassava must be able to be stored in ground for at least an eight month period after maturity, the variety must as well be able to maintain this minimum quality during this storage period.

The farm trial results on varietal starch content indicated a surprisingly high coefficient of variation for the introduced varieties. This characteristic appeared to respond negatively to stress factors. Certainly an environmental interaction for this starch characteristic is indicated. Evidence from the regional trials and the farm trials suggests that it is much more difficult to produce high quality cassava under stress conditions, including climatic, soil, and pathogen stress. The characteristic of starch content in the local variety appears to be well adapted to conditions in the farm trial site, consistently maintaining starch levels well above 30%. Farmers indicate that the local variety can maintain this quality with storage in the ground [5/]. Data on average day matter content of promising hybrids under much less stressful conditions on the coast indicate a drop from an average of 32% at 8 months to 28% at 12 months (Kawano, personal communication). Since there is such an apparently high genetic X environ-

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[4/] Product discrimination of cassava by consumers can and does take place in urban markets. Minimal quality is guaranteed by breaking the cassava and scraping the thumb nail over the medulla. If this is at all spongy or raises water, the cassava is rejected. Superior quality can as well become associated with skin or peel characteristics or in exceptional cases will be marketed through identification with production origin. Where such cassava is above average market quality and supply is large and regular enough, price premiums may develop, as has been the case in Bogota. However, new varieties must at least be equal to average market quality.

[5/] The interaction between yields, starch content and harvest date are currently being verified with an experiment planted in the farm trial site but as yet not harvested.

mental interaction for this characteristic, since it as well varies through the growth cycle and since it is very important in farmer adoption, starch content is an important evaluation and selection characteristic in the regional trials in addition to yield.

Conclusions

The older international agricultural research institutes, IRRI and CIMMYT, recognized that information was needed at the farm level as an input into the redefinition of their research programs. IRRI, after the release of their new varieties, initiated on-farm experiments to evaluate why yields of new varieties were yielding below their genetic potential and why they had moved only into particular regions.

The CIAT cassava farm trials have established this link between the farm and the research program far earlier in the technology development process. The trials become an integral part of the research testing and evaluation process. Moreover, a systems approach is utilized in the testing process. For crop programs a systems component at the final stage of the evaluation process appears to be the most efficient method for evaluating whole farming systems while still keeping the research focused. The farm trials fulfill the multiple objectives of problem identification, technology validation, and assessment of adoption constraints. All lead to a better assessment of research objectives and characterization of the appropriate technology.

