PNAAN 889
ISN 32611

INSTITUTIONAL INNOVATIONS IN NATIONAL AGRICULTURAL RESEARCH:
On-farm Research within IDIAP, Panamá

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CIMMYT Economics Program Working Paper 02/83

A partial version of this report was presented as an invited paper in the Farming Systems Research Symposium, Kansas State University, November 21-23, 1982. The ideas presented are those of the authors and do not necessarily represent those of the sponsoring institutions.

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PREFACE

In cooperation with researchers in national agricultural research programs, CIMMYT has sought to develop procedures which help to focus agricultural research squarely on the needs of farmers. The process involves collaboration of biological and social scientists (for the most part economists) for identifying groups of farmers for whom technologies are to be developed, defining their circumstances and problems, screening this information for research opportunities, and then implementing the resulting research program on experiment stations and in the fields of representative farmers.

The Instituto de Investigaciones Agropecuarias de Panama (IDIAP) is a young institution, having been created in 1975, with the basic goal of reaching Panamanian farmers with technologies appropriate to their specific agroeconomic circumstances. With this goal in mind, an agreement was sought with CIMMYT for cooperative work in an area-specific, on-farm research program, the first one of its kind to be carried out in Panama, and one which was expected to serve as a source of methodological and organizational experience in this type of research. The model program was designed for the area of Caisan under the leadership of IDIAP and with technical support from CIMMYT, drawing on the experiences of other countries where national program and CIMMYT staff were jointly engaged in farm-level research.

The essential elements of the process which emerged were: 1) the identification of potential research areas in terms of national priorities, 2) the organization of exploratory survey work, 3) the delineation of tentative recommendation domains, 4) the implementation of more intensive surveys where needed, 5) the prescreening of information to identify leverage points for biological research, 6) the initiation of on-farm experimentation under conditions of representative farmers and oriented by the survey process, 7) the adjustment of subsequent experimentation in terms of yearly results, and 8) the orientation of relevant experiment station research in terms of the findings from the

surveys and on-farm experiments. These are the themes around which the description of the work in Panama is organized.

The report describes the collaborative work undertaken in Caisan, the results in terms of technology development and farmer adoption, and the present and potential implications for the organization of IDIAP activities and allocation of resources. Emphasis is given to pre-screening and to the process through which annual trials were adjusted on the basis of earlier experimental results. We believe that the Caisan experience offers solid evidence of the utility of on-farm research and provides another example of how such research can be planned and carried out within a larger research program.

The selection of areas and farmers for this study was heavily influenced by national research priorities, especially by a desire to commit few resources in a convenient area so as to limit the cost of testing a new process. The process itself is readily applicable to limited or extensive areas and, prudently managed, is cost effective in either case.

Similar reports from other countries, based on their varied experiences, will follow in the near future. It is hoped that they will encourage an ever wider application of on-farm research as decision makers see the utility of the process and the alternative forms for its implementation.

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I. THE NATIONAL FRAMEWORK AND THE INSTITUTIONAL ORGANIZATION OF IDIAP

Panama has characteristics which distinguish the country from the rest of Central America. First, the effect of the Panama Canal on the economy has led to the development of an important financial and commercial sector geared toward international trade; this is reflected in the relative importance of the services sector within the country's gross national product (about 65%). Second, Panama's rich natural resources, in relation to its population of some two million, and its ecological diversity offer the potential for self-sufficiency in food production.

The agricultural policy of the government during the past decade is a clear indication of its intention to increase domestic production of basic grains to satisfy the rising per capita level of consumption of the growing population. In particular, the government's pricing policy has stimulated domestic grain production for import substitution. In the early 1970s, relative prices of basic grains increased as a result of a sustained program of government-guaranteed prices. In addition, the programs of MIDA, BDA, and IMA [1/] were broadened and geared toward production and income-redistribution objectives.

Until 1975, agricultural research had been carried out by the Ministry of Agricultural Development (MIDA), the University of Panama, and various public and private institutions. Then the Agricultural Research Institute of Panama (IDIAP) was created for the purpose of consolidating research forces to effectively reach Panama's farmers; research scientists from MIDA formed its nucleus.

A guideline of the institution was that of focusing research on specific regions and crops for the development of technologies appropriate to representative farmers in areas defined as high national priorities. Research could thus be concentrated on the most important

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1/ Ministerio de Desarrollo Agropecuario, Banco de Desarrollo Agropecuario, and Instituto de Mercado Agropecuario.

farmer problems and the scarce resources of IDIAP used to best advantage. Its activities were planned in a sequential pattern to permit methodological adjustments as experience was gained and to provide a framework for the training of a corps of national on-farm researchers.

In 1978, the first such program began in the area of Caisan with the cooperation of CIMMYT and a former CIMMYT trainee was assigned as coordinator of the program. At the same time, the issues which would shape IDIAP's institutional organization were being discussed and Caisan, its first area-specific, on-farm project, was expected to be a source of experience for the development of research procedures for IDIAP.

The Caisan program was planned and carried out strictly within the limits of the human and financial resources normally available to IDIAP. Thus, the cooperation of CIMMYT (development of procedures and in-service training) [2/] was designed in such a way as to not exceed normal resource allocation for area-specific programs.

Since the Caisan Program was designed to be one of learning by doing, no detailed, predetermined methodology was specified for use in the various research stages. Nevertheless, certain characteristics were defined which conditioned the procedures to be followed. They were:

1. To be area specific with the purpose of increasing, in the short run, productivity and income of representative farmers of Caisan.

2. To use a farming system perspective, focusing on priority crops and concentrating on the most promising research opportunities

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2/ For more detail see Martinez, Juan Carlos, and Gustavo Saín, "Evaluación Económica de los Programas por Area del IDIAP: El Caso del Programa de Caisan". Documento Preliminar, CIMMYT, México, Diciembre 1982, Section III.

in terms of their potential for increasing productivity and income for target farmers. [3/]

3. To use on-farm research procedures including: a) surveys to ascertain farmer circumstances and prevailing cropping patterns, and b) on-farm experiments carried out on fields of representative farmers and featuring major research opportunities identified through the surveys.

II. THE CAISAN PROGRAM: PLANNING STAGE

In the following sections, the lessons learned in carrying out the Caisan program will be described in terms of methodology used and specific technologies developed for the farmers of the area.

Information Gathering at the Farmer Level

In order to understand the agroeconomic circumstances of farmers in the Caisan area, available secondary information was analyzed as a first step. The area includes about 10,000 hectares with some 300 farmers from the communities of Fila Caisan, Caisan Arriba, Primavera, Caisan Centro, Plaza Caisan, Alto la Mina, Bajo la Mina, Caisan Abajo, and Bajo Chiriqui.

The agricultural zone is concentrated in the western part of Caisan, where the land is flat or slightly hilly. The rest of the area has irregular elevations and is used for perennial crops or for livestock. The annual average rainfall is 4,000 mm, and the temperature ranges from 18°C in the dry season to 22°C in the rainy season.

3/ Byerlee, D., L. Harrington, and D. Winkelmann, "Farming Systems Research: Issues in Research Strategy and Technology Design." American Journal of Agricultural Economics 64 (5): 897-904, 1982.

