EVALUATION OF NEW TECHNOLOGY ON FARMS: METHODOLOGY AND SOME RESULTS FROM TWO CROP PROGRAMS AT CIAT

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S U M M A R Y

This paper reviews the methodological development and results of three years of farm testing of new technology in the bean and cassava programs of the Centro Internacional de Agricultura Tropical (CIAT). Farm testing is the logical extension of the research evaluation process once a technology has been identified on the experiment station and regionally tested for adaptation. Farm testing is an especially important component of the research process in developing countries, where communication links between farmers and researchers are weak and farmers often do not have the information or management experience to combine and modify various technology components adapting experiment station observations to their own environments and production systems. The research problems at the farm are different from those at the experiment station or in regional trials so there are important distinctions in design and analysis in the farm trials. The evaluation process developed here successfully identified the technology adopted by farmers. For the unsuccessful technologies information was provided from the farm trials to the breeders and other scientists on further design requirements. The results of the farm trials substantially modified the policy recommendations, ~~arrived at utilizing~~ derived from the results ~~from the~~ of experiment al station or regional trials.

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I N T R O D U C T I O N

Farm yields of 57 to 93 percent of experiment station results have been reported in Australia in the sixties (Davidson and Martin, 1965). Not only are absolute yields generally reduced in the movement from the experiment station to farms but also the relative yield comparison between treatments can be reversed. Inputs dependent upon other inputs or excellent management often do not function as well or at all under farm conditions (for an example with fertilizer and water control see Barker, 1978, p.50). These documented yield differences between the experiment station and the farm in new technology performance are one basis for extending the research process into farm testing. Moreover, comparative yields are an inadequate criterion for evaluation of the potential of new technology since farmers are not yield maximizers. To measure the differences in yield response and to incorporate economic and systems analysis researchers are increasingly moving off the experiment station into regional and farm trials.

In the next section after reviewing the roles of regional and farm trials evaluation criteria for farm trial analysis are proposed. Then in the second section performance of the new technology in the bean and cassava programs is analyzed with these criteria.

A METHODOLOGY FOR FARM TESTING AS A COMPONENT OF THE RESEARCH PROCESS

The diffusion of best farmer practices may increase income of those farmers with similar resources (Biggs, 1980, p.141); however, larger income gains are expected from the introduction of new inputs. These new inputs are either developed or adapted at the public sector experiment station or at some private sector equivalent. Once a new technology is identified at the experiment station, adjustment to different environments becomes the research problem of the regional trials since the effect of most biological and chemical agricultural technologies is influenced by climatic, edaphic and other factors including diseases and insects. Intensive management on the experiment station may even accentuate the differences between experiment station and farm conditions. "Most experiment stations are managed in such a way that over time soil structure, fertilizer, weeds, pests and diseases are quite different to farmers' fields" (Byerlee, et.al., 1979, p.7). Before reaching the farmers' fields and after the experiment station regional trials compare new technology treatments with farmers' practices. Once the regional trials have identified a limited number of new technology combinations evaluation passes to the final stage, the farm trials (Figure 1).

The differences between regional and farm trials can be illustrated by identifying the research questions left unanswered in a regional variety trial. In most regional variety trials a number of new varieties are compared with one or more local varieties at some input level. This input level is generally neither the very high level of the experiment station nor the low level often found on farms in developing countries. It is some arbitrarily choosen intermediate level between the two. Experiment station input levels are often very high so that individual input effects can be analyzed for their maximum effect without other factors constraining yields. For many of the food crops farmers in developing countries utilize low density, low input systems with low but stable yields requiring few inputs except family labor. With farmers' cultural practices the effect of any one input change, such as a new variety, is expected to be minimal or at least very difficult to measure. New varieties typically are accompanied with recommendations for both higher density and higher input utilization than those of the farmer. Hence, it is appropriate that the input level of the variety trials is between the levels of the experiment station and the farms.

