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IMPEDIMENTS TO TECHNICAL PROGRESS ON SMALL VERSUS LARGE FARMS

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During the past four years, CIMMYT has been associated with a number of farm-level studies of the adoption of new wheat and maize varieties and fertilizer use. Most of these studies have now been published, and it is our purpose here to summarize some of the findings with respect to impediments to farmer adoption of new varieties.

Farm-to-farm differences in the date of adoption or the extent of adoption of new technology might be explained by a number of factors. The studies reviewed here considered farm-to-farm differences in the cost of acquiring and processing information, differences in the physical productivity of the new technology, differences in incentives due to tenure arrangements, differences in the cost of inputs, differences in prices received for the product, differential aversion to risk among farmers, and scale effects associated with farm or enterprise size. Policies to stimulate more rapid or more extensive adoption will vary in their success depending upon which of these factors are the most important in limiting the rate and extent of adoption. Of particular relevance to the topic of this session is the extent to which small farmers lag behind large farmers in adoption, and which of the above factors might account for that lag.

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The studies reviewed here were directed toward factors explaining differences in adoption of new varieties and fertilizer among farmers surveyed in a number of countries in 1972 and 1973. Since seeds and fertilizer are nearly completely divisible, one might ask why farm size effects might be expected at all. First there are likely to be economies of size in transactions costs. It takes about the same effort for the small and large farmers to acquire and evaluate information about a new technique, to learn how to use it and to make the purchase transaction. For an increase in net returns of $ 20 per hectare, the effort might be quite worthwhile for a 10-hectare farmer, but not for a 1-hectare farmer. These transaction costs will fall as community experience with and information about the new technique becomes more common. Because of this, the phenomenon of economies of size in trasaction costs can lead to a transaction lag in small farmer adoption even though ultimate adoption levels may be the same as on large farms. Hence, we will more likely observe size effects during the early phases of the adoption cycle.

Furthermore, experimentation with new techniques involves the risks of the unknown, usually involving additional investment, and small farmers may be less able to undertake such risks. This risk effect can lead to lower equilibrium levels of adoption, or to a lag in adoption by smaller farmers until the risks of the unknown are reduced with experience in the area.

A third potential source of size effects is that smaller farmers may face higher input costs. For example, quantity discounts might be available or government subsidies of information, credit or inputs may favor larger farmers.

The Study Areas

CIMMYT has been associated with maize adoption studies in Kenya (Gerhart), Colombia (Colmenares), El Salvador (Cutié), and Mexico (Perrin), and with wheat adoption studies in Tunisia (Gafsi), and Turkey (Demir). In addition, V.S. Vyas undertook, at CIMMYT's request, a review of the studies of wheat adoption which had been conducted in India. While the primary focus of these studies was the adoption of improved varieties, fertilizer use was also examined to some extent in each. The percent of surveyed farmers who had adopted improved varieties at the time of the studies ranged from 20 percent among Colombian maize growers to 67 percent among Kenyan maize growers (though adoption rates for subregions were as high as 100 percent).

The adoption trends shown in Figure 1 help to provide the dynamic contexts of the adoption processes at the time the studies were conducted. Adoption of hybrid maize in Western Kenya shows the most stable growth pattern, with use increasing steadily at the rate of an additional 8 percent of the farmers adopting each year after the hybrids were introduced in 1964. This rate slackened somewhat in the year immediately preceding the survey. Increases in the adoption of hybrid maize in El Salvador and Colombia have