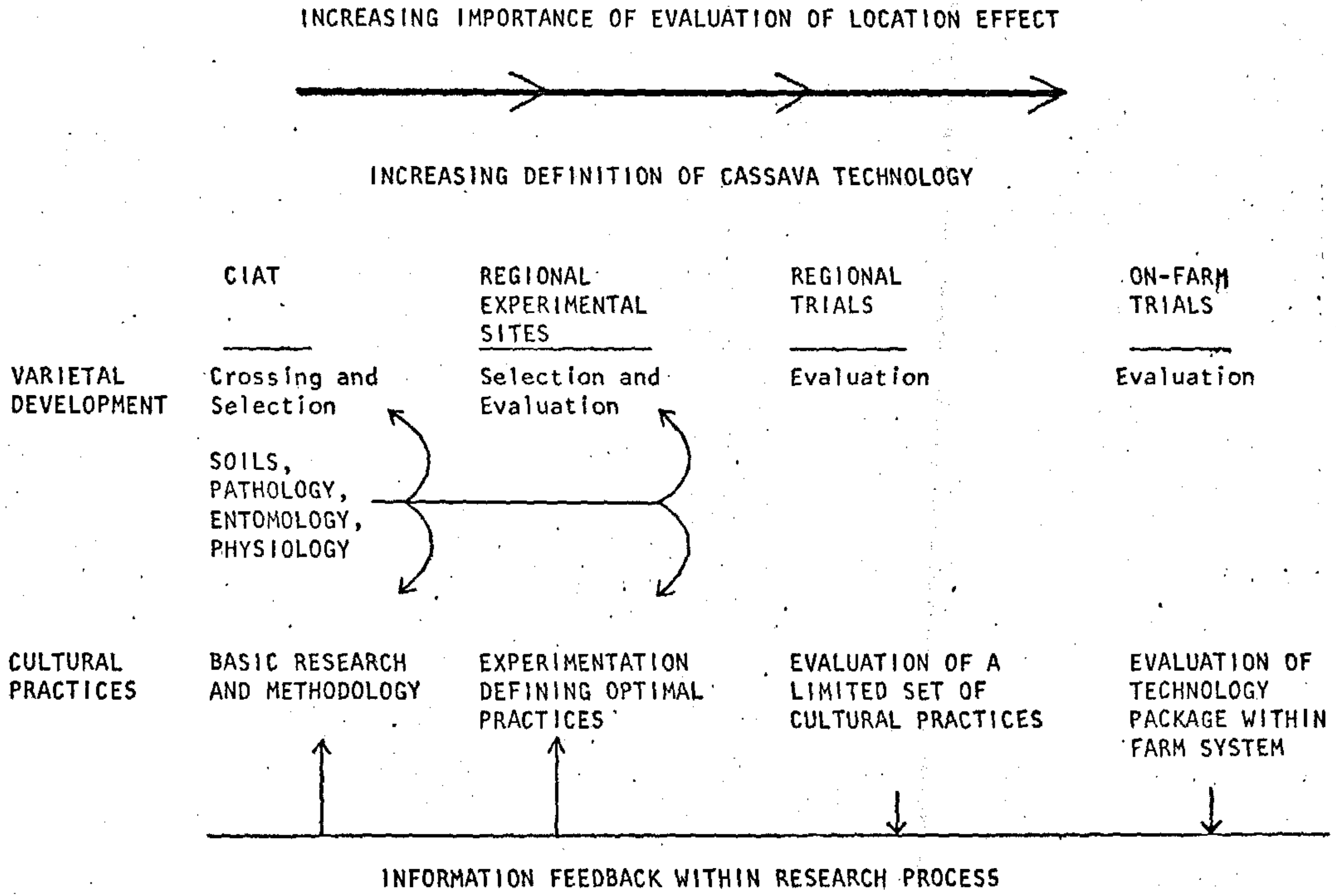
The analytical power of the farm trials increases with the number and diversity of the trial sites. Given the size and diversity of the target area for international centers, full coverage of this diversity becomes impossible without a network of cooperating national research institutions. The research is mutually beneficial in that the first issue to be assessed is the degree to which the technology can be modified by the national institution to meet locally identified constraints or whether a more fundamental change is needed in, ofr example, varietal characteristics. Optimally, hybrids, together with associated technology, would move from international trial evaluation to a network of farm trial sites.

Finally, these first farm trials demonstrated the complexity of what at first appeared to be a relatively simple farming system. At the inception of the trials a superficial study of the farms indicated that cassava was the dominant crop with virtually no alternatives, farmers were well integrated into the market, and since yields were low, low-cost cultural practices with high-yielding varieties would encounter few impediments in adoption. Marketing risk, substantial variability in production conditons, critical labor and cash flow constraints, and market entry constraints all combined to produce a very difficult farmer decision problem. Not only was the farming system found to be complex, but farm production conditions were characterized by an array of production constraints on both yields and quality characterisitcs, for which better adaptation of the variety selections appeared to be required. With a wider range of farm trial sites and the introduction of the hybrids into these trials, the information link between the farm and the breeding program will have been forged. This is more evidence for the general research principle that farmers' varieties and adaptation to their resource and management variable should not be underrated by casual empiricism.

