CIAT SEMINARIOS INTERNOS

Centro Internacional de Agricultura Tropical

Serie SE-2-82

METHODOLOGY IN THE CASSAVA ON-FARM TRIALS: AN INTERIM EVALUATION

JOHN K. LYNAM
FEB. 1982

The reemergence of farm management research in its new guise as farming systems research (FSR) has its impetus in two factors, the first lying in the attempt to understand the declining rate and less than full adoption of the dwarf wheat and rice varieties and the second in the necessity to move the Green Revolution off the irrigated areas and into the much more variable and complex rainfed areas. The term farming systems research has come to cover a broad spectrum of research activities, each having the common denominator that the farming system is the operational unit in the investigation.

The function of the on-farm trials carried out by the cassava program at CIAT differs substantially from most of the farming systems literature. The cassava trials are an integral part of the technology development and testing process, while most FSR concentrates on screening and modification of existing technologies; the principal function of FSR in the past has been technology transfer. Moreover, the cassava trials depart from the main body of FSR in one other fundamental respect, which is the focus on technical change in a single crop or cropping system but analyzed within a farming systems context. Research on technology development organized along FSR lines requires a dominant feature or constraint on the farming system, such as irrigated systems or farming systems in semi-arid ecosystems. Otherwise the heterogeneity of farming systems forces a high investment in decentralized FSR project areas. Integration of a FSR component in a crop research program is a lower cost alternative and has the advantage that the varietal component is much better integrated in the research.

What then is the basis for introducing an FSR component into a crop research program ? The rationale arises naturally out of the objectives and organization of the research process and the complexity of producing improved varieties for the rainfed areas. Apart from breeding for yield increases by searching for disease and pest resistance, the other major direction has been to breed for more efficient plant types (Evans, 1980; Donald and Hamblin, 1976) [1/]. Irrigation and moderate-to-high input use have traditionally substituted for the declining tolerance to stress but this becomes more difficult and uncertain under rainfed conditions. Combine this general trend in breeding with the tendency for crop technology (agronomic and varietal) components to be developed independently and a large element of uncertainty is inherent in the issue of what yields will be at the farm level over a heterogenous target areas. Logically then, as the final stage in the screening and evaluation process, varieties and agronomic practices are best combined and evaluated at the farm level. Moreover, since the ultimate evaluation criterion is farmer adoption, economic factors such as input/output price relatives,capital

---

1/ By efficient plant type is meant the greater portion of the photosynthate partitioning going to growth in plant organs determining economic yield as opposed to other plant organs. Yield improvement has appeared to be based on this change in partitioning as opposed to improved efficiency in photosysthate production itself (Evans, 1980).

constraints, etc. are most logically brought in at this stage in the evaluation process.

But the farm trials serve more than an evaluation or validation function. The trials also serve a research function, which is to fine tune the identification and measurement of yield constraints. Such yield contraints may arise from edaphic or biological factors, farming system factors, or market conditions. This information linkage between the experiment station and the farm level thereby makes the technology design and testing program an iterative process.

METHODOLOGY

The principal objective of the cassava on-farm trials is to provide input into the technology design and evaluation process and to serve as a check on the testing and evaluation system. Although the research and validation functions to a certain degree overlap, the development of the methodology will distinguish between the two. The principal distinction lies in the definition and flow of technology to be tested. The on-farm trials, as part of the testing and evaluation system (Figure 1), works on the basis of a flow of varieties and cultural practices from the experiment station down to testing at the farm level. In terms of the validation function then, the technology being tested is principally defined by what is available in the testing network. The research function, on the other hand, is essentially concerned with identifying and measuring the determinants of and constraints on yield. Technology is tested as part of the process of constraint identification; the definition of the technology in this case first arises at the farm or region level. The essential difference in the two functions is reflected in the design stage of the farm trials and the amount of information that goes into that design (Figure 2).

On-farm research has to a degree been underated in terms of its input into the research process because of it location specificity. Yet any experimental research that measures yields or yield differences and attempts to extrapolate those to the farm level must specify the conditions under which that extrapolation can be made. The farm trials in effect provide some basis for making that extrapolation. But, more that this, on-farm research in recognizing its location specificity attempts to deal directly with the problem; in particular, the on-farm trial methodology is designed to deal with variation. The farm trials work within the framework of a yield distribution (usually a non-normal distribution). The means of dealing with the location specifity problem is to understand what are the factors that determine the yield distribution and then to relate these to the known distribution (spatial or temporal) of these factors.

SITE SELECTION : Given the problem of location specifity, the first stage of the methodology focuses on site selection. This process rests on understanding the variation in the target area through stratification of the target area. Site selection will depend on the importance of the different strata in relation to research priorities. The number of sites will depend on budgetary resources available for the farm trials. Research priorities in the cassava program are based on edapho-climatic zone, market (or end-use), and to a certain extent, farm size. Site selection will then depend on a prior stratification of the target area and a prior ranking of research priorities. Target area stratification on the basis of edapho-climatic factors started in 1981; stratifibation on the basis of economic factors is planned and would entail cluster or factor analysis of census data using variables such as are presented in Table 1. Given then a ranking of research priorities, sites could be selected on the basis of these priorities and moreover, the data base to extrapolate the farm trial results to the larger target area would exist.

Unfortunately, when the farm trials began the target area analysis had not been started and site selection had to be made on a more ad hoc basis. Sites are described in Table 2 and were selected first on the basis of market characteristics and second on the basis of edapho-climatic zone. Finally, the trials were systematically biased toward small-scale farmers.

FARM TRIAL DESIGN : The next stage in the methodology involves the process of farmer stratification, hypothesis development on principal constraints, and farm trial design, a process which is interactive with farm surveys and/or analysis of the farm trial results (Figure 2). How an on-farm research program first enters this interactive process depends precisely on the needs of the research program and whether the function is principally validation or research. Table 3 presents three alternative strategies and the implications for the process of designing the trials. Where the function is principally validation farm trial design will derive (at least initially) from technologies identified at the experiment station and a certain constancy in design will be maintained across sites. Where the function is more research the design may arise directly from initial hypotheses about region level yield constraints, in which case a farm survey will be a necessary first step or the design may try to assess the importance of particular constraints across sites, in which case the design will have elements common to the constraint measurement and elements particular to the various sites.

The cassava farm trials at their inception in 1977 were initially conceived of as validation trials but on the basis of initial results the design of the trials evolved to a research function. The operating hypothesis in the cassava program is that yields are principally constrained by the limited genetic yielding ability of traditional varieties. However, within any particular edapho-climatic zone the relation between actual farm level yields and the yield potential of the improved varieties will depend on various management components common to most cassava cropping systems (Table 4). These management components together with variation in edaphic and biological constraints determine the yield distribution in the zone. Moreover, employment of or restrictions of the use of these management components are determined by farming and markeing system requirements. Thus, yields are not determined principally by independent management of the cassava cropping system and the need arises for farming systems research in evaluation of cassava technology, particularly the interaction between improved varieties and these management components -- that is, the farm trials focus on evaluating system stability of the improved varieties (Cock, 1981) and the ability of the farming system to maintain the higher yield levels of these varieties over time.

Design or identification of treatments in the cassava farm trials thus follows from the objective of evaluating the interaction of improved varieties and management components under the edaphic variation of the different regions. Treatment identification currently follows from the hypotheses on principal management components presented in Table 4 and the particular use of these components in each of the zones. Understanding the stability of management and varietal components across edaphic variation in each zone requires that the number of trials be minimally fifteen in number, unless the farms can be stratified on the basis of other information.

