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# Developing Appropriate Technologies Through On-Farm Research: The Lessons from Caisan, Panama

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*SUMMARY*

*This paper describes the methodological aspects and results of an area-specific on-farm research (OFR) program implemented (1978–1983) in the area of Caisan (Panamá) under the leadership of the Instituto de Investigaciones Agropecuariás de Panamá (IDIAP) with technical support from CIMMYT. Special emphasis is given to the links between the assessment of farmer circumstances and the identification of promising research opportunities, as well as to the integration of survey and experimental results at the end of each crop cycle, leading to recommendations for farmers, for policy makers and for future on-farm and station research. Farmers' adoption of the technologies generated and the cost efficiency of the OFR methods involved are also briefly assessed in the paper. Finally, the contribution of the Caisan experiences for the development of national OFR operations within IDIAP is described.*

## INTRODUCTION

Until 1975, agricultural research in Panamá had been carried out by the Ministry of Agricultural Development (MIDA), the University of



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Panamá and various public and private institutions. In that year, the Agricultural Research Institute of Panamá (IDIAP) was created with the purpose of consolidating research forces to effectively reach Panamánian farmers.

A guideline given to 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 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 research workers.

In 1978, the first such program began in the area of Caisan with the co-operation of CIMMYT and a former CIMMYT trainee was assigned as co-ordinator 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 co-operation of CIMMYT (development of procedures for on-farm research and in-service training) was designed in such a way as not to exceed normal resource allocation for area-specific programs.[4]

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.[1] They were:

(1) To be area-specific with the purpose of increasing, in the short run, the productivity and income of representative farmers in the Caisan area.
(2) To use a farming system perspective, focusing on priority crops and concentrating on the most promising research opportunities in terms of their potential for increasing the productivity and income of target farmers.
(3) To use on-farm research (OFR) procedures including: (a) surveys to ascertain farmer circumstances and prevailing cropping patterns and (b) on-farm experiments carried out on the fields of

representative farmers and featuring major research opportunities identified through the surveys.

The main purpose of this paper is to describe, in terms of the methodology used and specific technologies developed for the farmers of the area, the lessons learned in carrying out the Caisan program.

## FROM FARMER CIRCUMSTANCES TO EXPERIMENTAL STRATEGY

In order to understand the agro-economic circumstances of farmers in the Caisan area, available *secondary information* was analyzed as a first step. This included data on main crops, topography, climatological data and type of soils.

Within the framework provided by this secondary information, an *informal survey* was carried out to obtain 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. This was designed to clarify certain aspects of the prevailing production conditions which were identified in the exploratory survey, and to 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 per cent) and the majority of these rotated the crop with beans on the same plot (70 per cent). This confirmed the relative importance of the target crops, i.e. 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.

The results of the surveys were also used to identify two recommendation domains, groups of farmers whose agro-economic circumstances were sufficiently similar to permit the development of recommendations valid for all members of the group.[2]

## Recommendation domains

Secondary information had shown that Bajo Chiriquí, one of the communities which form the area of study, had agroclimatic characteristics similar to the rest of the zone, but that access roads into the area were often impassable, posing serious difficulties of access to market. This led to the hypothesis that farmer circumstances for Bajo Chiriquí (Recommendation Domain 1) were different than those in the remainder 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 in the two areas (Table 1). Since the Caisan research program staff worked with limited resources, efforts were concentrated on Recommendation Domain 2.

## Research opportunities

As mentioned earlier, experimentation must be carried out in relation to the representative agro-economic circumstances of the recommendation

**TABLE 1**

First Definition of Recommendation Domains: Comparison of Maize Production Practices for Bajo Chiriquí and the Remainder of the Caisan Area, Maize, First Cycle

| *Technological practice* | *Recommendation Domain 1: Bajo Chiriquí* | *Recommendation Domain 2: Remainder of the area* |
|---|---|---|
| | *(Per cent 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.

domain(s), concentrating on the most promising research opportunities in terms of their potential for increases in productivity and farm income.

The information obtained from the farmers themselves, along with the opinions of the research workers, made it possible to limit the 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—ideas to be verified during the first round of trials.

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 pay-offs 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 over which research pay-offs 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 rôle in the program in terms of their potential for increasing productivity and incomes. Also, the problems to be confronted in both components 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. These considerations led to these two components being assigned 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 phosphorus requirements. Interest in those components was not restricted to the area of production, but was also related to agricultural policy. Credit

**TABLE 2**

Experimental Strategy and Trial Management: Pre-screening of Technological Components, Timing of Research, Purely Production Problems Versus Production Problems Associated with Agricultural Policy, Management of Experimental and Non-experimental Variables

| *Pre-screened components* | *Problem nature* | *Timing of research* | *Exploratory trials* ($2^4$) | | | *Levels trials* | |
|---|---|---|---|---|---|---|---|
| | | | *Components included* | *Range of experimental variables* | *Non-experimental variables* | *Components included* | *Non-experimental variables* |
| (A) Weed control<br>(B) Plant density and spatial distribution | Production | Short term | A<br>B | FP and alternative | FP | A | FP |
| (C) Nitrogen requirements<br>(D) Phosphorus requirements | Production–Agricultural policy | Medium term | C<br>D | | | C<br>D | FP+H1 and FP+H1+D1 |
| (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.

