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Articles

Farmers' Stepwise Adoption of Technological Packages: Evidence from the Mexican Altiplano

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Agricultural research and extension programs in developing countries, rather than following the conventional package approach, should be designed to take into account the fact that farmers adopt improved technological components in a stepwise manner. On-farm experimental and survey data collected from two rainfall zones in a high valley of Mexico are synthesized to show that farmers have rationally followed a stepwise process of adopting improved varieties, fertilizer, and herbicide for barley, reflecting the relative profitability and riskiness of each component in each zone. Despite significant interactions between the components, it was still possible for farmers to adopt individual components in a sequential manner.

Key words: adoption, barley, Mexico, technological package.

In efforts to increase agricultural productivity, researchers and extension agents in developing countries have typically promoted a technological package consisting of a number of components such as variety, fertilizer, planting method, and weed control. Proponents of the package approach argue that a package is needed to capture the positive interactions between several components. A package may also provide a convincing effect to farmers by emphasizing the large yield difference between traditional and improved practices (Walker). However, because of capital scarcity and risk considerations, farmers are rarely in a position to adopt complete packages. As an alternative, it is hypothesized that packages can usually be disaggregated into subsets or clusters of one or two components which allow critical interactions to be exploited and which enable adoption to follow a stepwise pattern (Mann). In this scenario, elements initially adopted will be those that provide the highest rate of return on capital expenditures (Ryan and Subrahmanyan).

Despite the obvious importance of this issue in the formulation of research and extension strategies, the literally thousands of studies that have been conducted on the adoption of agricultural technologies have provided little evidence to decide between the package and the stepwise approach to the development and delivery of technologies to farmers.[1] Indeed, most adoption studies have considered adoption of single innovations in isolation and have ignored the process of adoption among a set of components of a technological package (Feder, Just, and Zilberman). Adoption studies have also had a "pro-innovation" bias that assumes that the innovation is "right." These studies have proceeded to analyze patterns of adoption in terms of different socioeconomic characteristics of farmers (Rogers).

In this paper, we relate the adoption of an array of technological components to the characteristics of these components, such as profitability and risk. We demonstrate how farmers in the Mexican altiplano have rationally followed a stepwise approach to the adoption of a package that reflects the characteristics of each component and the interactions between them. Farmers are divided into two relatively homogenous agroclimatic zones

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[1] For reviews of these adoption studies see Rogers; Byrnes; and Feder, Just, and Zilberman.

Table 1. Comparison of Different Components of the Traditional and Improved Technologies

Technological Component	Traditional Technology	Improved Techology
1. Variety	"Comun," a variety introduced by the Spanish in the colonial period and used mostly for animal feed	Apizaco, Cerro Prieto, and other malting-quality varieties released by the Mexican research institute, INIA
2. Weed control	None or some hand weeding	Use of a backpack sprayer to apply 2,4–D herbicide to control broadleaf weeds
3. Fertilizer	Use or organic manure in some years	Application of nitrogenous and sometimes phosphatic fertilizer (40 to 80 kg N/ha)

where the agronomic responses of the various components of the package are quite different. Beyond this, no effort is made to relate adoption to the characteristics of the farmer, which has been the dominant theme of previous adoption studies; rather, the emphasis in this study is on the characteristics of the technologies themselves.

The Setting

The study is set in the elevated areas of central Mexiço in the states of Tlaxcala and Hidalgo where barley is the main cash crop and maize the subsistence crop. (A detailed description of farming systems and production practices is given in Byerlee, Harrington, and Marko.) The region has been divided into (*a*) a dry, risky area with annual rainfall of 450–550 millimeters (mm), where farmers suffer total or almost total crop loss one year in five and (*b*) a wet zone with rainfall of 600–700 mm, where the probability of crop failure falls to one year in twenty. Average farmer yields of barley range from less than one ton per hectare in the dry zone to nearly two tons per hectare in the wet zone. Small farmers with less than 20 hectares predominate, although several farmers operate farms of over 100 hectares.