Experience has shown that non-treatment variance in the farm trials is substantial and often swamps within treatment variance. Since the objective is to evaluate the yield potential of new technology across farms in a region -- this assumes at least initially that new technology identified for a region for extension will be homogeneous across that region --, each farm is best conceived as a repetition [2/], and more information

---

2/ Each farm should be regarded as a random or stratified sample from the population of cassava farms in the region.

is gained (the design is more efficient) by replicating the trial across farms rather than within farmer plots. Various statistical methods can then be used to analyze the source of non-treatment variation, which can be used to stratify farms and more systematically evaluate the interaction between non-treatment yield variation and constraints on the productivity of the technology.

FARM-TRIAL ANALYSIS : The eventual test of the suitability of a new technology is farmer adoption. Since the farm trials are part of the overall technology testing system, evaluation is *ex-ante* in nature but the evaluation criterion still remains potential adoption by the farmer. *Ex-ante* evaluation of adoption by definition must focus on those factors that will influence a farmer to adopt, that is the evaluation must to a great extent simulate his decision-making process. The evaluation criteria are essentially economic, that is relative profitability between treatments, fit of the technology into the farming system - in particular compatibility with resource constraints -, and risk versus income-gain trade-offs. The trials provide the input-output coefficients on the new technology alternatives; data on prices, resource availability, other cropping activities, etc. comes from farm management records maintained during the course of the cropping year.

The analysis of the farm trial results is then carried out in a three stage process. The first level of analysis is the conventional significance of the yield difference between treatments (ANOVA). If the treatments are not significant but there are still large variations in treatment yields, *a priori* and statistical stratification of the farm are investigated. For example, responsiveness to fertilizer may depend on soil type or rotational system. If there are sufficient degrees of freedom after stratification, the reduced sample is returned to ANOVA. This first stage does not take into account farmer decision making; its principal purpose is to assess stability of treatment effects under variable production conditions, define factors which result in yield variation, and feed this information back into redesign of trials or to the research program. (Figure 3)

The second level of analysis ascertains whether the treatments are more profitable than the farmers' practices. Relative profitability defines the income gain to the farmer. New technology which may have resulted in a yield increase, may because of increased input use be less profitable than the farmer's. This stage of the analysis essentially provides a reading on the economic viability of increased input use. Also, where there are output price differences due to quality factors, profitability assessment may substantially narrow the superiority of new varieties. Since the cassava program focuses on raising farmer incomes through improved varieties with only minor changes in input use a profitability ranking of technologies will in fact depend essentially on yields and any price discounts due to quality differences. The latter is particularly important in determining potential of cassava to enter into alternative markets and to compete with cassava going into higher-price, traiditonal markets.

Almost more important than the profitability analysis for cassava is the next phase, the analysis of the feasibility of the new innovation in a whole farm context. As pointed out in Table 4 optimum management practices (and thus yield and/or output) are potentially restricted by several farming system or marketing system considerations. Nevertheless, the constraints are difficult to model in linear programming models of cassava farming systems. Cropping activities are usually limited in cassava producing areas and cassava tends to dominate in the solution without artificial bounds simulating market constraints. Modelling optimal harvest time is compounded by the multi-year nature of the problem and the risk factors inherent in the problem. Finally, modelling restrictions placed on delivery to the market is difficult from a perspective of farmer decision-making, and again could only possibly enter as a probalistic element in the objective function. Nevertheless, solution to these problems will then provide a basis for simulating the impact on incomes and production patterns from opening up alternative markets [3/].

Analysis of the farm trials results thus provides the basis for redesign of the next year's trials, for information feedback to the research program, and for planning policy intervention (such as development of alternative markets) accompanying the release of the technology. The methodological issues of farm trial design and analysis will now be illustrated with results presented in the next section.

Illustrative Results

The objectives and the design of the cassava farm trials have evolved since their inception in 1977; the trials now focus on three closely related objectives:

1) To understand the factors determining yields in traditional cassava production systems;
2) To determine the changes in these systems necessary to support the higher yield plateau of the hybrid varieties; and
3) To determine the changes in these systems necessary to adapt them to the requirements of new industrial markets.

Extension and adoption of improved, high yielding varieties will in most cases in Latin America be linked to some type of processing capability, which in most areas will entail development of new markets and investment in processing capacity. The farm trials thus attempt to forsee the changes in traditional production systems necessary to make this transition.

3/ The modelling effort has only just began.

Also, since a realistic measurement of yields is necessary to evaluate the economic viability of the projected investments, the trials as well focus explicitly on understanding the determinants of yield and identifying the appropriate conditions under which to accurately measure expected farm level yields. As such the farm trials are the final stage in varietal yield evaluation, and provide a check on the testing and evaluation system.

The on-farm trials were initiated in Media Luna, on the Caribbean Coast of Colombia. The area is a typical cassava growing zone, characterized by small farmers, relatively marginal production conditions to the extent that cassava was one of the very few potential cropping alternatives, and relatively good access to markets, in this case the fresh urban market in Barranquilla and a large-scale starch factory. The objectives and design of the trials evolved over time in response to conflicts between results and initial hypotheses.

At their inception the trials were designed to assess actual adoption, the hypothesis being that varieties and cultural practices were ready for direct extension to the farms. The common assumption, that yield advantage at the experiment station or regional trial, translates into adoption at the farm level, was quickly shown to be untenable. The objectives of the trials then successively evolved from evaluating actual adoption, to validating yield advantage at the farm level and finally to systematic evaluation of factors governing yield and adoption -- in order to more appropriately specify technology requirements (Table 5).

The yield advantage due to the minimum input agronomic package was established at an early stage (Table 6). However, the identification of an improved variety that was more profitable than the local variety and the establishment of the conditions under which this yield (and profitability) assessment should be done was more difficult. The first set of trials established the importance of quality factors in establishing which markets varieties could enter and thus either their price differential or their inability to be sold. The succeeding years established that both yield and quality characteristics were dependent on soil type (Table 7), time of planting (Table 8), and time of harvesting (Tables 8 and 9). Average yield level and the yield ranking of varieties often changed when evaluated under differing treatments of these three factors. Nevertheless, in the 1980-81 trial a hybrid that was more profitable than the local was identified, under at least a particular set of these factors (Table 8).

Moreover, achievement of the maximum yield in most cases was restricted by constraints placed on farmer management by higher level farming-system or marketing-system objectives (yield determining factors and restrictions on their management are set out in Table 10). Evaluating the so-called yield gap in cassava thus rests on first identifying the factors determining yield, second establishing the economic restrictions on management of these factors, and third relating this to the farmer population (as is done in the synthetic example in Figure 4). The farm trials are currently still at the first stage of this process, establishing each of these factors two or three at a time, due essentially to limits on space 4/. To estimate eventually the yield gap inherent in Figure 4, will require a very large, incomplete factorial trial based on adequate farmer stratification.

The farm trials in Mondomo in Cauca Department where initiated in the same manner as validation trials, testing the minimum input package, fertilizer, and improved varieties.

4/ Current trial size now ranges from a quarter to half a hectare in size, a large restriction in terms of space of these small-scale farms and in terms of seed material when new varieties are introduced.