The soil of the region is of relatively homogeneous fertility, being of volcanic origin with a sandy texture and granular structure. It is deep black soil, well drained and with a high organic content. The most important crops are maize in the first cycle (March to September) and beans in the second (October to January). These were to constitute the target crops of the program.

Within the framework provided through secondary information, an informal survey was made to get further information about the farmers of the area, their prevailing production systems, and their most important production problems.

The exploratory survey led to a formal survey, more rigorously focused on the production problems of the area. It was designed to clarify certain aspects of prevailing production conditions which were identified in the exploratory survey and would be of value for further research. The informal survey took place in August, 1978, and the formal survey in December of the same year.

The formal survey concentrated on maize in the first cycle within the maize/bean rotation system. The survey sample was taken from a list of farmers included in the 1970 National Census and updated during the informal survey; a random sample of 52 farmers was selected for interview.

The formal survey verified and, in some cases, quantified the hypotheses formulated from the informal survey. Almost all of the farmers produced maize (98%) and, of those, the majority rotated the crop with beans on the same plot (70%). This confirmed the relative importance of the target crops, maize in the first cycle and beans in the second.

It was found that beans were planted after the maize harvest and after complete seed bed preparation. Therefore, within this cropping system, the two crops presented a minimum of interaction.

Use of Survey Information to Plan Experimental Work

1 Definition of Recommendation Domains--With the results of the questionnaire in hand, the first task was that of developing tentative recommendation domains, groups of farmers whose agroeconomic circumstances were sufficiently similar to permit the development of recommendations valid for all members of the group. [4/] The first line of differentiation was by location. Secondary information had shown that Bajo Chiriqui had agroclimatic characteristics similar to the rest of the zone, but that access roads into the area were often impassable, posing serious market access difficulties. This led to the hypothesis that farmer circumstances for Bajo Chiriqui (Recommendation Domain 1) were different than those of the rest of the study area (Recommendation Domain 2).

This hypothesis was verified by the results of the survey which showed that there were marked differences in the use of inputs by farmers of the two areas (Table 1). Because of the differences, technologies feasible for the two groups for the near future were different. Since the Caisan research program staff worked with limited resources, efforts were concentrated on Recommendation Domain 2.

TABLE 1. First Definition of Recommendation Domains: Comparison of Maize Production Practices for Bajo Chiriqui and the Rest of the Caisan Area, Maize, First Cycle

TECHNOLOGICAL PRACTICE	RECOMMENDATION DOMAIN 1: BAJO CHIRIQUI	RECOMMENDATION DOMAIN 2: REST OF THE AREA
	(percent of farmers using the practice)	
Mechanized Land Preparation	0	74
Use of Herbicides	0	66
Use of Fertilizers	0	57
Use of Insecticides	0	20

Source: Caisan farm survey, December 1978

4/ Byerlee, Derek, Michael Collinson et al, "Planning Technologies Appropriate to Farmers: Concepts and Procedures." CIMMYT, Mexico, 1981.

2. Research Opportunities--As mentioned earlier, experimentation must be carried out in relation to the representative agroeconomic circumstances of the recommendation domain(s), concentrating on the most promising research opportunities in terms of potential increases in productivity and farm income.

The information obtained from the farmers themselves, along with the perceptions of the researchers, made possible the limiting of research components to a minimum number for incorporation in the on-farm experimental phase. Those technological components to be incorporated in the first round of trials were determined as well as tentative ideas for future research cycles to be verified during the first round of trials.

2.1 Technological Components for the First Cycle of On-Farm Experiments

Weed Control--Weeds constituted a major problem in Caisan maize production. The natural fertility of the soil plus the ample rainfall led to a high incidence of weeds in farmers' fields--a problem clearly perceived by the farmers themselves and confirmed by the formal survey (Table 2). Given the socioeconomic circumstances of representative

TABLE 2. Limiting Factors In Maize Production According to Farmers

PROBLEMS	GRADE OF INTENSITY SERIOUS No. Reports	%	NOT SERIOUS No. Reports	%	TOTAL REPORTS No.	%
Weeds	30	85.7	3	8.6	33	94.3
Lodging	27	77.1	6	17.1	33	94.3
Shortage of Farm Labor	18	51.4	7	20.0	25	71.4
Erosion	11	31.4	10	28.6	21	60.0
Insects	10	28.6	9	25.7	19	54.3
Lack of Machinery	14	40.0	2	5.7	16	45.7
Other	6	17.2	7	20.0	13	37.2

Source: Caisan farm survey, December 1978

farmers, e.g., scarcity of farm labor and high labor cost, timely weeding by hand was not feasible.

Caisan farmers, from the point of view of the weed problem, faced a situation that may be defined as "transitional"---they were already seeking methods other than hand weeding to improve overall weed control and increase the productivity of the limited farm labor force. For that reason, the majority were already using 2,4-D in applications of one liter per hectare, 30 days after planting.

As a result of this situation, there was an opportunity for developing, in the short term, alternative technologies in chemical weed control for increasing maize production and labor productivity, with clear economic benefits for the farmer. These alternatives were initially centered around the use of a selective herbicide, atrazine, although other chemical control possibilities were also analyzed.

Spatial Arrangement-Density--Almost all of the farmers used "mateado" planting, irregularly spaced hand planting. The hills were spaced about one meter apart, with four seeds per hill, thus giving a density of about 40,000 plants per hectare at seeding.

In this case, the research hypothesis was related to the weed control problem. The irregular planting arrangement made chemical weed control difficult and so program researchers proposed planting in rows. It was also felt that adequate chemical weed control would permit a greater plant density than that used by the farmer.

Fertilizer Requirements--As a result of the survey, the problem of fertilizer use was seen to have several distinct facets:

1. From the production point of view, the farmer seemed to be familiar with the use of chemical fertilizers; nevertheless, a large percentage (42%) did not use any. Those who used fertilizers (58%)

applied it at a rate well below the recommended 400 lbs/ha of 10-30-10 or 12-24-12. The hypothesis of the researchers was that response to fertilizer, if any, would not be substantial.

2. From the point of view of credit policy, the maize programs in the area had emphasized two things, mechanization and fertilizer use. While mechanization had been fully adopted by the farmers, the same was not true of fertilizers. As the bank was experiencing a high rate of repayment default in the area, it was important to clarify the importance of fertilizer use in the Recommendation Domain, especially as to whether, considering the farmers' practice (low dosage), the rate of return associated with additional fertilizer use would be greater than the opportunity cost of capital.

Lodging--The strong winds in the area, particularly during June and July, represented an important risk in the production process. In the farmers' eyes, lodging was one of the most important problems, second only to weeds (Table 2). Table 3 shows the frequency of wind damage in the last five years, and the months in which it occurred. Nearly 80% of the reported cases of wind damage took place during June or July. The frequency of damage was variable, although during the given period all the farmers had suffered some damage on at least one occasion, the magnitude of harvest losses depending on the size of the affected area and also on the state of maturity of the maize at the time. Among the elements that contributed to increased incidence of wind damage in the zone was the excessive height (usually over 3.5 meters) of the maize variety used by the farmers.

In spite of the fact that other shorter varieties had been tried in the area (among them Tocumen 7428), they had not been accepted by the farmers. According to reports they were not sufficiently resistant to the excessive humidity characteristic of the area--the ears rotted and the husks did not close well--and yield did not surpass that of the local variety.