Table 1. Price of fresh cassava at different levels in the marketing system, Barranquilla

Market Level	1969	1970	1971
		Colombian Pesos	
Farmer	347	429	931
Wholesale	1420	960	1030
Retail	1630	1570	1980
Marketing Margin as percentage of price to consumer	79%	76%	53%

Figure 1 . CASSAVA TECHNOLOGY DEVELOPMENT PROCESS



	CIAT	REGIONAL EXPERIMENTAL SITES	REGIONAL TRIALS	ON-FARM TRIALS
VARIETAL DEVELOPMENT	Crossing and Selection	Selection and Evaluation	Evaluation	Evaluation
CULTURAL PRACTICES	BASIC RESEARCH AND METHODOLOGY	EXPERIMENTATION DEFINING OPTIMAL PRACTICES	EVALUATION OF A LIMITED SET OF CULTURAL PRACTICES	EVALUATION OF TECHNOLOGY PACKAGE WITHIN FARM SYSTEM

TABLE 2 . Land Utilization by Farm Size, Magdalena State, Colombia, 1970

Farm Size	Farm Number	Temperary Crops	Permanent Crops	Fallow	Pasture	Unuseable land	Total Farm Area
			Hectares				
1 to 5 has	10.425	11.198	2.582	1.574	1.794	684	17.832
5 to 10 has	2.125	5.252	1.431	2.388	4.153	840	14.064
10 to 20 has	2.105	4.492	1.927	6.517	12.912	2.389	28.237
20 to 50 has	3.021	6.967	4.529	23.927	48.497	11.982	95.902
50 to 100 has	2.276	15.529	7.784	32.928	197.498	110.709	364.448
100 to 500 has	2.751	17.374.	6.745	33.950	336.213	165.798	924.528
more than 500 has	563	11.356	3.858	67.624	421.669	185.293	689.800
TOTAL	23.266	64.494	25.352	152.939	905.352	410.812	2.134.811

SOURCE: Departamento Administrativo Nacional de Estadistica (DANE), Censo Nacional Agropecuario, 1970, Bogotá, 1974.

FIGURE 2 . SEASONAL PRICE VARIATION FOR CASSAVA AND POTATOES IN BOGOTA, 1978.