Regional variety trials are useful for evaluating adaptation of a large number (often more than 20) of new materials and identifying several new materials for on-farm testing. The research question of the regional variety trials is whether there is a difference between one or more of the new varieties and the farmers' variety(ies). Breeders generally concentrate on the absolute size of the yield difference and agronomists customarily utilize some variation of analysis of variance to evaluate the statistical significance of the yield difference. The regional variety trials leave a number of important questions unanswered: there may be qualitative differences between the new and the commercial varieties reflected in the market price hence yield comparisons are not always an appropriate selection criterion; the

FIGURE 1. STAGES OF THE CROP RESEARCH PROCESS

	I	II	III
TYPE OF PRODUCT	BASIC RESEARCH	REGIONAL ADAPTATION	FARM LEVEL VIABILITY
LOCATION	EXPERIMENT STATION	REGIONAL SITES	FARMS IN TARGET AREAS
OUTPUT	PRODUCTION OF NEW TECHNOLOGY ESPECIALLY NEW GERMPLASM AND BASIC INFORMATION FOR FUTURE TECHNOLOGY PRODUCTION	SITE SPECIFIC WORK PRINCIPALLY ON PERFORMANCE OF NEW GERMPLASM IN SPECIFIC CONDITIONS, ALSO RESPONSE TO FERTILIZER AND HERBICIDE	IDENTIFICATION OF PROFITABLE TECHNOLOGIES WHICH FIT INTO THE FARMERS' PRODUCTION SYSTEM
INFORMATION FLOWS OF FARM LEVEL TESTING			

FEEDBACK TO RESEARCHERS FOR
TECHNOLOGY MODIFICATION

ON THE EXTENSION SERVICE
FOR FURTHER TESTING AND
DIFFUSION

input level utilized in the regional variety trials including the choice of cropping system may not be more profitable than the farmers' practices either with the commercial or the new varieties; even if one new variety and the accompanying inputs is more profitable than present farmer practices, there may be other constraints in the farming system preventing adoption of the new technology; regional variety trials do not take into account the large between farm variance in the performance of new technology. These problems are overcome by extending the research process onto farm trials. In the specific case above one or more new varieties are obtained from the regional variety trials and placed on a large number of farms in the target area at different input levels and compared with the farmers' variety at these input levels.

Before specifying in more detail the differences in the analytical techniques of the farm trials with regional trials it is useful to review the types of agronomic trials and the stages of analysis. There have been three primary approaches to analyze agronomical experiments. The first approach of the factorial experiments has already been mentioned for variety trials but is equally applicable in other agronomic trials (Table 1). The second approach of the optimal input level has proliferated since the Fifties with the increased sophistication of economists in differential calculus. Unfortunately, in agriculture optimal levels are not very meaningful unless variation in yield performance due to weather, insects, and diseases is also incorporated into the analysis. The influence and probability levels of these stochastic factors is difficult to measure. (To incorporate risk into farm decision making and the analysis of experimental data see Anderson, et.al., 1977, Anderson, 1973, and Dillon, 1977). Where the new technology has already been adopted on farms, division of the yield gap between the physical maximum on the farm in an experiment and farmers' yield into various components including the technical and economic capacities of the farmer in combining his inputs and responding to economic signals and the difference between a physical and an economic maximum is useful (Barker, 1979; Herdt and Mandac, 1979; Herdt and Wickham, 1975). However, in evaluating the potential of new technology the optimal recommendations generally come from response surfaces, which do not adequately integrate the importance of the stochastic factors in shifting the function.

Both the factorial and the optimal level experiments can incorporate

TABLE 1

PRINCIPAL TYPES OF AGRONOMY EXPERIMENTS, ANALYTICAL TECHNIQUES, AND THE RESEARCH PROBLEMS

Types of trials	Variety Fertilizer Herbicide Other Defensive Chemicals Density Seed Quality Timing of Practices Associated Cropping Minus One Plus One
Stages of analysis and the research problems	Factorial Experiments - Is there a significant yield effect from the input studied with other inputs[a] held constant[b]? Optimal Input Level - With other inputs[a] held constant[b] and known incidence levels of the stochastic factors (weather, diseases, and insects) what is the optimum level of the input studied? Evaluation of Combined Inputs - Are the combined treatments profitable compared with farmers' practices?

a/ Both factorial and optimal input level experiments can consider more than one input at a time; however, the analysis usually emphasizes the separation of individual input effects and interaction terms.

b/ There is a debate on the level of the inputs held constant. If a high or experiment station level is utilized, then the maximum physical yield effect on the farmers' field can be estimated for the input studied. If the farmers' level of other inputs is utilized, then the yield effect indicates the potential of this input alone to increase yields with farmers' present input use and cultural practices (Flinn, 1980).