In view of the experience of the farmers with other varieties, it was decided not to experiment with new varieties in the first stages of

TABLE 3. Date and Frequency of Lodging

MONTH	NUMBER OF YEARS IN WHICH WIND DAMAGE HAD OCCURRED IN THE LAST FIVE YEARS						
	1	2	3	4	5	No Response	Total
May	2	1	-	-	-	-	3
June	6	-	2	-	5	-	13
July	1	4	3	-	5	-	13
August	1	-	-	-	2	2	5
Total	10	5	5	-	12	2	34

Source: Caisan farm survey, December 1978

the work, but to design a modest program for the reduction of the plant height of the local variety. From the survey, it was believed that, in the short term, the increase in productivity and income from other research components (such as weed control and plant density) would be superior to that from the use of new varieties.

2.2 Technological Components Beyond the First Cycle--The foregoing section has presented the prescreening of technological components for inclusion in the first cycle of maize experiments. The idea was to concentrate the research on a minimum number of new technological components which could be managed by the researchers assigned to the program and thus quickly result in feasible technological alternatives for target farmers. By the very nature of the research strategy it is clear that the selection of technological components did not exhaust all of the problems of the area nor did it completely determine the future of the research.

In particular, there was concern about erosion as reported by the farmers (Table 2) and confirmed by direct observation; this together with the lack of machinery and scarcity of farm labor led to the consideration of future research on zero tillage as an alternative to the conventional tillage presently practiced.

It was decided to postpone the incorporation of tillage practice as an experimental variable until more information could be obtained to permit the validation of hypotheses associating it with chemical weed control. The technical aspects of the practice needed to be better understood before becoming involved in the relatively more complex research issues associated with zero tillage.

Information generated at the planning stage had not fully clarified the nature and magnitude of the insect problem, particularly soil insects. It was hoped that the first cycle of experiments would shed additional light on this research issue for inclusion in future phases of the research program.

Research Strategy and Trial Management

Through the process described in the previous section, five technological components were selected for inclusion in the initial stages of experimentation:

1) Weed control
2) Spatial arrangement - density
3) Nitrogen requirements
4) Phosphorus requirements
5) Lodging

It was decided that the last component would be handled separately from the others in a special maize improvement program to reduce plant height. If successful, the effort would permit a reduction in the

production risks associated with lodging. Given the nature of plant breeding, the payoffs from this effort would be in the intermediate term.

The remaining research components, all involving on-farm trials, were organized into two groups according to the nature of the problem being addressed, the time period in which research pavoffs could be expected, and the research priority assigned to the component.

The first group included the components weed control and spatial arrangement-density which were expected to play a key role in the program in terms of their potential for increasing productivity and income. Also, the problems to be confronted in the two areas were strictly ones of production; no limitations were anticipated in terms of policy or availability of inputs. Research on the components was set for the near term with results leading to recommendations expected after two cycles of experimentation. The above considerations led to these two components being asigned first priority in the research program.

For the medium-term research horizon, and of second priority in the initial research phase, were the components of nitrogen and phosphorous requirements. Interest in those components was not restricted to the area of production, but was also related to agricultural policy. Credit programs in the region had traditionally emphasized the use of fertilizers; nevertheless, even though the farmers were familiar with fertilizers, almost half did not use them, and of those who did, amounts less than those recommended were used. There was no evidence of fertilizer response in the area, and the perception of the researchers was that, given the natural fertility of the land, even if such a response existed it might not be substantial. Therefore, the inclusion in the research program of fertilizer treatments as experimental variables was addressed more towards policy makers than farmers. This more complex nature of the fertilizer problem (production/policy issues) decided the medium-term horizon assigned to this group.

The grouping of the components was not merely taxonomic, but rather had implications for the management of the experiments. The four

TABLE 4. Experimental Strategy and Trial Management: Prescreening of Technological Components, Timing of Research, Purely Production Problems vs Production Problems Associated with Agricultural Policy, Management of Experimental and Non-experimental Variables

PRESCREENED COMPONENTS	PROBLEM NATURE	TIMING OF RESEARCH	EXPLORATORY TRIALS (2^4)			LEVEL TRIALS	
			COMPONENTS INCLUDED	RANGE OF EXPERIMENTAL VARIABLES	NON-EXPERIMENTAL VARIABLES.	COMPONENTS INCLUDED	NON-EXPERIMENTAL VARIABLES.
A) WEED CONTROL B) PLANT DENSITY AND SPATIAL DISTRIBUTION.	PRODUCTION	SHORT TERM	A B	FP AND ALTERNATIVE	FP	A	FP
C) NITROGEN REQUIREMENTS D) PHOSPHOROUS REQUIREMENTS.	PRODUCTION-AGRICULTURAL POLICY	MEDIUM TERM	C D			C D	FP + HI and FP+HI+DI
E) LODGING	BREEDING	MEDIUM TERM	PROGRAM TO REDUCE PLANT HEIGHT OF LOCAL VARIETY				

Source: Caisan program, maize, first cycle

(FP--farmer practice; HI--improved practice in weed control DI--improved practice in spatial distribution-density)
Check levels on experimental variables in all trials = FP

technological components were incorporated as experimental variables in uniform trials of an exploratory nature, with the main effects and interactions studied through a factorial arrangement 2^4, in relation to the farmers' practice. The exploratory experiments were complemented by levels trials in which experiments were carried out on various types of herbicides, amounts and times of application, and application rates for nitrogen and phosphorus.

In the trials incorporating weed control and spatial arrangement-density as experimental variables, the nature and levels of non-experimental variables were set at the prevailing and representative practices of area farmers. This allowed the results of the trials to be evaluated directly in terms of their potential impact for representative farmers in the recommendation domain.

The fertilizer studies, oriented toward the medium term, were handled "as if" the farmers were going to adopt the improved weed control alternatives to be developed by the program. The researchers were confident that this would occur because of the information available through the initial surveys. Consequently, these variables were fixed at improved levels; the check levels in the experimental variables were in all cases the corresponding farmer practice.

III. FIRST CYCLE RESULTS AND THEIR IMPLICATIONS

Exploratory Trials

The exploratory trials of 1978 attempted to analyze the agroeconomic impact of the new technological components for representative farmers in the recommendation domain, as well as to see the interactions among the components. The exploratory analysis had a double purpose: 1) to verify the hypotheses set at the planning stage of the program in the identification of priority problems, and 2) to analyze the agroeconomic feasibility of developing corresponding technological alternatives. In other words, the hope was to identify the priority problems and, at the same time, contribute information for their eventual solution.

Thus, six trials incorporating four of the five technological components chosen as priorities for the first cycle of experiments were carried out, utilizing an incompletely randomized block design with a factorial arrangement of 2^4 and without replications. The criteria for fixing the levels of experimental variables was that 1) farmer practice was always used as one level, and 2) the other level was one that would permit the detection of main effects and interactions should they exist.

The reasons for not replicating the trials in each locality were of diverse nature: 1) in choosing between statistical vigor (more replications per site) and a wider sampling within the recommendation domain (more localities), the research team gave more weight to the latter; 2) researchers felt that trial plot size requested of farmers should be minimal in the initial stage of the research, when the farmers were not acquainted with either the staff or the nature of the program; 3) research sites were carefully selected to fit characteristics of the recommendation domain, presumably leading to less across-site variability and allowing sites to be treated as replications once across-site consistency was verified; and 4) the design-arrangement of the trials contained "hidden" replications which permitted partial statistical analysis per locality if necessary.

