Centro Internacional de Agricultura Tropical

EVALUACION DE NUEVA TECNOLOGIA EN FINCAS PRODUCTORAS DE FRIJOL: METODOLOGIA Y RESULTADOS

John Sanders

SE-1-81

Serie SE-1-81
Feb. 6, 1981

EVALUATION OF NEW TECHNOLOGY ON COLOMBIAN FARMS PRODUCING BEANS: METHODOLOGY AND RESULTS*

John H. Sanders

RESUME

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 there is not much communication between the potential users of new technology, the farmers, and the producers of the technology, the researchers. 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 between traditional agronomical experiments and farm trials. The evaluation process developed here successfully identified the technology adopted by farmers. The results of the farm trials often substantially modify the policy recommendations which could have been arrived at utilizing the results from the experiment station and/or regional trials.

---

*The enclosed paper includes the farm testing in both the Bean and Cassava Programs; however, the seminar will only be concerned with the Bean Program results. The methodology utilized for evaluation of the new technology is the same in Bean and Cassava Economics. Moreover, this paper is coauthored by Sanders and John Lynam.

INTRODUCTION

Farm yields of 57 to 93 percent of experiment station results have been reported in Australia in the late sixties (Dillon, 1977, p.175). In an Asian comparison of experiment station, farm trials, and farmers' yields a higher physical response to fertilizer was found on the experiment station due to better management of the complementary factors principally water and insect control (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 onto farm testing. Moreover, comparative yields are an inadequate criterion for evaluation 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 the distinctions between farm testing and traditional agronomical research are made and evaluation criteria for farm trial analysis are proposed. Then the second section analyzes the new technology performance of the bean and cassava programs with these criteria.

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

Most new agricultural technology is either developed or adapted at the public sector experiment station or at some private sector equivalent. The identification and diffusion of best farmer practices can also increase income of those farmers with similar resources (Biggs, 1980, p.141); however, the big income gains are expected to come from the introduction of new inputs. Once a new technology is developed at the experiment station, adaptation to different environments must be evaluated since the effect of most biological and chemical agricultural technologies can be influenced by climate, 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).

On the experiment station and in regional trials higher yields than the farmers' check generally indicate successful performance. Occasionally, economic analysis of experiment station or regional trials is done such as the response to fertilizer. However, in the first two levels of the research process (Figure 1), the analytical technique is predominantly some variation of the statistical significance of the treatments.

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 have developed low density, low input systems with low but stable yields requiring few inputs except family labor. Utilizing farmer's 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.

The research question of the regional variety trials is whether there is a significant difference between one or more of the new varieties and some proxy for the farmers' variety(ies). Non-treatment variance is minimized not only by utilizing the same input levels, but also with high levels of manage-

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 ment, and frequently on sites with higher soil fertility than that of most farmers.

There are four basic problems with these regional variety trials: there may be qualitative differences between the new and the commercial varieties reflected in the market price hence yield comparisons would not be an appropriate selection criterion; the arbitrary 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 traditional agronomical experiments it is useful to review the types of agronomic trials and the stages of analysis. (Table 1). There have been three primary approaches to analyze agronomical experiments. The first approach of the factorial experiments has already been discussed for variety trials but is equally applicable in other agronomic trials. It is some variation of analysis of variance to test the statistical effect of the treatments or the statistical significance of the difference between one or more new treatments from some proxy for farmers' practices. The second approach of the optimal input level has proliferated since the Fifties with the increased sophistication of economists and agronomists 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. Since the influence and probability levels of these stochastic factors is often very difficult to measure, optimal levels should be considered as a

TABLE 1

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

Types of trials	Variety Fertilizer Herbicide Other Defensive Chemicals Density Minus One Plus One
Stages of analysis and the research problems	Factorial Experiments - Is there a significant yield effect from the input studied with most other inputs[a] held constant at some arbitrary level? Optimal Input Level - At arbitrary levels of most other inputs[a] held constant and known incidence levels of the stochastic factors (weather, disease, and insects), what is the optimum level of the input studied? Evaluation of Combined Inputs - Is the combined treatment profitable compared with farmers' practices?