Source:

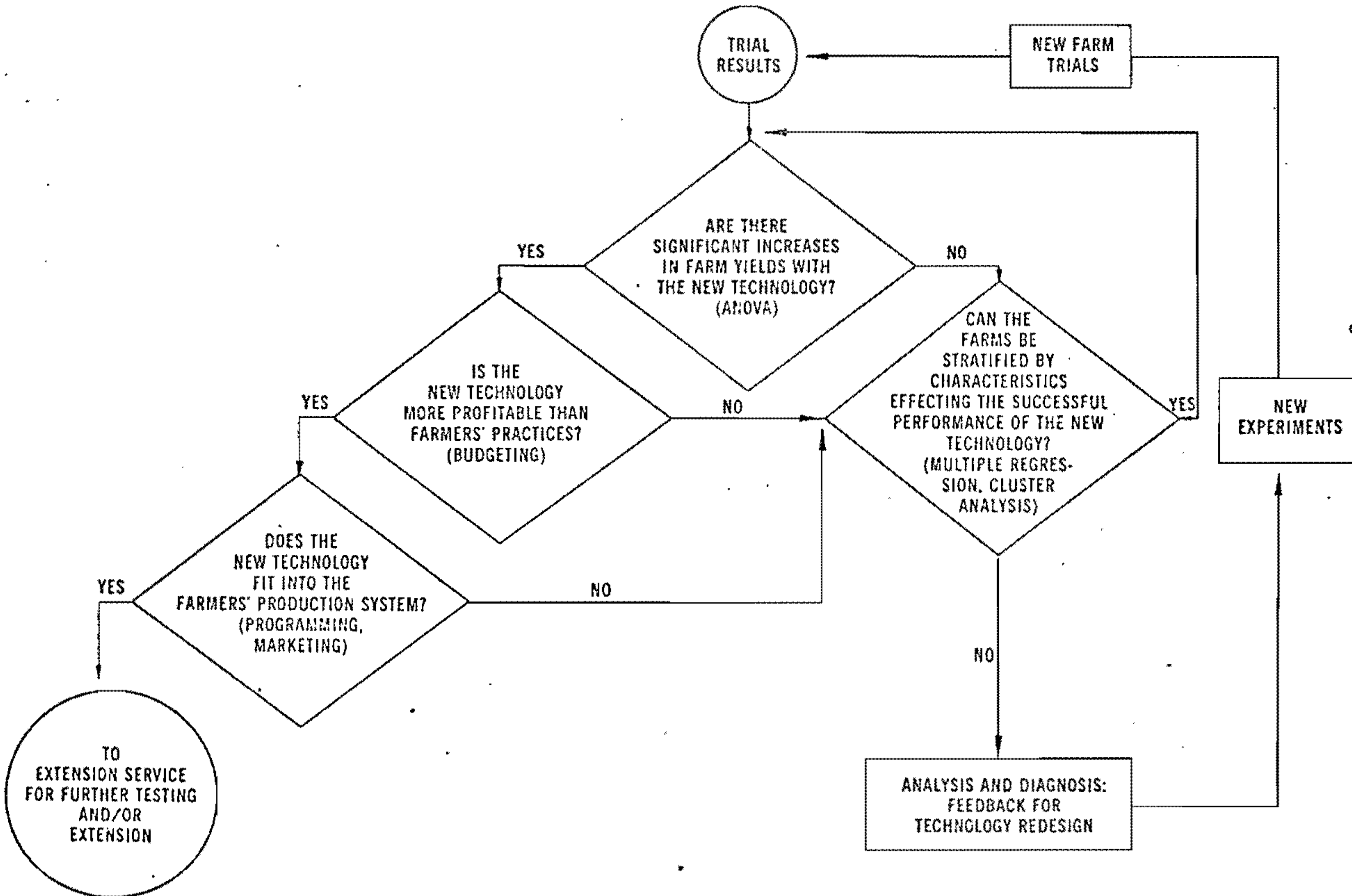
The stages are taken from the division of types of farm trials customarily utilized in CIMMYT. (Byerlee, et.al., 1979, Figure 2).