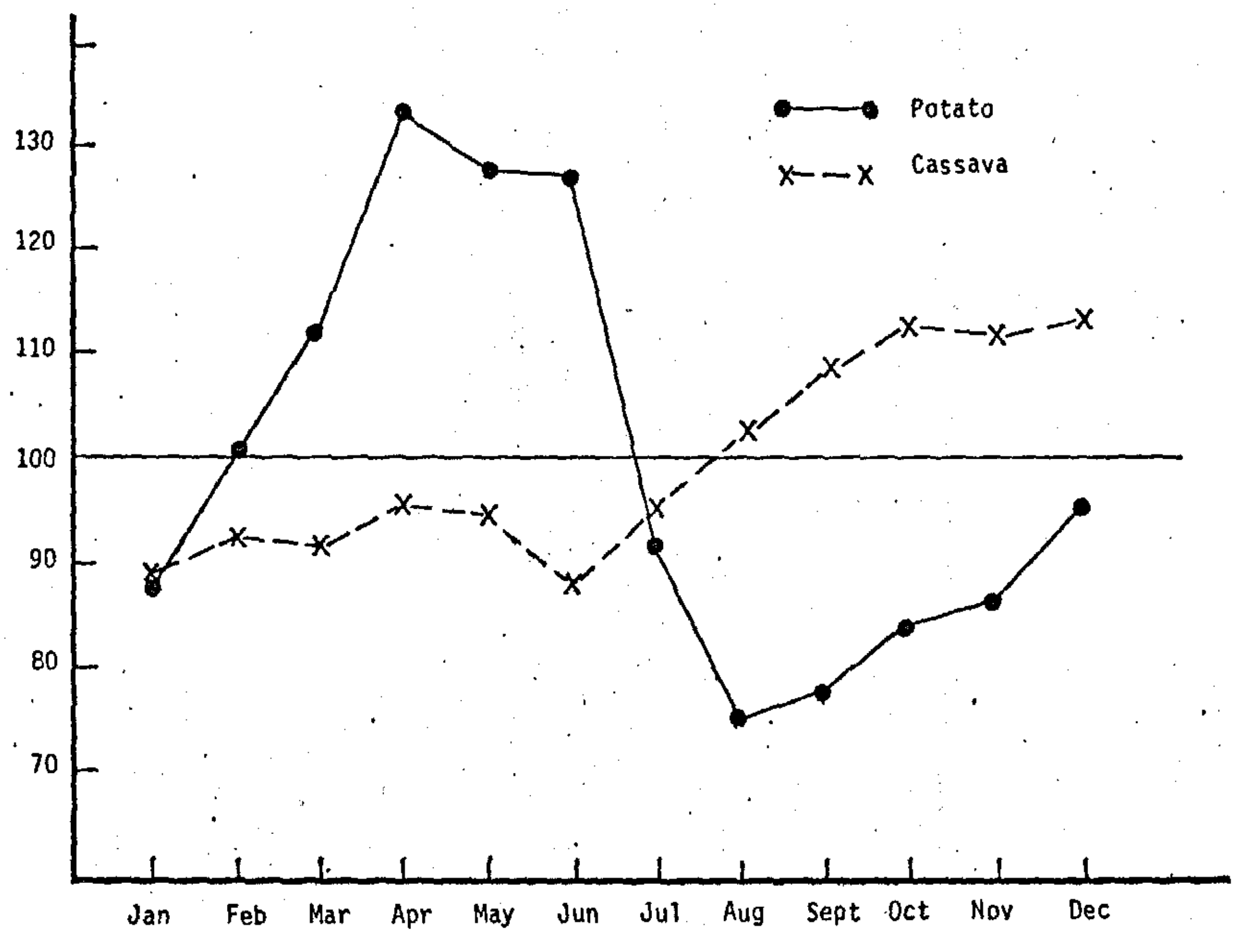


TABLE 3. Soil Characterization of Farm Trial Site and Minimum Critical Level for Cassava.

Nutrient	Measurement Unit	Red Soils	White Soils	Minimum[1/] Critical Level
Organic Matter	%	0.5	0.3	-
Phosphorous	Bray II	4.6	1.8	10.0
Potassium	Meq/100 gr.	0.09	0.06	0.15
Calcium	Meq/100 gr.	1.10	0.55	-
ph	-	6.2	5.5	4.0 and 7.8
C.E.C.	mm has/cm	1.5	0.4	0.5
Composition				
Sand	%	76.2	78.3	-
Silt	%	7.0	5.0	-
Clay	%	16.8	16.7	-

1/ R. Howeler, personal communication

FIGURE 3 . RAINFALL DISTRIBUTION AND 95% CONFIDENCE LIMITS, MEDIA LUNA.

