THE ADOPTION OF NEW MAIZE TECHNOLOGY IN PLAN PUEBLA, MEXICO

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FOREWORD:ON LAUNCHING THE STUDIES AND MOTIVATING HYPOTHESES

Launching the Studies

The study described in the following chapters is one of a series aimed at enlarging understanding of the factors impinging on the adoption of new maize and wheat technology. Better understanding of the elements shaping the diffusion of new cereals technology can help governments and development assistance agencies to increase farmer income, hence the interest in the topic. Interest increased as controversy about effects of introducing new technologies attracted widespread attention to the theme.

CIMMYT, with its mandate defining its role in the development and diffusion of maize and wheat technology, quickly assumed a participant's role in the discussions. The concern and the interest emanating from the critical importance of the theme stimulated CIMMYT to look for a modus operandi through which patterns of adoption and the forces shaping those patterns could be identified. Better understanding of these relationships would influence CIMMYT efforts to develop new technology, the orientation of its training program, and the approach taken in counseling governments about national programs.

In order to better comprehend what influences farmer response to new technology, CIMMYT set out to facilitate the research on which this and the other studies of the series are based. We decided to examine eight cases in which maize or wheat technology had been introduced to farmers. In identifying programs for study, we limited consideration to those in which the technology had been available to farmers for no less than five years and in which no less than 100,000 hectares of land might have been affected. Eight programs were selected for study. For maize the focus was on Colombia, El Salvador, Kenya west of Rift Valley, and Mexico's Plan Puebla. For wheat, programs in India, Iran, Tunisia and Turkey were considered. CIMMYT's maize and wheat staff participated in the selection of these programs. With their knowledge of programs around the world it was possible to choose a varied set of experiences—e.g. programs with and without irrigation, with and without effective price guarantees, with massive extension effort and with virtually none.

To the extent possible, each of the adoption studies was under the supervision of an indigenous economist. In only one case was it necessary to turn to an expatriate and there we had the good fortune to collaborate with a researcher with several years experience in the area. Each of the collaborators shared CIMMYT's concern for farmer response to new technology.

Beyond sharing this concern, each collaborator had an interest in farm level research done in close cooperation with agricultural scientists. The importance of this interest emerges from our conviction that agricultural scientists who are knowledgeable about a particular maize or wheat area can contribute substantively to research on the cereals economy of that area. Their special knowledge about the interaction between plants and their environments is important in identifying agro-climatic zones, critical periods for the crop, and activities which are essential to effective cultivation. Many agricultural scientists played a prominent role in these studies; each warrants our gratitude for his contribution.

As the studies were completed it became apparent that much could be said for publishing them in a standard format. With several serving as Ph.D. dissertations and others as less formal research pieces, a common format could only be achieved through reworking the original monographs. In every case but two, then, CIMMYT's publication is an abridgement of a longer piece. The Indian study, itself a review of the findings of several other research efforts, is being published in its entirety with no effort to recast it in the form of the others. The Puebla study is also presented unabridged.

In making the abridgements we have followed certain norms. Mathematical proofs have been eliminated, literature reviews have been included only where they relate to points which are unique to a given study, and the discussion of the hypotheses motivating the studies have been dropped. This last decision arises from recognition of the substantial commonality of these hypotheses among the studies. This suggested that, rather than presenting essentially the same discussion in the text of each abridgement, the hypotheses could be treated once in an abbreviated form for all studies.

The Hypotheses

While each of the studies examines a somewhat different set of circumstances, all depart from the same general assumption about farmer behavior. The assumption is that farmers are income-seeking risk averters who are sensitive to the nuances of the environment in which they farm and that they are generally effective in their decision making. For the six studies based on original survey data and to a more limited extent for the study of Plan Puebla, this common point of departure leads to a great deal of similarity in the motivating hypotheses.

Given a farmer oriented by the assumptions described above, we might expect to see relationship between the adoption of elements of the new technology and 1) characteristics of the farmer—his age, education, family size, farming experience, off-farm work, percentage of land owned, 2) characteristics of the farm—its agro-climatic region, competition of industrial crops, relative importance of cereals, nearness to markets, farm size, 3) characteristics of government programs—access to credit, access to information (though extension agent visits or visits to demonstration plots).

Some of the relationships between these variables and the adoption of elements of the new technology are more arguable, some less. Least arguable are hypotheses relating adoption to education, farming experiences, percentage of land owned, more favored climatic regions, relative importance of cereals, nearness to markets, farm size, access to credit, and access to information. With other things equal and accepting our assumptions that farmers are income-seeking, risk-averting, sensitive, and effective maximizers, virtually no one would argue that any one of these relationships should be negative.

Somewhat more arguable is the relation of age and family size to adoption. Even here it is likely that only a few would argue that these relationships might be positive.

Most arguable are the relationships linking adoption to off-farm work and competition of industrial crops. With respect to the former, some hold that the relationship is positive as more off-farm work implies more income, therefore a greater capacity to bear risk, hence a greater willingness to adopt new technologies. Others hold the converse, arguing that more off-farm work implies less interest in the farm, hence less willingness to put in the time and energy associated with taking on new technologies. So too for industrial commodities, where those who see the relationship as positive allude to greater experience with improved inputs and larger incomes while the contrary view rests on capital restrictions and the high opportunity cost of labor.

With knowledge of the relationships among these variables, researchers and policy makers can better develop and diffuse new technologies. Some of the variables considered, e.g. age and family size, are beyond the control of these decision makers. Nonetheless, by incorporating them in the analysis the effects of variables subject to their control are more clearly discerned. Knowledge of how these variables, e.g. agro-climatic zones and extension programs, relate to adoption can be of critical importance in affecting the development and diffusion of new technology.

With this rough sketch of the general argument, readers wanting more detail about the derivation of the hypothesized relationships can turn to the relevant original piece from which this series of abridgements was drawn. In all cases the studies feature the effects of agro-climatic region and farm size on adoption of elements of new technology. This emphasis is related to the earlier controversy about the effects of new technology where these two factors played prominent roles.

Before moving to the abridgement, some attention to the phrase "elements of the new technology" is warranted. Much has been made of the concept of a package of practices in the introduction of new technology. We've chosen to look at this a bit differently, taking the view that the differences in risk, expected income, and cost of each element of the technology are large enough to outweigh the effects of the interaction among these elements. That is to say, perceptive and prudent decision makers might well choose to take up only a part of the package rather than the entire package. For the programs studied, the two dominant elements in the package are improved seed and fertilizer. These two were analyzed as dependent variables in each of the studies. Of lesser importance are such elements as seed treatment, date of planting, method of planting, use of herbicides, use of pesticides, planting density, and seed bed preparation. Nevertheless, where any of these was recommended and where data are adequate, these are also treated as dependent variables.

While CIMMYT has been associated with these studies since their inception, the opinions expressed by the authors are not necessarily endorsed by CIMMYT.

What Follows

This report describes the adoption of more intensive maize technology in the Puebla area of Mexico. It is based on data made available to CIMMYT by Plan Puebla and relies especially on the annual yield survey. I'd like to thank, without implicating, several whose comments have helped the report, among them: James Bemis, Steven Breth, Hugh Bunting, Ralph Cummings, Jr., Reggie Laird, Gregorio Martinez, and Robert Osler. And a special thanks for Michael Sainz who worked up the data.

Donald Winkelmann
El Batan

I. SETTING THE SCENE

For some 20 years, from the mid-1940's to the mid-1960's, Mexico was the scene of active programs aimed at increasing agricultural production, especially of maize and wheat. These programs were a joint undertaking of the Ministry of Agriculture and the Rockefeller Foundation. By 1965 the efforts in wheat had achieved preeminent success, with average yields moving from roughly three quarters of a ton to some 2.5 tons per hectare, an increase of over 200 percent. This substantial increase rested on new varieties, widespread use of fertilizer, irrigation, and weed control – all commonplace in the wheat economy. The situation was sharply different in maize, even though parallel efforts had been made. Average yields increased from roughly 0.7 tons to a bit over 1.1 tons per hectare, something under 50 percent.

Several critics sought to explain why the one program worked so well, with virtually 100 percent adoption of new varieties and dramatic increases in yields, while the other lagged behind, with less than 15 percent of potential area in new maize varieties and barely perceptible annual increases in yields. One explanation [1] held that the difference emerged from wheat's cultivation on irrigated land by large farmers as contrasted with maize's cultivation on rainfed land by small farmers. These differences in the natural and economic circumstances of farmers were seen as primary forces in shaping the very dissimilar evolutions of the two programs.

A second related explanation held that small traditional farmers are not amenable to change. Something, perhaps an intransigent traditionalism, made such farmers unreceptive to new technologies, no matter what these promised in terms of yields and profits.

How, then, to improve the livelihood of small farmers? Under what circumstances would they shift to new technologies? Indeed, would they shift at all?

These were the questions being asked by Mexican specialists in agriculture and their colleagues in the Rockefeller Foundation's Mexico office in the mid-1960's. They were particularly relevant questions given the threat of world wide food shortages and the related problem of low incomes and malnutrition among farming populations. It was precisely the small traditional farmers of Mexico and the world who suffered most from low incomes and malnutrition, precisely these farmers who seemed most reluctant to take up new practices which apparently promised relief from their straitened condition.

Motivated by the difficulties with maize in Mexico, a picture reinforced by similar scenes from around the world, Rockefeller Foundation set out to design a new program. It was to have a thrust unlike that of previous efforts and it was to be set in an environment carefully chosen to make evident its strengths and weaknesses.

The program came to be called Plan Puebla, named after the valley where it was implemented. This monograph describes Plan Puebla. It draws heavily on data made available by Plan Puebla staff and, in its early chapters, on the substantial number of papers already written about the Plan. While an attempt is made to describe each of the Plan's important features and experiences, attention is concentrated on the extent to which various classes of farmers adopted the recommended technologies and the elements which might have been instrumental in shaping their diffusion.

The remainder of the introduction describes in more detail the goals of Plan Puebla, outlines the factors leading to the choice of the Puebla Valley, and presents some characteristics of maize production in the area.

Program Goals

Plan Puebla is a development effort aimed at the traditional farmer. At its inception it was described as. . . "an attempt to tackle simultaneously. . ." two development problems –food shortage and low incomes in agriculture. . . "by obtaining massive increases in yield among small holders. . ." [2].

From its initiation the program had two overriding objectives. The first was to develop, field test, and refine a strategy for increasing yields of a basic crop among small holders. The second was to train technicians in the use of this strategy. A third objective, added later and probably designed to provide a standard against which progress could be measured, was to double maize yields in the program area.

Consider the two primary goals in the light of earlier experience in Mexico and elsewhere. Those involved in developing and diffusing new maize technologies for Mexico had apparently followed the classic pattern. They had worked diligently on experiment stations to develop new varieties and the results of trials showed that they had been effective in these efforts, at least for certain areas. Varieties in hand,

and again based on experimental work, they had formulated agronomic practices — dates of planting, fertilizer levels, etc.

These new technologies or production strategies seemed to promise substantial increases in yields over traditional practices. More important, they apparently promised a sharp increase in profits. The technologies were then put in the hands of the extension service for diffusion among farmers.