Of the trials, one was eliminated because of unusual damage by animals; of the remaining experiments, the lowest average yield was obtained using present farmer practices (2.9 t/ha) while the greatest yields were obtained when all alternatives to the farmers' practices were included (6.1 t/ha). Table 5 shows the results by location and the average for the recommendation domain.

Table 5 also illustrates the potential impact of the factors considered. On the one hand, there is marked yield advantage for the alternative herbicide and planting distribution-density practices, with the average yield advantage being 0.9 tons per hectare for each component. On the other hand, the effect of chemical fertilizer use is

TABLE 5. Exploratory Trials: Main Effects by Location

MEANS OF TREATMENTS	AVERAGE YIELDS BY LOCATION (tons/ha, 14% humidity) I	II	III	IV	V	AVERAGE YIELD FOR THE RECOMMENDATION DOMAIN
H_o	4.1	3.8	3.8	3.6	4.1	3.9
H_1	5.4	5.3	4.8	4.0	4.7	4.8
Main Effect	1.3	1.5	1.0	0.4	0.6	0.9
D_o	4.3	3.8	3.4	3.6	4.2	3.9
D_1	5.3	5.2	5.2	4.0	4.5	4.8
Main Effect	1.0	1.4	1.8	0.4	0.3	0.9
N_o	4.9	4.3	4.3	4.0	4.3	4.3
N_1	4.7	4.7	4.4	3.6	4.5	4.4
Main Effect	-0.2	0.4	0.1	-0.4	0.2	0.1
P_o	4.7	4.7	4.2	3.7	4.0	4.3
P_1	4.9	4.4	4.5	3.9	4.7	4.5
Main Effect	0.2	-0.3	0.3	0.2	0.7	0.2

Source: Caisan trials, first cycle, 1979

(H--chemical weed control; D--spatial arrangement-density; N--nitrogen; P--phosphorous; $_1$ -- improved practice; $_o$ -- other practices)

practically nil, with positive and negative values around zero, depending on the location. With this consistency in results obtained across locations, a statistical analysis was carried out for the group of experiments, treating the locations as repetitions. The results are presented in Table 6.

One can clearly see the high significance obtained for the weed control and planting distribution-density components. The interaction of the two components was statistically significant at the 10% level which, even if not conclusive, clearly indicates a research path to be continued. Since each factor of the interaction is highly significant, the agronomic explanation that stems from this relationship would seem to be that more efficient weed control might eliminate weed competition

TABLE 6. Exploratory Trials: Combined Anova for the Five Locations

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F. CALC.
Repetitions	4	8.5531	2.1383	2.2688
Blocks	5	2.4207	0.4841	0.5136
H	1	19.7011		20.9031*
D	1	19.5031		20.6930*
N	1	0.0211		0.0224
P	1	0.9901		1.0505
HD	1	2.8501		3.0240
HN	1	1.0811		1.1471
HP	1	0.0061		0.0065
DN	1	0.0781		0.0829
DP	1	0.0361		0.0383
NP	1	0.0001		0.0001
HDN	1	2.1451		2.2760
HDP	1	0.5611		0.5953
HNP	1	0.2101		0.2229
DNP	1	3.0031		3.1863
Error	56	52.7798	0.9424	
TOTAL	79	113.9400		

CV = 22%

Source: Casian trials, first cycle, 1979

* Significance 0.01

(H--chemical weed control,; D--spatial arrangement-density; N--nitrogen; P--phosphorous)

for light, space, and perhaps nutrients, allowing a more densely planted and better distributed planting alternative.

With respect to the nitrogen and phosphorous components, Table 5 showed that there was virtually no impact on yield. The statistical analysis (Table 6) also indicates that there were no significant differences in yield due to the use of those chemical nutrients. There is an agronomic explanation for this fact, resulting from certain characteristics of the recommendation domain. First, Caisan is a relatively new maize production area with good soil structure and high natural fertility. In addition, in the maize/bean rotation, the bean crop probably contributes nitrogen to the maintainance of natural soil fertility; there could also be a residual effect from the phosphorus applied to the beans in the second cycle (around 10 kilos of N, 40 kilos of P_2O_5, and 10 kilos of K_2O).

In analyzing the economic feasibility of the technological alternatives incorporated in the exploratory trials, the agronomic impact was used as the basis. In this manner, the components that showed significant yield impacts and first order interactions (weed control and spatial arrangement-density) were analyzed for their economic viability as compared to the actual farmer practices in the recommendation domain. Table 7 shows that the H_1 and D_1 alternatives presented an ample margin of profitability, with marginal rates of return (MRR) of around 700%. Based on the interactions detected in the agronomic and statistical analyses of the components, the MRR of H_1D_1 suggests that the components should be considered together.

Up to this point, the empirical evidence from the analysis of the first cycle of exploratory trials indicated, with an ample margin of confidence, clear opportunities for the development of new technological alternatives for chemical weed control and spatial arrangement-density.

For the rest of the variables considered in the exploratory trials, (nitrogen and phosphorous), there were no significant differences in

TABLE 7. Economic Analysis of Exploratory Trials: Viability of Alternative Technologies in Chemical Weed Control and Spacial Arrangement-Density*

CONCEPT	TECHNOLOGICAL ALTERNATIVES H_oD_o	H_oD_1	H_1D_o	H_1D_1
Yield, ton/ha	3.6	4.2	4.2	5.5
Adjusted Yield (-10%)	3.24	3.78	3.78	4.95
GROSS BENEFIT ($114/ton)**	369.36	430.92	430.92	564.30
VARIABLE COSTS (VC)	15.23	23.05	31.57	39.39
Weed Control				
2,4-D ($1.63/lt)	1.63	1.63		
Gesaprim ($7.19/2.5 kg)			17.97	17.97
Planting				
Seeding Rate, kg/ha	13.00	16.00	13.00	16.00
Cost/ha ($0.22/kg)	2.86	3.52	2.86	3.52
Labor, days/ha	3	5	3	5
Labor ($3.58/day)	10.74	17.90	10.74	17.90
NET BENEFIT (NB)	354.13	407.87	399.35	524.91
Increase in NB		53.74		117.04
Increase in VC		7.82		16.34
Marginal Rate of Return		687%		716%

Source: Caisan trials, first cycle, 1979

* Nitrogen and phosphorous requirements show no significant differences between treatments and so were not included in the economic analysis

** Field price of maize

yields. Without going through the economic analysis of the data, it can be tentatively inferred from the agronomic responses that the farmers' practice was the most reasonable technological alternative. [5/]

In short, the exploratory trials confirmed the original preliminary identification of the problems facing farmers in the recommendation domain and, at the same time, permitted the exploration of alternative technologies that promised significant economic benefits for the farmer.

Levels Trials

Complementing the information from the exploratory trials, the levels experiments provided greater depth and detail about the behavior of some of the experimental variables considered in the exploratory experiments. For the first cycle, levels trials were carried out for: a) types of herbicides and dosages, b) types of herbicides and application timing, and c) levels of nitrogen and phosphorus.