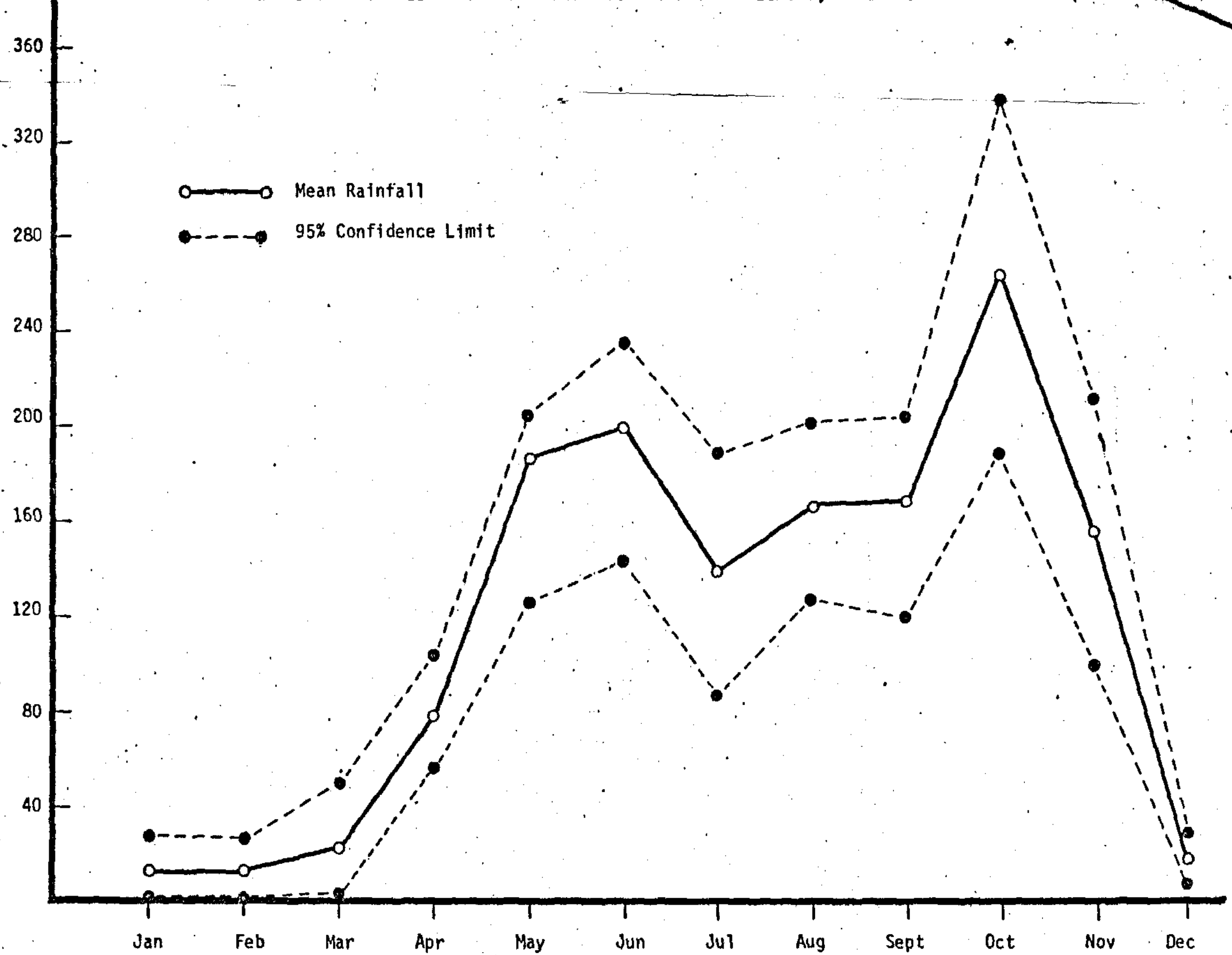


Table 4. Farm Size and Cropping Pattern of Farm Sample, 1977-1978

Farm Size	Total Area Cultivated	Cassava Monoculature	Cassava Maize	Cassava Sesema	Cassava Cowpea	Sesame Monoculture	Guinea Fallow
			Hectares				
3.7	3.7	.5	2.1	-	-	1.1	-
10.1	3.2	1.2	2.0	-	-	-	6.9
4.3	3.6	.6	3.0	-	-	-	.7
2.9	2.1	.6	-	-	-	1.5	.8
12.0	11.4	3.4	3.5	4.0	-	.5	.6
5.6	3.4	.4	3.0	-	.3	-	2.2
5.4	5.3	3.2	1.0	-	-	-	.2
2.9	2.6	.2	-	2.1	-	.3	.3