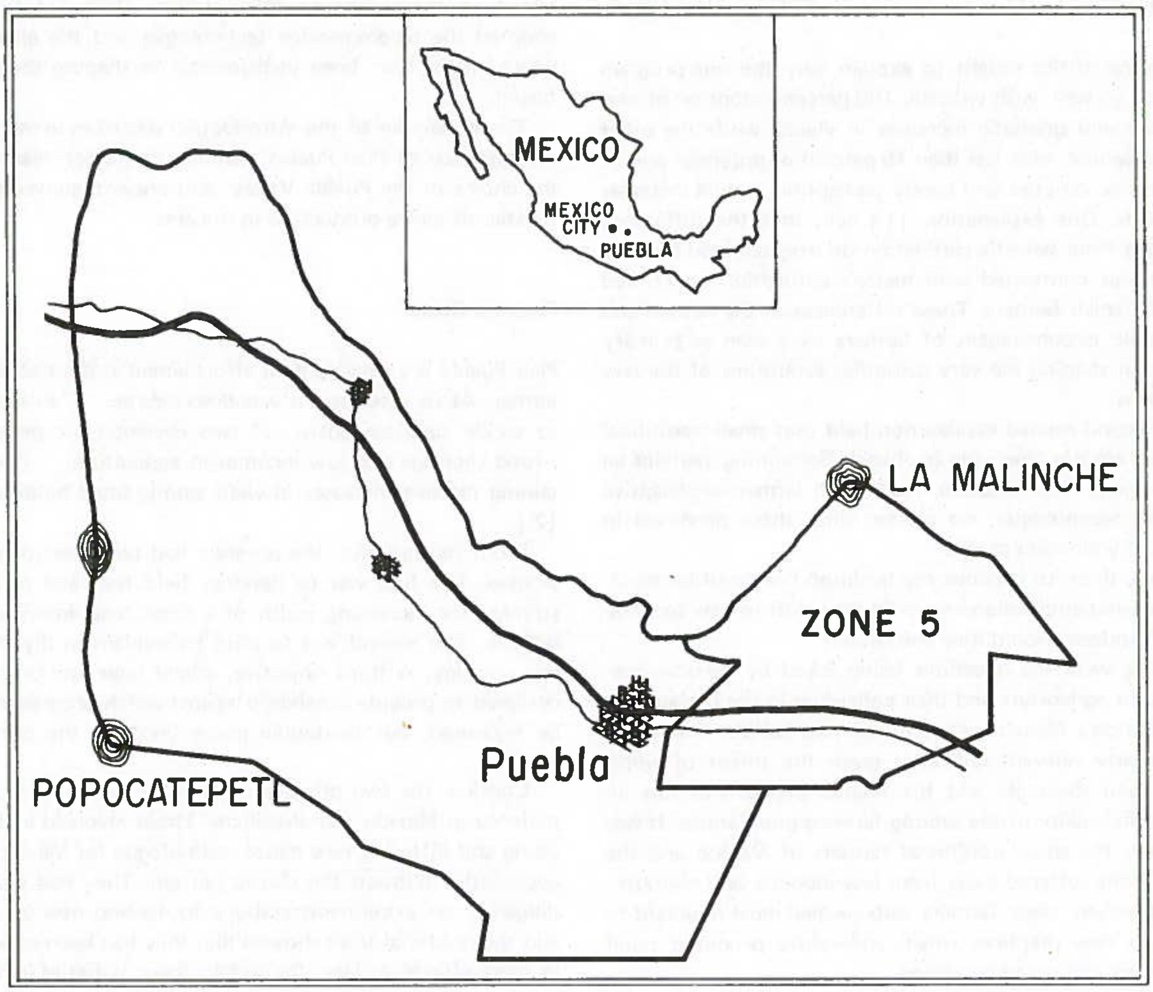
There, in substantial measure, the expectations of researchers were disappointed. Farmers, especially those of the rainfed altiplano where the bulk of Mexico's maize area is found, persisted in their old ways, rejecting the strategies offered by representatives of Government's agricultural establishment.

What went wrong? Were the strategies too complex? Too expensive? Did they not fit the cropping pattern? Were such essential inputs as viable seed and fertilizers not available? Had the farmer no credit? Were the promised profits more apparent than real?

These experiences and questions led some of those associated with Mexico's maize program, with the Graduate School of Agriculture, with The International Maize and Wheat Improvement Center, (CIMMYT), and with the Rockefeller Foundation to organize a new experiment. The experiment postulated that a method for attaining yield increases could be found. What was required was an experimental approach, an approach which took nothing for granted but regarded each element in the chain from researcher to farmer as a variable.

There was in all of this one critical assumption, never made explicit but always there. The farmer was regarded as purposive in his behavior, goal oriented and with profits as an important goal. Little heed was given to the possibility that traditionalism was the force blocking change. Rather, the difficulty was seen to be on the side of the institutions charged with developing, diffusing, and supporting new technology. This view was not widely held in 1966, certainly not among leaders of those critical agricultural institutions. Their view, again not often made explicit, was that,

Fig. 1. The Plan Puebla area.



in fact, small farmers were tradition-bound and that the traditions themselves prevailed against the diffusion of new technology no matter how profitable the technology nor how effective the extension service.

With the view that farmer behavior is purposive, with emphasis on profits, what was needed was a system for developing and delivering useful technology to farmers. Discovering that system was the primary objective of the project.

Once the new system was operational and demonstrably effective in fomenting yield increases, the second primary goal would become critical. That goal was to train others, from Mexico and the rest of Latin America in particular, in the use of the system. These newly trained people were to then transfer the methodology to their own regions or countries, promoting yield increases there.

All of this, of course, would lead straight away to increases in food production and to improvements in the nutritional status of the adopting farmers. It would also lead to other changes in practices as researchers, extensionists, and farmers applied the lessons learned in maize to other crops. The system, then, would be a vehicle for introducing a dynamic element into traditional agriculture.

And what of those suspicious decision makers, those who pointed to traditional farmers as recalcitrant conservatives? Their attitudes would necessarily change as changing practices and yield increases signaled the farmers' willingness to adopt new technologies.

These were the goals that oriented the efforts of those associated with the project —ambitious but pragmatic, emerging from their own frustrated attempts to foster change.

Selection of a Site

Once committed to the idea of the project a site had to be found. Clearly it was neither feasible nor wise to think in terms of the entire country. Given the intentions, what was needed was an area with appropriate characteristics.

After careful deliberation among professionals representing several disciplines — e.g. soils science, maize breeding, communications — a set of characteristics was identified. In a general way it was thought necessary to site the project in an area which offered the possibility of obtaining a marked increase in maize yields.

More specifically, the experiment would best be undertaken in an area: 1) with a large number of small farmers; 2) where maize played an important role in the cropping pattern; 3) where the probability of loss due to drought, frost, or hail was small; 4) where government infrastructure in the form of credit agencies, market roads, and crop insurance was available; 5) and where farmers had ready access to markets with stable prices [3, pp. 130-1].

Given these characteristics, it was decided to locate the project in the Puebla Valley. The area is in a high valley, ranging in altitude from 2150 to 2700 meters above sea level, some two hours drive east of Mexico City. (See Fig. 1).

The list of desirable characteristics again signals the conviction of the project's initiators that, with the right circumstances, small traditional farmers would change their farming practices. What this list emphasizes is potential average profits and ready access to credit, to inputs, and to product markets. This is a tacit assertion that farmer behavior is purposive, oriented toward profits. What was needed was a profitable technology and a system for diffusing it. A unified strategy for achieving these ends was the aim of the project's experiment.

Characteristics of the Project Area [1]

Maize yields in the area selected appeared to average between 1 and 1.5 metric tons. In 1967 they were 1.3 tons per hectare according to data from a bench mark survey carried out by the project. Four weather stations in the area reported average rainfall from just under 800 mm to over 850 mm in the seven months from April through October. Soils vary but over 60 percent of the arable land is in essentially problem-free soils while about 35 percent is in soils where yields might be limited because compacted or impermeable horizons restrict root growth. Even so, given the rainfall, soils, and the growing season, it seemed clear that substantial increases in yields could be achieved through the introduction of new technology.

Farms and farmers. Looking now at the other characteristics thought to be desirable, the area fits all of the criteria well. The roughly 117,000 hectares of cultivated land were divided into farms which averaged 2.7 hectares according to surveys made in 1967 and 1970. This implies 43,300 farms in the area. Two thirds of the farms had less than 2.5 hectares of cultivated land.

Only 27.5 percent of the farms were completely privately owned. The remainder were in ejidos or were a combination of ejido and private property. The ejido is a peculiarly Mexican tenure form. Emerging from Mexican experience in land reform in the 19th century, its distinguishing characteristics are that it invests usufruct rights in the farmer but does not permit him to sell, rent, or mortgage the land. Roughly half of Mexico's cultivated land, both irrigated and rainfed, is in ejidos.

While the amount of land in ejido farms varies from place to place, such farms are generally small. In the project area farms with only ejido land averaged a fraction over 2 hectares. Again about half of the total of cultivable land was in ejidos. It should be noted that ejidos are usually farmed individually; something under 2 percent of Mexico's ejidos are collectives and none of these are in the project area.

About 75 percent of the farmers had 3 years or less of schooling. Many of them worked off the farm, with off-farm wage income making up nearly one quarter of the estimated net income. Crops contributed some 30 percent to net income. Nearly all of the area's farmers had heard of chemical fertilizer and over 80 percent of them had used it prior to the project's initiation.

Importance of maize. Maize occupied nearly 70 percent of the cultivated land according to the surveys of 1967 and 1970. The next crop in importance was beans – pole beans, bush beans, and scarlet runner beans, all of the genus *Phaseolus* – occupying just over 15 percent of the cultivated area. Maize and pole beans were often found intercropped.

Weather. Analysis of weather data suggested that probabilities of loss due to weather damage were moderate to slight. Two of the weather stations reported no frost in May and June, one station reported frost in May in 17 percent of the years and June frosts in 5 percent of the years. Frosts occur mainly in October through March causing little or no damage to maize. In 1974 an early September frost, one of the earliest on record, did cause extensive damage to the area's maize.

While hail occurred occasionally it didn't appear to be particularly worrisome. Three of the area's four weather stations averaged one hail storm in July and August, half that number in September.

Rainfall patterns were such that project specialists estimated the probability of severe drought at 0.1, with an estimated 60 percent reduction in yields, and moderate drought at 0.3, with an estimated 30-60 percent reduction in yields. The estimated drought frequencies and losses were thought to be low enough as to not influence average yields unduly, hence not significantly affect farmer response to a new technology.

Access to credit. Mexico has long had agricultural agencies catering to the needs of some of its small farmers. Notable among these was Banco Ejidal, a Government agency established in 1935 and reorganized several times since.[2] The Ejido Bank served Mexico's ejido farmers, i.e. the ejidatarios. The services it offered varied enormously from one part of the country to another.

There were also Government banks which served private farmers, the so-called pequeños propietarios who operate virtually all farms not classed as ejido. Chief among these banks was Banco Agricola. As might be imagined, banking services available to the smallest private farmers were limited.

In 1967 the Ejido Bank in Puebla made loans to only 925 farmers in the entire state. The Agriculture Bank made 60 loans, few of those to the smallest farmers. At least two factors contributed to the small number of loans. Bank procedures were cumbersome and at times demeaning, so that farmers were something less than eager to seek credit. The banks, on the other hand had suffered low repayment rates on their loans to small farmers. The Ejido Bank in Puebla reported repayment of about 40 percent of the loans made in 1967 [6, p. 196].

In short, then, while banking services existed in Puebla, they were not widely used by the area's farmers, neither ejido nor pequeño propietario.

Insurance. Crop insurance was also available, indeed was mandatory for those borrowing through the government banks. This service in Puebla is a part of a national program under Aseguradora Nacional Agrícola y Ganadera. That program has been roundly criticized by Puebla farmers as not paying out when payments are justly due and/or being too expensive. Moreover, until recently the insurance covered the loan rather than the crop itself. Critics of the program say that it is less an actuarially oriented insurance program, more oriented toward redistributing incomes from richer to poorer farming regions. Nonetheless, farmers wanting loans from the Ejido Bank or from the Agricultural Bank were required to buy insurance [6, p. 128].

Markets. Market roads in the area were good. Several paved roads ran through the project's domain, connecting all of the larger towns. Virtually every small town lies along or near to the feeder road.

Finally, markets with stable prices were available. Mexico has long had a system of price supports for basic commodities – maize, wheat, beans, and rice. Individual farmers were not always able to sell at these prices as CONASUPO, the agency responsible, was at times short of funds, or storage space, or particularly keen on enforcing quality control. Nonetheless, the very existence of the agency kept prices up and ensured that annual price fluctuations were not notable. The guaranteed price of maize remained at $940/ton from 1967 through 1972, and then went to $1200 in 1972, $1350 in 1974, and to $1750 in 1975. Meanwhile, area market prices ranged from a low of about $750/ton in 1967 to a high of over $2000/ton in early 1976 (12.50 pesos = 1 dollar).

Preview

What follows is a review of the experience of what has come to be called Plan Puebla. The next chapter treats the organization of the project's activities. The third chapter deals with what happened by describing the promise of the new technology, as manifested in the demonstrations and trials on farmers' fields, and the response of farmers to the technology, as manifested in its adoption. The fourth chapter treats factors which might have limited adoption of the technology. A final chapter offers a summary and conclusions.

The report focuses on Plan Puebla experiences during the period, 1967 through 1975. Its early chapters rely on several studies, especially [2], [4], [6], and [8]. It also relies heavily on two sets of data developed by Plan Puebla. The first comes from surveys undertaken in 1967 and in 1971 and the second from annual yield surveys.

Notes

1. Discussion in this section relies heavily on [4,p. 1-7].

2. In 1975 three Mexican agricultural credit banks were merged in what is now the Banco Nacional de Credito Rural.

II. ORGANIZATION OF PLAN PUEBLA

It was evident from the discussions that led to the founding of Plan Puebla that several levels of activities would be emphasized as work evolved. The two major questions were how to organize the experimental work so as to formulate recommendations and how to diffuse the information among the Plan area's farmers.

Experimental Work

Early consideration suggested that work on formulating technology should feature plant breeding and agronomy. This emphasis led to immediate incorporation of the relevant professionals on the Plan's staff. Research was initiated in 1967 with two plant breeders and two agronomists. Each was assisted by several field workers, often themselves farmers from the area. Their work was reinforced by professionals from CIMMYT headquarters, nearby in the Valley of Mexico.

Recommendations were formulated for the 1968 season. In that year they were tried on the farms of 103 farmers, the first participants in the Plan. The recommendations emphasized agronomic practices and relied on local maizes. These recommendations aimed at maximizing the average profits from fertilizer use.