Types of Herbicides and Dosage--Two herbicide by dosage trials were planted using a complete randomized block design with four repetitions. The variables considered were application dosages and combinations of Gesaprim 80, Prowl, Alachor, and 2,4-D, including in the trials farmer practice (2,4-D 30 days after planting). The results showed significant differences for both locations (at the 1% significance level) between the farmers' practice and the alternative chemical controls considered in the experiments. The analysis by location showed that the farmer could significantly increase his yields by using alternative methods of chemical control. The combined analyses from the two locations show significant differences in the treatments.

With these results, economic analyses were carried out for the locations, both individually and combined. The Gesaprim 80 treatment,

5/ Likewise, if we act "as if" the differences were significant and complete the economic analysis, we will find that the increase in yield far from compensates the costs incurred in the purchase and application of the chemical nutrients under consideration.

using a 2 kg/ha application during the pre-emergence stage, was superior to the other alternatives, with a marginal rate of return greater than 1250% at each location as well as in the combined analysis. This chemical control alternative is the same as that used in the exploratory trials, except that, in the latter case, the dosage was slightly higher (2.5 kg/ha). This application rate showed an equally high marginal rate of return.

Both groups of experimental trials (exploratory and levels) showed consistent results for this experimental variable, both in the qualitative (type of herbicide) and quantitative (dosage) aspects, and confirmed the viability for the farmer of more efficient alternatives of weed control.

Types of Herbicides and Timing of Application--Two herbicide experiments were conducted to compare alternative application timing patterns, using a complete randomized block design with four repetitions. The applications were made 0, 5, 10, 20, and 30 days after planting, and Gesaprim 80 and 2,4-D (including the farmer's practice) were used as well as a check treatment of no chemical control.

In both experiments, problems with lodging due to high winds affected the accuracy of the results. The lodging problems occurred near plant maturity and, consequently, the impact on average yield levels was not great. Nevertheless, from the point of view of trial management, the presence of lodged plants within the plots affected the accuracy of the agronomic and yield data obtained from the trials.

With this qualification, significant differences were not found for the different treatments, except when compared to the check treatment. The information obtained from this group of experiments did not contribute to the clarification of the issues involved as had been the case in the preceding trials.

Levels of Nitrogen and Phosphorous--Two nitrogen by phosphorus levels experiments were planned. The design utilized was the complete randomized block with an incomplete factorial arrangement and three repetitions. These included five levels of nitrogen and phosphorus (from 0 to 150 kg/ha) with a density of 37,500 plants per hectare. An additional treatment was added which consisted of intermediate level applications of nitrogen and phosphorus with a density of 50,000 plants per hectare.

The statistical analysis in both cases indicated that no significant differences existed between treatments. In this group of experiments some management problems were also experienced, e.g., insect attack and minor animal damage. In spite of those problems, the consistency of the results with those previously reported for the exploratory trials added support to the original hypothesis that there were no significant differences in yield due to the use of nitrogen or phosphorus.

Integrating Survey and Experimental Results

The methodology used in the program included, after each cycle, the integration of the information from the surveys with the results of the on-farm experiments. The data were reviewed, new hypotheses formulated, and new lines of research charted, both for the on-farm research program and for experiment station research. Where appropriate, recommendations for farmers were made as well as those for agricultural policy.

The exploratory trials showed significant first order effects for herbicides and spatial arrangement-density and, to a lesser degree, interactions between those variables. The marginal rates of return for the research components, planting 50,000 plants/ha and using Gesaprim 80 at 2.5 kg/ha, were above 700%. This confirmed the hypothesis that clear opportunities existed in these technological components for the development of viable alternative technologies for representative farmers to increase the productivity of the land and labor devoted to maize production.

The results of the levels trials on herbicides were qualitatively (types of herbicides) and quantitatively (dosage of 2 kg/ha in this case) consistent with the results of the exploratory trials. This, along with the high economic margin of profitability for the various components, led IDIAP to formulate recommendations for area farmers after only one cycle of experiments.

The use of chemical fertilizers, in the exploratory trials as well as in levels trials, gave a nonsignificant response confirming the original hypothesis formulated in the planning stage--the use of nitrogen and phosphorous, separately as well in combination, resulted in negative marginal rates of return. These results remained the same even when fertilizer was used with improved weed control and spatial arrangement-density practices. This represented a challenge for recommendations on the use of fertilizers, at least until the information obtained in the first cycle could be confirmed in later cycles. It also suggested that emphasis placed on fertilizer use in credit programs be re-examined.

Finally, the results obtained using the local maize variety in the first cycle of trials confirmed the hypothesized yield potential of the farmers' variety.

For the future orientation of the research program, the results of the first cycle, together with the diagnostic surveys done in the planning stage, suggested the following lines of research for the second cycle:

1. Given that the hypothesis about the agroeconomic impact of adequate weed control seemed to be validated, and considering erosion problems and the lack of machinery, it was decided to incorporate the tillage system as an experimental variable in the next cycle. This would entail analyzing the prevailing conventional tillage system (mechanized) against an alternative of zero tillage with chemical weed control.

2. Given the impact obtained from the trials on herbicides and spatial arrangement-density, and the interactions observed between the components, the levels experiments for the next cycle would examine the variables jointly (herbicides by density) in order to determine more precisely the relationships between them and confirm optimum levels.

3. Given the efficiency shown by the contact herbicide, Gramoxone, in the control of prevalent weeds in the bean cycle and its relative lower price, it would be incorporated into the program as a complement and/or alternative to Gesaprim 80.

4. Given the impact that Gesaprim had in the first cycle, and the prevalent maize/bean rotation system, it was decided to analyze the residual effect that Gesaprim had on the bean crop, using a factorial arrangement (dosage of Gesaprim per days after its application in which beans are planted). In order to save time and reduce research costs, this factorial arrangement would be carried out on the border rows of the herbicide by density trials. The hypothesis was that high precipitation would eliminate any residual effects on the beans.

5. Given the impact of spatial arrangement-density, plant population would be more closely monitored in future experiments, particularly during the first month of crop development.

6. Given the results of the fertilizer trials, plus the medium-term horizon used for those variables, experiments would be carried out on continuous plots to analyze, in the longer term, the impact on natural soil fertility of more intensive production practices in the maize/bean crop rotation.

IV. BEYOND THE FIRST CYCLE: TECHNOLOGY VERIFICATION, TRANSFER, AND ADOPTION

Research results described in the previous section provide a solid basis for the orientation of the Caisan research program in subsequent cycles. Further, they provide empirical evidence of the utility of the research methodology used by the program. Accordingly, the same research strategy was followed for subsequent research cycles.

Most Important Implications of the Second and Third Cycle of Trials

The most important change in the second cycle of trials was the inclusion of tillage systems as an experimental variable. The tillage experimental variable was incorporated in the exploratory trials in place of weed control, although the latter variable continued to be part of the "levels" trials.

The hypothesis regarding zero tillage as an alternative to conventional tillage was that it would be "cost saving" rather than "yield increasing." In particular, researchers felt its use as an alternative technology would have the following results:

1) Maintain basically the same yield levels.
2) Reduce the cost of tillage practices per hectare and, consequently (if point one is verified), reduce average production costs.
3) Significantly reduce soil erosion, identified in the intial planning phase as a problem by both farmers and researchers.
4) Relieve the small farmer of having to depend on contracted mechanization service for land preparation.
5) Increase farmers' time flexibility at planting by considerably shortening the time required for land preparation.
6) Decrease the competence of weeds during the first weeks of plant stand development, as a result of fewer days between land preparation and planting.