Agriculture in the area has undergone rapid technological change in the past ten to fifteen years. Table 1 compares the "traditional" and "improved" practice in barley production for the three biochemical technologies under study.[2] Several institutions have had a role in promoting this improved technology as a package in the area since the mid-1960s. A private organization of major breweries has promoted a barley production package by supplying improved seed and recommendations and by offering a premium price for malting quality varieties, especially to the large farmers. The extension service has worked with the official credit bank and requires as part of the loan the use of a package that usually includes an improved variety, herbicide, and fertilizer. These government services have largely emphasized the smaller farmers of the area.

Finally, farmers themselves have been a major source of innovation. Many large farmers have contacts with farmers in more advanced irrigated areas of the country, or even abroad, and have brought back new ideas and inputs for experimentation.

An unusually rich data base enables us to treat some of the major deficiencies in previous adoption studies. In 1975, a survey of barley production practices was conducted for fifty-four randomly selected farmers. We revisited these same fifty-four farmers in 1980 and collected data on the same production practices and where possible for the same field.[3] In 1979, another survey of a larger sample of eighty-seven farmers was carried out in the wet zone. In this survey, farmers were asked the year in which they first used selected new practices. Because of the larger sample size and greater detail, information from this survey is used to supplement the longitudinal surveys.

Data on responses to improved practices under farmers' conditions were obtained from the analysis of 106 on-farm experiments conducted by CIMMYT in the same area from 1976 to 1980.[4] These experiments included

[2] At the same time mechanization including use of tractors for land preparation and combine harvesting has also proceeded rapidly. (See Byerlee and Hesse de Polanco for details.)

[3] In two cases, the selected field was farmed by a different farmer; these farmers were included in the 1980 sample. In eight cases, the farmer did not plant barley in 1980, so that the final sample size in 1980 was reduced to 46 farmers.

[4] These experiments were conducted primarily for training in research methods. Only a few of the surveyed farmers hosted these experiments; however, they have no doubt helped spread the improved technologies in the area.

both single-factor experiments, e.g., variety or fertilizer, as well as 17 factorial experiments that allow a measure of the interactions between two or more factors. The number of experiments in the dry zone is somewhat smaller (33); and, with more variability, estimated agronomic responses in this zone are less reliable.

Characteristics of the Technological Components and the Predicted Adoption Pattern

The adoption pattern of a particular technological component can be represented by the time of initiation of adoption and the rate of adoption, once initiated. Given a series of independent technological components, we hypothesize that this pattern is a function of five characteristics of the component: (*a*) profitability, (*b*) riskiness, (*c*) divisibility or initial capital requirements, (*d*) complexity, and (*e*) availability.[5] In turn, profitability and riskiness of a component are a function of elements of the agroclimatic and socioeconomic environment, such as rainfall and prices. Finally, interactions between technological components will affect adoption patterns. Where positive interactions exist, the adoption of one technological component is expected to accelerate the adoption of related components. In the extreme case where inputs are perfect complements, these technological components would be adopted as a package since there would be no response to one component without the presence of the others.

We first consider the average responses of each technological component without regard to interactions between different components. (Interactions will be considered below.) Yield increases, profitability, and riskiness were calculated for each rainfall zone using the results of the on-farm experiments (fig. 1). All components increased yield, and this increase was statistically significant except in the case of variety and herbicide in the dry zone.[6] The

Table 2. Changes in Profitability of Technological Components, 1975–80

	Marginal Rate of Return on Investment			
	Wet Zone		Dry Zone	
	1975	1980	1975	1980
	(%/year)			
Improved variety	1,419	2,172	411	667
Herbicide	281	430	77	146
Fertilizer	91	223	163	444

Source: Calculated from 106 on-farm experiments using actual prices paid and received by farmers in each year.