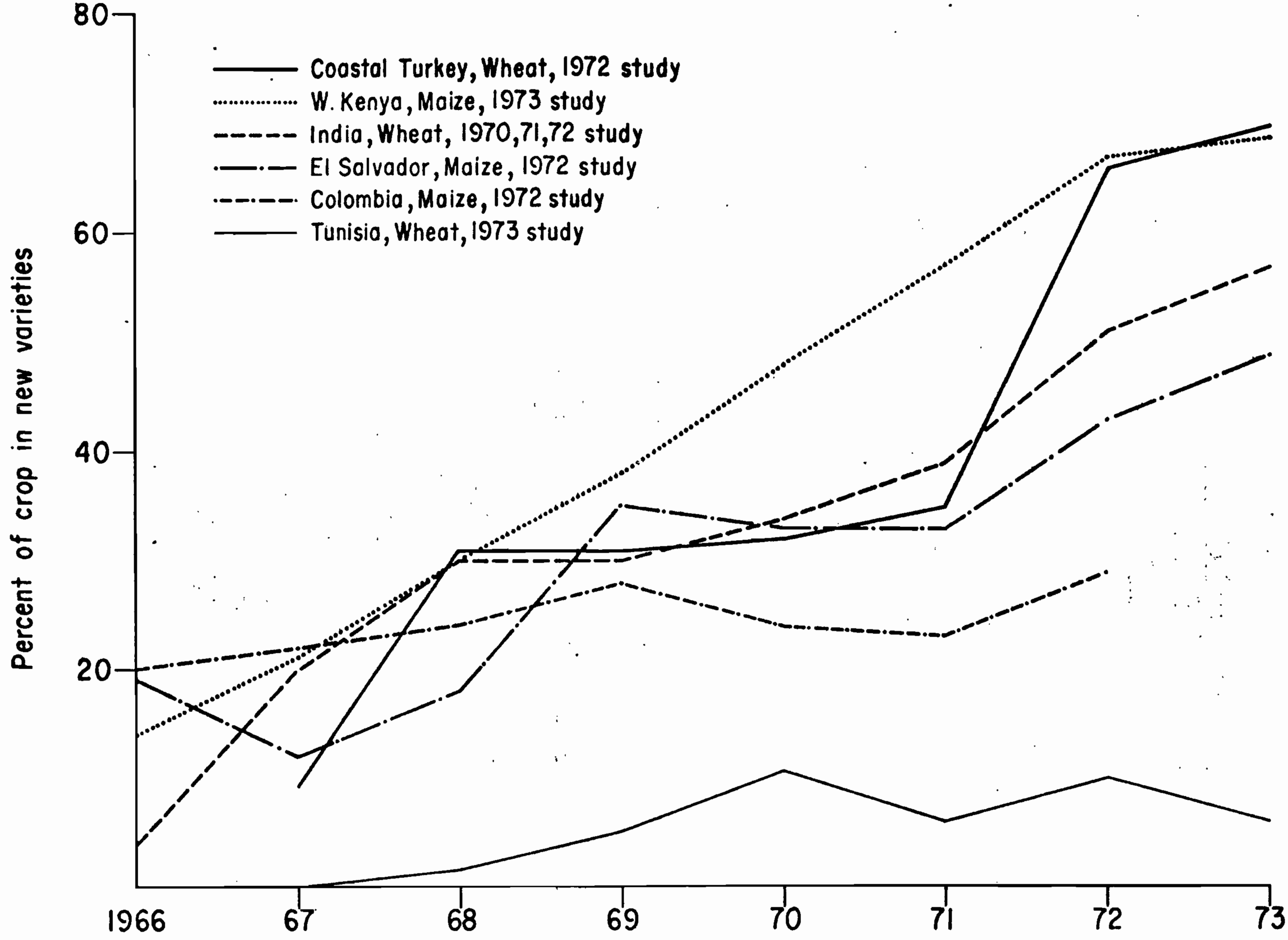

Fig.1 Trends in adoption of new varieties in the study areas.

been both more modest and more irregular. While the earliest hybrids were introduced into El Salvador in the late 1950's, not until after the introduction of H3 and H5 (after 1966) did the increase in use of hybrids become steady. In Colombia, on the other hand, the level of hybrid use has been relatively static in the past ten years.