With these hypotheses about zero tillage, four exploratory trials were planted that included this variable along with spatial arrangement-density and nitrogen and phosphorous requirements. The results of three of the trials (one was lost due to heavy lodging) confirmed the results of the previous cycle with respect to the last three variables. The new experimental variable, the tillage system, showed statistically significant differences (5%) in yield levels at only one of the harvested locations. In that case, the main effect was positive, with higher yields for zero tillage. In the other two locations, no significant differences were encountered nor did across-site analysis show significant yield differences. The results, therefore, were consistent with the research hypothesis that zero tillage would not significantly affect yields.

With respect to the economic dimension, Table 8 shows partial budgets for conventional tillage and zero tillage assuming that yield would remain the same under both tillage systems. A comparison of the costs associated with the two systems shows that zero tillage results in a 44% reduction as compared to the conventional tillage system. This reduction is only in terms of immediate savings, not taking into account the implicit cost of erosion associated with conventional tillage, a cost clearly apparent to representative farmers in the area.

In the levels trials, three herbicide by plant density and three fertilizer trials were planted. The herbicide by density trials were included to confirm the interactive effects observed for those variables in the exploratory trials conducted during the first cycle. Also the herbicide, Gramoxone (paraquat), was included in order to compare its effectiveness with the previously used herbicide, Gesaprim 80.

Unfortunately, the loss of a considerable number of plots in the levels trials due to heavy lodging made it impossible to carry out the quantitative analysis, and only the field observations made during the growing stages were available for use by the research team. (The lodging occurred late and had little impact on yield. It did, however, make measurement so difficult that there were doubts as to accuracy.) Those observations indicated that both the preemergence applications of

TABLE 8. Exploratory Trials: Partial Budgets for Conventional and Zero Tillage Systems

ACTIVITY	AMOUNT	UNIT COST	VARIABLE COSTS
Conventional Tillage			45.00
Plowing, 3 Passes	3 hrs, tractor	15.00	45.00
Zero Tillage			26.00
Chopping	2 days	4.00/day	8.00
Herbicide	1.8 liters	5.00/l	9.00
Labor, Herbicide Application	2 days	4.00/day	8.00
Rent, Backpack Sprayer	1 day	1.00/day	1.00

Source: Caisan trials, first cycle, 1980

Gesaprim and the postemergence applications of Gramoxone provided effective weed control. The same effectiveness was not observed for 2,4-D, confirming the results obtained in the previous cycle. With respect to the residual effects of Gesaprim on the subsequent bean crop, the trials showed that after 90 days there was practically no residual toxicity in the soil.

Once again, fertilizer trials showed no economic response, reinforcing previous conclusions on those components. These results, together with an increased flexibility in the credit program operating in the area, [6/] may lead, in the near term, to a decrease in fertilizer use with no effect on yields. In spite of the incidence of risk factors, risk analysis was not needed because: 1) some of the alternatives were cost saving and 2) the others implied only small additions to variable costs but had high rankings in benefits.

6/ Starting in 1980, the credit program for maize deemphasized fertilizer use.

The above results had the following implications for the orientation of the program in the third cycle of experiments:

1. Add the control of soil insects as an experimental variable in the exploratory trials. The spatial arrangement-density variable proved to be significant for yield potential in the two previous cycles, and insect control would help assure improved plant stand.

2. Maintain tillage systems and spatial arrangement-density as experimental variables in the exploratory trials. The second experimental variable is related to soil insect control and demands more frequent countings of plant population during the first month after planting to determine the effectiveness of the insecticide control.

3. Maintain phosphorus requirements as an experimental variable in the exploratory trials, but eliminate nitrogen.

4. Repeat the herbicide by plant density trials that were lost in the previous cycle due to heavy lodging. Also, repeat the experiments on residual toxicity to beans on the border rows of those trials.

5. Continue the medium-term fertility studies on continuous flat land plots (slope less than 5%) and initiate fertilizer trials on sloping lands (slope more than 5%).

6. For evaluating technological alternatives, conduct verification trials (based on information obtained in the first two cycles) combining tillage systems, spatial arrangement-density, weed control, and fertilizer use.

7. Enlist representative farmers to plant demonstration plots on zero tillage, under the supervision of the research team but with costs assumed by the farmers themselves.

With this basic orientation, experiments planted in the third cycle included: five exploratory trials; four levels trials on herbicides by density, which also tested residual toxicity to beans on the border rows; three fertilizer experiments on continuous flat land plots, and two experiments on sloping land; three verification trials, and three demonstration plots on zero tillage.

There were adverse growing conditions throughout the area during this cycle, with drought, insect attack (Agrothis sp., gallina ciega), and heavy incidence of Helminthosporium spp. These factors made the analysis of trial results difficult. Among the experimental variables included in the exploratory trials, insect control treatment using an insecticide showed a strong marginal rate of return due to the heavy incidence of insect attack. In other years, when insects are not as prevalent, there might be little return to insecticide application. Consequently, insecticide use represents "insurance" for adequate plant stand although the probability of insect attack has not been clearly assessed. For the other variables, the analysis of exploratory and levels trials verifie the conclusions of previous cycles. 7/

Verification Trials

The three verification trials conducted during the third cycle combined the best technological alternatives identified in the exploratory and levels trials, and were designed to confirm their agroeconomic viability for representative farmers. Consequently, the plot size in the verification trials was larger than in the previous trials and the farmers had greater participation in their management.

In accordance with the results of the first two cycles of experimentation, the verification trials included technological alternatives on tillage systems, chemical weed control, spatial

7/ For a detailed description of these results see Martínez, Juan Carlos, and José Román Arauz, "Innovaciones Institucionales en la Investigación Agrícola Panameña: El IDIAP en Caisan". Forthcoming.

arrangement-density, and fertilizer applications. In light of the fact that the new herbicides were already displacing 2,4-D in the area, the incorporated farmers' weed control practice was changed to that of Gramoxone use. The rest of farmer practice was kept as defined at the planning stage. The design of the three verification trials was as follows:

1. Farmer Practice (FP)
   a) Conventional tillage
   b) Chemical weed control with Gramoxone: 1 lt/ha 30 days after planting
   c) Fertilization: 200 lbs of 10-30-10 at planting
   d) 40,000 plants per ha, planting arrangement "mateado," hills about one meter apart, four seeds per hill

2. Technological Alternative 1 (TA 1)
   a) Zero tillage
   b) Chemical weed control with Gesaprim 80: 2 kg/ha after planting
   c) No fertilization
   d) 50,000 plants per ha, planted in rows

3. Technological Alternative 2 (TA 2)
   a) Zero tillage
   b) Chemical weed control with Gesaprim 80: 2 kg/ha after planting
   c) Fertilization: 200 lbs of 10-30-10
   d) 50,000 plants per ha, planted in rows

According to previous research results, it was hypothesized that TA1 would successfully compete with FP in terms of decreased cost per ha, but only marginally in terms of yield. TA 2 implied greater costs per ha than TA 1, due to fertilizer application, and increase in yield was not expected to be significant.