Prior to Plan Puebla the Ministry of Agriculture had a single recommendation for rainfed maize in the area. This was used as a point of departure by Plan professionals in designing their experimental work. At the conclusion of the first year's experiments this recommendation was revised in a second approximation to suitable recommendations. Successive approximations were made in 1969 and 1970. In 1971 there were additional recommendations for compacted soils and for an additional region. In 1972, recommendations were made for sixteen producing systems. For each system two recommendations were given, one for limited and one for unlimited capital. Some of these recommendations were altered slightly in ensuing approximations.

Work on varieties proceeded through 1972 when it was decided to phase out the program on varietal improvement. The decision was largely a consequence of evidence that some local varieties had extraordinarily high yield potential, on the order of five times the area's average yields.

Diffusion

It was decided to expand work on communications slowly, starting with one specialist in 1968, to four specialists in 1969, and to five specialists in 1970. This number was dictated by the decision to divide the area into five zones, the fifth coming under program recommendations for the first time in 1971. Each extension agent worked with field assistants, many of them farmers from the area. Supplemental professional expertise was available from CIMMYT.

In addition to disseminating information on the recommendations the extension technicians worked with groups of farmers to help them obtain credit, achieve timely delivery of inputs, and repay loans. This set of activities became so important in the early 1970's that the number of demonstration plots and field days was actually cut back because the extension force lacked time to both work with farmer groups and to mount demonstrations.

All of these activities must be seen in the context of the Project's goals — to develop and field-test a methodology and to train others in its use. During the first years the methodology evolved, a method which came to distinguish Plan Puebla from other programs with similar intent.

Plan Puebla Methodology

By 1969 the methodology was essentially fixed. It featured experimental work on farmers' fields; the use of farmer groups for disseminating information, getting credit, acquiring inputs, and repaying loans; socio-economic evaluation; and administration aimed at coordinating the work of researchers, extensionists, agencies providing credit and inputs, and farmers.

Experimental work on farmers' fields was a part of the Plan from the outset. Working through farmer groups was introduced in 1969. Socio-economic evaluation and coordination were part of the project from the beginning but their roles expanded as new potential for these functions became evident. Coordination especially increased in importance as work with the several government agencies in the area expanded.

After 1974 emphasis within Plan Puebla changed. Coinciding with a growing concern by the government for increasing production in traditional agriculture, Staff began to concentrate even more on the training function. Extension workers from all over Mexico were brought to Puebla where they were trained in the Plan Puebla approach to facilitating change among small farmers.

In effect, after 1974 Plan Puebla operated two sets of activities in tandem. The one, through the operational arm of Plan Puebla, continued to emphasize increasing the area's production of maize and responding to other demands of the area's farmers. The second, through a training center, emphasized training advisors for other programs in Mexico. Collaboration between the two is close with Plan Puebla providing the expertise and the laboratory for the training center.

Training

Training of Mexican and foreign nationals was initiated in 1970. Over the next four years 45 Mexican and 25 foreign national participated in the training program. Of these, 44 received six to nine months of training at the technical level while 22 were trained in technical issues at Puebla in conjunction with work on Masters' degrees in the Graduate College at Chapingo.

The orientation of training clearly bore the stamp of the experiences and philosophy of a program aimed at developing and diffusing new technology. First, it featured concentration on interdisciplinary work, work combining the functions of breeding, agronomy, evaluation, and coordination. Second, since coordination and planning were recognized as critical functions within Plan Puebla, the program aimed at developing trainee skills in project planning and management. Finally, just as training was emphasized in Plan Puebla, the training program sought to develop the training skills of the trainees so that they might in turn serve as trainers.

With the change in program financing in early 1974 and the accompanying change in program emphasis, the training program has also shifted its orientation to one more in keeping with the Plan's new responsibilities.

Financing Plan Puebla

For the first years of its operation Plan Puebla was financed by grants from the Rockefeller Foundation through CIMMYT, by CIMMYT itself, and by the Graduate College of Chapingo. During that period, from 1967 through 1973, Rockefeller Foundation contributed $560,000, CIMMYT contributed $333,000, while the Graduate College contributed $30,000. This is a total of $925,000 for activities in Puebla aimed at developing and field testing the methodology. Related activities and costs were $87,000 for consulting services to the Project team, $112,000 for consulting with other programs within Mexico and in other countries, and $168,000 for training.

In 1974 the program was taken over by the Mexican Ministry of Agriculture and directed from the Graduate College at Chapingo, a dependency of the Ministry. At that time, as noted previously, the aims of the program changed with much more emphasis put on the training of Mexican extension agents.

Staffing

The initiators of Plan Puebla regarded the selection of staff as a crucial element in determining the success of the Plan. It was evident that the work would be physically demanding, that it would require a great deal of knowledge about the decisions faced by farmers, and that it would require a sound knowledge of the biological phenomena impinging on maize production in the area. This list of qualities meant that every effort had to be made to attract and hold energetic, well trained, and innovative people.

The criteria employed in staff selection led to a team than was not representative of the general level of competence found in agricultural programs within developing countries. In a sense, then, here the experiment loses generality. If, that is, the methods developed required qualities different from those generally found in national programs, then the resulting methodology would have limited applicability. While recognizing this possibility and emphasizing the crucial role of competent staff, the program's initiators believed that developing and field testing the program required more skills than would be required to operate the program once a system was established. Given this perspective, they could, at one and the same time, insist on high standards for staff and still maintain that the methods developed would be generally applicable.

Table 1 shows the staffing pattern from 1967 through 1975. Two classes of personnel are represented in the table. The first is people associated with the project on a full time basis. Some 53 man years of staff time, involving 43 different people were absorbed by the project from 1967 to 1973. In 1974 and 1975, over 30 man years of professional time were contributed by staff. The second is additional professional counsel from technical advisors. Most of these were staff members of the Post Graduate College at Chapingo or of CIMMYT. As a final note on staffing, many of those associated with Plan Puebla in the past are still involved in agriculture in Mexico, most with programs aimed at small farmers.

Summary

Plan Puebla's organizational format and *modus operandi* emerged early in the life of the project. The format featured a coordinated effort in agronomy, communications, and evaluation. In terms of methods, the hallmarks of Plan Puebla are research in farmers' fields, diffusion of technology and inputs through groups of farmers, continuing evaluation and feed back to the professional staff, coordination of the interests of farmers, plan staff, and local institutions.

In one sense the experimental phase of Plan Puebla, i.e.

Table 1. **Professional personnel associated with Plan Puebla from 1967 to 1975.**

	1967	1968	1969	1970	1971	1972	1973	1974	1975
Staff	5	6	10	11	12	10	9	16	25
Coordinator	1	1	1	1	1	1	1	1	1
Agronomy	2	1	2	2	2	2	2	2	2
Breeding	2	2	2	2	2	1	—	—	—
Evaluation	—	1	1	1	1	1	1	1	1
Extension	—	1	4	5	5	5	5	5	5
Trainers	—	—	—	—	—	—	—	7	10
Advisors	2	3	4	5	5	6	6	4	4

the phase in which methods were identified, tested, and evaluated, was brief. By 1970, after some two years of effort in the area, the methodology was largely fixed. Moreover, it appears that the research for alternative approaches was limited. Still, there is evidence that emphasis on activities changed as experiences accumulated.

III. RECOMMENDATIONS, POTENTIAL GAINS, AND FARMER RESPONSES

The intent of this chapter is to compare the yields associated with the recommended technology with that of the technology typically used in 1967. It will be seen that apparent potential gains are substantial. By contrast, farmer adoption of the technology does not meet the expectations engendered by yield differences.

Recommendations and Experimental Yields [1]

A ministry of Agriculture recommendation was available to Puebla farmers in 1967. It featured the hybrid H-28, 80 kg/ha of nitrogen, and 40 kg/ha of phosphorus with 40,000 plants per hectare. This recommendation was used as the point of departure for plan sponsored experimental work

According to the 1967 bench mark survey some 62 percent of the farmers applied fertilizer on maize. Some 72 percent used less than 40 kg/ha of nitrogen [3, p. 134]on maize. The average fertilizer application was 34 kg/ha of nitrogen, 14 kg/ha of phosphorus, some potash. Approximately 25,000 plants were being grown per hectare. Many farmers were applying a fertilizer mixture of nitrogen, phosphorus, and potash supplied by the national fertilizer monopoly, Guanomex. Few farmers used hybrids, less than one percent in 1967, but most farmers knew of them and many had tried them.

In 1967 agronomic work was initiated on farmers' fields. The experiments used both local maizes and recommended hybrids. The results suggested that hybrids had little advantage over the local maizes, that fertilizer levels could be increased, and that planting densities could also be increased. For 1968 the Plan recommendation was 130 kg/ha of nitrogen, 40 kg/ha of phosphorus, and 50,000 seeds per hectare of the farmer's local variety.

Experimental work in 1968 and 1969 led to three recommendations in 1970. By that time the area had five extension zones. Two of the recommendations applied to four of the zones — 130 of nitrogen, 50 of phosphorus, and 50,000 plants for deep soils and 110 of nitrogen, 50 of phosphorus, and 50,000 plants for areas with a compacted horizon. The third recommendation applied to the fifth zone and featured 80 kg/ha of nitrogen, no phosphorus, and 40,000 plants. A reduction of the relative price of fertilizer in 1971 led to an increase in the recommended nitrogen levels, from 80 kg/ha to 100 kg/ha, and planting densities from 40,000 to 50,000 plants in the fifth zone.

New sets of recommendations have been developed — e.g. recommendations for those with limited capital and recommendations incorporating local peculiarities. In general, however, the recommendations described are the basic strategies for the area. As compared to practices in use when the project was initiated they feature more nitrogen, more phosphorus, and a greater planting density.

The new strategies also call for early application of some nitrogen and all of the phosphorus as contrasted with the then prevalent practice of applying all fertilizer with the first cultivation. Application of phosphorus at the first cultivation makes that nutrient virtually unavailable to the plant at the time when it is most critically needed.

The additional yields promised by increasing fertilizers and plant densities were notable. In 1968 [see 4, p. 24] for deep soils the average estimated yield was 7462 kg/ha of maize using profit maximizing levels of 187 kg/ha of nitrogen and 81 kg/ha of phosphorus. This compared with a yield of 1028 kg/ha for the control treatment. Even so, such high levels of inputs were not recommended because it was recognized that 1968 was an extraordinarily favorable year for maize.

Based on yields and yield differences for a longer period the potential promised by the recommendations is lower but still significant. These differences are shown in Table 2. The yields are based on data from [4, Table 3.11, p 33] and include estimates for two soils types and three planting dates.

Even after deducting the farmgate cost of the extra fertilizer the potential advantage of the Plan recommendations seems attractive. This is evidenced in Table 3 where the cost of fertilizer has been put in terms of maize and the extra fertilizer implied by the Plan recommendations deducted from the extra yield attained.

Table 2. **Estimated average experimental yields (ton/ha) 1967-73 for various treatments in three zones of Plan Puebla.**

Zone	Conventional technology [b]	Plan-like technology [c]
1 - 4 (deep soils) [a]	1.72	3.91
1 - 4 (compacted soils) [a]	1.88	3.18
5	2.50	4.55

a/ [4, p. 33] reports experiments for several soils types and planting dates. Two soils types with three planting dates each make up 55 percent of Zones 1-4. An average of the six, weighted by area, was calculated and then used as described in footnote c. Remaining soils types in the region were characterized by few observations so were excluded from the averages. b/ [4, p. 33] reports zero N: zero P, 50 N:25 P, and 80 N:40 P. The average fertilizer application in 1967 was 34 N:14 P. This is called the Conventional Technology. Observations on the three points were plotted and the yield of the Conventional Technology estimated by interpolation. c/ Data reported in [4, p. 33] are estimated farmer yields, 80 percent of experimental yields. These were increased by 25 percent to give experimental yields.

Farmer Yields

As noted in the previous section, researchers were able to demonstrate substantial increases in yields with the recommended technologies. In this section the yields obtained by farmers are examined.

In each year from 1969 to 1975 Plan staff conducted a yield survey of farmers' fields. Samples were selected from each of two classes of farmers, from all farmers in the project area (general sample) and from farmers who were obtaining credit for maize under Plan auspices or through official banks (participant sample). Each sample was randomly selected. In the first case a two stage sampling procedure was used which identified first a segment and then a strip of maize within a segment. The farmer associated with the strip was then interviewed. In the second case farmers were selected from the list of credit users and then a strip of maize was identified for each selected farmer.

In 1969 and 1970 only the yield and plant density at harvest were estimated for each strip. From 1971 through 1975, in addition to yield and density, each farmer was asked about the application of nitrogen and of phosphorus. For 1972, 1973, and 1975, farm size was also recorded. The discussion of this section is based on yield data from 1971 through 1973. Early frosts, the earliest in over 50 years, make 1974 an extraordinary year. Yield data for 1975 were not available when this report was written.