FIGURE 4. RAINFALL, LABOR AND CROPPING ACTIVITY DISTRIBUTION THROUGH A GROWING SEASON

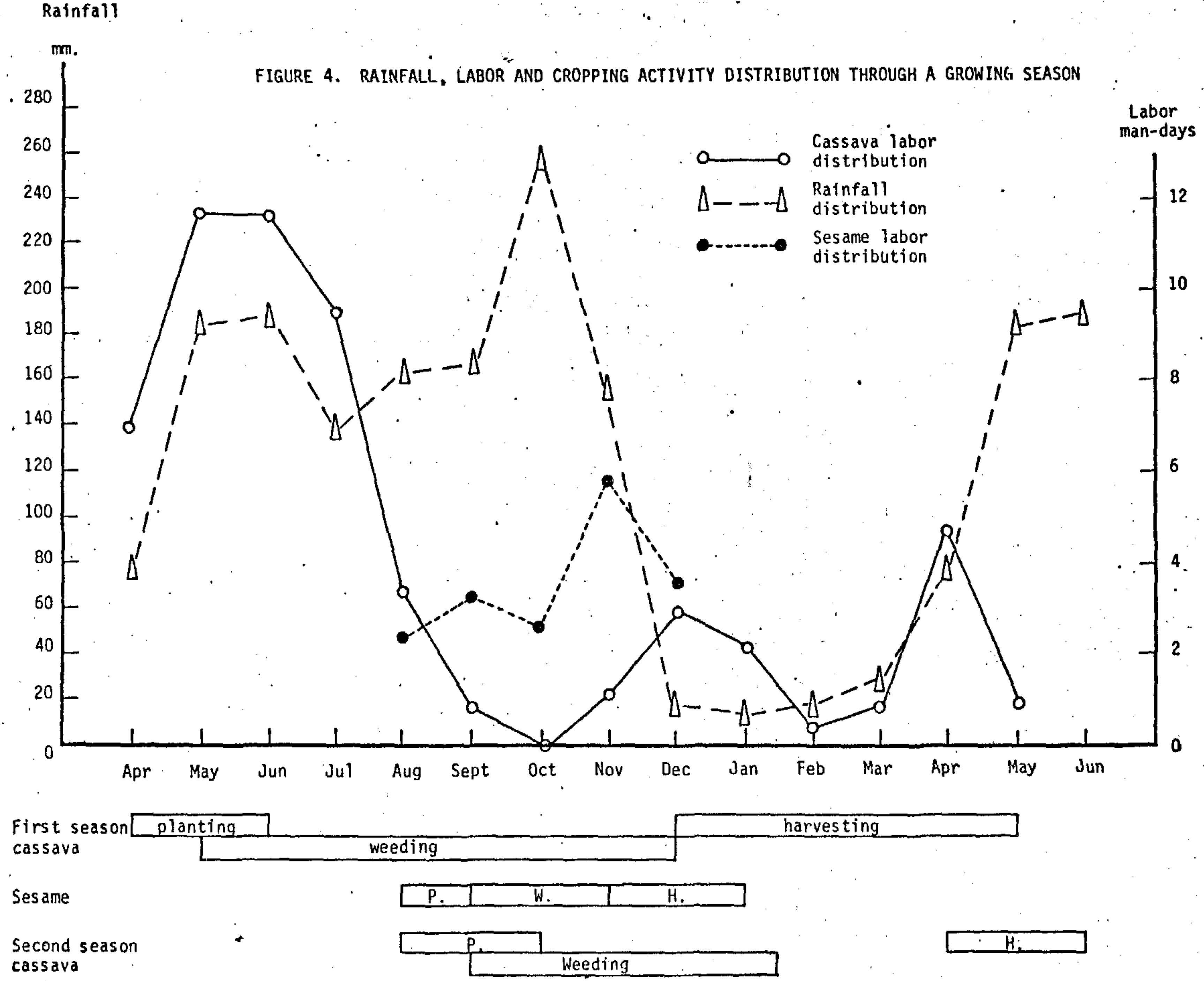


TABLE 5 . Total Labor Distribution for One Cropping Year, May 1977 to April 1979

Area Cultivated	Total Labor Utilization	Year	Period May-June	July-Sept	Oct-Nov	Dec-Apr.
ha.	Man-days			man-days		
2.1	194.1	1	73.4	70.2	6.0	22.0
		2	10.5	12.0	-	-
2.2	127.3	1	56.0	31.8	1.0	21.0
		2	4.5	13.0	-	-
3.3	238.0	1	139.5	60.5	-	26.5
		2	3.0	4.5	4.0	-
1.8	83.7	1	6.5	31.5	41.0	1.0
		2	1.5	2.3		
11.0	594.1	1	181.5	252.0	48.6	35.5
		2	40.0	36.5	-	-
3.0	180.1	1	93.0	137.4	-	21.7
		2	21.0	-	-	-
4.4	345.5	1	157.6	111.4	12.0	36.5
		2	18.0	6.2	17.5	8.0
2.5	179.1	1	79.5	21.1	24.5	28.2
		2	13.0	3.0	9.8	
TOTAL 30.2	1.941.9	1	765.3	622.9	133.1	192.4
		2	111.5	77.4	31.3	8.0

Table 6. Production and Marketing of Cassava Planted in May-Sept. 1977 Period, Farm Sample

Farm Size	Market 1/	Total Production	1977-1979 Period			
			Dec-April	May-June	July-Oct.	Nov-April
			Metric Tons			
3.7	F	9.5	6.1	3.4	-	-
	I	8.0	-	1.5	6.5	-
10.1	F	8.4	3.9	1.0	3.5	-
	I	1.2	-	-	1.2	-
4.3	F	21.7	14.4	5.3	-	2.0
	I	-	-	-	-	-
2.9	F	2.4	.4	.6	1.4	-
	I	-	-	-	-	-
12.0	F	51.0	17.4	27.5	6.1	-
	I	11.7	-	-	11.7	-
5.6	F	12.2	7.3	4.9	-	-
	I	6.1	-	6.1	-	-
5.4	F	15.4	13.9	-	.4	1.1
	I	19.7	-	7.2	9.4	3.1
2.9	F	10.7	4.8	.6	5.3	-
	I	3.8	-	3.8	-	-
Total Production	F	131.3	68.2	43.3	16.7	3.1
	I	50.5	-	18.6	28.8	3.1