The yields, variable costs, and net benefits associated with the three production alternatives considered in the verification trials

planted at three locations are shown in Table 9. As can be seen from the data, yields varied considerably across locations and were particularly affected by the degree of disease incidence (Helminthosporium spp.). The combined economic analysis indicates that TA 1 dominated the other alternatives. When the trial results from Location 1 were removed from the across-site analysis (it had the most serious disease incidence), TA1 showed even greater dominance. These results confirmed, therefore, that the superiority of alternative TA 1 was basically due to decreased costs per hectare (zero tillage, no fertilizer).

Demonstration Plots

During the third cycle, three representative farmers in the area agreed to grow their crop using zero tillage. These demonstrations, to be fully valid, were to be totally managed by the cooperator with only some technical advice from the research team. 8/ The cooperating farmers paid for the majority of the production inputs and assumed production risks; IDIAP paid a portion of the herbicide cost. The research team maintained informal contact with the cooperators throughout the growing season, particularly during zero tillage practices, in order to monitor their reactions to the use of the new technology.

The size of the demonstration plots varied between one and two hectares. The type of zero tillage practices followed for each demonstration plot varied slightly according to previous land management (animal grazing or not) and the level of weeds encountered. Only in Location 1 was it necessary to clear weeds and stubble from the previous growing cycle before herbicide application. In Location 2 farm animals had grazed the land after the previous bean crop harvest. The amount of Gramoxone used for the demonstrations varied between 1 and 2 lt/ha. In consequence, the cost of zero tillage varied between $19.25 and $26.50 per hectare, with the average being lower than the $26/ha cost estimated during the analysis of the 1980 exploratory trials (Table 8).

8/ The level of farmer interest in the new technological alternative is shown by the fact that some cooperators tested the tecnology on their own without any technical assistance from the research team.

TABLE 9. Economic Analysis of Verification Trials

CONCEPT	TECHNOLOGICAL ALTERNATIVES FP	TA 1	TA 2
Yield, t/ha			
Location 1 (heavy disease)	1.91	1.42	2.93
Location 2 (light disease)	4.25	4.24	3.89
Location 3 (light disease)	2.86	4.02	3.34
Average Yield, t/ha	3.01	3.23	3.39
Ajusted Yield (-10%)	2.71	2.91	3.05
GROSS BENEFIT ($193/ton)*	524.70	563.40	590.50
VARIABLE COSTS	126.70	65.60	129.50
Soil Preparation	48.00	29.30	29.30
FP (3 tractor passes)	48.00		
Chopping, 2 days	-	10.00	10.00
Gramoxone (1.5 lt/ha)	-	8.30	8.30
Labor (herb. app., 2 days)	-	10.00	10.00
Rent, Backpack Sprayer	-	1.00	1.00
Planting	19.30	30.30	30.30
Seeding Rate, kg/ha	13.00	16.00	16.00
Cost/ha ($0.33/kg)	4.30	5.30	5.30
Labor, days/ha	3	5	5
Labor ($5/day)	15.00	25.00	25.00
Weed Control	5.50	16.00	16.00
Gramoxone (1 lt/ha)	5.50		-
Gesaprim (2 kg/ha)	-	16.00	16.00
Fertilizer	53.90		53.90
200 lbs 10-30-10	43.90	-	43.90
Labor, 2 days	10.00	-	10.00
NET BENEFIT	398.00**	497.80	461.00**

Source: Caisan trials, first cycle, 1981

* Field price of maize
** Dominated alternatives

Farmer Response: Adoption of Recommended Practices

Evidence from CIMMYT technology adoption studies shows that, when technological recommendations are not adopted by farmers, it is usually because at least some component in the recommendation is not consistent with the circumstances of the farmers to whom the technology is

directed. [9/] The Caisan research program was guided by the principle that the best guarantee for the adoption of recommended technologies was to assure that farmer circumstances were taken into account from the outset, leading to recommendations which were appropriate to those circumstances.

The relationship between the researchers and representative farmers was central to the research paradigm of the Caisan project. This interaction began with the survey sequence, and continued through the on-farm experiments and the monitoring of the adoption of the recommendations derived from the program. Thus, the research process began and ended with the farmer.

The technology transfer process followed in the project involved farmer field days at experiment and demonstration sites to discuss the alternative technologies involved. With these elements, and the degree of communication which existed between farmers in the area, [10/] their response exceeded initial expectations. Furthermore, farmers themselves played an active role in the process of technology generation. For example, cooperating farmers modified the Gramoxone container so that it could be used as an applicator in the field. Similar farmer-originated adaptations occurred in zero tillage. Some farmers (particularly larger landholders) found it difficult to find the labor required by the manual chopping of old stands, the initial step of the zero tillage alternative. In consultation with the research team, they used a light harrowing pass instead of hand chopping to cut back the weeds and crops residues, thus arriving at a minimum tillage system.

Given the response of representative farmers to the technological alternatives developed through the research project, IDIAP decided, after only three cycles of research activity, to conduct an evaluation of the

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9/ Perrin, R.K., and D.L. Winkelmann, "Impediments to Technical Progress on Small versus Large Farms," American Journal of Agricultural Economics, 58:5, 1976.

10/ The farmers were organized in three "Juntas Agrarias," mainly for buying inputs and obtaining credit.

TABLE 10. Adoption Survey: Levels of Recommended Technologies

TECHNOLOGICAL ALTERNATIVES	FARMERS	MAIZE AREA
	(percent)	
Appropriate Weed Control	61.4	60.9
Planting in Rows/Higher Density	70.5	62.7
No Fertilizer Used	79.5	79.5
Zero or Mininum Tillage	43.5	23.0

Source: Caisan survey, first cycle, 1982

project, including the assessment of the social rate of return for its investment in the program. 11/ The evaluation focused on two basic aspects: 1) the impact on area farmers of the adoption of recommendations formulated by the program, and 2) the methodological and institutional spillovers of the program to other regions of the country.

The evaluation included an adoption survey related to the technologies generated by the project. Table 10 illustrates the level of adoption by 1982 for four of the components. Through contrast with data from the original 1978 survey, the patterns of adoption over time were also derived. 12/ The difference in the percentage of farmers adopting minimum or zero tillage (43%), and its percentage of cultivated area (23%), reflects the fact that small landholders had the least difficulty in adopting the practice. This was probably because they relied on hand labor, and the adoption of minimum or zero tillage practices was appropriate to their circumstances. In contrast, those farmers with larger holdings had more difficulty in switching to minimum

11/ Martínez, Juan Carlos, and Gustavo Saín,"Evaluación Económica de los Programas de Investigación en Fincas del IDIAP: El Caso de Caisan", CIMMYT and IDIAP, 1982.

12/ Ibid., Section IV.

or zero tillage because labor constraints were more serious for them, and a mechanized zero tillage alternative was not yet available. (Subsequently, IDIAP purchased mechanized zero/minimum tillage equipment for examination in the project area starting in 1983.)

The high rate of adoption of recommended practices among Caisan farmers, particularly considering that the research project had only been in operation for four years (three cycles), stands as testimony to the validity of the research methodology which led in such a short time to the development of appropriate technology for target farmers--the final judges of the usefulness of production-oriented research.