[a]Obviously, 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.

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

mathematical concept without many practical applications in agriculture. (To incorporate risk into farm decision making and the analysis of experimental data see Anderson, et.al., 1977; Anderson, 1973, and Dillon, 1977).

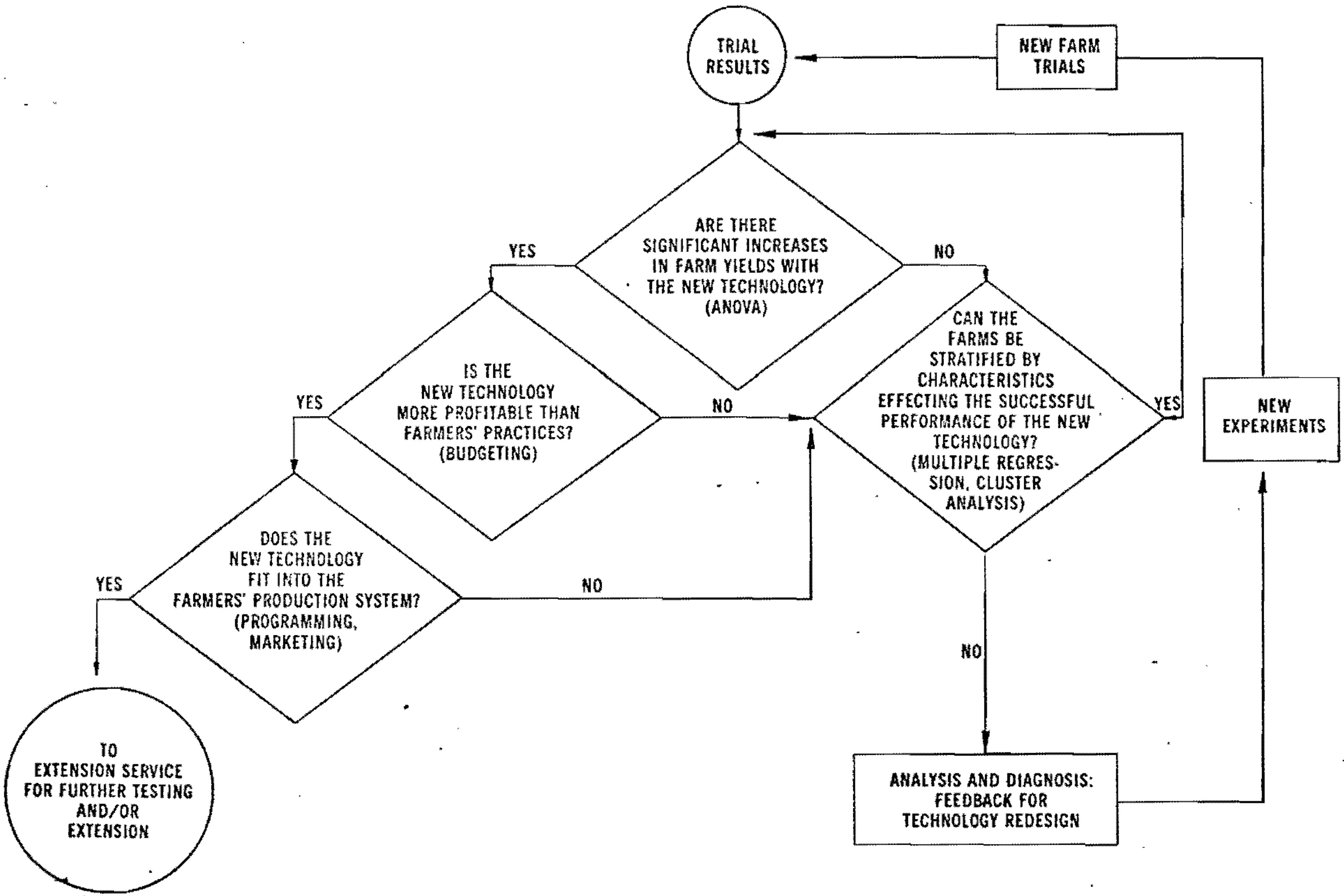
Both the factorial and the optimal level experiments can incorporate several inputs and analyze interaction effects. However, unless the critical variables determining yields have already been narrowed down for a region, the evaluation of a large number of factors (more than three) can lead to very large individual experiments, thereby discouraging the researcher from undertaking many farm experiments (see the country studies in IRRI, 1977). The summary comments on methodology of the IRRI statistician working with the rice farm trial network in Asia focus on the principal problems of farm experimentation: "the number of farms used for the (farm) experiment is usually too small to adequately represent the widely different farming conditions existing in the study areas. Most agronomists responsible for the field tests have the tendency to emphasize the need for more replications at the sacrifice of the requirement for more farms. There is also a tendency to include too many test factors (so as not to miss any major ones), resulting in large experiments and, consequently, fewer experiment farms. Because of familiarity with experiment station trials, there is a tendency to follow the same method of management and data collection" (Gomez, 1977, p.6).