Selection of varieties was based on regional trial results at Santander de Quilichao (1070 m in altitude versus around 1400 m for the farm trial site). Varieties were found to be non-adapted, apparently due to the slight temperature differential. Moreover, yield differences in treatments were non-significant, the between farm variance being significantly greater than the between treatment variance (Tables 11 and 12).

In order to analyze treatment effects the variance had to be controlled for, essentially by bringing in other information that would account for yield variation. Initial soil analysis revealed very low levels of phosphorous, high aluminium saturation, and low to moderate potassium levels. Moreover, farmers in the zone attempted to control for declining soil fertility through a long term fallow system. The effect of the fallow system on yields could be seen by ordering the results on the basis of a simple fallow index (Table 12). The correspondence between the two was very high.

Alternatively, multiple regression was applied to the results with additional variables for soil factors. Different specifications of the model are presented in Table 13. All the varietal dummies are consistently significantly different (i.e. less) than the local variety, Algodona. Seed treatment did not give a significant yield effect. On the other hand, coefficients on the soil variables were found to be highly dependent on whether a fallow dummy was included [5/]. However, the model results appeared to be stable when the P and K variables were expressed as only an interaction term and together with the rotation index gave the highest R^2. Again the rotation variable was critical in explaining yield variance and in the

---

5/ Multicollinearity may be a problem in this case but simple correlation between the fallow dummy and soil factors was not high.

eventual model determined whether there was a significant response to fertilizer. Stratifying the farmers and rerunning the analysis of variance, led to significant fertilizer response when the length of fallow was inadequate (Table 14).

In the trials in Mondomo, as in Media Luna, quality factors as well as yield were found to vary on the basis of management factors. As is shown in Table 15 starch content and HCN content were found to vary on the basis of soil fertility status of the soil. Even though there were "sweet" varieties in the trials, which maintained this characteristic under the higher fertility levels, under the shortened fallow HCN levels went above the critical 100 ppm level. Maintaining quality thus becomes more difficult, the higher the stress cassava is grown under. The ability to manage these quality factors depends on restrictions within the farming system, such as fallow length in relation to farm size and their importance in end markets.

While the farm trial analysis shows the types of results obtainable from assessing between treatment variation and between farm variation, there remains the concept of between site variation. The latter only becomes feasible when the evaluation is focusing on a technology or variety that is relatively widely adapted. Such a focus was essentially used in the IRRI constraints research (IRRI, 1979); however, in cassava it is unlikely that there will be much similarity in technology introduction in different sites. However, the approach is useful in regards to what can be learned from a comparative analysis. Also, in more advanced modelling efforts (eg. market-spatial equilibrium type models) the trials could be used to assess changes in comparative advantage in producing for different end-markets, particularly where quality differences were a factor.

In the spirit of a comparative analysis, the farm trials in 1980-81 were designed to assess the effect of different planting and harvesting dates as determinants of yield. Choice of planting and harvesting dates were set by the particular farming system requirements of each site. The results taken together demonstrate the yield gains from storing the cassava in the ground (percent increase in profitability is even higher) but that this storage comes at an increasing risk (Table 16). Risk factors include production risk, such as in Mondomo where root rot set in due to unseasonable high rainfall, or in Media Luna where root quality tends to decline.

More important is market risk, which besides the risk of a price fall through the course of the harvest period, includes access to market. Farmers across the different regions have adopted different marketing strategies. In Socorro farmers face a very limited fresh market in which buyers change prices through the course of the marketing day as they gauge supplies coming into the market. Farmers rarely harvest more than 150 to 200 kg. for any market day. Farmers in the Llanos (for the fresh market in Bogota) and Mondomo (for small-scale starch plants) sell their lots on contract. Farmers are therefore not interested in higher yields and buyers are interested more in supply continuity rather than yield increases. In Media Luna farmers can sell to the fresh urban market for which there is a substantial price premium or to the industrial starch market. The problem is access to the fresh market, to which they sell whenever a marketing opportunity exists. Farmers sell almost exclusively to the fresh market at the beginning of the harvest period and to the starch market at the end, when planting season approaches.

The conclusions then is that cassava yields vary markedly depending on time of planting and particularly time of harvesting. However, cassava is in general harvested earlier than may be considered optimum due to higher level farming and marketing system constraints. To the extent that alternative markets and small scale processing units are developed, there will be scope for substantial efficiency gains through better linkages between cassava production and processing systems.

Conclusions

Farming systems research tied to technology generation or evaluation can be used for several different purposes, such as defining technology design requirements, validating and testing technology, identifying technology components or packages appropriate for extension, or project planning and evaluation. While quite different, there is nevertheless considerable overlap in these objectives and because of this, FSR programs often tend to try to do everything. The implementation and design of a successful FSR program requires that the objectives are made clear. As regards the objectives of technology design or technology validation, these are best carried out as part of a research program, which in most cases will be a crop research program.

Even given this differentiation, the discussion of the cassava on-farm trials at CIAT has as well hopefully shown that the design of the methodology will as well depend on the particular stage of development of the research program (i.e. whether the focus is essentially on the research functions vs.on the validation function) and the particular characteristics of the crop or cropping system. The cassava on-farm trials were initiated in a research program that was essentially six years old and in a crop that had little previous research history. Since yield increases were being sought through varietal development with minimal increases in supporting inputs, the initial issues faced were in linking the on-farm trials to the varietal testing system and in developing an appropriate design for measuring yields that reflected constraints on the cassava cropping system.

What this process quickly made clear was that it was impossible in any particular region to specify an unconditional, point estimate of yield for a particular variety associated with the minimum input package. There was a very marked yield distribution and to understand what that distribution was (and thus what average yields were) required either that a very large number of trials be put out on randomly sampled farms or that factors causing yield variation could be identified and related to more readily available secondary data. As opposed to more traditional agronomic trials, the methodology was therefore oriented toward working with substantial variation in the yield estimates. A principal, and partially obvious, conclusion that came out of these initial trials was that yield and quality variation was much greater between farms than between treatments.

This yield distribution was caused by variation in edaphic and biotic yield constraints and by farming and marketing system constraints on management of the cassava crop (Table 4). Farmers did not achieve optimum yield either in a physical or even in a simple budgeting sense due to higher level constraints on such factors as time of planting, time of harvesting, fallow period, and weed control (eg. where it conflicted with coffee harvest in Mondomo). Moreover, it is such management factors as opposed to purchased input use that principally determine yield. Cassava production lends itself to minimal use of purchased inputs. Disease insect control is in general either prohibitively expensive or ineffective due to the long growth cycle of the crop. Fertilizer application must compete with a fallow rotation. Moreover, because of its inefficient root system (ameliorated by mycorrhizal infestation) fertilizer application tends to be large in order to generate a yield response. Farmers may either face capital constraints and/or have alternatives which give a better return to fertilizer application. Nevertheless, a soil fertility management strategy will be critical to the effectiveness of the improved varieties.

The profitability and therefore, potential adoption of the improved varieties will critically depend on the type of end-use market available, in that the type of market will determine where quality requirements are strict. The farm trial results have suggested that it will be difficult (and costly) to produce high-yielding varieties that have the quality characteristics necessary to compete with traditional varieties in urban fresh markets. The stress conditions that cassava is usually grown under adversely affect quality characteristics, such as starch and HCN content, as much as they affect yield.