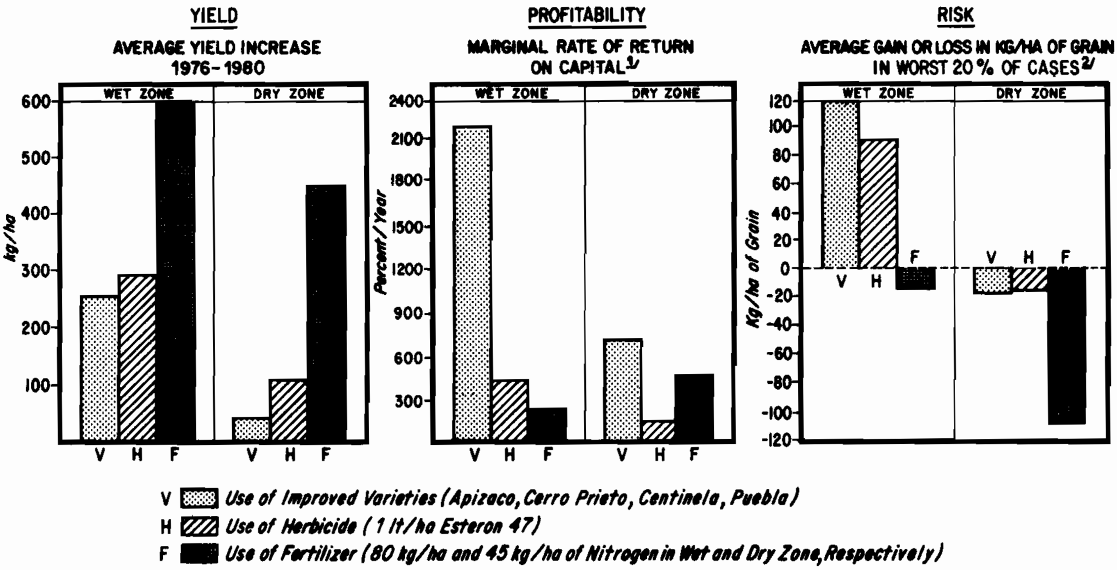
yield increase was largest for fertilizer, followed by herbicide, and then variety in each rainfall zone. The marginal rate of return on capital for each technological component was calculated following the methodology of Perrin et al. In each zone improved variety gave the highest return despite its relatively low yield increase. Improved varieties are a low cost change (seed can be used for several years) and in this case gave an average price premium of 10% for malting quality. In the wet zone, herbicide and then fertilizer followed variety in terms of profitability. However, in the dry zone where weed problems are less severe, fertilizer was more profitable than herbicide.[7] In all cases, and especially in the case of fertilizer which was increasingly subsidized, price relationships moved sharply in favor of adoption from 1975 to 1980 (table 2), and this might be expected to influence the adoption path (Jarvis). However, with an estimated cost of capital in the informal market of around 50%, it should have been profitable to adopt all components in each zone even in 1975.

The distribution of yields in the experiments was used to calculate the risk from adopting each technological component in each zone, measured as the profits (or losses) (in grain equivalents) for the lowest 20% of the distribu-

[5] Byrnes hypothesizes similar, but not identical, characteristics consisting of observability, comparability, profitability, reliability, and trialability.

[6] These data are calculated as the average across all experiments whether single factor or multifactor. Most single-factor experiments were conducted with the other components set at the improved level. In the case of factorial experiments, average effects of each factor were used in the calculations. Experimental treatment levels and designs varied from year to year, hence it is not possible to present a full analysis-of-variance table. Rather, pairwise *t*-tests were used to test the difference between the check treatment and the treatment closest to the economic optimum. This provided 24, 22, and 34 observations on variety, herbicide, and fertilizer, respectively. In the case of fertilizer an attempt was made to fit a response function; but lacking variables on site characteristics, the fitted form indicated constant marginal returns. The economic optima for fertilizer were calculated using discrete points following Perrin et al.

[7] However, we believe that the fertilizer response in the dry zone is an overestimate because of the dominant effect of two unusually high-yielding sites in a relatively small sample of 12 experiments.



Source: Based on results from on-farm experiments, 1976–80.
[a] Calculated at 1980 prices.
[b] Net return calculated in 20% of experiments with lowest returns. Monetary returns converted to kg/ha of grain at 1980 prices.