High-yielding varieties of wheat were first introduced commercially in India in 1966-67. There followed a rapid adoption of these varieties by about 30 percent of the farmers within two years. The adoption level began to rise again after 1970, as irrigation facilities were extended and improved, until nearly 60 percent of Indian wheat was in new varieties by 1973. The data reported by Vyas were largely gathered in 1969-1971, after the initial surge of adoption had slowed. In the coastal spring wheat areas of Turkey, very rapid adoption of Mexican varieties occurred the first two years following their introduction in 1967. A second very rapid rise in the use of new varieties occurred in 1972 and 1973 after the introduction of the Russian winter variety Bezostaya into the winter wheat producing areas of Thrace and Marmara. In Tunisia, on the other hand, adoption of the Mexican bread wheat varieties increased only slowly from their introduction in 1968 until 1970, after which it fell in 1973, reportedly due to problems with seed quality. The majority of new varieties which have been adopted there are high-yielding varieties of durum wheats (durums constitute three-fourths of the national wheat acreage).

In each of the survey studies, the population to be studied was prestratified by agro-climatic zone as determined in collaboration with agricultural scientists. The samples were later post-stratified into size groupings. Analytical procedures included both multivariate analyses and interpretation of two-way tables. The summary here is restricted to a general interpretation of the results of somewhat diverse analytical approaches to a similar issue.

The Effects of Farm Size and Other Factors on Variety Adoption

In Table 1 we present the levels of adoption of new varieties by farm size groupings within agro-climatic zones of the study areas. In about half of these situations, there appears to be little relationship between farm size and adoption. This occurs in areas of Kenya, India, and Turkey where adequate time has elapsed since introduction and nearly all farmers have adopted regardless of size, and in the medium and high valleys of Colombia where few farmers have adopted but little additional diffusion has been taking place (Figure 1). In these areas equilibrium levels of adoption appear to have been realized, and we would consequently expect little correlation between farm size and adoption decisions.

The multivariate analyses in the cited studies offer some insight into which factors are important in explaining farm-to-farm differences in adoption behavior in areas where equilibrium adoption

TABLE 1.- Farm size and percent of farmers adopting new varieties

Crop and area	Number of farmers	Farm size limits (ha)	Percent of farmers adopting by farm size		
			Small	Medium	Large
Kenya maize					
1) high, wet	96	3.2	96		96
2) high, dry	93	4.5	84		95
3) low, dry	95	2.4	15		17
Colombia maize					
1) low-valley	203		19		65
hillside	49	2.6	0		15
2) med-valley	50	2.6	19		30
hillside	170	2.1	10		15
3) high-valley	135	1.0	5		12
hillside	126	1.5	4		4
Salvador maize					
1) valley	177	1.4,3.5	34	46	71
2) hillside	126	1.4,3.5	28	13	36
Veracruz maize					
1) valley	42	1.0,3.5	27	37	55
2) hillside	69	1.0,3.5	18	32	36
India wheat					
1) Kota	100	4.5,13.6	52	61	81
2) Faisabad	60	4.5,13.6	47	100	100
3) Karnal	60	4.5,13.6	100	100	100
4) Amritsar	100	4.5,13.6	100	100	100
5) Saharanpur	60	4.5,11.4	36	76	86
6) Ferozepur		4.0,11.0	93	96	100
7) Muzaffarnagar		4.7,10.7	37	55	57
Turkey wheat					
1) Mediterranean valley		6.0	95		97
hillside		8.0	92		90
2) Aegean valley		3.9	60		77
hillside		4.6	4		23
3) S.Marmara valley		4.4	70		43
hillside		3.4	13		32
4) Thrace hillside		8.0	62		85
Tunisia wheat					
1) low rainfall	175	15.0,40.0	15	43	57
2) high rainfall	200	15.0,40.0	13	34	66

Sources: Gerhart, Colmenares, Cutié, Perrin, Vyas, Demir and Gafsi.

levels have not been realized. The factors considered varied from study to study, but included zone and topographic variables to capture differences from farm to farm in yield superiority of the new varieties, plus variables representing differences in farmer incentives arising from input and product prices, differences in farmer perceptions of or reactions to risk, and farm size effects. Due to the differences from study to study in variables used and analytical techniques, we can present here only a brief summary (Table 2) of the results of these multivariate analyses. For each factor included in the analysis, either a yes or a no is entered in Table 2; yes if the factor was significant statistically (t-ratios of 1.5 or more) with a coefficient sufficiently large to be of practical significance, and a no otherwise.