Improved varieties will therefore tend to be adopted more rapidly in those areas where a processing capacity for cassava as well exists, that is where quality characteristics are not as rigid. In most cases in Latin America outside Brazil this will usually require development of alternative markets. Evaluating potential adoption of the improved varieties and evaluating potential development of alternative markets thus become related problems. Prices used in the analysis will need to come from demand analysis; economic viability of cassava in the alternative markets will come from the farm trial results. The farm trials will thus eventually evolve as a tool for ex-ante evaluation of integrated cassava production and market development projects. The trials will as well need to link the requirements of the new markets to an analysis of necessary changes in production systems. The cassava on-farm trials thus provide the key link between the varietal testing system and the planned expansion of cassava production and utilization.

Bibliography

1. Cock, J.H. (1981). "Stability of Performance of Cassava Genotypes", mimeo.

2. Donald, C.M. and J. Hamblin (1976). "The Biological Yield and Harvest Index of Cereals as Agronomic and Plant Breeding Criteria", Advances in Agronomy (28):361-405.

3. Evans, L.T. (1980). "The Natural History of Crop Yield", American Scientist (68): 388-397.

4. IRRI (1979). Farm-level Constraints to High Rice Yields in Asia: 1974-77, International Rice Research Institute, Los Baños, Philippines.

Table 1. Types of Variables Used in Target Area Stratification of Cassava Farming Systems

Characteristics	Variables
Edapho-Climatic Characters	
Farming System Characters	
Farm Size	Average Farm Size Percent of Farmers Below 10 ha.
Farm Tenancy	Farm Owners as % of All Farmers
Cassava Crop Characteristics	Cassava Area Per Farm Cassava Area as % of Cultivated Area Cassava Monocultire as % of Total Cassava Area
Labor Force	Economically Active Population per Farm Economically Active Population per Cultivated Area
Power Source	Tractor Population per Farm Tractor Population per Cultivated Area
Market System Characters	
Price	Cassava Price Cassava Price Relative to Competing Crop
Commercialization	Percent of Production Marketed
Processing	Percent of Production Processed
Marketing Costs	Distance to Principal Market
Market Dynamics	% Change in Cassava Area Over Time % Change in Cassava Price Over Time

Table 2. Locations and characteristics of the zones where on-farm trials are currently being carried out in Colombia

Location	Altitude (masl)	Rainfall (mm)	Soil Characteristics Bray II-P (ppm)	K (meq/100 g)	pH	Average farm size (ha)	Principal competing Crop	Principal market
North coast								
Media Luna	10	1400	3.9	0.08	6.0	5.8	Sesame	Fresh urban and large-scale starch
Cauca								
Momdomo	1450	2402	1.6	0.12	4.3	15.1	Coffee	Small-scale starch
Santander								
Palmas del Socorro	1225	2560	2.5	0.20	4.0	5.9	Sugarcane	Subsistence
Llanos Orientales								
San Martin	350	2500	3.1	0.10	4.6	60.0	Coffee	Fresh urban

Table 3: Differentiation of Farm Trial Design on Basis of Research Objective

Research Focus	Trial Design Characteristics	Example
Location or Site Focus:		
Site Specific Constraint Evaluation or Within-Site Validation	Treatments Follow From Farm System Characteristics of the Region	Technology Evaluation in New Edapho-Climatic Zone, eg. Amazon Basin
Constraint Identification Across Sites	General Design Evaluation Single Constraint; Specific Treatments Based on Farm System Characteristics of the Region	Evaluating System Stability of New Varieties; Comparative Evaluation of Production Systems
Validation Across Sites	Complete or Incomplete factorial Design with Constant Treatments	Evaluation of Wide Adaptability of Varieties; Testing Minimum Input Package

TABLE 4 : DETERMINANTS OF YIELD AND OUTPUT IN CASSAVA CROPPING SYSTEMS

CASSAVA CROPPING SYSTEM COMPONENTS	VARIETAL INTERACTION	EDAPHO-CLIMATIC INTERACTION	HIGHER SYSTEM LEVEL DETERMINANTS : FARMING SYSTEM	MARKET SYSTEM
SOIL FERTILITY MANAGEMENT	??	HIGH	CAPITAL CONSTRAINT CROP ROTATION LAND CONSTRAINT/FALLOW SYSTEM "LAND QUALITY" ALLOCATION	OUTPUT/FERTILIZER PRICE RELATIVE FERTILIZER/QUALITY INTERACTION
EROSION CONTROL	LOW	HIGH	CROP ROTATION/LAND ALLOCATION TENURE SYSTEM	-
INTERCROPPING	MODERATE	MODERATE	LABOR CONSTRAINTS CASH FLOW CONSTRAINTS	OUTPUT PRICE RELATIVES
WEED CONTROL	MODERATE	MODERATE	LABOR CONSTRAINTS	WAGE RATE
STAKE MANAGEMENT	??	LOW/MODERATE	-	-
PEST MANAGEMENT	HIGH	HIGH	CAPITAL CONSTRAINTS 1/	OUTPUT/PESTICIDE PRICE RELATIVE QUALITY CHANGES
TIME OF HARVEST	MODERATE	MODERATE	LABOR CONSTRAINTS COMPETING USES OF LAND	SEASONAL OUTPUT PRICE MARKET ACCESS
TIME OF PLANTING	?	HIGH	RESOURCE ALLOCATION TO OTHER CROPS	SEASONAL OUTPUT PRICE MARKET ACCESS
VARIETAL "QUALITY" CHARACTERISTICS	HIGH	MODERATE/HIGH	FERTILITY MANAGEMENT	OUTPUT PRICE DISCOUNTS MARKET ACCESS

1/ BECAUSE OF THE LONG GROWTH CYCLE IT IS DOUBTFUL THAT FUNGICIDES, PESTICIDES, ETC. WILL BE AN OPTION.

Table 5 : Media Luna : Evaluation of Cassava On-Farm Trial Objectives and Design

Year	Objectives	Trial Design Characteristics	Results
1977-78	Evaluate actual adoption of new varieties plus minimum input technology	Two selections and local variety with three treatments; each treatment evaluated on different farm.	1. Importance of quality characteristics in farmer adoption (starch content) 2. Yield return to minimum input package 3. Evaluation of adoption not practical, need to redesign trials
1978-79	Validate widely adapted varieties and recommended cultural practices	Two selections and local variety with minimum input package and minimum input package plus fertilizer.	1. Yield and fertilizer response difference on the basis of soil type 2. Concept of wide adaptability did not apply to Media Luna 3. Starch content influenced by environmental factors such as soil type 4. Yield response to minimum input package but fertilizer not profitable
1979-80	Screen hybrids and evaluate yield and quality as a function of harvest date	Local and three hybrid varieties with six harvest dates	1. Yield and quality highly dependent on date of harvest 2. Ranking of varieties changes as function of time of harvest 3. Variety selection most efficiently linked to regional trial
1980-81	Variety evaluation as function of different planting and harvest dates	Local and hybrid variety evaluated under three management systems with two planting dates each with two harvest dates	1. Hybrid variety more profitable than local variety, even with price discount 2. Substantial interaction between fertilizer response and weed control 3. Planting date and harvesting date heavily influence eventual yield 4. Hybrid more responsive under good management to fertilizer
1981-82	Evaluate yield and fertilizer response as a function of fallow system and soil type	Local and hybrid variety evaluated under six fertilizer treatments across three fallow states and two soil types	Yet to be harvested

TABLE 6. MEDIA LUNA: PRODUCTIVITY AND STARCH CONTENT OF LOCAL AND CIAT VARIETIES UNDER IMPROVED AGRONOMY 1/ AND IMPROVED AGRONOMY PLUS FERTILIZER.