Figure 1. Comparison of yield increase, marginal rate of return on capital and risk of the three biochemical technological components

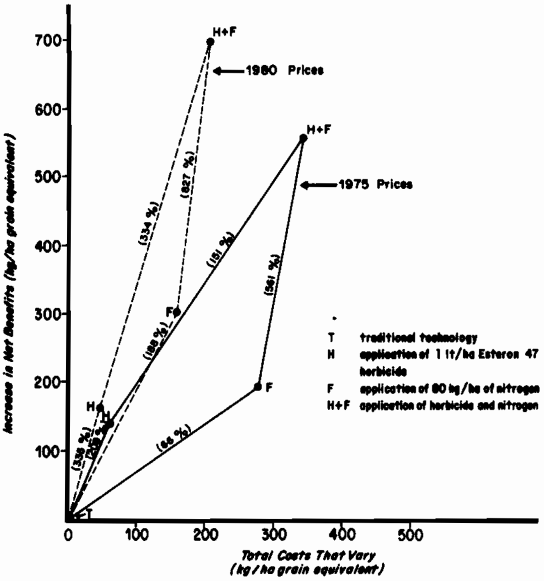
tion (Perrin et al.).[8] In the case of variety, there was no measured risk from adoption in the wet zone and only a very small risk in the dry zone (fig. 1). Herbicide was not risky in the wet zone. However, in the dry zone, because the incidence of crop loss is about one in five, use of any input is risky. Even so, absolute losses from herbicide use in the dry zone were not high because of its low cost. Fertilizer was by far the most risky of the inputs considered, although at 1980 prices losses were small in the wet zone. In the dry zone, fertilizer use (at a lower dose of 45 kg/ha of nitrogen) was risky, with expected losses in the driest years of over 100 kg/ha in grain equivalents.[9]

Limited data were available on the interaction between variety, herbicide, and fertilizer. Five factorial experiments were conducted on variety by management, with local and improved varieties being tested with and without the application of fertilizer and herbicide. At low management levels, there was no significant yield difference between local and improved varieties. At high management levels, the improved variety gave significantly higher yields since the local variety tended to lodge with the application of fertilizer. However, because of the low cost of a change in variety and the price premium for improved varieties, it was still quite profitable to adopt improved varieties without adopting the other components (marginal return of 365%).

Twelve factorial experiments were conducted on fertilizer by herbicide use, mostly in the wet zone. As expected, in the wet zone there was a strong positive interaction between herbicide and fertilizer (statistically significant at the 5% level). Marginal returns analysis, shown in figure 2, strongly suggest that the sequence of adoption should be herbicide followed by fertilizer. The addition of herbicide alone costs little and provided high returns. The addition of fertilizer alone, however, gave much lower returns and was only marginally profitable at 1975 prices. Again, figure 2 indicates the extent to which real costs of adoption fell from 1975 to 1980. In the dry zone, only three herbicide by fertilizer experiments were conducted, and no significant in-

[8] The distribution of yields over many sites and years is assumed to represent true year-to-year variation faced by farmers. In practice, the distribution also includes site-to-site variation which we have reduced but not eliminated by stratifying by rainfall zone. It should be noted that rainfall is erratic and often very localized, so that there is much within-year site-to-site variability which is essentially random.

[9] These measures of risks were calculated at 1980 prices. Calculation at 1975 prices does not change the relative risk ranking of technological components in each zone; however, at 1975 prices, fertilizer incurred significant risks even in the wet zone of over 100 kg/ha loss (in grain equivalent) in the worst 20% of cases.



—— *Net benefit and marginal rates of return calculated at 1975 prices.*

---- *Net benefit and marginal rates of return calculated at 1980 prices.*

Source: Calculated from data from nine on-farm experiments, 1976–80.

Note: Numbers in brackets are marginal rates of return on investment.

Figure 2. Net benefit curves showing interaction of herbicide and fertilizer in the wet zone at 1975 and 1980 prices

teraction was observed. That is, the profitability of each component appeared to be independent of the adoption of the other component. However, the small sample size precludes a more definite conclusion.

No three-way factorial experiments have been conducted that would enable a precise ranking of variety, herbicide, and fertilizer, taking into account all two- and three-way interactions. However, from the above two factorial experiments the rate of return to improved variety only (with no herbicide or fertilizer applied) was still about double the rate of return to applying fertilizer and herbicide (together) to the local variety in the wet zone. This again suggests the adoption sequence of variety, herbicide, and fertilizer.