Some factorial trials may be necessary to identify the appropriate chemical or variety for a specific soil type or micro-climate and to indicate a limited number of input combinations for the final stage of economic evaluation. This final stage after the analysis of individual input effects is the farm trials. The principal research problem of farm trials is the profitability of the new combined treatments. Can the farmer make money with the new technology? 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, may also be necessary (CIAT, 1980 and 1981). The multiplicative effects of combined input utilization are indicated by the large interaction terms frequently observed in factorial trials (Gomez, 1977, p.12 ff). In summary, the most interesting results to farmers are obtaining income gains from input combinations, hence the farm trials need to move as rapidly as possible to the economic and systems evaluation of the combined effects.

Besides profitability the new technology 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. Linear 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, the modeling of linear 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.

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 difference 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 erros. Type I error is the rejection of the null hypothesis when it is true and

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



Type II error is the acceptance of the null hypothesis when it is not true. For a given 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 not by tradition.

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 sucessful, is attempted. A large sample size is utilized to overcome one major research proble 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 low and high 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 as is done in most agronomical experiments, the on-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 more 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 new technology either passes the economic, whole farm evaluation or is returned to the biological scientists responsible for the design. 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, 1977-1980

In 1976 a series of potential new technologies were identified based upon experiment station and regional trial results in two major crop programs of CIAT. From 1977 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.

TABLE 2

EVALUATION OF NEW TECHNOLOGY IN THE COLOMBIAN FARM TRIALS OF THE BEAN AND CASSAVA PROGRAMS, 1977-1980

Crop Program	New Technologies	ON-FARM EVALUATION CRITERIA			Farmer Adoption
		Significant Yield Increase	Profitable	Fit into Farmers' Production System	
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	—	

"Clean seed" was reported to increase yields on the experiment station by 85% and to be a major factor in a regional trial 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. There is still some discussion among CIAT pathologists on the exact definition of "clean seed"; however, 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 these investments to improve seed quality. Farmers evidentally were effective in selecting their seed and improved seed quality at feasible levels of disease management and cleaning of seed for Latin American conditions did not appear to be an adequate substitute for disease resistant bean varieties. The "clean seed" case is the clearest example to date of the danger of making recommendations before undertaking farm trials.

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). 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 farmer adoption has been observed as yet (Sanders and

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, and CIAT, 1981.

Lynam, 1980a, pp. 7 and 8).