To better reflect the change in yields accompanying the use of the recommended technology each observation, irrespective of sample, was considered for one of four groups. The first group approximates the 1967 conventional technology in Zones 1 through 4 and includes all of those applying less than 50 kg/ha of nitrogen, less than 25 kg/ha of phosphorus, and with between 15,000 and 35,000 plants at harvest time. The second includes the same observations but for Zone 5. The third group is made up of those observations from Zones 1 through 4 with 90 to 160 kg/ha of nitrogen, 30 to 70 kg/ha of phosphorus, and 40,000 to 55,000 plants at harvest time. The fourth includes observations from Zone 5 with 70 to 140 kg/ha of nitrogen, less than 40 kg/ha of phosphorus, and 35,000 to 55,000 plants at harvest time.

Groups one and two are representative of prevailing practices in 1967 while groups three and four approximate the practices recommended by the Plan. The average yields over three years 1971 through 1973 are seen in Table 3. Earlier years, 1968 through 1970 were excluded because of the absence of data on fertilizer use. In all cases the experimental yields for trials on farmer's fields exceed the estimated farmer yield. The difference is far more notable in Zone 5 than in Zones 1-4.

To compare farmer yields with those of Table 2 it is necessary to average the two yields given there for Zones 1-4. Data in [4, p. 33], can be used to establish the proportions of land in deep soils and with connected horizons. These proportions can then be used as weights. With 60 percent of the area thought to be in deep soils the resulting averages are 1.78 tons/ha for the conventional technology and 3.62 tons/ha for Plan recommendations. These averages represent Zones 1-4.

Comparison of the yields in Table 4 again show that those using roughly the recommended treatments achieving substantially higher yields than those using 1967's conventional practices. Even after deducting the cost of fertilizer (see Table 5) the yield advantages are still evident.

Yield increases in Zones 1-4 under farmer circunstances (Table 5) compare with those under experimental circumstances (Table 3) in Zones 1-4. For Zone 5, the increase under farmer circumstances is somewhat smaller than under researcher control. In either case yield increases appear to be large enough to appeal to the area's farmers.

Farmer Response

The first effort to attract farmers to the new technology was made in 1968 when demonstration plots were set out on the fields of 103 farmers. These plots were under the supervision of Plan professionals who worked closely with farmers to ensure that all recommendations were carried out.

By 1969 four extension agents were assigned to the Plan, one to each of the first four areas incorporated in Plan activities. These men, each supported by one or two field assistants, were involved in a multi-media campaign incorporating radio, newspapers, a movie, and portable sound systems. Their aim was to attract farmers to the Plan, to then help interested farmers form groups, to instruct the groups, and to then help groups to obtain credit and needed inputs.

From 1970 on each of the Plan's five Zones had an extension agent with assistants. Their work, which started with emphasis on demonstration plots and field days, moved even more toward assisting groups in obtaining inputs and repaying loans. By 1972 and 1973 the number of demonstration plots actually declined as extension agents, by now heavily committed to helping groups, found themselves with insufficient time to maintain the number of demonstration plots [6].

The combination of activities — experimenting, demonstrating, promoting the Plan, facilitating input flows —undertaken by Plan staff, led to rapid expansion in the number of farmers associated with the Plan. Since that early flourish the number has increased at a lower rate.

Participation in the Plan has been measured in several ways but two predominate. One is the number of farmers who received credit for producing maize. A second relates to the number of farmers following some portion, perhaps all, of the Plan's recommendations. The second measure seems the most appropriate, because some farmers receiving credit are not following recommendations while some farmers not receiving credit are doing so. Even so, data on the first measure is instructive. Table 6 describes a series of

Table 3. **Estimated adjusted yield increase (ton/ha) of Plan-like strategy over conventional strategy under experimental circumstances.**

Zone	Net yield increase
1 - 4 (deep soils)	1.35
1 - 4 (compacted horizon)	0.58
5	1.57

a/ Adjustment is made for the cost of extra fertilizer by converting each year's farm price of maize, multiplying and subtracting. Calculations based on [5, pp. 67-72], prices are average for 1967, 1971, and 1973.

Table 4. **Estimated farmer yields (kg/ha) with 1967-like and Plan Puebla-like strategies, averages for 1971 through 1973.**

Zone	Conventional technology a	Plan-like strategies b
1-4	1685	3434
5	1946	3113

a/ less than 50 kg/ha of N, less than 25 kg/ha of phosphorus, and 15,000-30,000 plants/ha in both areas. b/ 90-150 kg/ha of N, 40 to 70 kg/ha of phosphorus, 40,000-55,000 plants/ha for Zones 1-4 and 70-140 kg/ha of N, under 40 kg/ha of phosphorus, 35,000-55,000 plants/ha for Zone 5.

Table 5. **Adjusted yield (ton/ha) increase of Plan-like strategy over conventional strategy, under farmer circumstances, average 1971-73 (ton/ha).**

Zone	Net yield increase a
1-4	1.08
5	0.71

a/ Average yields for the conventional strategy were subtracted from average yields for the recommended strategy (see Table 4) and the on farm maize cost of additional fertilizer for each year was then deducted.

Table 6. **Number of farmers and area receiving credit for maize through Plan-associated agencies.**

	Farmers a		Area b	
Year	No.	Percent	Ha.	Percent
1968	103	0.2	76	0.1
1969	2,561	5.9	5,838	7.3
1970	4,833	11.1	12,601	15.8
1971	5,240	12.1	14,438	18.0
1972	6,202	14.3	17,533	21.9
1973	7,194	16.6	20,604	25.8
1974	8,159	18.8	26,351	32.9
1975	8,701	20.1	28,140	35.1

a/ Total number of farmers estimated at 43,300. b/ Total maize area estimated at 80,000 ha.

Table 7. **Percentage of plots in annual general survey receiving different levels of nitrogen, phosphorus and reporting different pre-harvest plant densities, Zones 1-4.**

	1971	1972	1973	1974	1975
Nitrogen [a]					
low	46.0	42.4	42.4	32.8	35.6
medium	18.5	12.4	19.4	17.6	16.1
high	35.5	45.2	38.2	49.6	48.3
Phosphorus [b]					
low	51.8	47.5	62.5	64.1	56.4
medium	5.3	11.3	7.6	6.1	5.4
high	42.9	41.2	29.9	29.8	38.2
Density [c]					
low	43.9	22.6	33.3	32.8	28.2
medium	29.6	32.8	32.7	29.8	37.6
high	26.5	44.6	34.3	37.4	34.2

a/ low, 0-50 kg/ha; medium, 50-80 kg/ha; high, over 80 kg/ha; *b/* low, 0-20 kg/ha; medium, 20-30 kg/ha; high, over 30 kg/ha; *c/* low, 0-30,000 plants/ha, medium, 30,000-40,000 plants/ha; high, over 40,000 plants.

variables related to credit lists.

While it can be expected that the number of farmers and the area in maize varies from year to year, no estimates of annual values are available. They were assumed to be constant, at an estimated 43,300 farmers and 80,000 ha. of maize, in calculating the percentages of Table 6. The number of farmers must vary less year by year than does the area in maize. Given this, it is likely that changes in participation are better reflected by the percentages related to farmers than to those related to area in maize.

Looking now at the second measure of participation, that based on use of the elements of the recommended technology, Table 7 represents the developments from 1971 to 1975 for Zones 1-4 and Table 8 for Zone 5. The data are from the annual general survey of yields. Fertilizer rates and plant densities used to fix limits on categories are arbitrary and parallel those set by Plan staff in their reports [2, 4]. They differ slightly, except for the high category of Tables 7 and 8, from the Plan technology of Table 4.

The high category includes a number of plots receiving very high levels of nitrogen. This usually occurred on very small plots and sometimes exceeded 300 kg/ha. These observations, included in High in Tables 7 and 8, were excluded from Table 4 because of the notable effect they would have had on the average net yields presented there. The next chapter will show that applications of nitrogen above, say, 120 kg/ha had little effect on yields. Why, then, did some farmers apply so much? These were usually cases in which small quantities of fertilizers were applied to very small plots. The quantities involved were so small that caution in their use promised only minimal absolute gains.

Table 8. **Percentage of plots in annual general survey receiving different levels of nitrogen and reporting different pre-harvest plant densities, Zone 5.**

	1971	1972	1973	1974	1975
Nitrogen [a]					
low	33.3	12.0	15.8	31.6	16.4
medium	18.2	28.0	21.0	0.0	8.9
high	48.5	60.0	63.2	86.4	74.7
Density [a]					
low	72.7	64.0	15.8	21.0	34.2
medium	18.2	36.0	47.4	63.2	45.6
high	9.1	0.0	36.8	15.8	20.2

a/ See table 7.

If participation in Plan Puebla is measured in terms of the application of plant nutrients and of plant densities, the data of Tables 7 and 8 evidence changes in participation since 1971. More tenuous comparisons can be made with data emerging from the 1967 survey, but they are not attempted here.

Looking first at nitrogen, and thinking of participation as being related to the High category, participation increased by 36 percent in Zones 1-4 and by 54 percent in Zone 5. Similarly, using plant density as the measure of participation, the increase was 29 percent in Zones 1-4 and over 100 percent in Zone 5.

With somewhat more stringent qualifications the number of plots on which recommendations can be said to be followed shrinks appreciable. Starting with nitrogen as the major element of the new technology, and recalling that recommendations range from 110-130 kg/ha in Zones 1-4 and are 100 kg/ha in Zone 5, define an adopter as any farmer who reports on at least one plot more than 100 kg/ha of nitrogen per hectare in Zones 1-4 and more than 90 kg/ha in Zone 5. Second, define adoption in terms of nitrogen, as above, and plant density at harvest of more than 40,000 plants per hectare for Zones 1-4 and 40,000 plants in Zone 5, both on at least one plot. Recommendations for both are a seeding rate of 50,000 plants. Finally, define adoption in terms of nitrogen and plant density as above and add phosphorus of over 40 kg/ha, in Zones 1-4, all on at least one plot. Recommended levels vary from 50 to 60 kg/ha in Zones 1-4 and no phosphorus is recommended in Zone 5.

With these definitions of adoption the proportion of adopters are given in Table 9 for 1971 and for 1975. Data limitations make it impossible to include 1967, 1968 and 1969 and the data source for 1970 differs from that of 1971 and 1975, hence the presentation of 1971 and 1975.

While comparison with the first years of the program must be speculative, it is probable that few farmers fit the second description of adoption (nitrogen and density) in 1967 and 1968 and it seems unlikely that more than 10-15 percent fit the first definition in 1968. Less than 2 percent used over 100 kg/ha of nitrogen in 1967, but this was an acknowledged bad year.

If impressions concerning 1968 are correct, then adoption of nitrogen in Zones 1-4 between 1968 and 1971 was substantial. The number of farmers applying 100 kg/ha of nitrogen nearly doubled, from 5600 thought to be doing so in 1968 to an estimated 11,000 in 1971. From 1971 to

1975 the increase in the absolute number of adopting farmers was roughly the same but the relative change was lower than in the first four years. With adoption measured in terms of nitrogen application and plant density the absolute number of adopters is smaller and the year to year changes are also smaller. Adding the third element to the definition reduces both percentage changes and absolute changes drastically. With adoption defined in terms of all three elements, only 6.7 percent of the farmers, roughly 2500 individuals, had adopted the recommendations by 1975.

In Zone 5 it appears that fertilizer use was more widespread in 1967 than in Zones 1-4. Although Plan activity started in Zone 5 only in 1970, by 1971 42 percent of the farmers surveyed reported using over 90 kg/ha of nitrogen. The proportion increased to 67 percent, which is to say an additional 25 percent of the Zone's farmers, by 1975. Almost equally notable was the increase in the number of farmers reporting over 40,000 plants at harvest time. From zero in 1971 this increased to 13 percent of the Zone's maize plots by 1975. Defining adoption in terms of nitrogen use and plant density, 13.3 percent of the surveyed farmers were adopters. Extrapolating to the population this is over 700 farmers.

What conclusions can be drawn from the data of the annual surveys? They indicate that only a small proportion of the area's farmers are following Plan recommendations completely, even given the apparent potential profits and eight years of Plan efforts. For Zones 1-4 only 6.7 percent of the plots featured all three major dimensions. Meanwhile, in Zone 5 only 13.3 percent of the surveyed plots had the two elements of the recommended technology. And these are not exactly the recommendations of the Plan but count those employing somewhat less intensive practices. With the recommendations themselves as lower bounds, the adoption rate shrinks further.

Table 9. **Percentage of plots by region receiving part or all of the recommended technology[a] in 1971 and 1975.**

Year	Nitrogen	Nitrogen and density	Nitrogen, density, and phosphorus
		Zones 1 - 4	
1971	29.1	7.4	4.2
1975	34.5	13.4	6.7
		Zone 5	
1971	42.4	0.0	0.0
1975	67.1	13.3	13.3

a/ Recommended technology is defined in terms of the following three elements: Nitrogen—over 100 kg/ha in Zones 1-4, over 90 kg/ha in Zone 5; Density—over 40,000 plants/ha at harvest time in all zones; Phosphorus—over 40 kg/ha in Zones 1-4, zero or more in Zone 5.