Variety and Treatment	Yield		Starch Content	
	Mean	Standard Deviation	Mean	Standard Deviation
	Ton/hectare		Percent	
Secundina				
Improved agronomy	12.1a 2/	3.9	33.0a	1.1
Agronomy and fertilizer	13.1a	4.6	30.8ab	2.9
CMC 40				
Improved agronomy	15.4a	5.7	23.8c	2.5
Agronomy and fertilizer	15.7ab	3.5	19.6c	6.4
M Col 22				
Improved agronomy	13.7a	3.1	27.1b	1.9
Agronomy and fertilizer	17.5b	4.4	29.0b	2.3

1/ Includes plant population of 10,000 per hectare, stake selection, and stake treatment.

2/ Values followed by different letters are significantly different ($P = 0.05$).

Note: Average yield level with traditional technology was 7.1 t/ha.

TABLE 7. MEDIA LUNA: AGRONOMIC TRIAL RESULTS BROKEN OUT BY SOIL TYPE

Soil type	Fertilizer Application	Varieties					
		Secundina		CMC 40		M Col 22	
		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/	29.3	13.2	15.8	16.6	28.5

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

TABLE 8. MEDIA LUNA : EFFECT OF TIME OF PLANTING, TIME OF HARVEST, AND WEED CONTROL ON YIELD OF TWO VARIETIES

TREATMENT	MAY PLANTING				SEPTEMBER PLANTING			
	FEBRUARY HARVEST (273 DAYS)		MAY HARVEST (345 DAYS)		JULY HARVEST (303 DAYS)		SEPTEMBER HARVEST (357 DAYS)	
	YIELD	DRY MATTER	YIELD	DRY MATTER	YIELD	DRY MATTER	YIELD	DRY MATTER
	T/HA	%	T/HA	%	T/HA	%	T/HA	%
GOOD WEED CONTROL								
SECUNDINA								
TRADITIONAL	6.5	-	10.0	32.8	9.0	38.1	7.7	34.1
IMPROVED	12.4	33.4	16.5	32.4	9.4	35.5	11.6	33.5
FERTILIZED	11.1	33.7	14.4	35.9	10.4	35.6	14.3	34.2
CM 342-170								
TRADITIONAL	20.9	-	20.4	20.6	15.6	31.3	13.6	29.6
IMPROVED	17.2	29.9	21.4	25.3	16.9	29.9	20.4	29.6
FERTILIZED	23.5	28.6	29.8	24.1	19.8	28.6	20.4	28.8
POOR WEED CONTROL								
SECUNDINA								
TRADITIONAL	2.8	-	6.1	31.3	4.2	33.3	5.2	36.2
IMPROVED	7.7	33.5	10.5	32.1	4.2	34.8	3.4	33.6
FERTILIZED	7.1	31.9	9.6	31.0	3.3	33.2	7.2	36.4
CM 342-170								
TRADITIONAL	11.4	-	9.5	28.0	9.6	29.6	13.8	31.7
IMPROVED	17.7	32.2	19.6	28.0	12.9	30.3	17.2	32.3
FERTILIZED	16.2	29.3	16.7	28.3	11.4	26.8	19.1	30.9

Table 9. Media Luna: Varietal Characteristics as a Function of Different Times of Harvest, 1979-80.

Varietal Characteristic	Months After Harvest					
	10	11	12	13	14	15
Rainfall (mm)	0	3	50	170	240	180
Root Yield (tons / hectare)						
Secundina	8.4	7.7	8.6	9.1	12.2	12.3
CM 323-375	7.6	6.6	7.8	9.6	16.0	16.0
CM 305-38	5.7	5.4	5.8	6.6	7.4	10.4
CM 391-2	6.6	3.6	3.8	7.7	9.0	10.2
Dry Matter Content (%)						
Secundina	36.6	33.1	32.3	32.2	41.4	34.5
CM 323-375	28.5	22.5	23.6	23.1	25.6	23.7
CM 305-38	28.9	27.3	25.9	24.6	28.0	22.7
CM 391-2	29.8	26.8	27.2	21.1	33.2	30.2
Root Putrefaction (% of total roots)						
Secundina	0.8	1.0	0.7	0.3	1.1	0.4
CM 323-375	4.1	13.3	6.3	2.8	4.5	4.5
CM 305-38	4.8	10.4	10.9	4.1	3.0	5.6
CM 391-2	2.2	18.3	14.1	5.8	4.3	1.0
Fiber Content (%)						
Secundina	2.8	2.6	4.8	N.A.	3.4	4.0
CM 323-375	3.1	3.6	5.3	N.A.	3.9	3.3
CM 305-38	3.2	4.1	N.A.	N.A.	4.4	6.4
CM 391-2	3.3	3.4	6.4	N.A.	4.5	3.3

Table 10: Media Luna: Determinants of Cassava Yield and Quality and Restrictions on Farmers Control of These Factors

Yield Determinant	Restriction on Farmer Control
Time of Planting	Tractor Hire Availability Ability to Harvest Previous Crop
Time of Harvest	Market Access Price Expectations
Soil Type: Red or White	Soil Distribution Fallowing System
Length of Fallow	Farm Size Fertilizer Price
Stake Management	Water Availability Time of Harvest
Weed Control	Labor Availability and Price Seasonal Labor Peaks
Disease and Insects	Unprofitable Control Measures

Table 11. Mondomo: Yield and Dry Matter Results for the Varieties and Fertility Treatments Tested in Farm Trials, 1979-80.

Fertility Treatment	Variety		
	Algodona	Americana	CM 323-375
Root Yield (tons / hectare)			
Lime + Fertilizer	10.3 a 1/	6.3 a	5.5 a
Fertilizer Only	10.4 a	4.9 a	6.2 a
Lime Only	9.3 a	4.8 a	4.7 a
Control	9.1 a	4.9 a	3.1 a
Dry Matter Content (%)			
Lime + Fertilizer	36.8 a	35.9 a	37.6 a
Fertilizer Only	36.6 a	33.7 a	36.2 a
Lime Only	36.1 a	35.1 a	36.4 a
Control	35.4 a	34.3 a	37.5 a

1/ Means in the same colomn followed by the same letter are not significantly different at P = .05

Table 12. Mondomo: Algodona and Americana Yields by Farmer as Related to Plot History and Farm Size

Root Yield Americana	Root Yield Algodona	Previous Plot History	Rotation Index 1/	Farm Size
t/ ha	t /ha			ha
8.5 a 4/	16.6 a	1 year cassava; 15 years fallow	13	44.8
2/	13.7 b	2 years fallow; 1 year cassava; 10 years fallow	10	12.6
3/	11.4 bc	10 years fallow	10	19.2
6.6 ab	8.7 cd	8 years fallow	8	4.5
6.2 b	6.9 d	6 years fallow	6	5.8
3.5 c	6.5 de	2 years fallow	2	15.1
4.6 c	4.7 e	2 years cassava; 8 years fallow	4	5.0
2.7 c	2/	2 years cassava; 2 years fallow	-2	12.6

1/ Calculated as number of years in fallow minus 2 times number of previous years in cassava.

2/ Same farmer but different plot histories for the two varieties.

3/ Plot lost.