All the inputs are quite divisible. Even herbicide which requires a back-pack sprayer for application was often applied by small farmers with rented or borrowed equipment. All the components are also relatively simple to adopt. Fertilizer and herbicide are more complex inputs than improved variety since both require calculation of dosages per unit area and judgment on the appropriate time of application in relation to crop development and weather conditions. There were also a number of different fertilizer products with varying nutrient composition, which complicated calculation of appropriate dosages.

The above characteristics of profitability, riskiness, divisibility, and complexity describe the demand for the technology—the focus of this study. The adoption of the technology is also determined by supply factors, primarily the availability of inputs required for adoption. Through interviews with input suppliers and early adopting farmers, we have tried to reconstruct a picture of input availability over the adoption period (table 3). Before 1968, supply of all inputs was very poor. Inputs for all three technological components became generally available around 1968, a considerable time before the period of widespread adoption. Improved seed and herbicide were distributed through the private sector and after 1970 through the official bank and were generally readily available. Fertilizer distribution was in the hands of the public sector, and distribution points were fewer and stocks of fertilizer (especially of nitrogenous fertilizer) were erratic, so that farmers often had to travel a considerable distance to get supplies. Hence, supply constraints may have retarded the adoption of fertilizer, especially by small farmers.

The profitability and risk analysis of agronomic responses observed in the on-farm experiments clearly point to a rational sequence of adoption of the technological package in the wet zone of variety followed by herbicide and then fertilizer. Although there were strong positive interactions between the three components, it was still profitable to adopt each component separately in this sequence. Note that yield increases run in the reverse order from about 600 kg/ha for fertilizer to only 250 kg/ha for improved variety. Neither the divisibility nor the complexity of these changes appear to differ sufficiently to change this adoption sequence, although supply constraints on fertilizer may have slowed its adoption by small farmers.

In the dry zone, the evidence again suggests that variety should be adopted first followed by fertilizer and then herbicide. However, fertilizer was substantially more risky, and this might change this sequence. In this zone,

Table 3. Summary of Supply Situation for Inputs at Three Periods of Adoption

Input	Before 1966 (Little adoption)	1966 to 1970 (Early adoption in wet zone, mainly by large farmers)	After 1970 (Period of widespread adoption in wet zone)
1. Seed of improved variety	Release of variety, Toluca in 1960; but because of late maturity and poor agronomic type, received little acceptance.	Apizaco released in 1966 and seed commercially available two years later; variety became widely used and was still dominant in 1980.	Seed distributed by private dealers, official bank and from farmer to farmer. Readily available.
2. Herbicide	A few large farmers obtained chemicals from irrigated areas of Mexico.	First distributor set up in 1968 just outside study area.	Increasingly available through private dealers in villages and through official bank.
3. Fertilizer	Not available, especially nitrogenous fertilizer.	First distributor set up in 1966 at 75 km from study area. However, products of high P and K composition distributed.[a] Nitrogenous fertilizer distributed by 1970.	Available only through public sector and official bank. Few distribution points and stocks erratic (especially for nitrogenous fertilizers). Supply situation improved steadily in the 1970s.

[a] Agronomic experiments indicate little response to P and K in the area.

profitability of the components was much lower (except for fertilizer) and risks much higher than in the wet zone, so that we would expect slower adoption of all components.

Analysis of Farmers' Actual Adoption Patterns

Logistic curves of cumulative adoption levels, based on farmers' recall of adoption years, were fitted to describe the adoption path of each technological component in each rainfall zone. The logistic curve is defined as

$$Y_t = K/(1 + e^{-a-bt}),$$

where Y_t is the cumulative percentage of adopters by time t, K is the upper bound on percentage adoption,[10] b is the rate at which adoption occurs, and a is the constant term. Using the logistic curve, the adoption pattern can be described by two parameters from each curve. First, we calculated the year in which 20% of the farmers had adopted a given practice as a measure of the time of initiation of adoption. Second, we measured the rate of adoption as the number of years required for 50% of the farmers to adopt the practice during the period of most rapid adoption (i.e., the period required to go from 25% to 75% total adoption).