Summary

The discussion of the chapter describes an apparent anomaly. On the one hand Plan recommendations appear to promise significant increases in average profits; this is evident from the researchers' trials and, more importantly, from the experiences of farmers. On the other hand, farmers are not adopting the recommendations in the measure that might be expected, given their apparent profitability.

Note

1. This section uses information from [4].

IV. FACTORS IMPEDING THE DIFFUSION OF PLAN TECHNOLOGIES

Before looking at factors which might have restricted the spread of Plan Puebla recommendations it is worthwhile to look again at the assumptions on which the analysis rests. These assumptions, set out in the preface, are that: 1) farmers are purposive in their behavior, and, more specifically, that they are income seeking risk averters; 2) that farmers are sensitive to the nuances of the environment in which they farm; and 3) that they are reasonably efficient in managing the resources at their disposal. This is not to suggest that peasant farmers are agricultural savants. It is to say that traditionalism itself rarely restricts the spread of new technology.

This view of the farmer signals the elements which might be intervening in diffusion of new technology, i.e. in farmers following Plan recommendations. The discussion which follows reconsiders the assumptions, then looks at access to information and to inputs, profits and risks. In considering these points, emphasis will be given to official institutions, drawing on the work of Heliodoro Díaz [6], to profits and risks, drawing on the work of Edgardo Moscardi [7], and to how the latter are influenced by the opportunity cost of family labor, drawing on the work of Manuel Villa Issa [8]. A final section will deal with the sense in which diffusion has, in fact, been impeded.

On the Behavior Assumptions

This discussion takes as given that purposive behavior is a characteristic of small farmers and that they are sensitive to the nuances of their farming environment. This is not to say that cause and effect are understood to the degree that they might be in the modern world, but farmers certainly know well the agricultural cycles and the implications of aberrations for diseases, insects, choice of variety, and so on.

What needs to be discussed further is the assumption about the ends to which purposive behavior is directed. The view presented here is that first income and then risk aversion are most influential among farmers' ends.

The literature citations which could be adduced to support the assumption that farmers seek greater incomes are legion. Certainly among economists income is regarded as the primary element influencing behavior. There are, of course, those who argue that income's role has been vastly overstated and that social elements play the dominant role in shaping farmer response to their environment.

The position taken in this paper is nicely summed up in the following assertion by George Foster, cultural anthropologist: "In earlier chapters examples were given showing how social and cultural factors have caused people to forego economic gain:. . . Yet in the final analysis these attitudes appear to be delaying or holding actions, rather than a definite barrier. Sooner or later the economic pull seems certain to out-weigh other factors" [9, pp. 150-1].

The influence of risk aversion on farmer behavior is less certain. The argument has a strong intuitive appeal — i.e. as average incomes approach subsistence levels then, in the absence of facilities for borrowing against future income, survival requires that one give heavy emphasis to achieving yearly or even seasonal subsistence requirements with high probability, placing less emphasis on longer run averages. This emphasis on the near future occurs because, without access to vehicles for transferring income from period to period (e.g. assets or loans) income below subsistence requirements in one period can make contemplation of long run averages academic.

On an empirical note, interviews with a sample of farmers from the Puebla area reported in [10] are consistent with this intuition. Nineteen farmers selected at random from a larger group of non-adopting farmers were asked why they didn't follow Plan recommendations. Seventeen responded with answers indicating the unwillingness to go into debt when the weather, hence the resulting production, is uncertain. Empirical studies undertaken in other countries, e.g. [11] and [12] support the view that farmers are risk averters.

It will, then, be taken as given that the behavior of farmers is shaped by income and risk, not completely determined by these variables, but in large measure conditioned by them. It will also be taken as given that farmers are sensitive to their environment. The degree to which farmers are efficient in managing scarce resources must vary from farmer to farmer, some doing so quite efficiently, others not so well. On balance, we assume that farmers are reasonably effective in allocating resources.

Table 10. **Percentage of surveyed plots receiving one, two, or three elements [a] of the recommended technology by extension zone in 1975.**

Technology element	Zone 1	Zone 2	Zone 3	Zone 4	Zones 1-4	Zone 5
N	37.5	45.2	23.3	30.0	34.9	67.1
N + D	16.0	12.0	3.8	17.5	13.4	13.3
N + D + P	10.0	6.1	0.0	4.0	6.0	—

a/ Nitrogen—over 100 kg/ha in Zones 1-4, over 90 kg/ha in Zone 5; Density—over 40,000 plants/ha; Phosphorus—over 40 kg/ha in Zones 1-4.

Access to Information and to Inputs

Provision of information and inputs to the farmers of Puebla is a function of a group of institutions operating in the area. Information is the responsibility of Plan staff, of extension agents, and of the technical staff of the official credit agencies. Access to inputs comes through a private fertilizer dealer and through government banks. These institutions and their effect on the diffusion of the recommended technology is the subject of this section.

Some have argued that a major factor impeding the diffusion of new technology is inadequate service from the institutions responsible for supporting agriculture. In the case of Plan Puebla, this view is most cogently argued by Díaz. The motivating hypothesis of his study is "that the very roots of backwardness are found in the dysfunctional institutional structure which serves agriculture in Mexico". [6, p. 4].

In treating institutional impediments to Plan progress Díaz details relationships with the Plan staff, relationships between the staff and other service institutions, and between both staff and agencies and farmers.

In examining farmer experience in acquiring services from Banco Agrícola and Banco Ejidal, Díaz reports that: 1) procedures for obtaining and repaying loans were cumbersome and time consuming, 2) promised inputs often arrived late and 3) little technical assistance was offered to clients by the banks. In functional terms this meant that the flow of information through official channels was inadequate, that the cost of obtaining credit through official sources was too high, and that returns to fertilizers were sometimes reduced by late deliveries.

With the advent of the Plan, efforts were made to improve the services of the banks and of the private fertilizer dealer. These efforts focused on speeding the processing of loans and repayments, ensuring timely delivery of promised inputs from the banks, and improving the capacity of bank technical staff to counsel farmers on the use of modern inputs.

A significant measure of success accompanied these efforts as the banks added staff for processing loans, improved the working conditions of technical staff, and waged successful campaigns to improve deliveries. One manifestation of the improved services offered to farmers was their vastly improved repayment of loans – they profited from the loans and wanted to maintain them. By 1973 both Banco Ejidal and Banco Agrícola were enjoying over 90 percent repayment rates on loans made to Plan participants as compared with repayment rates of 40 percent for Banco Ejidal prior to the Plan's initiation.

A second function provided by Government for the farmers of Puebla is agricultural insurance. Farmers criticize this service because the charges, even though heavily subsidized by Government, seem high, the coverage seems limited and, indeed at times, capricious. While attempts were made to introduce new formats for self insurance and other innovations, none of these were deemed acceptable by those administering the insurance program. Their response, coupled with regulations which tie insurance to the type of bank loans most commonly made to the farmers, meant that whatever problems characterized insurance at the outset were still evident several years into the project [6].

Díaz also comments on the adequacy of efforts to disseminate information about the program to area farmers. His assessment [6, p. 379] is that the change of emphasis of extensionists from demonstration and field days to loan and payment processing had a negative influence on diffusion of the technology. A second critic of Plan Puebla questions the efficacy of the communications program [13], arguing that too few farmers are aware of even the existence of Plan Puebla. In this same vein, Avila Dorantes [14, p. 106] argues that the primary reason that participants in the Plan, i.e. those appearing in Table 6, are themselves not following recommendations exactly is that they do not know what is being recommended, especially as relates to seeding density. He concludes by presenting the possibility that farmers might will have heard of the recommended densities but were unconvinced of their utility and, being unconvinced, have forgotten that recommendation.

Díaz summarizes his attitude towards the role of institutions by saying that, even after the changes induced through the efforts of Plan staff, "... the existence of institutional problems have prevented the project from reaching the vast majority of campesinos inhabiting the region". [6, p. 496].

It is evident that the services offered by institutions charged with supplying Puebla's farmers could be further improved – in particular that the time required to obtain and repay loans could be shortened, that input delivery could be made more timely, and, that Plan staff could relate more closely to farmers. It is also likely that such improvements would lead to higher rates of adoption of Plan recommendations as they would increase awareness of the Plan's advantages and reduce the cost (essentially the value of the time spent in dealing with administrative issues) of following the recommendations. Even so, however, it does not appear that these institutional shortcomings are the major impediments to more widespread farmer acceptance of Plan recommendations.

The argument to support the preceeding assertion rests on three elements. The first is the marked difference in the adoption of Plan recommendations among the five zones of the Plan region. (See Table 10). The second is an assumption that the services offered by supporting institutions, whether adequate or not, did not vary from one zone to another in a way consistent with the variation seen in Table 10. The third element is that area farmers have access to information and to inputs through sources which are not a part of the formal apparatus of the project.

If institutional shortcomings are taken to be the primary factor preventing the region's farmers from following Plan recommendations, then they must also be the principal cause of the differences in input use among the zones. But there is no evidence that institutional services varied from zone to zone in a way consistent with Table 10's differences among zones. Indeed conversation suggests that Zone 5 might well have received less attention, had less access to institutional services, than did Zones 1-4. Certainly research and distribution of information was initiated later in Zone 5 than in the other zones.

It might be argued that the differences among zones in 1975 emerged from initial differences in, e.g. nitrogen use and that these were maintained by institutional restrictions. Data by zone from the 1967 survey are not at hand but, as less than one percent of the surveyed farmers reported using more than 100 kg/ha of nitrogen, the differences among zones were obviously quite small in 1967.

Turning now to the third element it must be recognized that farmers do not look only to officialdom for information and inputs. Much of the information flow on new technology is from farmer to farmer. And it is certainly evident that inputs can be acquired without resort to official channels.

That last point is graphically demonstrated by comparing use of inputs through official sources with overall use of inputs. For 1975, as a measure of farmer access to inputs through official sources, Table 6 reports that 20.1 percent of the farmers were fertilizing 35.2 percent of the maize area through Plan associated credit sources, principally through the fertilizer distributor and the two government banks. Turning to the 1975 yield survey, Table 9 implies that over 45 percent of the maize area was fertilized with over 90 kg/ha of nitrogen. More dramatically, the 1975 survey implies that 89.3 percent of the maize was receiving some fertilizer. With 35.2 percent of the maize area fertilized through official channels and 89.3 percent of the maize fertilized, there is clearly a great deal of fertilizer bought and applied independently of the official institutions.

If differential access to services does not explain Table 10's differences in adherence to the recommendations, then it is unlikely that institutional services are the primary factor accounting for the overall pattern of adoption characterizing the region. There must be other factors explaining that pattern. This is not to say that institutional shortcomings have not prevented some farmers from taking up Plan recommendations, they have certainly played some role in restricting their adoption. Making them the principal restriction, however, is questionable, leaving too much unexplained — *viz.* the interzonal differences and input use exceeding Plan sponsored use. What is required is an explanation that is consistent with low rates of acceptance of Plan recommendations and with access to information and inputs through unofficial channels.

Profits

It was posited earlier that farmers are profit seekers. The data of Tables 3 and 5 suggest that substantial gains in adjusted yield accrue to those who follow Plan recommendations rather than the conventional strategies. But it must be remembered that these are not the only strategies open to the farmers. They can, for example, use an intermediate strategy — with less nitrogen, less phosphorus and a lower plant density than is recommended but more than with the conventional strategy of 1967.

Table 11. **Average farmer yields in 2 years for two plant densities with nitrogen levels roughly constant.** [a]

Density [b]	Avg. year Yield kg/ha	Avg. year Nitrogen kg/ha	Better year Yield kg/ha	Better year Nitrogen kg/ha
		Zones 1-4		
Medium	3136	110	3017 [d]	120
High	3116	120	3406	115
		Zone 5		
Medium	2933 [c]	114	3179	108
High	2500 [c]	102	4166	107

a/ Only those plots receiving 90-150 kg/ha of nitrogen were included in calculating the averages in Zones 1-4 and only those receiving 80-150 kg/ha in Zone 5. b/ Medium—over 35,000 to 40,000 plants/ha at harvest. High—over 40,000 to 60,000 plants/ha at harvest. c/ Less than 4 observations. d/ Two observations of 20 were eliminated because of disastrously low yields.

Moscardi [7] estimates response surfaces for two soils types in the Puebla area. One is for the deep soils of Popocatepetl and the other for the soils of La Malinche. The deep soils of Popocatepetl dominate Zones 1 and 2 and account for about 25 percent of the Plan area's maize. The soils of La Malinche represent a bit over 25 percent of the area's maize and make up virtually all of Zone 5.

The data on which the response surfaces are based are from 1967 through 1971 for the first and for 1967 and 1969 through 1971 for the second. Plan investigators used the same data in generating recommendations but did so on an annual basis and for each site. Moscardi pooled data over years and over sites. Pooling the data, he also included soil variables measuring organic matter, soil phosphorus, and soil acidity. Moscardi examined three models commonly used in response surface analysis — quadratic, square root, and exponential. For exponential models he used ridge regression procedures.