4/ Means in the same column followed by the same letter are not significantly different at P = .05

Table 13: Mondomo: Yield Determinants as Measured in Multiple Regression Analysis

Variable	COEFFICIENT ESTIMATES 1	2	3	4
Intercept	11675***	12941***	8057***	12889***
Soil Factors:				
Phosphorous	- 3625***	- 187	-	-
Potassium	15351***	3122	-	-
Organic matter	- 49	293	- 49	303
Calcium	- 1010	-3405***	- 272	- 3346***
P* K	-	-	2661***	986**
Varieties				
Americana	- 4019***	- 3141***	-4674***	-3191***
CM 23-375	- 5042***	- 4072***	-5812***	-4140***
M Col 1684	- 6800***	- 5749***	-7560***	-5822***
CMC 59	- 3993***	- 2491***	-3908***	-2485***
Strake treatment	419	433	422	434
Fertilizer	905*	921*	908	917**
Fallow dummy	_	- 6349***	-	-6424***
R^2	.55	.64	.49	.65

NOTE: Asterisks denote the significance level of the coefficient as follows:

*** P > .01 ; ** P > .05 ; * P > .10

Table 14: Mondomo: Fertilizer Response by Algodona as Related to Length of Fallow Period.

Fertility Treatment	Rotation Cycle: Adequate (rotation index>6)	Rotation Cycle: Shortened (rotation index≤6)
	---------- t/ha	----------
Fertilizer + lime	11.3 a	7.7 a
Fertilizer	11.1 a	8.9 a
Lime	12.1 a	2.5 b
Control	11.0 a	4.2 b

Note: Figures with same letter within same column are not significantly different at the 5% level.

TABLE 15: MONDOMO: Effect of Fallow System and Fertilizer on Root Quality

Variety	Adequate Fallow 1/				Shortered Fallow 2/			
	Fertilized		Unfertilized		Fertilized		Unfertilized	
	Dry Matter %	HCN ppm	Dry Matter %	HCN ppm	Dry Matter %	HCN ppm	Dry Matter %	HCN ppm
Algodona								
March Planting								
March Harvest	34.5	-	35.2	-	30.7	-	26.6	-
June Harvest	36.0	328	26.9	335	31.8	219	29.7	623
Sept Planting								
Sept Harvest	41.9	94	42.3	128	37.0	243	37.4	317
Dec Harvest	32.4	85	33.8	107	32.0	251	30.5	285
CMC 92								
March Planting								
March Harvest	37.3	-	37.7	-	30.2	-	26.2	-
June Harvest	33.7	182	27.9	83	29.8	154	32.9	409
Sept Planting								
Sept Harvest	38.3	195	37.1	306	39.3	287	35.6	624
Dec Harvest	34.3	181	33.4	258	32.1	365	32.2	350
Barranqueña								
March Planting								
March Harvest	38.7	-	37.0	-	29.7	-	28.8	-
June Harvest	37.2	113	37.2	167	34.1	122	29.0	253
Sept Planting								
Sept Harvest	37.0	80	37.0	165	36.6	111	36.0	139
Dec Harvest	32.2	30	34.3	46	30.2	92	33.3	93
Sata Dovio								
March Planting								
March Harvest	35.2	-	34.5	-	28.8	-	29.4	-
June Harvest	41.3	71	36.3	179	33.9	123	33.5	194
Sept Planting								
Sept Harvest	34.5	107	37.5	207	34.8	266	37.0	224
Dec Harvest	34.7	43	37.3	37	35.7	110	34.7	154

1/ For March Planting Plot 2; for Sept. Planting Plot 4

2/ For March Planting Plot 1; for Sept. Planting Plot 3

TABLE 16 : EFFECT OF TIME OF PLANTING AND TIME OF HARVESTING ON YIELD AND PROFITABILITY OF CASSAVA 1/

REGION AND VARIETY	FIRST PLANTING: HARVEST INITIATION (TON/HA)	FIRST PLANTING: HARVEST TERMINATION (TON/HA)	PERCENTAGE CHANGE IN: YIELD (%)	PERCENTAGE CHANGE IN: PROFITABILITY (%)	SECOND PLANTING: HARVEST INITIATION (TON/HA)	SECOND PLANTING: HARVEST TERMINATION (TON/HA)	PERCENTAGE CHANGE IN: YIELD (%)	PERCENTAGE CHANGE IN: PROFITABILITY (%)
MEDIA LUNA :								
SECUNDINA								
UNFERTILIZED	12.4	16.5	33	50	9.4	11.6	27	42
FERTILIZED	11.1	14.4	30	65	10.4	14.3	38	89
CM 342-170								
UNFERTILIZED	17.2	21.4	24	32	16.9	20.4	21	27
FERTILIZED	23.5	29.8	27	36	19.8	20.4	3	4
MONDOMO :								
ALGODONA								
UNFERTILIZED	11.4	9.5	- 17	- 27	16.9	26.9	59	80
FERTILIZED	22.3	2.4	- 89	-	19.5	30.8	58	90
BARRANQUENA								
UNFERTILIZED	15.4	9.2	- 40	- 56	5.2	9.1	75	444
FERTILIZED	17.7	20.7	17	28	12.5	13.5	8	18
CMC 92								
UNFERTILIZED	9.1	3.6	- 60	-	12.1	30.9	155	242
FERTILIZED	18.3	3.6	- 80	- 70	14.5	36.2	150	288
SOCORRO :								
CHILE								
UNFERTILIZED	12.9	21.5	67	38	21.5	16.9	- 21	- 28
FERTILIZED	13.4	26.3	96	105	23.3	18.5	- 21	- 29
CMC 92								
UNFERTILIZED	10.6	16.2	53	39	2/	2/	-	-
FERTILIZED	13.4	22.3	66	69	2/	2/	-	-
HMC 2								
UNFERTILIZED	4.6	17.5	280	-	2/	2/	-	-
FERTILIZED	14.7	15.7	7	68	2/	2/	-	-
LLANOS								
CHIROSA								
UNFERTILIZED	11.2	18.0	61	86	N.I.	N.I.	-	-
FERTILIZED	13.4	14.9	11	18	N.I.	N.I.	-	-
CUPA								
UNFERTILIZED	5.8	7.1	22	50	N.I.	N.I.	-	-
FERTILIZED	7.9	10.3	30	80	N.I.	N.I.	-	-

N.H. = NOT YET HARVESTED, N.I. = NOT INCLUDED AS A TREATMENT, 1/HIGH MANAGEMENT TREATMENTS, 2/ STAKES DESTROYED IN SHIPMENT