several inputs and analyze interaction effects. However, unless the critical variables determining yields have already been narrowed down for a region, th evaluation of a large number of factors (more than three) can lead to very large individual experiments, thereby discouraging the researcher from undertaking many farm experiments. One of the principal refinements after three years of farm trials in the Asian rice network was to simplify the experimentε design and increase the number of replications (farms) to more adequately reflect the environmental and management factors leading to the large yield variance within production regions for a given technology (Barker, 1979, p.22) "The three year experience of IRAEN (International Rice Agroeconomic Network) indicates that at least 20 farms are needed for a study area, if an acceptable degree of precision in estimation of yields is to be achieved" (Gomez, et.al., 1979, p.37). The IRAEN simultaneously utilized factorial and combined input ("management package") trials in the same regions. In the CIAT experience there has been a two stage process of a very few factorial trials per region to first narrow down the number of inputs in the combined treatments. Then a large number (10 to 15) of combined input trials were implemented in each production region. For example, the factorial or regional trials identified the appropriate herbicide for a specific soil type and a limited number of new varieties (two or three) for a specific region (Table 1).

Since there are a large number of research problems in the farm trials, the evaluation is a complex process involving several analytical techniques (Figure 2). The standard statistical test of the significance of the differen between one or more new technologies and the farmers' practices is first utilized. One important qualification should be put on this analysis. There is nothing sacred about 5% or 1% probability levels for Type I error. Type I error is the rejection of the null hypothesis when it is true and Type II error is the acceptance of the null hypothesis when it is not true. For a giv number of observations demanding a lower Type I error will increase the probability of a Type II error. These are practical or applied decisions and not governed by some iron law of statistics. The choice of probability levels should be determined by the costs of a mistake of Type I or Type II and <u>not</u> by tradition.

The principal research problem of farm trials is the profitability of the new combined treatments. Can the farmer make money with the new technology?

FIGURE 2. FLOW CHART FOR NEW TECHNOLOGY EVALUATION IN FARM TRIALS



One input changes are expected to have little effect in agriculture due to the interrelated or systems nature of crop production. A modification in one part of the system precipitates other changes. For example, increased density in Antioquian bean production requires better disease control due to higher anthracnose incidence. Moreover, with higher density an improved support system or less vigorous varieties and modifications in methods of performing the other cultural practices, such as weeding and spraying, also are necessary (CIAT, 1980 and 1981). In summary, the farm trials move away from the reductionist approach of most biological research, in which the effects of individual factors are isolated, to the holistic approach of the analysis of the effects of input combinations (Dillon, 1976). The new production systems must give higher returns than the farmers', but the contribution of individual components is not always identified.

Besides profitability the new technology combination must fit into the whole farm system. A new technology may be highly profitable in budgeting analysis but still less profitable than another alternative or it may have high seasonal labor requirements, when family labor is not available and hired labor is very expensive. Moreover, the off-farm resource requirements such as capital may be very high. Programming analysis considers the whole farm context with the different alternatives and resources available to the farmers. Programming analysis is very data and computer intensive hence an alternative methodology has been suggested of utilizing large plots and farmer management to identify labor or management constraints (Zandstra, 1979, p.149). However, farm modeling through liner or more sophisticated programming enables the consideration of more constraints at a reduced cost of field operations. Moreover, an evaluation of the potential fit of new technology into the farmers' system by observing farmer utilization makes very strong assumptions about the sample selection of potential adopters and the farmers' ability to instantaneously adjust his resource allocation when presented with new alternatives. The assumption of instant optimal managerial adjustment to the new activities and resource combinations involved in the introduction of new technology ignores the phenomenon of learning by doing whereas sensitivity analysis in programming can handle different management abilities.

At any stage of the evaluation process a new technology may be unsuccessful. Before returning to the design process in the experiment station or regional site stratification of farms, where the technology is and is not successful, is attempted. A large sample size with each farm treated as a replication is utilized to overcome one major research problem of farm trials, the large between farm variation of new technology performance. For example, diffusion between farms of new varieties of wheat and corn has been shown to be principally related to "differences (sometimes subtle) in soils, climate, water availability, or other biological factors" (Perrin and Winkelmann, 1976, p.893). This stratification can be done with a priori theoretical considerations or statistical searching devices, such as cluster analysis or multiple regression. Obvious examples are fertilization on soils of different fertility or a stress resistant variety on sites with and without the particular stress. If the stratification identifies a sub-group of farms with a particular set of conditions, in which the technology was successful, then the evaluation process can be resumed for this sub-sample. To summarize, rather than minimize non-treatment variance, the farm trials analyze the sources of this variance to identify the farm level factors effecting the economic performance of the new technology.