In regional trials excellent responses to inoculation with Rhizobium for nitrogen in beans fixation have been obtained. (CIAT, 1978, p.B-41 and Table 4). With the same variety and altitude as in the regional trials farm trials wer carried out over two years on 30 farms. The inoculated treatment gave lower yields and lower net income than the treatment 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 (fusarium) not encountered in the regional trials. Thus, the farm trials identified for the bean micro-biologist the need for a fungicide effective against fusarium and compatible with the Rhizobium.

The principal product of most international centers is new varieties, which are usually combined with improved agronomy (Evans, 1980, p.396). In 1976 varietal evaluation 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 producers often 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.

In the evaluation of bean varieties the results were similar though the differences were not as dramatic as in cassava. In regional trials 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

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.

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.

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 Roman, 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 30 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.

trials no chemical control of disease was employed and the farmers' variety is especially susceptible to anthracnose. Farmers, however, 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). Net income comparisons of the farmers' variety and the selections indicated substantial improvement over time in the selections. The bean farm trials indicated to the breeders 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 new bean and cassava technologies (Sanders and Lynam, 1980b, p.12).

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 in this region and semester (CIAT, 1981).

Only the improved agronomy combination successfully passed all three criteria and is being accepted by farmers (Table 2). This diffusion 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 availabitilies and other opportunities; 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.

C O N C L U S I O N

Most of the experiment station output of the first five years of the two crop research programs did not pass the tests for farm level suitability. This should not be surprizing with those familiar with the long lag time necessary to first identify the constraints to yield increase and then to build new varieties and associated agronomic improvements to overcome these constraints (Sanders and Lynam, 1980b). The dramatic differences between the performance of new technology at the different levels of the research process make obvious the importance of designing, implementing, and evaluating farm level performance of new technology. The cases of "clean" or improved seed, inoculation, and new selections of cassava all clearly illustrate the dangers of making policy recommendations before systematic evaluation at the farm. Not only is 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 about the fit of the new technology into the whole farm context.

In the enthusiasm for farm surveying and experimentation there has been a recent overemphasis of the yield increasing potential of farm level adjustments to new technology (Gilbert, et.al., 1980, Norman, 1978, 1980). At the farm fine tuning of new technology can be done by improving management and adapting for environmental differences (Zandstra, 1979, pp. 138-143). However, the yield gains from fine tuning are expected to be small compared with those of the principal products of experiment stations, new varieties with improved agronomy. Farm testing is appropriate for the feedback to researchers on new technology and to specify further research requirements. 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).

R E F E R E N C E S

ANDERSON, J. R. (1973). "Sparse data, climatic variability, and yield uncertainty in response analysis". American Journal of Agricultural Economics, 55, pp. 77-82.

ANDERSON, J. R., DILLON, J. L., HARDAKER, J. B. (1977). Agricultural decision analysis, Ames: Iowa State University Press.

ARCIA, G. (1980). "Risk, institutional change and technology adoption for low income farmers: An analysis of new bean alternatives for the southern Huila region of Colombia, South America", unpublished Ph.D. thesis, University of Missouri, Columbia, Missouri.

ARCIA, G., and SANDERS, J. H. (1980). "Ex ante analysis of new bean technology in southern Huila", CIAT mimeo, Cali, Colombia.

BARKER, R., DE DATTA, S. K., GOMEZ, K. A., HERDT, R. W. (1977). "Philippines 1974, 1975, 1976" in Constraints to high yields on Asian rice farms: an interim report", The International Rice Research Institute, Los Baños, Philippines, pp. 121-156.

BARKER, R. (1978). "Yield and fertilizer input" in IRRI, Changes in rice farming in selected areas of Asia, International Rice Research Institute, Los Baños, Philippines, pp. 35-66.

BIGGS, S. B. (1980). "On-farm research in an integrated agricultural technology development system: case study of triticale for the Himalayan hills", Agricultural Administration (7), 133-43.

BYERLEE, D., BIGGS, S. D., COLLINSON, M., HARRINGTON, L., MARTINEZ, J. C., MOSCARDI, E., and WINKELMANN, D., (1979). "On-farm research to develop technologies appropriate to farmers". Paper presented at the conference of the International Association of Agricultural Economists, Banff, Canada.