Plant density. Looking first at plant density in the deep soils of Popocatepetl, Moscardi related yields to seeding densities. For the range between 40,000 and 60,000 plants he concluded that, other things held constant, yield is independent of density. For each model, the analysis shows a slightly negative relationship but with low statistical significance. [7, p. 87].

In Zone 5 on the soils of La Malinche the results were essentially the same. Moscardi again found a slight negative relationship but with low statistical significance [7, p. 87]. In another study of the soils of La Malinche, Hernández [15, p. 257], presents graphs showing a modest increase in yield as seeding density varies from 25,000 to 50,000 plants. The data are from 1971. For nitrogen constant at 100 kg/ha the estimates for his model suggest an increase of some 200 kilos of maize, from 3800 to 4000 kg/ha, as seeding density changes from 25,000 to 50,000 plants per ha.

These results suggest that the gains from seeding more than 40,000 plants/ha are slight, if indeed there are gains at all, in any given year. It was also found that densities of less than 35,000 plants/ha contribute to lower yields.

Even so, it is likely that in good years yields will be higher, other things equal, where density is higher. Poorer

Table 12. **Estimates of yields (ton/ha) and of adjusted gross revenue per hectare** [a] **for two soils types at various levels of fertilizer use.**

Level	Soils of Popocatepetl Fert/ha	Yield	Value [b]	Soils of La Malinche Fert/ha	Yield	Value [b]
Profit maximizing	190-21-0	4.30	1894	74-5-0	2.54	1350
0.75 maximizing	140-16-0	3.85	1864	55-4-0	2.40	1349
0.50 maximizing	100-11-0	3.42	1792	37-2.5-0	2.20	1314
0.25 maximizing	50-6-0	2.60	1521	18-1.2-0	1.89	1200

a/ Gross revenue is the farm value of production less the cost of applying fertilizer and of harvesting, shelling, and transporting maize to market as estimated in [5, p. 379]. b/ Mexican pesos.

years, on the other hand, might well lead to the reverse. This idea is supported in Table 11, where a good year is compared with an average year. Yields with plant densities at harvest time of 35,000 – 40,000 plants are compared with those of 40,000 – 60,000 plants. Nitrogen and phosphorus are roughly constant, with the same ranges used for each year and each plant density. For the better year, yields are appreciably higher with higher density. For the average year, yields are roughly the same. In a poor year, like 1967 for example, it could be expected that yields for lower densities would exceed those of higher densities. In these examples, with fertilizer use roughly constant, yields are a good measure of profits.

The studies of Hernández, for one year, and Moscardi, over several years, suggest little if any advantage to seeding densities greater than 40,000 plants/ha. These studies are based on research done on farmers' fields. Evidence from farmers' experiences suggest that, if weather is good, higher densities pay, if weather is poor, lower densities pay. This is treated again below. Other evidence points to marked yield declines when densities fall below 35,000 plants.

In 1975, some 56 percent of the fields in Zones 1-4 and 52 percent in Zone 5 had plant densities at harvest between 30,000 and 45,000. Only about 15 percent had densities over 45,000/ha. In the Plan area, seeding 50,000 plants should, on the average, leave more than 45,000 plants at harvest time.

With the evidence at hand, it is not surprising that few fields are planted at the recommended seeding densities of 50,000 plants. There might well be little benefit on the average from doing so and considerable loss could result in the poor year, when yields are low anyhow. The income seeking risk averter might well decide that seeding rates slightly below the recommended level but well above 30,000 plants/ha are preferred.

Fertilizer use. Marked differences among zones in fertilizer use were shown in Table 10 of the preceeding section. These differences are especially evident between Zone 3 and Zone 5, where 23 percent and 67 percent of the plots received approximately the recommended levels of nitrogen. Differences are also evident in comparing Zone 5 with Zones 1-4, where 35 percent of the plots receive roughly the recommended levels of nitrogen.

For insights into potential profit from the recommended fertilizer strategies we can again turn to the work of Moscardi [7]. Plan recommendations for the deep soils of Popocatepetl depend on planting dates but are essentially 130-40-0. Moscardi [7, p. 83, 124] estimates that the average profit maximizing recommendation is 190 kg of nitrogen and 21 kg of phosphorus for seeding densities between 40-60,000 plants and with soils variables at average values. Leaving aside the level for the moment, an interesting aspect of the result is the vastly higher ratio of nitrogen to phosphorus. While this is on the order of 3 to 1 in the recommendation for deep soils of Popocatepetl, Moscardi's results show a ratio of 9 to 1.

The two response surfaces estimated by Moscardi were used to consider the question of what might happen to yields and to adjusted gross revenue with lower levels of fertilizer use. It is not uncommon in response surface analysis that, over the high part of the range for inputs, significant reduction in inputs leads to small reductions in adjusted gross revenues. Table 12 shows this to be true for data from the deep soils of Popocatepetl and from the soils of La Malinche in Zone 5 as well.

For the deep soils of Popocatepetl, fertilizer use can be reduced to 75 percent of the average profit maximizing level while adjusted gross revenue declines by only 2 percent. With half the profit maximizing fertilizer use, the reduction in adjusted gross revenue is less than 6 percent. The same comparison applied to the soils of La Malinche is even more dramatic – less than 1 percent and less than 3 percent reduction in adjusted gross revenue for reductions of 25 and 50 percent in the use of fertilizer.

Two questions can be asked here. What happens to the conclusion that substantial reductions in input use imply small reductions in adjusted gross value of yield, if other values for soils variables are substituted? A different set of values, representing one of the Zone 5 experimental sites, was substituted in the estimating equation for the soils of La Malinche. The estimated profit maximizing values of nitrogen and phosphorus increased to 131 and 7 kg/ha respectively. But a reduction of 50 percent in fertilizer use reduced the adjusted gross value of yield by only 2 percent. For this case, the weak relationship between fertilizer and adjusted gross revenues at high levels of fertilizer use is not a consequence of the values assigned to the soils variables.

The second question concerns the extent to which the result, i.e. that small changes in adjusted value of yields accompany substantial changes in fertilizer use, is a direct consequence of the use of an exponential function in fitting the fertilizer/yield data. Said a different way, would the same result emerge were a quadratic function used? In this particular case, a quadratic function was estimated with similar results. This need not always be true as different functional forms might well show different results.

This sensitivity of results to the choice of functional form and the difficulty of properly accounting for the myriad of elements influencing the relationships between yields and inputs has led some to argue that the precision manifested by this kind of analysis is pretentious. That view is developed and simpler procedures for making recommendations are presented in [16]. It also underlies the slope/plateau approach to recommendations seen in [17].

And what of the farmer data, what do farmer yields net of fertilizer costs show? Data for 1971, 1972, and 1973 were sorted into groups for Zones 1-4 and for Zone 5. (Data for 1974 was omitted because an extraordinarily early frost affected many plots severely. Yield data for 1975 were not available at the time of writing). For Zones 1-4, the groupings were: 1) plots receiving 120 to 160 kg/ha of nitrogen and 40 to 70 kg/ha of phosphorus along with 35,000 to 60,000 plants, 2) plots receiving 90 to 120 kg/ha of nitrogen and 20 to 50 kg/ha of phosphorus along with 35,000 to 60,000 plants at harvest, and 3) plots receiving 0 to 50 kg/ha of nitrogen, 0 to 25 kg/ha of phosphorus and 15,000 to 35,000 plants at harvest. For Zone 5 the groups were plots receiving: 1) 101 to 160 kg/ha of nitrogen along with 33,000 to 60,000 plants, 2) plots receiving 80 to 100 kg/ha of nitrogen along with 33,000 to 60,000 plants at harvest time, and 3) plots with less than 50 kg/ha of nitrogen and with 15,000 to 33,000 plants at harvest time. Phosphorus is not recommended in Zone 5. Setting the lower bound at 33,000 plants, rather than 35,000 as in Zones 1-4, made several more observations eligible for inclusion and the shortage of observations in Zone 5 made these necessary. Frequency distributions of yields adjusted for the farm cost of fertilizers are presented in Table 13. Average yields are presented in Table 14. Yields adjusted for the farm cost of fertilizer are in Table 15.

Before looking at farmers' yields and their relation to the diffusion of various technologies, certain caveats must be considered. If it could be assumed that each grouping, i.e. Zones 1-4 and Zone 5, makes up a completely homogeneous region then it could be said, e.g. from Table 11 that in the average year those Zone 1-4 plots with over 40,000 plants at harvest and yields of 3116 kg/ha would have had yields of 3133 kg/ha had density been 35-40,000 plants or, from Table 14, those Zone 5 plots using intermediate levels of fertilizer with yields of 3133 kg/ha would have had yields of 3523 kg/ha with larger applications of fertilizer.

It is known that each region is not homogeneous. As a measure of the variability of Zone 5, Moscardi employed sets of values for soil variables, one for each of the 20 sites on which experiments were conducted in the Zone 5 soils of La Malinche. He then solved for the estimated profit maximizing level of nitrogen use. The estimated level ranged from 36 kg/ha of nitrogen at one site to 131 kg/ha at another. All of this variability in estimating profit maximizing levels of nitrogen occurs within a region of 24,000 ha. made up of one soil type [7, p. 118].

Moscardi's evidence of variability is supported by the data of Table 13. Each of the technologies in each of the regions manifests a substantial amount of variability. This is the result of weather differences from place to place and year to year and of the heterogeneity of the agronomic circumstances within regions. It is this heterogeneity which prohibits viewing a given frequency distribution as if it represented a probability distribution of yields open to any given farmer within a region.

Nonetheless it is interesting to notice that, for each region, the conventional technology had the largest proportion of observations at very low adjusted yields, 39 percent of the plots reported estimated adjusted yields below 1200 kg/ha in Zones 1-4 and 46.2 percent in Zone 5. This contrasts dramatically with intermediate technology plots, 5.5 percent below 1200 kg/ha in Zones 1-4 and none in Zone 5.

A weaker assumption, which would still permit the same statements about the consequences of changing plant density or fertilizer use for average yields, is that the observations included in the calculations proportionally represent each region's micro-environment. This is clearly unlikely even if representativeness characterized the larger sample from which the included observations were selected.

Looking now at the average adjusted yields of Table 15, how well do each of the technologies fare within the region? In Zones 1-4, both the intensive and the intermediate technologies had far greater adjusted yields than did the conventional technology on the average. The intermediate technology averages slightly higher than did the intensive technology. A profit seeking farmer with average plots would choose the intermediate technology. Within Zones 1-4, however, some farmers fared better with the intensive technology than did others with the intermediate strategy, e.g. see the frequency distribution in Table 13 for adjusted yields over 3600 kg/ha. Assuming that 1971-73 were representative years, what all of this suggests is that, while some

Table 13. **Frequency distribution of average adjusted maize yields [a] for three maize technologies[b] in the area of Plan Puebla.**

Yield	Zones 1-4			Zone 5		
kg/ha	Conventional	Intermediate	Intense	Conventional	Intermediate	Intense
0- 600	14.8	–	8.0	15.4	–	–
601-1200	24.2	5.5	1.6	30.8	–	2.4
1201-1800	32.6	8.3	14.2	23.1	11.8	4.8
1801-2400	14.8	19.3	20.6	15.4	29.4	14.4
2401-3000	5.3	38.8	27.0	–	23.6	28.6
3001-3600	5.3	19.3	15.8	15.4	23.5	26.2
3601-4200	3.1	5.5	11.1	–	11.8	16.8
4201-4800	–	2.8	1.6	–	–	7.2

a/ Yields reduced by maize cost of fertilizer on the farm. *b/* Conventional: Zones 1-4 0-50 N, 0-25 P, 15,000-35,000 plants; Zone 5, 0-50 N, 15,000-33,000 plants (per ha.) Intermediate: Zones 1-4, 90-119 N, 20-50 P, 35,000-60,000 plants; Zone 5, 80-100 N, 33,000-60,000 plants (per ha.) Intensive: Zone 1-4, 120-160 N, 40-70 P, 35,000-60,000 plants; Zone 5, 101-160 N, 33,000-60,000 plants (per ha.).

profit seeking farmers of Zones 1-4 can be expected to use over 120 kg of nitrogen, over 40 kg of phosphorus, and over 35,000 plants per hectare, it does not seem likely that the majority will do so.

For Zone 5 the intensive technology has higher average adjusted yields than has either the conventional or the intermediate technology. The profit seeking farmer with average plots would tend to choose the intensive technology. Given the averages of Table 15 and the variability seen in Table 13, it might be expected that the bulk of the farmers of Zone 5 would turn to the intensive technology.

These conclusions — widespread adoption of intensive technology in Zone 5 and only limited adoption in Zones 1-4 — are entirely consistent with the survey data of 1975. Those data show that 64 percent of the plots in Zone 5 received over 100 kg of nitrogen/ha while only 38 percent of the plots in Zones 1-4 received over 110 kg of nitrogen/ha. (Recall that recommended nitrogen is 100 kg in Zone 5 and averages roughly 115 kg/ha for Zones 1-4). An effort was made to relate use of the intensive technology to adjusted yields within zones of Zone 1-4. While adjusted yields explain inter-regional differences in the use of intensive technology, they are only roughly related to differences in use among zones within Zones 1-4. The limited number of observations for some technologies in some zones — averages based on one or two observations — undoubtedly contributes to the weak relationship between the two measures among the zones of Zones 1-4.