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 opinions of the research workers were 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.

## Experimental strategy

The grouping of the components was not merely taxonomic, but rather had implications for the management of the experiments. The four 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 herbicide, 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 the area's 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 research workers were confident that this would occur because of the information available from 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.

Table 2 summarizes the research strategy followed for the five technological components.

## FIRST CYCLE RESULTS AND THEIR IMPLICATIONS

### Exploratory trials

The exploratory trials in 1978 attempted to analyze the agro-economic impact of the new technological components for representative farmers in the recommendation domain, as well as 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 agro-economic feasibility of developing corresponding technological alternatives. In other words, the hope was to identify the priority problems and, at the same time, to 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 $2^4$. 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 the main effects and interactions, should they exist. 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 3 shows the main effects by location and the average for the recommendation domain. As can be observed in the Table, 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 practically nil, with positive and negative values around zero, depending on the location. With this consistency in results obtained across locations, a combined statistical analysis was carried out for the group of experiments, treating the locations as repetitions.

A highly significant difference was found for the weed control and planting distribution-density components (at the 1 per cent level). The interaction of the two components was statistically significant at the 10 per cent level which, even if not conclusive, clearly indicated a research path to be followed. Since each factor of the interaction was highly significant, the agronomic explanation that stemmed from this relation-

**TABLE 3**
Exploratory Trials: Main Effects by Location

| *Means of treatments* | *Average yields by location* | | | | | *Average yield for the recommendation domain* |
|---|---|---|---|---|---|---|
| | *I* | *II* | *III* | *IV* | *V* | |
| | (*tons/ha, 14 per cent humidity*) | | | | | |
| $H_0$ | 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 |
| $D_0$ | 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 |
| $N_0$ | 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 |
| $P_0$ | 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*—phosphorus.)

ship seemed to be that more efficient weed control might eliminate weed competition for light, space and perhaps nutrients, allowing for a more densely planted and better distributed planting alternative.

With respect to the nitrogen and phosphorus components, Table 3 shows that there was virtually no impact on yield. The statistical analysis confirmed that that 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 a good soil structure and high natural fertility. In addition, in the maize/bean rotation, the bean crop probably contributes nitrogen to the maintenance of natural soil fertility; there could also be a residual effect from the phosphorus applied to the beans in the second cycle (around 10 kg of N, 40 kg of $P_2O_5$ and 10 kg of $K_2O$).

In analyzing the economic feasibility of the technological alternatives incorporated in the exploratory trials, the agronomic impact was used as

**TABLE 4**

Economic Analysis of Exploratory Trials: Viability of Alternative Technologies in Chemical Weed Control and Spatial Arrangement-Density*

| *Concept* | *Technological alternatives* | | | |
|---|---|---|---|---|
| | $H_0D_0$ | $H_0D_1$ | $H_1D_0$ | $H_1D_1$ |
| Yield (ton/ha) | 3·6 | 4·2 | 4·2 | 5·5 |
| Adjusted yield (−10 per cent) | 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 phosphorus requirements show no signficant differences between treatments and so were not included in the economic analysis.

** Field price of maize.

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 with the actual farmer practices in the recommendation domain. Table 4 shows that the $H_1$ and $D_1$ alternatives presented an ample margin of profitability, with marginal rates of return (MRR)[6] of around 700 per cent. 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 other variables considered in the exploratory trials (nitrogen and phosphorus) there were no significant differences in 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.

## 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 dosage, (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 conducted 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 per cent 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, 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 per cent at each location, as well as in the combined analysis. The 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 at 0, 5, 10, 20 and 30 days after planting, and Gesaprim 80 and 2,4-D (including the farmers' 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 with 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 phosphorus*

Two nitrogen by phosphorus levels experiments were planned. The design utilized was a 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 these problems, the consistency of the results with those previously reported for the exploratory trials added support to the original hypothesis, i.e. 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 results of the exploratory trials with respect to herbicides and spatial arrangement-density, together with the high marginal rates of return for the research components, planting 50 000 plants per hectare and using Gesaprim 80 at 2·5 kg/ha, 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. These results were qualitatively (types of herbicides) and quantitatively (dosage of 2 kg/ha in this case) confirmed by the results of the levels trials. This, along with the high economic margin of profitability for the various components, led IDIAP to formulate recommendations for farmers in the area after only one cycle of experiments.

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

(1) Given that the hypothesis about the agro-economic 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. The conventional tractor tillage, which prevailed in the area, was to be contrasted with zero tillage.

(2) Given the impact obtained from the trials on herbicides and spatial arrangement-density, and the interactions observed between both 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 to 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, this 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 to 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 these 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.