The research process proceeds from the experiment station to regional trials and finally to farm level evaluation. Feedback from the farm enables a direct farm level input into future technology design as well as testing the new technology under the variability of the farm conditions in the target area (Gilbert, et.al., 1980). Once the technology has passed the economic and systems criteria, the research evaluation process is terminated and suggestions can be made for extension (Figure 1). The farmers' goals are undoubtedly more complex than maximizing profit; nevertheless, these simple economic criteria and the fit of the new technology into the production system move the evaluation closer to the farmers' goals than the conventional yield maximization criterion. The farm testing separates the technology flow into three parts, technology that passes all the criteria and is recommended to the extension service for all farms in the target region, technology that passes these criteria only on farms with certain characteristics and therefore is appropriate for extension only on those farms or with certain restrictions, and technology, which does not pass these criteria and hence returns to the biological scientists for further modifications. In the next section this methodology is applied to various new technologies in the Bean and Cassava Programs of CIAT.

RESULTS OF THE FARM TRIALS IN COLOMBIA, 1978-1980

In 1977 a series of potential new technologies were identified based upon experiment station and regional trial results in two major crop programs of CIAT. From 1978 to 1980 farm level experimentation with these technologies was undertaken in both the field bean and cassava programs. This section summarizes the principal results of these trials utilizing the methodology of the previous section (Figure 2).

In both crop programs the effect of fertilizer depended upon the original soil fertility and the crop rotation. With stratification of the farm trials according to these factors sub-samples were identified, in which fertilization had a significant effect on yields (Table 2). On twenty percent of the bean producers in the Huila farm trials and in all of the farm trials in Restrepo increased fertilization was highly profitable but substantially increased the capital requirements (CIAT, 1979, 1980). In the low fertility soils of the marginal coffee region, if the capital were available, profit maximizing bean producers would utilize much higher fertilization levels according to the programming analysis (Stabile, 1979 and CIAT, 1980). There was a yield response to cassava fertilization on the poor soils of the Colombian coast; however, fertilizer use was unprofitable on both traditional and new varieties there (Sanders and Lynam, 1980a, p.8).

In crops produced principally by small farmers for local food markets without price supports the utilization of more fertile soils (beans) or rotation (beans and cassava) traditionally has been substituted for fertilization. Regional fertilization trials often show a dramatic physical response by selecting sites where the initial fertility levels are extremely low (CIAT, 1979, p.C-47, 48). With such large differences between regional trials and farm sites the importance of the farm trials before making recommendations is obvious. To produce beans in the lower fertility soils, as in marginal coffee areas, chemical fertilization will have a high return and will be necessary or yields will be extremely low (Stabile, 1979). In the future as area expansion becomes more difficult, the profitability of the substitution for land with fertilizer will increase.

"Clean seed" was reported to increase yields on the experiment station by

TABLE 2

EVALUATION OF NEW TECHNOLOGY IN THE COLOMBIAN FARM TRIALS OF THE BEAN AND CASSAVA PROGRAMS, 1978-1980

		ON-FARM EVALUATION CRITERIA			
Crop Program	New Technologies	Significant Yield Increase	Profitable	Fit into Farmers' Production System	Farmer Adoption
BEANS:	Fertilization	Sample stratified by initial soil fertility	In sub-sample	Substantially increased capital requirements	
	"Clean" or Improved Seed	NO	—	—	
	Improved Agronomy:				
	-Higher density -Chemical control of diseases and insects	YES	YES	Huila: Low rate of return due to price collapse at harvest. Antioquia: High density makes cultural operations more difficult Restrepo: High capital requirements as soil fertility is the most limiting constraint	Huila: Higher density, some spraying Antioquia: Change of chemical controls but no density increase Restrepo: Higher density and spraying but still little fertilization
	Inoculation	NO	—	—	
	New Varieties	For most varieties - NO For one variety - YES	Price discount makes it unprofitable compared with farmers' varieties. Taste requirements are fairly rigid for color and seed size	—	
CASSAVA:	Fertilization	Sometimes	NO	—	
	Improved Agronomy:				
	-Higher density -Stake treatment -Weed control	YES	Highly profitable; small cash outlay	Large management requirements	
	New varieties	YES	No due to a substantial price discount. Importance of starch content and starch maintenance with a longer time in the ground as breeding criteria	—	