Logistic curves are shown in figure 3, and parameters are presented in table 4. In addition, the actual use of each practice, based on the surveys in 1975 and 1980, is reported.[11] It is clear that farmers' sequence of adoption closely followed that predicted by the profitability and riskiness of each component calculated from the observed agronomic responses. In the wet zone there was a clear sequence of adoption of variety followed by herbicide and then fertilizer. By 1980, almost all farmers had adopted improved varieties and two-thirds had adopted fertilizer. In the dry zone, initiation of adoption of all components was much later, but once initiated the rate of adoption has been somewhat faster, probably reflecting the more favorable price incentives in later years. In 1980, 61% of farmers used improved varieties in the dry zone compared to only 29% in 1975. In the dry zone, fertilizer was more rapidly adopted than herbicide, although both practices were still used by only a small proportion of farmers in 1980. The earlier adoption of fertilizer relative

[10] Depending on the expected terminal adoption rate, K may vary. In our case, all technological components are expected to be completely adopted in the long run because of their profitability, and hence 100% adoption was assumed. In the wet zone most farmers had already adopted the three technological components by 1980, and it is known that this proportion has continued to increase since the survey.

[11] Differences between the two sets of results arise from the different definitions of adoption (the logistic curves are based on farmers who have ever used the practice) as well as possible uncertainty on the part of farmers about the year in which they first used a practice.

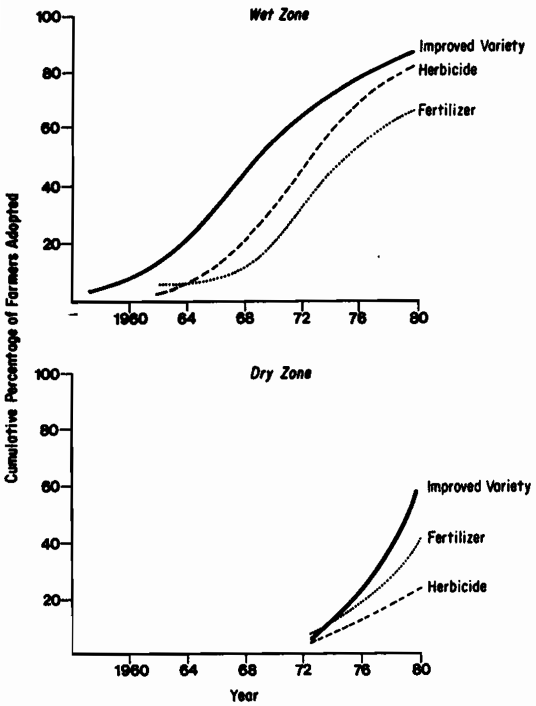


Figure 3. Logistic curves of adoption of improved technological components

to herbicide in this zone conforms to results from the on-farm experiments, which indicate high but risky returns from fertilizer use relative to herbicide use. However, the small number of observations available from on-farm experiments and the low adoption rates for these two components prevent us from drawing definite conclusions for the dry zone.

In the wet zone, the larger 1979 survey enables a disaggregation of adoption patterns by farm size. This shows that both small and large farmers followed the same sequence of adoption of fertilizer followed by herbicide (table 5). In each case small farmers lagged large farmers in adoption; but once adoption had been initiated, small farmers adopted just as rapidly or more rapidly than large farmers. Because large farmers faced fewer supply constraints, these results suggest that profitability and risk were the major determinants of the sequence of adoption.