There is one final point which needs to be made about profits and the increase in fertilizer use evident in Table 7 and 8. Since 1971 there has been a steady decline in the maize price of fertilizer as maize prices have increased more rapidly than fertilizer prices. Starting at 5.6 kg of maize/kg of nitrogen in 1971, the maize price of nitrogen had declined to 3.2 kg by 1975. With the assumption that farmers are profit seekers, this decline in the relative price of fertilizer could, itself, increase the use of fertilizer. Nonetheless, the rate of increase in the Puebla area has exceeded the rate of increase in the country's other maize growing areas.

Opportunity cost of labor To this point discussion of the relative merits of technologies has abstracted from the possiblity that labor — the farmers' or his family's or hired labor — has a cost. If labor is costly, in an opportunity sense or in a direct sense, then the returns from the technologies must be adjusted to include a cost for whatever labor is utilized to reflect differences in labor utilization.

The Plan area is characterized by a good bit of industrial and commercial activity. These two, coupled with work in farming itself, offer area farmers many opportunities for off-farm work. In the 1967 benchmark survey the average income from off-farm work was 75 percent of the average income from crops [4, p. 7]. In a more recent survey Villa Issa [8, p. 55] reports that 87 percent of those farmers not following the recommended technology worked off the farm as compared with 56 percent of those roughly following the Plan recommendations. Villa Issa also estimated that the average non-adopter worked 251 days in 1974 while the adopter worked an estimated 222 days [8, p. 65]. Both adopters and non-adopters report hiring labor for farm work, an average of 41 days for non-adopters and 40 days for adopters [8, p. 82].

Table 14. **Average yearly yields [a] for two regions, Zones 1-4 and Zone 5, of Plan Puebla for 1971-73 for three production strategies. [b]**

Zone	Conventional technology	Intermediate technology	Intensive technology
1-4	1685	3347	3315
5	1946	3133	3523

a/ Yields (kg/ha) by plot were averaged for each year and then the yearly averages were summed and divided by 3 for each technology. *b/* See footnote *b*, Table 13.

All of this gives evidence that in comparing the technologies some charge must be made to represent the additional labor needed by the intermediate and intensive technologies. Two parameters are critical to the estimation of this charge — the number of units of extra labor and the cost of each unit.

On the quantity of extra labor needed, Villa Issa [8, p. 86-87], estimates that what he calls the recommended technology requires 8.7 more days of labor than does his so-called traditional strategy in order to affect all of the operations as well as to harvest and transport the extra grain. In [4, p. 91] the extra labor utilized is estimated at 10.3 days, after eliminating labor associated with hand shelling. (Machine shelling is widely available, is inexpensive, and is widely used.)

In both [4] and [8] the descriptions of the traditional technology and of the recommended technology accord well with the conventional and intensive technologies used here. It will, then, be assumed that intensive technology absorbs 8.7-10.3 days of labor more than does the conventional technology. For the intermediate technology, which requires the same operations as the intensive technology but with some at slightly lower levels, it is estimated that two days less labor are required than for the intensive technology, most of this at harvest time.

Table 15. **Average yields, 1971-73, adjusted for the on farm maize cost of fertilizer [a] for three production technologies. [b] Plan Puebla.**

Zone	Yield, kg/ha Conventional technology	Intermediate technology	Intensive technology
1-4	1570	2668	2447
5	1887	2637	2892

a/ Yields by plot were averaged for each year and then the yearly averages were summed and divided by three for each technology. Maize cost of fertilizer at the farm gate was subtracted from each yield. (Data from 1971-73 yield survey. *b/* See footnote *b*, Table 13.

These estimates relate to days utilized in the field. Acquiring credit, arranging for delivery of inputs, repaying loans, and finding out about the new technology might well take additional time. How much time is difficult to say, first because the time required to service loans varies from institution to institution and from farmer to farmer, second because nearly all of the area's farmers are already using some fertilizer on maize and a substantial portion are apparently self-financed, and, third, because the acquisition of knowledge might be unnecessary or fast. In order to recognize that some charge might be necessary for these concepts, it is assumed that one day per hectare is spent in these activities beyond what is spent in similar activities by those using the conventional technology.

This all leads to the assumption that the intermediate technology requires 7.7-9.3 more days of labor and the intensive technology requires 9.7-11.3 more days of labor than does the conventional technology.

Turning now to the value of the extra time utilized, Villa Issa, in a private communication, reported that there is little seasonal change in wage rates. There are periods in which farm labor is relatively more scarce, most evidently at planting and harvest.

A reasonable lower bound on the daily charge for labor is the amount farmers are paying to hire casual labor. According to Villa Issa [8, p. 82] this was 41 pesos per day in 1974. A meaningful upper bound is the estimated average wage received by those farmers working off the farm in non-agricultural pursuits. Villa Issa [8, p. 58, 63] reports data which permits estimating a rate of 65 pesos per day. In 1974 the estimated price of maize in the Puebla area was 1370 pesos per ton at the farm. Measured in maize, this implies that the lower and upper bounds on the cost of labor were 29.9 and 47.4 kg per day respectively.

Looking back at the adjusted yields in Table 15, the estimated difference between the average yield for conventional technology and intermediate technology is 1098 while that between intermediate and intensive technology is — 221. On the average and employing the data for 1971-73 the intermediate technology is preferred to the intensive technology, even without including an additional charge for labor.

And what about the estimated difference in adjusted yields between the conventional and intermediate technologies, was it large enough to compensate for the extra labor? With the daily cost of labor between 29.9 and 47.4 kg of maize the extra estimated average yield difference between the conventional and the intermediate technologies is between 657 and 868 kg of maize after adjusting for the maize cost of fertilizer and for the extra cost of labor. The incorporation of a charge for labor would not dissuade the income seeking Zones 1-4 farmer from taking up the intermediate strategy.

For Zone 5, the comparable figures show that the extra estimated difference in average yields between the conventional and the intermediate and intensive technologies ranges from 339 to 550 kg/ha of maize and from 469 to 715 kg/ha respectively, after adjusting for the extra cost of fertilizer and for the extra cost of labor.

Comparing the intermediate and the intensive technologies the estimated two days of additional labor are associated with an estimated 255 kilos of maize (see Table 15). Assuming two extra days of labor and the costs per day given above, the extra estimated average yield difference between intermediate and the intensive technology is from 160 to 195 kilos of maize/ha.

The income seeking farmer in Zone 5 operating under average circumstances, would, then, move towards the intensive strategy even after compensating for the cost of the extra fertilizer and the extra labor required.

It should be noted that the conclusions here do not quite accord with those of Villa Issa. His findings are based on two production functions, one for adopters and one for non-adopters. Using marginal analysis, he finds that non-adopters are using roughly that quantity of labor on their farms such that the marginal returns to labor are equal to the opportunity cost of labor. Non adopters would not, he concludes, use the additional labor required by the more labor intensive strategy.

Two elements differentiate the construction used here from that employed by Villa Issa. The first is that the yield differences between our conventional and intensive technologies, roughly comparable to his traditional and recommended technologies, are larger. He reports a difference in gross yields of 1208 kg [8, p. 86, 87] for 1973 while Table 15 shows a difference of 1630 kg for Zones 1-4 and 1577 kg for Zone 5 for 1971-73.

The second difference is in procedure. Villa Issa bases his conclusions on production function analysis which attributes production under each technology to fertilizer and to labor. The procedure followed here is to account for the maize costs of the extra fertilizer and of the extra labor and then to see if the associated yield difference is sufficient to compensate for these extra costs. The point of departure is that extra fertilizer requires extra labor so that the two can be viewed as a joint input. The conclusion is that the income seeking farmer with plots like the average plots reported in Table 14 would find the intensive technology preferred to the conventional strategy in both Zones 1-4 and Zone 5 but would find the intermediate strategy preferable to the intensive technology in Zones 1-4, even after allowing for the extra cost of fertilizer and labor.

Risk

Given the observations made in the previous sections, especially as they relate to yields adjusted for the cost of fertilizer and the cost of labor, what can be said about the impact of risk on the adoption of the recommended technology? Conclusions about the effect of risk can be closely related to what assumption is made about how risk aversion is manifested. A simple and intuitively appealing way to express risk aversion holds that the farmer wishes to keep the probability of disaster below some level. This introduces two critical questions: what constitutes a disaster and at what level should the probability be set. Even without precise answers to these questions, there are circumstances under which technologies can be compared and inferences drawn about relative risk.

Data requirements for the analysis of risk are stringent. What is needed is a set of observations representing a distribution function, relating yields from a given technology to probabilities while holding other than random factors constant. Were the agronomic circumstances the same within regions for the plots providing the data of Table 14 and were 3 years of observations judged sufficient to represent the area's weather, the frequency distributions of Table 13 could be used to assess the risks of the three technologies presented. While acknowledging that these conditions are not met, the frequency distributions of Table 13 are nonetheless suggestive about the relative risks of the three technologies.

Let it be assumed for the moment that the frequency distributions of Table 13 represent proper probability distributions. Then what do the distributions imply about comparative risk? If the disaster level is taken to be 1200 kg/ha, then in each region the conventional technology has a far greater probability of falling below the disaster level than has either of the others. For Zone 1-4, a risk averter would prefer the intermediate technology over the conventional technology for any probability level of disaster but he would select neither if that probability were below 0.055. The same would hold for the comparison between the intermediate and the intensive technologies. Setting the disaster level at 600 kg/ha the intermediate technology is preferred for any probability level. In Zone 5, with other things equal, the risk averter will tend to choose the intermediate over the intensive technology if disaster is taken as 1200 kg, and is indifferent between the two if disaster is taken as 600 kg.

Even given the strong assumptions, assumptions which almost certainly contradict fact, needed to employ the frequency distribution of Table 13 as probabilities, the data are still mute with respect to the possible impact of risk in Plan Puebla. This is because rankings of the technologies made in terms of risk accord almost exactly with rankings made in terms of average adjusted profits. In Zones 1-4, the income seeking average farmer would choose the intermediate strategy. So would the risk averter who wanted the probability of less than 1200 kg of maize to be less than 0.056 or the probability of less than 600 kg to be less than 0.080. Both criteria indicate the same technology. So too for Zone 5, roughly. The income seeker would choose the intensive technology. The risk averter who wanted the probability of less than 600 kilos of maize to be less 0.01 would do the same. A risk averter unwilling to accept a probability greater than 0.023 of less than 1200 kg would choose the intermediate technology. This seems unlikely, because this disaster level is high and the probability level is quite low. Again, the risk averter would choose the same technology as the income seeker.

Table 16. **Average application of nitrogen (kg/ha) to maize on plots sampled in 1975 for smaller and larger farms by zonal groupings.**

Farms[a]	Zone 2	Zones 1-4	Zone 5
Smaller	94	88	108
Larger	84	86	123

a/ For each grouping farms were arrayed by size and each array separated at the median.

The frequency distributions of Table 13 are not proper probability distributions. They are only suggestive of how risk averters might respond to the three technologies. In considering the possible effect of risk averse behavior on the diffusion of input intensive technology in Plan Puebla, it can only be said that the table does not give evidence that knowledgeable risk averters would prefer the conventional technology. There is, of course, always the chance that farmers' perceptions of the relationship between yields and probabilities for a given technology are incorrect. With experience, perceptions become better approximations of reality.

There is other indirect evidence that risk was not playing a prominent role in the utilization of fertilizer in 1975. Were risk a prominent element in shaping fertilizer use, one might expect to see a relationship between fertilizer use and farm size within regions. The rationale is that larger farmers, with more assets and income, would be less risk averse than smaller farmer, hence more disposed to use larger quantities of fertilizer than smaller farmers.

Simple regressions were made of nitrogen use on farm size. For Zone 5, the estimated coefficient was positive but with a t value of less than 1.0 indicating low statistical significance. For Zones 1-4, and after eliminating one ultra extreme observation out of 149, the estimated coefficient is negative but with a t value of less than 1.0, again indicating low statistical significance. In both cases, explanatory power of the model is very low, with coefficients of determination under 0.05.

A simple comparison of fertilizer use among farms of various sizes is presented in Table 16. First, farms were arrayed by size for Zones 1-4, for Zone 2 and for Zone 5. One soil type, deep soils of Popocatepetl is dominant in Zone 2 and a second, soils of La Malinche, is dominant in Zone 5. For each half of each array the average quantity of nitrogen used on the surveyed plot was calculated. These averages are reported in the table. They offer a mixed picture of the relationship between fertilizer use and farm size.

It is readily acknowledged that farm size and fertilizer use might be related through factors other than risk, e.g. larger farms have better access to credits and to information and have lower transaction costs than have smaller farms. If operative, these relationships will all tend to be positively related to fertilizer use. That is to say, large farmers have better access to credit, greater access to information, lower transactions costs, and will tend to be less risk averse than small farmers; each of these considerations tends to permit or to encourage large farmers to apply more fertilizer than small farmers. In the case at hand, as evidenced by the data of Table 16, there is no clear evidence that any of these factors is stimulating larger farmers to apply more fertilizer than smaller farmers.