CIAT (1975 and 1978), Annual reports for the years 1974 and 1977, Centro Internacional de Agricultura Tropical, Cali, Colombia.

CIAT (1979, 1980, 1981), Bean program annual reports, for the years 1978-1980, Centro Internacional de Agricultura Tropical, Cali, Colombia.

CIMMYT (1980), Planning technologies appropriate to farmers - Concepts and procedures, Economics Program, Centro Internacional de Maíz y Trigo.

CGIAR-TAC (1977), "Report of the quinquennial review mission to the International Center of Tropical Agriculture", Consultative Group on International Agricultural Research, Technical Advisory Committee Secretariat, Food and Agriculture Organization of the United Nations, Rome.

DE DATTA, S. K., GOMEZ, K. A., HERDT, R. W., BARKER, R. (1978). A handbook on the methodology for an integrated experiment - survey on rice yield constraints, International Rice Research Institute, Los Baños, Philippines.

DILLON, J. L. (1976). "The economics of systems research", Agricultural Systems (1), 5-22.

DILLON, J. L. (1977). The analysis of response in crop and livestock production, second edition, Pergamon Press, Oxford.

EVANS, L. T. (1980). "The natural history of crop yield", American Scientist (68), 388-397.

GILBERT, E. H., NORMAN, D. W. & WINCH, F. E. (1980). Farming systems research: A critical appraisal, Michigan State University Rural Development Paper No. 6, East Lansing, Michigan.

GOMEZ, K. A. (1977). "On-farm assessment of yield constraints: methodological problems" in IRRI, Constraints to high yields on Asian rice farms: An interim report, International Rice Research Institute, Los Baños, Philippines, pp. 1-16.

HERDT, R. W. and MANDAC, A. M. (1979). "Overview, findings and implications of constraints research: 1975-1978". International Rice Research Institute (IRRI), Agricultural Economics Paper No. 79-04, mimeo.

IRRI (1976). Annual report for 1975, International Rice Research Institute, Los Baños, Philippines.

IRRI (1977). Constraints to high yields on Asian rice farms: An interim report, International Rice Research Institute, Los Baños, Philippines.

NORMAN, D. W. (1978). "Farming systems research to improve the livehood of small farmers", American Journal of Agricultural Economics (60), 813-818.

NORMAN, D. W. (1980). The farming systems approach: Relevancy for the small farmer, Michigan State University Rural Development Paper No. 5, East Lansing, Michigan.

PERRIN, R. & WINKELMANN, D. (1976). "Impediments to technical progress on small versus large farms", American Journal of Agricultural Economics (58), 888-894.

PERRIN, R. K., WINKELMANN, D. L., MOSCARDI, E. R., ANDERSON, J. R. (1976). From agronomic data to farmer recommendations - An economics training manual, Information Bulletin 27, Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT).

ROMAN, A., DAVIS, J., GARCIA, S., GRAHAM, P., TEMPLE, S. (1980). "Informe de trabajos 1979, convenio ICA-CIAT, La Selva, Programa de Fríjol", mimeo, La Selva, Antioquia, 52 pages.

SANDERS, J. H. & LYNAM, J. K. (1980a). "Economic analysis of new technology in the bean and cassava farm trials of CIAT", paper presented at a workshop on farm trials in CIMMYT, Mexico, D. F., March, 1980.

SANDERS, J. H. and LYNAM, J. K. (1980b). "Definition of the relevant constraints for research resource allocation in crop breeding programs", Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, mimeo.

STABILE, M. F. (1979). "Evaluation of a diversification scheme in a marginal coffee region of Colombia utilizing new bean technologies", unpublished M. S. thesis, University of Guelph, Canada.

ZANDSTRA, H. G. (1979). "Cropping systems research for the Asian rice farmer", Agricultural Systems (4), 135-53.