85% and to be a major factor in regional trials on 84 hectares in Guatemala where bean yields were increased from 515 to 1.545 kg/ha (CIAT, 1975, pp.124 and 151). "CIAT has clearly demonstrated the major yield increases possible simply by using clean seed" (TAC, 1977, p.31). The report above recommended that CIAT help national programs develop the capacity to produce "clean seed" principally upon the basis of these experiment station and regional results. In the Colombian farm trials four different types of improved seed were tested in two regions over two years on approximately fifty farms. Two of the seed sources for the farm trials were produced with irrigation, intensive roguing of sick plants, and high levels of management and chemical protection. In general, there was no yield effect on the farms from any of these investments to improve seed quality. There is still a definitional problem of "clean seed" as even with large investments in irrigated seed production common mosaic virus incidence was 2 to 8% from one region and 25 to 40% from another. Even the former level is above the maximum incidence allowed in the U.S.; however, it is unlikely that it would be profitable for either the private or the public sector in Latin America to invest more in seed production facilities than was done for the seed production utilized in these farm trials. When resistance to this virus is obtained in a new variety, another analysis of the farm level return to "clean seed" would be appropriate. Nevertheless, the previous policy recommendation for "clean seed" production by national programs was premature as it was not possible at the farm to substitute improved seed quality for a bean variety resistant to common mosaic virus. As a footnote to these contrasting results between the experiment station and the farm were the regional trials in Bean Agronomy in three sites in 1976, which also showed a non-significant yield effect from "clean seed" (CIAT, 1977, pp.40-42). Since "clean seed" did not even successfully pass the regional trial test, it should not have gone onto the farm trials much less been recommended to national programs.

Improved agronomy practices of both beans and cassava, including higher density and better disease and insect control with either spraying in beans or stake treatment in cassava, gave significant yield increases in the farm trials and were highly profitable in the budgeting analysis. In the whole farm context the return on capital from the improved bean agronomy was very low, only 11 percent. However, combining this improved bean agronomy technology with new storage technology to avoid the post-harvest price collapse gave reasonable rates of return to capital, 33 to 69 percent (Table 3).

Table 3. Incomes, Credit Requirements and Returns to Capital from Various New Technologies on Small Farms, Southern Huila, 1979.

	Typical Farm (2.4 ha)	Introduction of High Technology Caturra Coffee	Introduction of High Technology Caturra plus Various Bean Technologies		
			Monoculture Beans -Improved Agronomy (MBIA)	MBIA plus 50% Storage	MBIA plus 100% storage
Farm Income (Pesos)	76,796	106,881	118,319	134,519	155,219
Income Increase (%)	-	39	11	14	15
Capital Borrowing (Pesos)	9,333	18,593	26,532	30,000	30,000
Return on an Additional Unit of Capital	-	0.11	0.11	0.33	0.69

Sources: The typical farm estimate is synthesized from farm data collected in Huila, Colombia in 1979. The impacts of new technology are the profit maximizing linear programming results from the model farm with new technologies introduced sequentially.

See Arcia and Sanders, 1980, CIAT, 1981, and Arcia, 1980.

Capital requirements were increased by over three times and the farmer has to wait another four months to sell his beans. Nevertheless, the improved agronomy technologies in beans successfully passed the three evaluation criteria and are presently being adopted by farmers in all three regions with modifications (Table 2). With a very small cash outlay the improved agronomy cassava technology increased income by 65% in the budgeting calculation; however, management requirements are substantial and no small farmer adoption has been observed as yet on the Colombian coast (Sanders and Lynam, 1980a, pp.7 and 8). Nevertheless, this entire improved agronomy package plus good soil preparation has been adopted on several Cuban state farms with excellent results. (Cock, personal communication).