Packages versus Stepwise Adoption Pattern of Individual Farmers

The above patterns of adoption indicate that farmers have adopted in a sequential manner rather than as a package. In fact, data on adoption patterns by individual farmers in the wet zone show that in no case did a farmer adopt all three technological components in the same year and only about 20% of farmers adopted two components together, usually herbicide and fertilizer (see table 6). Furthermore, among farmers using all three components of the package, the average lag from adoption of the first to the last component of the package was nearly five years. Seventy-three percent of farmers using at least one of the three components had adopted variety first, usually independently of other compo-

Table 4. Parameters of the Logistic Function and Actual Levels of Adoption in the Wet and Dry Zones in 1975 and 1980

	Parameters of Logistic Function		Actual Use of Practice		
			Percent of Farmers		
	Time of Initiation or Adoption (year by which 20% farmers adopted)	Rate of Adoption (number of years required for middle 50% of farmers to adopt)	Used 1975	Used 1980	Ever Used 1980
Wet Zone					
Improved varieties	1964.0	9.6	76	91	96
Herbicide	1968.2	7.2	77	74	82
Fertilizer	1969.2	10.3	46	62	65
Dry Zone					
Improved varieties	1975.6	5.4	29	61	61
Herbicide	1978.4	[a]	11	13	17
Fertilizer	1975.4	6.5[a]	14	16	30

Note: Using a Chow test, differences between fitted functions are statistically significant at the 1% level for all components except for the adoption functions for improved variety and fertilizer in the dry zone.

[a] Adoption of these components was only in the early stage in these zones so that the rate of adoption can only be predicted. In the case of herbicide there were less than five recorded cases of adoption which was considered insufficient for prediction.

Table 5. Parameters of the Logistic Functions for Adoption of Herbicide and Fertilizer by Small and Large Farmers in the Wet Zone

	Time of Initiation of Adoption (year by which 20% of farmers had adopted)	Rate of Adoption (number of years required for middle 50% of farmers to adopt)
Large farmers (>20ha)		
Herbicide	1964.8	5.2
Fertilizer	1965.4	7.3
Small farmers (<20ha)		
Herbicide	1965.4	7.3
Fertilizer	1971.1	6.0

Table 6. Adoption Sequence of Technological Components for Individual Farmers in the Wet Zone

Percent of farmers using at least one technological component who adopted:	
Variety before herbicide and fertilizer	68
Herbicide before variety	14
Fertilizer before variety	9
Variety and herbicide in the same year	5
Variety and fertilizer in the same year	0
Herbicide and fertilizer in the same year	18
All three components in the same year	0
Percent of farmers using herbicide or fertilizer who adopted:	
Herbicide before fertilizer	61
Fertilizer before herbicide	17
Fertilizer and herbicide in the same year	22

nents. Among farmers who had adopted fertilizer and/or herbicide, more than half used herbicide before fertilizer and less than one quarter adopted both in the same year (table 6). Two-thirds of the farmers who used both herbicide and fertilizer and who adopted fertilizer first, followed within three years with the use of herbicide. Only one-third of farmers adopting herbicide first, followed with fertilizer use in the same space of three years. These results reinforce the stepwise adoption behavior based on the aggregate rates of adoption of each component.[12]

Conclusions

The present study has clearly documented the adoption pattern followed by farmers during a period of rapid technological change. During this period of ten to fifteen years, most farmers, especially in the wet zone, have adopted a package of biochemical technological components in a stepwise manner. In the wet zone, the sequence followed by farmers was variety-herbicide-fertilizer. Adoption in the dry zone, where economic returns were generally lower and risks higher, considerably lagged adoption in the wet zone. However, the adoption sequence in the dry zone is similar to the wet zone except that fertilizer generally preceded herbicide. In each zone, the adoption sequence of the three technological components is strongly correlated with estimated economic returns of each component in that zone.

Although there were strong positive interactions between all three components of the package, few farmers adopted more than one component at the same time. Rather, adoption followed a clear stepwise pattern with components giving highest returns on capital being adopted earliest. Hence, farmers over time and in a stepwise manner will adopt the complete package of technology. The evidence presented is, of course, limited by the fact that we have used data from only two points in a long period of adoption of ten to fifteen years when relative prices changed considerably. Furthermore, differential supply constraints on the three technological components have probably operated at some point during this adoption period. Nonetheless, results strongly suggest that farmers have rationally chosen a particular stepwise adoption path. More studies of this type which combine information on both adoption patterns and agronomic responses are needed to confirm these conclusions.