FIGURE 1. CASSAVA TECHNOLOGY DEVELOPMENT PROCESS

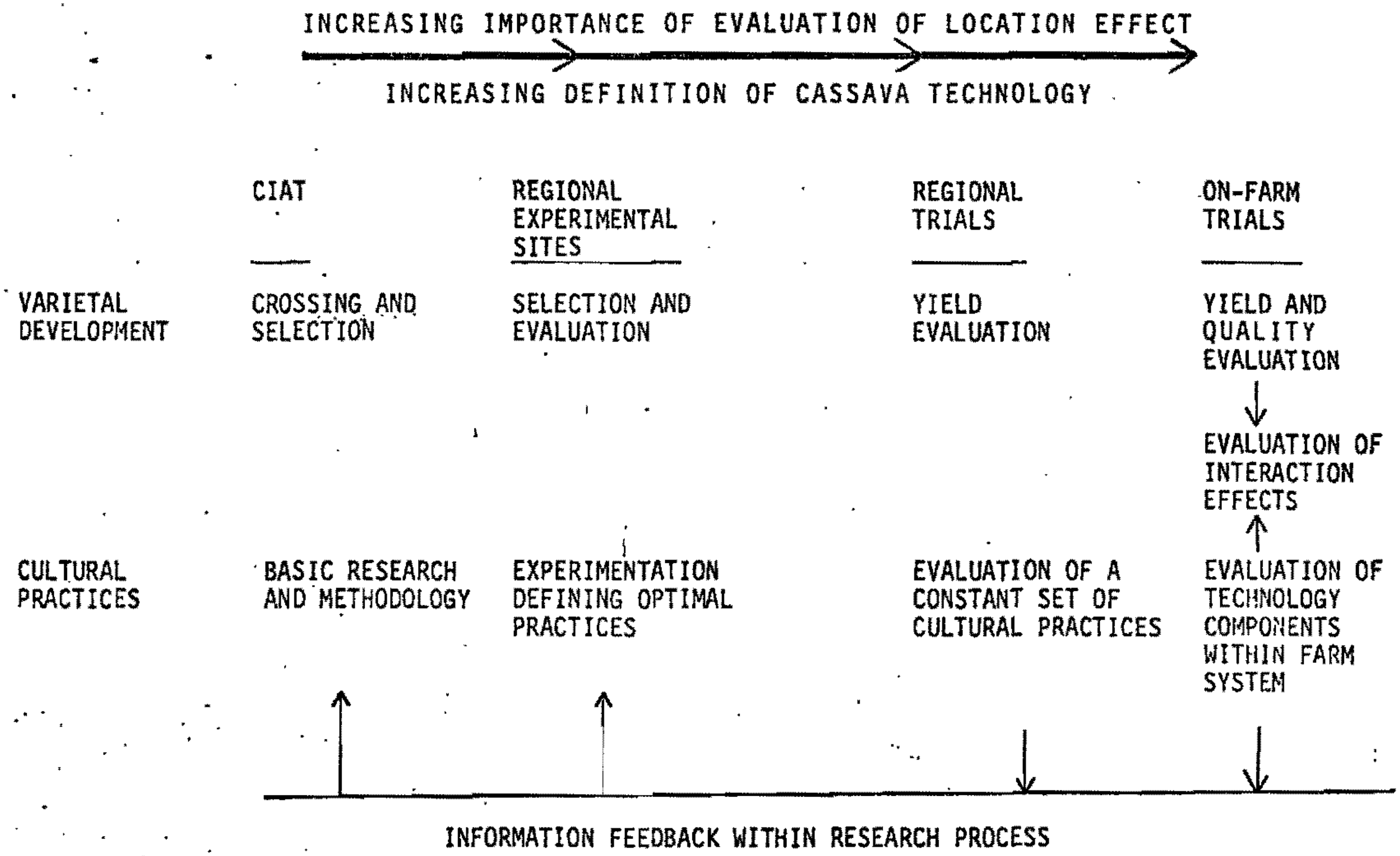


Figure 2. Methodology Flow Chart in Cassava On-Farm Trials

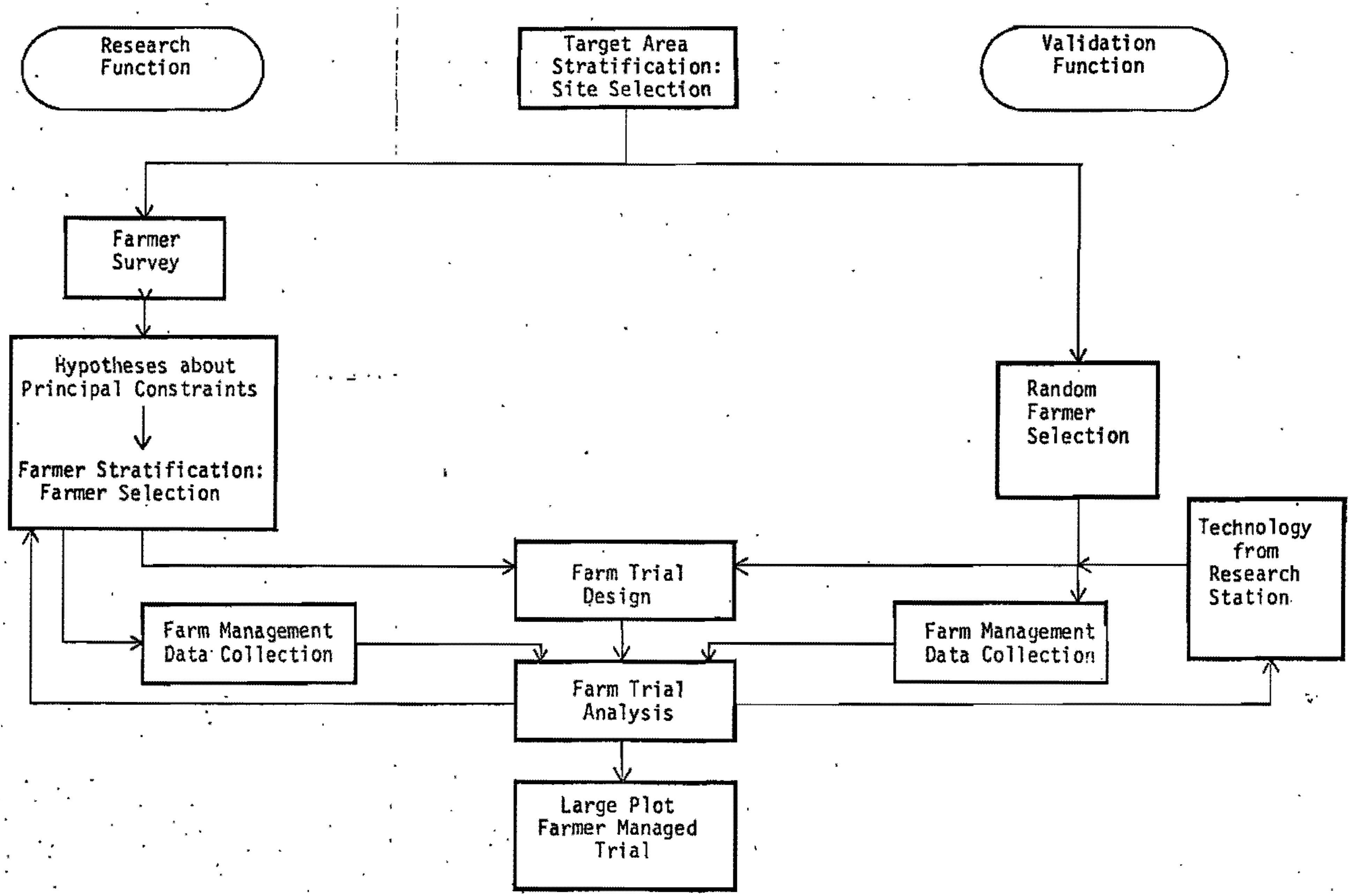


FIGURE 3. FLOW CHART FOR NEW TECHNOLOGY EVALUATION IN FARM TRIALS