In regional trials excellent responses to inoculation with Rhizobium for nitrogen fixation in beans have been obtained. (CIAT, 1978, p.B-41 and Table 4 of this paper). With the same variety and altitude as in the regional trials farm trials were carried out over two years on 30 farms. The inoculated treatment gave lower yields and lower net income than the check with nitrogen in spite of the lower fertilizer costs of the inoculated treatment (Table 4). On the farms there were heavy infestations of one root rot (fusarim) not encountered in the regional trials. The farm trials helped identify the need for a fungicide to control fusarium with a minimal negative effect on the Rhizobium.

The principal product of most international centers is new varieties combined with improved agronomy (for the reasons for the combination see Evans, 1980, p.396, Kawano and Jennings, 1980, p.13 ff). In 1977 varietal development was more advanced in the cassava than in the bean program. Several new varieties more than tripled farmers' mean yields (CIAT, 1978, p.C-44). In the cassava farm trials one new varietal selection and improved agronomy outyielded the traditional variety with the farmers' cultural practices by 108%; however, the yield advantage was much smaller over the traditional variety with improved agronomy, only 27%. Unfortunately, the lower starch content of the new varieties resulted in a 40 to 60% price discount since the new varieties could only be sold on the industrial starch market hence they were less profitable than the traditional variety with improved cultural practices (Sanders and Lynam, 1980a, pp.11 ff). Moreover, the starch content of the farmers' variety was more stable over time and under stress than the new varieties. Cassava spoils rapidly after the harvest and small cassava

Table 4. Regional yield trials, farm trials, prices and net incomes from inoculation with Rhizobium and from different varieties, La Selva and El Carmen, Antioquia, 1979 and 1980

	Regional trial yields	Farm trials	
		Yields	Net income
	(kg/ha)		(Col $/ha)
Inoculation[a], 1979			
Yields of the check with nitrogen	3,386	1,999	87,121
Average yields of the three best Rhizobium strains	3,584		
Average yields of the inoculated treatments at two densities		1,649	59,827
Varietal effect, 1979			
Farmers' variety (Cargamanto)	1,159	2,183	102,373[b]
G-5653 (Ecuador 299)	1,635	1,708	6,901[b] (58,171)[c] (65,770)[d]
G-2333	1,947	1,075	9,579[b] (22,671)[c] (30,270)[d]
Varietal effect, 1980[e]			
Farmers' variety (Cargamanto)	1,159	2,287	31,619[f]
E 1056	2,307	1,947	20,585[g] (29,358)[h]
G 4727	1,793	2,007	16,617[g] (25,390)[h]

a. The selection from the land race, Cargamanto, was utilized in the inoculation comparison. Regional trial yields were with artificial support and higher inputs than the farm trials. All input levels except inoculation were identical in the farm trials. On the check with nitrogen both chemical fertilizer and chicken manure were employed. In the inoculated treatments P_2O_5 and K_2O were employed at the same levels as in the combined chemical and organic fertilizers in the check without nitrogen.

b. The price received by farmers for Cargamanto was 75 pesos/kg. Farmers estimated that the two small red varieties, G-5653 and G-2333, would receive approximately 30 pesos/kg on their local markets. Income calculations were also made at only a small price discount for these new varieties.. See footnote c.

c. Net income was reestimated with a minimal price discount from the 75 Col. $/kg of Cargamanto to 60 pesos/kg for these two small seeded varieties.

d. The costs of the new varieties were reestimated with the assumption that no sprayings were necessary. The price of 60 Col. $/ha was retained.

e. These are the same regional variety trials reported for 1979 in Román, et.al.

f. The mean price received by farmers for Cargamanto was 45 pesos/kg.

g. Farmers estimated that these larger grain size selections would receive 40 pesos/kg (E 1056) and 38 pesos/kg (G 4727).

h. The costs for the production of the selections were reestimated without the costs of chemical protection against diseases and insects.

Sources:

The regional trial observations were taken from Alberto Román, et.al., 1980, pp.25 and 50 and CIAT, 1981.

producers sell their harvest over a long time period beyond the optimum physical maturity leaving the cassava in the ground until the sale. Hence, not only starch content but also its maintenance over time beyond maturity were both indicated as important selection characteristics for cassava breeders especially in the adverse agricultural environments, such as the north coast of Colombia, characteristic of small farmer cassava production in Latin America.