The findings of this study have a number of implications for an efficient strategy for development and diffusion of improved agricultural technologies. First, although the research strategy might aim to develop a package of practices that exploits positive interactions between technological components, this package should be a goal for adoption over time and not for direct extension to farmers. Rather, researchers should seek a stepwise pattern of adopting components in such a way that each step is both profitable to farmers and appropriate to their capital constraints. Facto-

[12] The sample size of adopters in the dry zone is too small to conduct this analysis for the dry zone. In the wet zone there was no significant difference in the individual adoption behavior of small and large farmers; that is, there was no tendency for large farmers to favor adoption of packages.

rial experiments that examine interactions between components enable the identification of an appropriate sequence. Furthermore, the check plot in each experiment should reflect existing farmer practice or a projected farmer practice in the future. In this study, herbicide trials would be conducted with improved varieties but without the application of fertilizer. Fertilizer trials to establish optimal levels of application would be conducted using both improved varieties and herbicide weed control. Second, the need to divide farmers into relatively homogenous subgroups or recommendation domains[13] for the purpose of research and extension is illustrated by the sharp distinction in economic returns, risks, and adoption rates between the wet and dry zones. However, definition of these recommendation domains needs to take a long-term perspective. In particular, after a time lag, small farmers followed the same adoption path as large farmers.

Finally, the identification of research priorities should be based on economic analysis of the likely profitability of each component rather than potential yield increases. The strategy of many research programs of focusing on "yield constraints" or the "yield gap" would have emphasized research on fertilizer, which in fact was the last component to be adopted. Farmers apparently do not need to see large yield increases to be convinced about adoption of a given practice.

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References

Byerlee, D., and E. Hesse de Polanco. *The Rate and Sequence of Adoption of Improved Cereal Technologies: The Case of Rainfed Barley in the Mexican Altiplano.* Mexico City, Mexico: CIMMYT Econ. Work. Pap. No. 82/4, 1982.

Byerlee, D., L. Harrington, and P. Marko. *Farmers' Practices, Production Problems and Research Opportunities in Barley Production in the Calpulalpan/Apan Valley, Mexico.* Mexico City, Mexico: CIMMYT Econ. Work. Pap. 80/2, 1980.

Byrnes, K. J. "Diffusion and Adoption of Innovations in Fertilizer-Related Agricultural Production Technology in Developing Countries." Muscle Shoals AL: International Fertilizer Development Center, unpublished report, 1982.

Feder, G., R. E. Just, and D. Zilberman. "Adoption of Agricultural Innovations in Developing Countries: A Survey." *Econ. Develop. and Cultur. Change* 33 (1985):255–98.

Harrington, L., and R. Tripp. *Recommendation Domains: A Framework for Onfarm Research.* Mexico City, Mexico: CIMMYT Econ. Work. Pap. 02/84, 1984.

Jarvis, L. S. "Predicting the Diffusion of Improved Pastures in Uruguay." *Amer. J. Agr. Econ.* 63(1981): 495–502.

Mann, C. K. "Factors Affecting Farmers' Adoption of New Production Technology: Clusters of Practices." Paper prepared for the Fourth Regional Winter Cereals Workshop—Barley, Amman, Jordan, 24–28 April 1977.

Perrin, R. K., D. L. Winkelmann, E. R. Moscardi, and J. R. Anderson. *From Agronomic Data to Farmer Recommendations: An Economics Training Manual.* Mexico City, Mexico: CIMMYT Info. Bull. No. 27, 1976.

Rogers, E. M. "Where Are We in Understanding the Diffusion of Innovations?" *Communication and Change,* ed. W. Schramm and D. Lerner, pp. 205–22. Honolulu: University of Hawaii Press, 1976.

Ryan, J. G., and K. V. Subrahmanyan. "Package of Practice's Approach in Adoption of High-Yielding Varieties; An Appraisal." *Econ. and Political Weekly,* (1975), p. A110.

Walker, T. S. "A Package Versus Gradient Approach in the Development and Delivery of Technology in Dryland Agriculture." Paper presented at the Third Workshop on Agro-Economic Research in Drought Prone Areas, University of Agricultural Sciences, Bangalore, 25–28 Feb. 1981.

[13] A recommendation domain is a roughly homogenous group of farmers who will use the same recommended technology (Harrington and Tripp).