Has Diffusion Really Been Impeded?

Two measures of the adoption of new technology have been presented. One of these defines adoption in terms of farmer association with Plan connected credit agencies. On this measure, 20 percent of the farmers with 35 percent of the maize had 'adopted' Plan recommendations by 1975. This measure excludes those who employ the technology but do not appear on the official credit lists. It includes some users of Plan connected credit who do not follow the recommendations.

A second measure describes adoption in terms of what the farmers are doing with respect to fertilizers and plant densities. The proportion of adopters depends, of course, on how adoption is defined. This is the measure of Table 10 or of Tables 7 and 8. The more stringent the conditions the lower the estimated proportion of adopters. On these measures of adoption, especially the second when stringently defined, diffusion has been slow.

The question that emerges here is whether or not either of these measures is really relevant. Surely the first is not a proper measure. Interest is in what farmers are doing with fertilizer and planting densities, not in whether or not they had official credit.

As defined, the second does not appear to be an appropriate measure either. If it could be assumed that there were some special motives for following the recommendations exactly, then progress could be measured through the number of farmers using the recommendations. For example, if the existing recommendations could be held to be optimal for each of the area's farmers, then measuring in terms of farmers following the recommendations would be appropriate.

But it is unlikely that the recommendations, even the system of 16 recommendations, fits a large proportion of the area's farmers exactly. The heterogeneity in agronomic circumstances (witness the variability among experimental sites in Zone 5) and the differences in farmer circumstances – e.g. in the opportunity cost of capital; in the opportunity cost of labor because of farm size, off-farm work, and cropping pattern differences; in the distance to markets; or in managerial ability – all combine to make it most unlikely that one set of recommendations will fit all farmers.

What happens then is that farmers alter recommendations to the extent that they can so as to make them more consistent with their own circumstance. Given this, measures in terms of a strict interpretation of the recommendation are excessively stringent. Many farmers, as in Puebla, might find the recommendations too intensive for their circumstance but will, because of activities of the Plan, move from conventional to intermediate levels. These farmers have benefitted from Plan activities, are producing more maize, and generating more income. The strict interpretation of adoption would exclude them.

What this suggests is that progress be measured in more general terms, e.g. in terms of the proportion of farmers now employing intermediate levels of fertilizer or of plant density. The data of Tables 7 and 8 are approximations to this sort of measure. Alternatively, the measure of progress might be couched in terms of the average use of fertilizer. This increased from 34 kg/ha of nitrogen in 1967 to over 80 kg/ha in 1975. A third measure is in terms of the proportion of plots with more than 40 kg/ha of nitrogen which increased from 28 percent in 1967 to 49 percent in 1971 and to 77 percent in 1975.

Each of these measures is more relevant than those derived from credit lists or from those following the recommendations strictly. In this case, all imply a wider diffusion of new technology, not necessarily the recommended technology but an improved technology nonetheless.

And all of that heterogeneity alluded to earlier also has implications for the formulation of recommendations. With all of the differences which characterize farmers – differences in natural and in economic variables – it is just not likely that average profit maximizing recommendations can be made for large groups. As agronomic recommendations become more and more precise, or as circumstances become more heterogeneous, recommendations fit fewer and fewer farmers. This suggests that the strategy should aim at formulating agronomic recommendation which will: 1) promise significant increases in profits for any user but 2) be less intensive than the optimum levels for many users.

There are two immediate advantages of this strategy. First, general recommendations of this kind require less research than do recommendations which aim to be precise. Second, the rate of return for investment in intermediate levels of inputs will be higher than that for more intensive technologies, hence more appealing to risk averters and to those with high opportunity costs. Over time, each farmer can move towards his own optimum, guided by the knowledge of his particular circumstances and his accumulating experience.

Summary

Chapter IV focuses on considerations which might be impeding a more rapid diffusion of recommendations. Emphasis was given to institutional constraints, to profits – with attention to the cost of labor — and to risk as potential factors forestalling diffusion.

In considering the possible restrictions imposed by inadequate institutional support it was first noted that there are sharp differences in the use of inputs among the zones of the Plan. There is no evidence that the quality of institutional services varies from zone to zone in a way consistent with the variation in input use. It was concluded that institutional services do not explain the differences among zones. It is also evident that farmers had access to credit, to inputs, and to information through non-official channels. With institutional factors not responsible for difference among zones and with farmer access to services not dependent on official institutions it was concluded that institutional factors are not responsible for slow rates of diffusion in the area as a whole. While more effective services would probably contribute to more rapid diffusion, inadequate services cannot be regarded as the principal factor preventing the region's farmers from following Plan recommendations.

In considering profits experimental data are marshalled which suggest that planting densities in excess of 40,000 plants per hectare do not contribute strongly to yields, that yields adjusted for cost of fertilizer change only slightly (if at all) when fertilizer use is reduced from intensive to intermediate levels, and that it might be possible to reduce phosphorus applications relative to nitrogen applications.

Data from farmer plots for Zone 5 imply that, after reducing yields to compensate for the farm cost of fertilizer and for the opportunity cost of labor, the intensive technology (one with recommended rates of nitrogen but permitting plant densities down to 33,000 plants/ha at harvest) is the most profitable technology. In Zones 1-4 an intermediate technology (an average of 90 percent of the recommended nitrogen, 80 percent of the recommended phosphorus, and with plant densities down to 35,000 plants at harvest) is most profitable. In both regions, the conventional technology offered less profits than did either the intermediate or the intensive technology on the average even after adjusting for the farm cost of fertilizer and the opportunity cost of additional labor required. According to the analysis, the cost of labor, even when valued at average wages in non-agricultural activities, is not motivating farmers to stay with the conventional technology.

A substantial amount of variation is evident in adjusted yields for each of the technologies and for both regions. Using frequency distributions of yields to represent probability distributions, a risk averting farmer would not choose the conventional technology over the other technologies in either region and would be disposed to choose the intermediate technology in Zones 1-4 and the intensive technology in Zone 5. This is exactly consistent with selection based on profit seeking. A second look at the possible influence of risk, in which fertilizer use is related to farm size, showed no consistent relationship between the two and no statistically significant relationship in either region. On balance it was concluded that there is no evidence in the 1975 survey data that risk is influencing the adoption of fertilizer. Risk might be inducing farmers to favor lower planting densities, around 35,000 plants at harvest.

After examining potential profits and risks of the three technologies in each region it was concluded that Zone 5 farmers would be more likely to use high rates of nitrogen than would farmers in Zones 1-4, and that few farmers in Zones 1-4 could be expected to use over 100 kg/ha nitrogen. This conclusion emerges from comparison of average adjusted yields and the variability in yields. It accords exactly with the 1975 survey data which showed only 38 percent of the Zones 1-4 plots receiving at least the average recommendation of 110 kg/ha of nitrogen while 65 percent of the Zone 5 plots were receiving at least the recommended 100 kg/ha.

Two additional points remain. First, the farmgate maize price of fertilizer has declined substantially since 1971, from 5.6 to 3.2 kg of maize per kg of nitrogen in 1975. This has almost surely encouraged profit seeking farmers to use more nitrogen. Second, it can be asked why 38 percent of the plots of Zones 1-4 received 110 kg or more of nitrogen when intermediate levels were more profitable on the average. A myriad of explanations come to mind but it seems likely that the most important lies in the heterogeneity of the area. As Table 13 shows, for some plots amounts in excess of 110 kg/ha were more profitable than lesser amounts.

V. REVIEWING CONCLUSIONS

This final summing up treats three themes: the first combines two lessons which Plan experience helped make more evident; the second relates to conclusions about factors which have been important in shaping farmer compliance with Plan recommendations; and the third deals with the implications of the conclusions for some of the hallmarks of the Plan.

Lessons Reinforced by Plan Experience

The experience of the Plan testifies to the willingness of small farmers to change from traditional practices when given the opportunity and inducement. Tradition, after all, is nothing more than the embodied experiences of the past, garnered in a stable environment and interpreted in the light of the goals and circumstances of the participants. With changes in their environment and circumstances, the farmers of Puebla have shown their willingness to change their practices.

Plan Puebla's early demonstration of this willingness of farmers to follow more intensive practices captured the attention of decision makers in much of Latin America. Now convinced that traditionalism itself is not a lasting barrier to change, they have set out to stimulate changes among the farmers of their own countries. Many such efforts – in Honduras, Peru, Colombia, and in Mexico – are consequences of the early activities in Plan Puebla. The project, then, has contributed in a substantial way to the recognition that something can be done to improve the lot of small farmers.

Beyond this, Plan personnel demonstrated that formal rules and working rules differed markedly for some of the institutions charged with supporting the area's agriculture. This realization led to changes in certain procedures, changes which improved the services of the institutions. This experience has sensitized other decision makers to the possibility that attainable changes in their own working rules could facilitate flows of information and inputs to farmers with consequent increases in production.

Farmer Compliance with Recommendations

The preceding chapters focused on factors which might have been influential in preventing farmers from following the practices recommended to them. While emphasis was given to profitability, other factors were also considered. One of these is the adequacy of farmer access to credit, inputs, and information. It was argued that, while improvement in these services has facilitated adoption of recommendations, inadequate services are not one of the principal barriers to more widespread use of the recommended technology.

A second factor sometimes said to be restricting the use of Plan recommended technology is the opportunity cost of labor. Again, while in some cases this might be an important consideration, the evidence suggests that it is not playing a significant role in limiting adoption of the recommendations. Yield survey data shows that, on the average, yields from improved technologies as compared with conventional technologies are more than sufficient to compensate for the extra labor required. A third factor, risk, was also considered, but with inconclusive results.

Differences between the farmers of two sub-regions in the use of recommended technology was found to be consistent with differences in profits associated with their use. What emerged from the analysis, then, is the conviction that profit is the principal factor influencing farmer compliance with Plan recommendations.

Implications for Plan Hallmarks

Turning now to specific attributes of the Plan and potential modifications, several characteristics are regarded as Plan hallmarks: experimental work in farmers' fields, research aimed at precise recommendations, extension work and arrangements for credit organized through groups of farmers, and an evaluation unit within the staff. These final paragraphs will focus on precision in recommendations and on evaluation.

The project's emphasis on two-way communication with farmers has reaffirmed the importance of on-farm research, combining careful research with farmers' conditions. This approach is far more likely to produce useful recommendations than research carried out on experiment stations with little contact with farmer clients. In formulating recommendations researchers aimed at a high degree of precision, arguing that small errors can have consequences for yields and income which, because the farmers are poor, will be significant.

The effort to achieve precision appears to have run afoul of the region's heterogeneity, heterogeneity which emanates from differing agro-climatic circumstances and from differing farmer circumstances. The range of values encountered for soils variables in Zone 5 is a graphic testimony to the agroclimatic differences. The likely differences from farmer to farmer in opportunity cost of capital, opportunity cost of labor, distance to markets, cropping patterns, sensitivity to risk and so on distinguish one farmer's circumstances from another's. With such heterogeneity it is unlikely that precise recommendations — recommendations near the optimum — for one farmer will fit many of his neighbors. What is more likely is that a great deal of variability in input use will emerge as farmers move towards individual optimums.

It is clear that a recommendation for each of the plots of each of the farmers is not feasible and it is evident that heterogeneity precludes formulating precise recommendations with general applicability. This suggests that intermediate recommendations that are below average profit maximizing levels but high enough to promise substantial returns, are preferred. Certainly this is what farmers are doing as they reduce planting densities and fertilizer levels below recommended levels.

It can be claimed that, if farmers are already making adjustments, the course now followed suffers no disadvantages. But there are two disadvantages. The first is that precise recommendations are more expensive to generate than are more general, less ambitious recommendations. Concentration on intermediate recommendations provides substantial savings, especially in the time of trained agronomists.

The second disadvantage emerges from the implications for evaluating the project. If the project's progress is measured by farmer use of precise recommendations and if the precise recommendations don't exactly fit all of the farmers, then "adoption rates" will be low and evaluation will be unfavorable. Certainly this is the result of a stringent evaluation of the data from the 1975 yield survey. This shows that adoption, defined in terms of the recommendations, occurred on less than 10 percent of the plots. Measured in terms of intermediate recommendations, however, program progress would be more favorably viewed. And this view would seem to accord better with what has taken place — a sharp increase in the proportion of farmers applying high levels of fertilizers.

As a final thought, then, while the farmers of Puebla are using more fertilizer and increasing seeding densities, they are not moving quickly to follow the Plan's recommendations exactly. The evidence cited in this monograph suggests that the major factor impeding widespread diffusion of the recommendations is that they promise little, if any, increase in profits over intermediate levels of input use but do require larger expenditures and might involve larger risks. Farmers are moving toward intermediate levels of input use. There are advantages in concentrating research and recommendations in that range as well.

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