A cursory glance at Table 2 shows that productivity factors--agro-climatic zone and topography--are the most consistent in explaining why some farmers adopt new varieties and others do not. While these factors were generally far more important in explaining behavior than any others, we are convinced that much more of farmers' adoption behavior could have been explained by productivity considerations, had more accurate measurement of agro-climatic factors related to productivity been possible. This became clear in retrospect, as for example when we re-examined some villages within a few miles of one another in the Aegean area of Turkey where farmer adoption patterns seemed to make little sense. We found that the elevation on one valley village was just enough higher than the others that frost problems precluded the use of new varieties, and no farmers were using them, though some had tried. Within a lower valley village, the land parcels were divided between two types of valley land-- a lower alluvial terrace and an upper alluvial terrace. The upper terrace soils were shallower and lighter than those of the lower terrace, and soil water holding capacity was so low that farmers preferred the local varieties, which yield as well as the new varieties under limited rainfall conditions where little fertilizer is used.

Thus, within a small geographic area, we had observed three villages, ostensibly similar, with markedly different patterns of adoption--no adopters in one village, nearly all adopters in a second, and a mixed pattern of adoption in a third. Yet with a better insight into agro-climatic factors affecting the productivity of new varieties versus the old, this pattern of behavior was understandable quite apart from considerations of information, prices and risks. It was not that agro-climatic factors were not considered prior to the study, but rather that relatively subtle agro-climatic gradients can lead to dramatic changes in farmer behavior. Gerhart's Kenya study and an as yet unfinished maize study in Pakistan reinforce this observation, as do studies with rice (Barker). It is also a point stressed by Evenson (p. 201) and his co-workers. Gerhart (p. 26) concluded that "if anything, this study shows how very site-specific agricultural technology is, even within one region of one (admittedly very diverse) country".

TABLE 2.- Factors explaining within-region variability in farmer's decisions to adopt improved varieties.

Country: Crop: % Adopters:	Kenya Maize 67%	Colombia Maize 20%	El Salvador Maize 36%	Veracruz Maize 34%	Tunisia Wheat 31%	Turkey Wheat 64%
Productivity						
Agro-climatic zone	yes	yes			no	yes
Topography		yes	yes	yes	yes	yes
Information						
Schooling	yes	yes	yes		no	no
Extension visits	no	yes				
Demonstrations	yes			yes		no
Age	no					no
Tenure		no			no	no
Inputs						
Credit-use		yes	no	no	yes	
Credit-availability	yes				no	
Co-op membership						yes
Product Market						
Variety discounts					yes	no
Market sales of crop				no		no[a]
Risk						
Perceived yield risk			no	no		yes
Use of drought crops	yes					
Off-farm income	no			no	no	no
Farm size[b]	no	yes	no	yes	no	yes

Sources: Gerhart, Colmenares, Cutié, Perrin, Gafsi, and Demir.

a/ Market participation was important in one of four Turkish regions.

b/ Farm size was important in one of three Colombian,. two of four Turkish regions.

These experiences force us to recognize that within any farming area, there exists a wide range of expected yield increments from a given new variety or new technology. The differences can be the result of gradients in soil depth, texture or other characteristics, differences in quantity of rainfall or irrigation water, differences in night-time low or daytime high temperatures in certain seasons, differences in disease incidence related to these factors, and so on. In a truly homogeneous agro-climatic zone, the frequency distribution of expected yield increments across farmers' fields would be bunched rather tightly about the mean. For practical purposes, however, either for developing and recommending new technologies or for analyzing farmer behavior, we must deal with groups of farmers for whom the frequency distribution of expected yield increments will not be very compact due to agro-climatic variability. Because of this, it will often be difficult to identify to what extent productivity factors are affecting farmers' decisions versus differences in economic factors such as information, tenure, input and product markets, scale economics, etc.