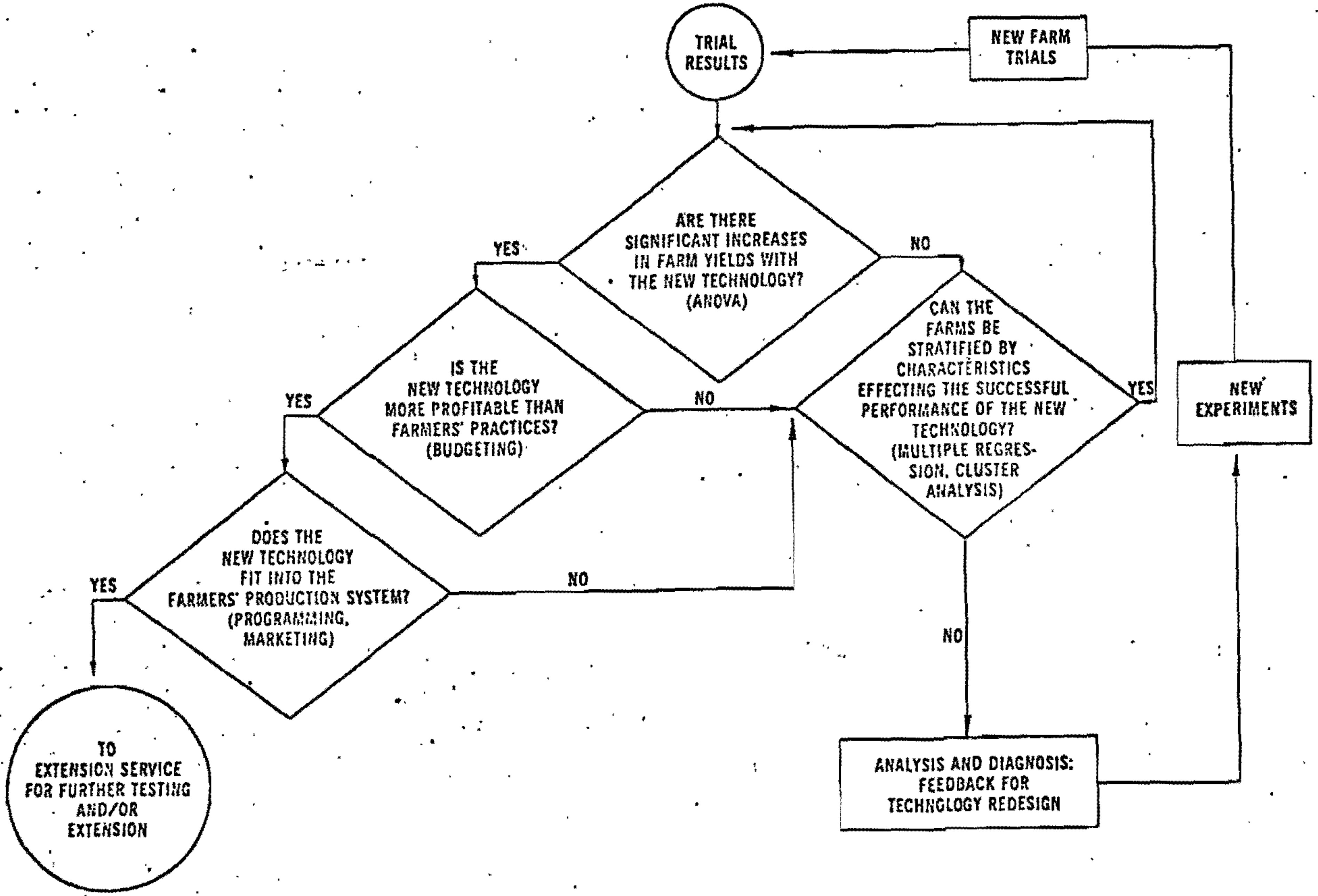
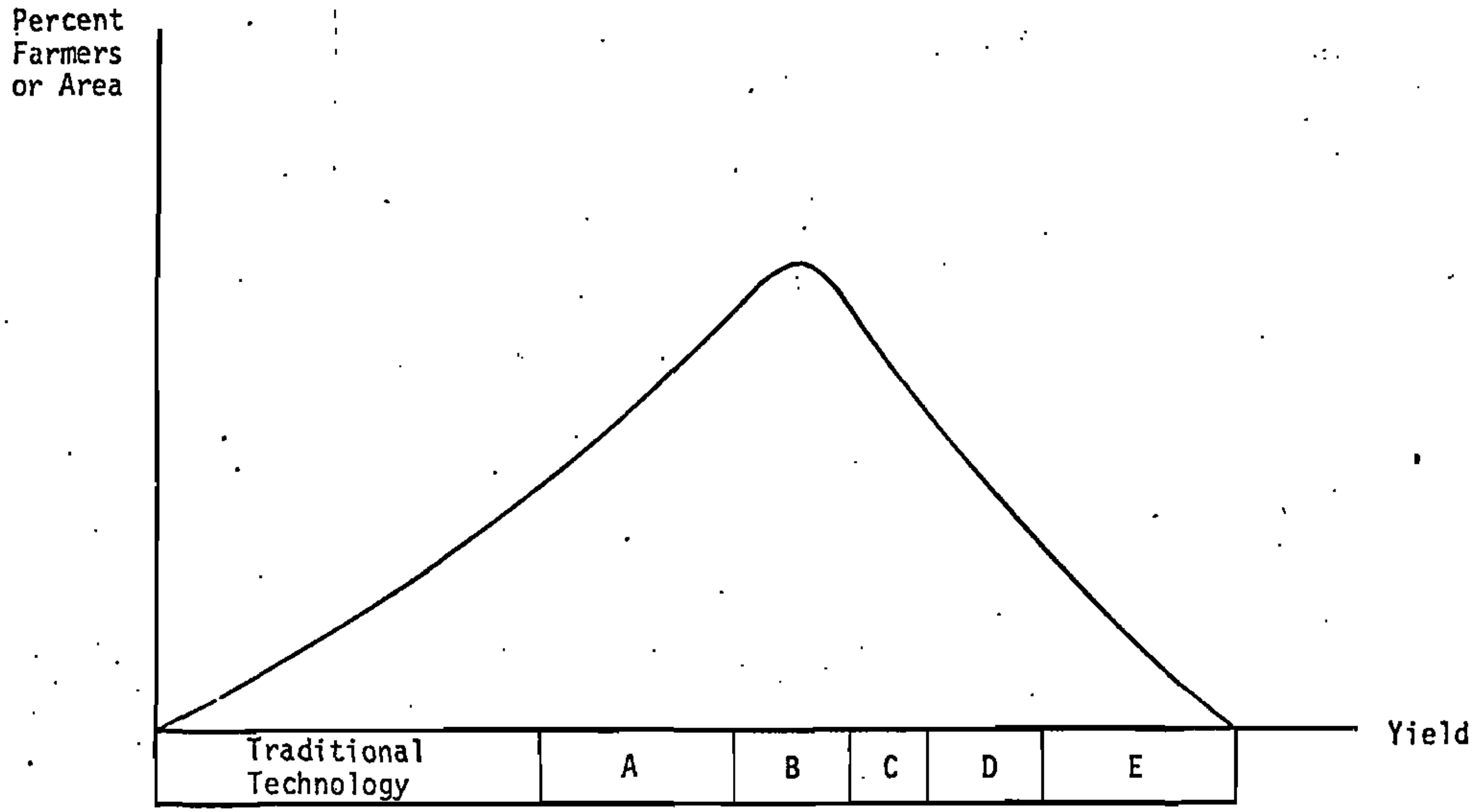


Figure 4. Yield Distribution as a Function of Underlying Yield Gap



A : Optimal Weed Control
B : Stake Management
C : Optimum Planting Date
D : Optimum Harvest Date
E : Optimum Fertilizer Use or Fallow