In the evaluation of bean varieties the results were similar though the differences were not as dramatic as in cassava. In regional trials of climbing beans the yields of the farmers' variety were inferior to those of the new selections; however, these yield results were reversed in the farm trials with the farmers' variety outyielding all four new selections in 1979 and 1980 (Table 4). In the regional trials no chemical control of disease was employed and the farmers' variety is especially susceptible to anthracnose. Farmers in this region utilize high levels of fungicide so the farm trials included this input. The price discount for the new bean selections as compared with the farmers' variety was substantially reduced from 1979 to 1980 (see the footnotes to Table 4) as the climbing bean breeder began selecting larger mottled seeds closer to those of the farmers' variety. In 1980 one new selection gave approximately the same net income as that of the farmers' variety if the same yields of this selection could be maintained without spraying (income comparisons underlined in Table 4). The farm trials indicated to the breeder other yield constraints not observed on the experiment station. Moreover, the price discount was substantial for the smaller seed size of the new varieties in 1979. Taste preferences are very important in determining the profitability of both bean and cassava technologies.

In one site a new variety without commercial potential in Colombia but with multiple resistances was utilized to test the disease resistance emphasis of the bean program. This variety outyielded the farmers' variety with and without chemical controls. Regressing the yields of this variety on the insect and disease incidences across farms indicated a second generation constraint of substantial yield losses from Web Blight. Obtaining resistance to this disease would have increased yields by a mean value of 1.6 t/ha with this variety in this region and semester (CIAT, 1981). Besides technology evaluation farm trials help identify yield constraints, which then become breeding requirements for new material (Sanders and Lynam, 1980b, pp.14-16).

Only the improved agronomy combinations successfully passed all three criteria and is being accepted by farmers (Table 2). This diffusion of bean agronomy onto Colombian farms in three regions is one validation of the screening criteria utilized to evaluate the farm trials. Farmers undoubtedly have other objectives besides profit maximization constrained by their resource availabilities and other alternatives; however, new technology satisfying these criteria apparently will be adopted at least by some farmers. The farm trials and the screening criteria also appear to be effective in identifying applied research problems and other design requirements of new technology for breeders and other scientists at the experiment station.

C O N C L U S I O N S

When agricultural research is undertaken on crops without high levels of environ mental control, i.e. without irrigation or high input levels, substantial yield variation between experiment station, regional trials, and farm trials can be expected. These differences in sites not only reduce yields absolutely but also the relative yield comparisons between different treatments and farmers' practices can be reversed. The cases of "clean" or improved seed, inoculation, and new selections of cassava all clearly illustrate the importance of evaluating the performance of new technology on the farm. Not only was yield performance of new technology often very different at the farm than in the regional trial but also the farm is the appropriate level of the research process to do economic analysis and to respond to the systems questions.

The bottom line of new technology evaluation is the profitability and the fit into the farmers' system of the new input combinations. This type of evaluation is also the final stage of agronomic testing in the farm trials of both IRRI and CIMMYT. In IRRI the Asian network of farm trials differentiated between the factorial component to separate input effects and the management package component to evaluate the profitability of different input combinations (Gomez et.al., 1979, pp.33, 34). The CIMMYT stages of agronomic analysis were already summarized (Table 1). In the CIAT trials the analysis of this final stage of farm testing has been extended into programming and regression analysis of the treatment yields between farms to identify the second generation constraints.

Recombinations of technologies already available in a region are unlikely to lead to large yield increases. However, there is a demand for farm level adjustment of new technology and substantial yield gains are possible from this adjustment. This on-farm fine tuning of new technology concentrates on improving management and adapting for environmental differences (Zandstra, 1979, pp. 138-143). Environmental adaptation involves the adjustment of input use in response to the on-farm and off-farm resources available to the farmer and the climatic and economic conditions of the region. The yield gains from fine tuning depend upon the increased yield potential of the new input from the experiment station. Farm testing is appropriate for the feedback to researchers on the new technology performance and to specify further research requirements by identifying other constraints to yield increase. Farm testing can also link farmers into the research design process and serve as a final check on the economic viability of new technology. However, farm testing begins with the experiment station output and therefore has to be well linked to this primary research unit (Byerlee, et.al., 1979, p.3; Zandstra, 1979, p.143; Biggs, 1980, p.135).

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