Percent Distribution	F	72%	37%	24%	9%	2%
	I	28%	-	10%	16%	2%

1/ F = Fresh Urban Market; I = Industrial Starch Market

Table 8 . Yield Variation in Cassava due to Various Production and Management Factors

Regression Factor	Yield Advantage Tons/Hectare	 Description
Labor For Weeding	.10*	Per additional Man day
Soil Color	1.14**	Red over White soils
Cropping System	.34	Monoculture over Intercropping
Fallow Rotation	1.42*	Fallow over successive cropping
Planting season	.47	Early over late planting

Average yield level = 7.13 tons/ha

R^2 of regression = .24

Level of significance = **($P < .1$)
*($P < .2$)

Table 9 . Description of Results of the Various Treatments of the Agronomic Field Trials

Variety	Increased plant population, stake selection and treatment			Fertilizer and Agronomic Practices		
	Mean	Standard Deviation	(C.V.)	Mean	Standard Deviation	(C.V.)
Secundina						
Yield (Ton/ha)	12.1	3.9	(.32)	13.1	4.6	(.35)
Starch Content(%)	33.0	1.1	(.03)	30.8	2.9	(.09)
CMC 40						
Yield (Ton/ha)	15.4	5.7	(.37)	15.7	3.5	(.22)
Starch Content(%)	23.8	2.5	(.11)	19.6	6.4	(.33)
M Col 22						
Yield(Ton/ha)	13.7	3.1	(.23)	17.5	4.4	(.25)
Starch Content(%)	27.1	1.9	(.07)	29.0	2.3	(.08)

Table 10. Significance of Differences between Treatments in Agronomic Trials

Treatment: Response to Fertilizer

	Significance	
Variety	Yield	Starch
Secundina	N.S.	N.S.
CMC 40	N.S.	N.S.
M Col 22	$P < .05$	N.S.