## BEYOND THE FIRST CYCLE: TECHNOLOGY VERIFICATION, TRANSFER AND ADOPTION

### Results and implications of the second cycle

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.

Four exploratory trials were planted which included this variable along with spatial arrangement-density and nitrogen and phosphorus 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 per cent) 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, a comparison of the costs associated with the two systems showed that zero tillage resulted in a 44 per cent reduction as compared with the conventional tillage system. This reduction was 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. 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. Those observations indicated that both the pre-emergence applications of Gesaprim and the post-emergence 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 (starting in 1980, the credit program for maize de-emphasized fertilizer use) may lead, in the near term, to a decrease in fertilizer use with no effect on yields.

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 to assure an 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 per cent) and initiate fertilizer trials on sloping lands (slope more than 5 per cent).

(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 the costs to be assumed by the farmers themselves.

## The third cycle: Verification and demonstration

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.

Because the analysis of exploratory and levels trials verified the conclusions of previous cycles, the remainder of this section concentrates on verification trials and demonstration plots. (For a detailed description of these results see Martínez and Arauz.[3])

### *Verification trials*

The three verification trials conducted during the third cycle combined the best technological alternatives for representative farmers identified in the exploratory and levels trials. They included tillage systems, chemical weed control, spatial arrangement-density and fertilizer applications. In the light of the fact that the new herbicides were already displacing 2,4-D in the area, the 'farmer practice' in weed control was changed to that of

Gramoxone use. The rest of farmer practices were kept as defined at the planning stage. The design of the three verification trials was as follows:

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

*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 hectare, planted in rows.

*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 hectare, planted in rows.

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

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 5. 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), TA 1 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).

**TABLE 5**
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 |
| Adjusted 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 (three tractor passes) | 48·00 | | |
| Chopping (2 days) | — | 10·00 | 10·00 |
| Gramoxone (1·5 liters/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 litre/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.

*Demonstration plots*

During the third cycle, three representative farmers in the area agreed to grow their crop using zero tillage. These demonstrations were totally managed by the co-operator with only some technical advice from the research team, The co-operating farmers paid for most of the production inputs and they assumed the production risks; IDIAP paid a portion of the herbicide cost. The research team maintained information contact with the co-operators 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 1 and 2 ha. 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 one location was it necessary to clear weeds and stubble from the previous growing cycle before herbicide application. In the other locations 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 liters. 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.

**Farmers' response**

Besides the implementation of verification and demonstration plots, the technology transfer process followed in the project involved farm field days at the plot sites to discuss the alternative technologies involved. With these elements and the degree of communication which existed between farmers in the area (they were organized in three *Juntas Agrarias*, mainly for buying inputs and obtaining credit), their response exceeded initial expectations.

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 project, including an assessment of the social rate of return to the investment required in order to implement OFR methodologies in Caisan.[4]

The evaluation included an adoption survey related to the technologies generated by the project. Table 6 shows the levels of adoption by 1982 of the technological alternatives recommended to farmers. By comparing these with data from the original 1978 survey, the patterns of adoption over time were also derived.[4]

The high rates of adoption of the recommended practices among Caisan farmers, particularly considering that the research project had only been in operation for four years (three cycles), stands as a testimony

**TABLE 6**
Adoption Survey: Levels of Recommended Technologies

| *Technological alternatives* | *Farmers* | *Maize area* |
|---|---|---|
| | (*per cent*) | |
| 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 minimum tillage | 43·5 | 23·0 |

Source: Caisan survey, first cycle, 1982.

to the validity of the research methodology which led, in such a short time, to the development of appropriate technology for the target farmers—the final judges of the usefulness of production-oriented research.

## CONCLUSIONS: COST EFFICIENCY AND SPILLOVER EFFECTS OF CAISAN

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 their operational development.

In this respect, IDIAP and Caisan illustrate the process of institutionalization of on-farm research within national research structures. The institutional strategy of IDIAP provided the framework for the initial development of Caisan. The progress of the program and the methodological experiences arising from its implementation have provided solid evidence of the validity of the research procedures used. Farmer response, in terms of their adoption of the resulting technologies, is proof of the degree to which program recommendations fitted their circumstances. Also, the speed at which the adoption took place is a clear indication that the research opportunities incorporated in the program were, in fact, important production problems for representative farmers in the area.

The best indicator of the cost efficiency of the methodology utilized is the social rate of return to the investment required to implement the OFR methodologies; the evaluation carried out in 1982 provided this information. The rate of return, using the most conservative figures, was

118 per cent, clearly exceeding the opportunity cost of capital. When less conservative assumptions were made, the rate of return rose to 325 per cent. These results, together with experiences of other countries,[5] reaffirm the conviction 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), Sub-programs (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. The central management of IDIAP was organized under 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 research workers. At present they include five priority areas in agriculture, involving the work of 24 national research workers, and three priority areas in livestock, with 21 research workers.

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