V. CONCLUSIONS: COST EFFICIENCY AND IMPLICATION OF THE CAISAN PROGRAM

Within national agricultural research programs there has been considerable progress during the last five years in the relative importance of on-farm research activities and the operational development of of methodologies for its implementation. As this process evolves, methodological and technological problems are resolved and new ones take their place, among them that of the institutionalization of on-farm research within national research structures. The starting point for this institutionalization process has been the experience arising from the ongoing on-farm research programs, programs which have usually been managed in the initial stage by ad-hoc technical groups from within the research structure. From CIMMYT's perspective, the process builds from the bottom up--from basic methodological ideas to on-farm research experiences to the institutionalization of these activities within the national program. In other words, it goes from on-farm research actions to an articulated on-farm research program.

IDIAP and Caisan illustrate this process. The institutional strategy of IDIAP provided the framework for the development of Caisan. The progress of the program and the methodological experiences arising from

it were closely followed by the national directing staff and intensively discussed by researchers and directing staff in national meetings, field days, and regional workshops.

In this way, the Caisan program reinforced the initial orientation of IDIAP towards site-specific, on-farm research. Also, in the methodological dimension, it provided concrete experiences, not only in terms of what to do in on-farm research (surveys, experiments, etc.) but, more important, how to do it, i.e., the informal survey leading to a well-focused formal questionnaire, the prescreening of best-bet technological components based on the assessment of farmer circumstances, and the management of experimental and nonexperimental variables within the trials.

The program has provided solid evidence of the validity of the research procedures used. Farmer response, in terms of adoption of resulting technologies, is proof of the degree to which program recommendations fitted their circumstances. Also, the speed at which adoption took place is a clear indication that the research opportunities incorporated in the program were in fact important production problems for representative area farmers.

The best indicator of the cost efficiency of the methodology utilized is the social rate of return on the investment required to implement the program; the evaluation carried out in 1982 provided this information. 13/ In fewer than four years, even assuming no further adoption after 1982, the social returns (basically accruing to area farmers) were much greater that the amount invested by IDIAP. The rate of return, using the most conservative figures, was 188 percent, clearly exceeding the opportunity cost of capital. When less conservative assumptions were made, the rate of return rose to 332 percent. 14/ These

13/ Ibid.

14/ Ibid.

results, together with experiences of other countries, [15/] reaffirm that the approach used was efficient for reaching target farmers with appropriate technologies in the near term.

While the Caisan program was being carried out, IDIAP was going through a systematic planning effort which resulted in an organization of its activities into Programs (Agriculture and Livestock), Subprograms (crops groupings--for example, basic grains) and Commodity Research Projects. While these were the groupings at the national level, they were cut across by the Regional Research Programs whose basic operational unit was the area-specific, on-farm research project. [16/] The central management was organized with a Director General, a Deputy Director General and National Directors for Agricultural Research, Livestock Production Research, Planning, Transfer of Technology, Administration and Special Projects.

The area-specific, on-farm research activities have gone through considerable expansion since 1978 when the Caisan program was begun with only two national researchers. At present they include five priority areas in agriculture, involving the work of 24 national researchers, and three priority areas in livestock with 21 researchers.

While this growth leaves no doubt as to the importance given to such activities by IDIAP, it also brings to the surface a set of pressing issues on the institutionalization of on-farm research which demand the attention of IDIAP central management. For this reason, a workshop for IDIAP directing staff was organized, with the cooperation of CIMMYT, for an intensive discussion of the issues (organizational, managerial, and

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15/ For example see Edgardo Moscardi et al, "Creating an On-Farm Research Program in Ecuador. The Case of INIAP's Production Research Program." CIMMYT Economics Program Working Paper, January 1983.

16/ "Plan Anual de Trabajo 1982", IDIAP, Panama, May 1982.

technical) arising from the field experiences in on-farm research. [17/] While the discussions were centered around Caisan, other experiences from IDIAP and INIAP, Ecuador were considered as well. The moving from on-farm research actions to an articulated on-farm research program had presented many difficulties, some of which were intensively discussed through the workshop. Institutional adjustments may follow pending an internal "self evaluation" meeting of IDIAP to be held in the near future.

From these experiences, several points emerge for consideration for the consolidation of efficient on-farm research operations within IDIAP. On the methodological front, it would seem that the diagnostic phase should concentrate on those areas important for the experimental phase. Also, research should begin with prevailing farming systems, trying to develop, for target crops within those systems, simple technological alternatives rather than complete packages on complete alternative systems for the farmer. This responds to the near-term time preference prevalent in the political and institutional environment of IDIAP, i.e., results arrived at in three years are preferred to those taking ten years.

Also, there is a need for the assimilation by new staff members who have joined IDIAP of the methodologies used for on-farm research as those activities have expanded. This has multiplied the in-service training demands to a point where they can no longer be satisfied by the training provided in international centers; it brings about the need for alternative mechanisms for in-country training.

Closely related to the previous point, as the ad-hoc on-farm research technical groups are institutionalized, covering more areas and involving more personnel, the problem of the management of on-farm research activities becomes more complex. Among other things, it requires

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17/ Managing the Institutionalization of On-Farm Research within IDIAP. A Workshop for Directing Staff. IDIAP-CIMMYT, Volcan, Chiriqui, Panama, February 23-25, 1983.

greater technical supervision of new area programs, in order to capitalize on the methodological experiences from the earlier ones. This suggests a sequential type of development of these activities, in which efforts are concentrated initially in few areas with a "built in" mechanism of on-the- job training which permit a progressive extension of the work to new areas. In this process, the more-experiences practitioners will become supervisors. Accordingly, training should be addressed to those practitioners with the potential of becoming supervisors.

Also, a national on-farm research program demands a decentralized style of management to provide the logistic and financial support required by increased off-station field operations. IDIAP has already moved in that direction, decentralizing management to three regional research centers which are being organized and equipped. This decentralization will have implications for financial management, for example, field researchers may have access to a rotative fund for a more autonomous and time efficient coverage of operational costs.

Finally, from an organizational point of view, close links are required between area-specific, on-farm research and national crop research and extension activities. The formulation of farmer recommendations (often agronomic in nature) is the responsibility of the area specific on-farm research teams. The role of extension in this process should be clearly defined since more results will be forthcoming from the ongoing research operations. In the case of Panama, this will involve the National Directorate of Technology Transfer of IDIAP, as well as MIDA's extension network. 18/ Ideally, extensionists should participate in the planning phase of the research, and then have an increasing responsibility as new technological alternatives are generated in the experimental phase. At least, extensionists should assume clear responsibilities in the technology verification and demonstration stages, with assistance and eventual training from the on-farm researchers. Under this arrangement extensionists would work closely with farmers, and would

18/ Extension services are a direct program activity of MIDA.

become completely familiar with the technological alternatives developed and tested. In our view, this type of linkage (integration) is essential for an effective transfer of improved technological alternatives to farmers.

The strategy of IDIAP has been to emphasize on-farm research in the initial stages of institutional development. The relative importance of station research has, accordingly, decreased as more human and financial resources have been allocated to off-station work. As on-farm research activities prove to be successful, in term of impacts in productivity and income of target farmers, IDIAP may find itself in a position to attract more political attention and financial support for expanding its experimental station research programs. This strengthening of station-based research is an important element for generating a continuous flow of improved technological components. As the central management of IDIAP moves to resolve these issues, the institution will come closer to realizing its full potential for benefiting Panamenian farmers and the society as a whole.