Treatment: Local versus Selected Varieties

	Significance	
Variety	Yield	Starch
CMC 40-not fertilized	$P < .10$	$P < .001$
CMC 40-fertilized	N.S.	$P < .001$
M Col 22-not fertilized	N.S.	$P < .001$
M Col 22-fertilized	$P < .05$	N.S.

Table 11. Agronomic trial results broken out by soil type

		Varieties					
	Fertilizer	Secundina		CMC 40		M Col 22	
Soil type	Application	Yield	Starch	Yield	Starch	Yield	Starch
Red	no	12.4	33.5	17.8	24.6	15.1	27.3
Red	yes	15.7	32.1	18.1	23.3	18.3	29.5
White	no	11.3	31.6	8.4	21.5	9.5	26.6
White	yes	7.9[1/]	28.3	13.2	15.8	16.6	28.5

[1/] Includes only one observation, in which yield was significantly reduced by water logging.

ble 12. Profitability of the Cassava Technology Tested on the Colombian Coast in Farm Trials, 1977-78.

Profitable New Technology

ocation	Technological Practice	Income Increase Pesos	%	Increased costs of Inputs	Comments
edia Luna, tlantic Coast	Agronomic Practices: Stake Selection Stake Treatment Plant Population Timely Weeding	11,750	65%	$ 155[a]	This practice is dependent upon an intensive extension input to substitute management for high input use.

All New Technologies Tested in Media Luna

echnology	Yield (t/ha)	Profitable	Comments
raditional Technology	7.1	Yes	Low plant populations due to intercropping with maize; germination problem due to inadequate stake storage.
gronomy Practices: Seed Selection Seed Treatment Plant Population Timely Weeding	12.1	Yes	Higher plant populations and greatly improved initial germination raise yields Discarding maize may introduce cash flow problem.
mproved varieties	14.6	No	Though giving a slight yield advantage, starch content was lower resulting in a price differential, which the yield advantage does not overcome.
ertilizer			
Local variety	13.0	No	Not profitable and starch content was reduced by fertilization.
Improved varieties	16.6	No	Not profitable due to sharp price discount.

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[a] Few or no cash inputs are utilized by these small farmers.

TABLE 13 . YIELD COMPARISON OF SELECTED VARIETIES AND REGIONAL VARIETIES IN CIAT REGIONAL TRIALS.

REGIONAL TRIAL SITES	1975-78 FOUR YEAR AVERAGE				SELECTED VARIETY AVERAGE	REGIONAL VARIETY AVERAGE
	CMC 40	MEX 59	CMC 84	M COL 22		
				Tons/hectare		
Zone 1						
Popayan[2/]	3.8	0.9	1.0	0.3	1.5	22.9
Tambo	22.2	18.7	25.2	11.1	19.3	24.3
Quilichao	22.8	27.5	22.9	-	24.4	27.7
Zone 2						
Pereira	36.6	17.9	18.1	8.8	20.4	35.7
Caicedonia	27.8	33.6	26.5	25.2	28.3	25.4
CIAT	38.4	24.8	35.0	27.9	31.5	23.9
Zone 3						
Rio Negro	24.7	34.4	30.4	19.8	27.3	13.9
Nataima	34.1	31.0	24.0	26.0	26.3	17.2
Zone 4						
Florencia	20.6	21.2	12.2	8.8	15.7	18.5
Carimagua	23.9	22.6	24.1	15.5	21.5	13.5
Zone 5						
Media Luna	21.9	21.9	13.5	14.5	18.0	8.3
Colombian Average[1/]	26.1	26.6	21.3	17.8	23.0	14.6

[1/] Average for Colombia weighted by total cassava production in individual zones.

[2/] Location above 1500 m in altitude.