Turning now to the effect of these economic factors in the six studies, with some exceptions farmer behavior was not found to be significantly or consistently related to them. One exception was the availability or use of credit. In four of the six studies in which it was considered, this variable was significantly related to the adoption of high-yielding varieties. However, even though farmers using credit were more likely to be using new varieties (44 percent more likely in Colombia, for example), this does not necessarily imply that the existence of credit programs is critical to farmer adoption decisions. Where a new variety or new technology is marginally profitable, the subsidies implied by government credit programs could be expected to affect many farmers' decisions. But if the new technology is profitable even at unsubsidized capital and input prices, farmers could be expected to adopt the technology and to purchase the inputs through the credit program if it in fact provided capital and inputs at subsidized prices. In the latter case, we would see a high correlation between the use of credit and adoption, even though the credit program itself had little effect on the adoption decision.

Market conditions accounted for very little of observed adoption behavior. Differences in price discounts for new wheat varieties from village to village in Tunisia were significant in explaining farmer adoption decisions, but this was the only case in which product market circumstances or market participation were related significantly to new variety adoption. The availability of seed appeared to be a limiting factor in adoption of winter wheats in Turkey and durum wheats in Tunisia, where the introduction of new varieties was fairly recent and seed multiplication had not kept pace with farmer demand.

Differences in the cost of acquiring and processing information as measured by extension activity and schooling, had only a slight relationship to adoption. Extension visits or demonstration attendance appeared to increase the probability of adoption by 10 to 15 percent in certain subregions of Colombia and Turkey, less or none in other areas. Each additional year of schooling increased the probability of adoption by an estimated 8 percent in Colombia, less in other areas.

The question of whether risk aversion is affecting adoption decisions was not really very satisfactorily addressed in these studies, and it is difficult to imagine how one can do so. In three studies, farmer perception of the risk of low crop yields was used as an index of farmers' risk aversion, while in Kenya the existence of drought resistant "famine" crops was used. While these indexes were in general correlated with adoption, the interpretation of this result is not straightforward. It is true that where crop failures are more common, risks are greater. But it is also true that where crop failures are more common, average yields will be lower. Where farmers perceive high risks of crop failure, reluctance to adopt could be evidence of risk aversion or simply evidence that the average returns to adoption are too low. To determine which of these factors are contributing to the observed correlation, we would require more specific information than was available about farmer perceptions of expected yields versus yield risks for both new and old varieties.

This brings us again to the question of the relationship between farm size and adoption decisions. We previously noted that in about half of the agro-climatic situations of Table 1, farm size appeared to have an important effect on adoption. Yet in the multivariate analyses, farm size was not correlated with adoption decisions in some of these areas. In the low elevation areas of Colombia, where Table 1 indicates an important size effect, the multivariate analysis showed that once credit and extension contacts are considered, the residual effect of size was minor, with each hectare increase in size being associated with only one-tenth of 1 percent increase in the probability of adoption. After a careful consideration of extension and credit activities, Colmenares concluded that the orientation of these programs toward larger farmers contributed substantially to the greater adoption rate among larger farmers. In Tunisia, it appears that smaller farms' lower adoption rates are due to differences in topography, credit use and local price discounts, rather than to factors related to farm size *per se*. The multivariate analyses of hybrid maize adoption in El Salvador likewise fail to show any effect of farm size *per se*, though it is not clear yet what factors may be contributing to the apparent size effect revealed in Table 1. In India, Vyas reports that most of the observed differences in variety adoption by farm size were due to differences in the availability of irrigation water, and to a seed distribution policy which initially favored larger farmers.

In the remaining areas in which size effects are notable in Table 1, variety introductions were quite recent in Veracruz, Mexico, (maize) and in the South Marmara and Thrace areas of Turkey, and the multivariate analyses indicated definite size effects associated with adoption even when other factors were considered. Thus, of all the areas considered, only in the Aegean area of Turkey did there appear to be significant size effects in adoption which were not plausibly explained by differences in productivity, differences in effective market prices for inputs or products, or by the early stage of adoption in which small farms can be expected to lag behind larger farmers because of economies of size in transaction costs in evaluating and acquiring the new varieties.

By contrast, the scale effect in fertilizer adoption in these studies was more pronounced. Space precludes a summary of the analyses of fertilizer adoption decisions, but there appeared to be significant size effects in fertilizer adoption in nearly half of the agro-climatic situations considered. Apparently fertilizer use is more heavily influenced by farm size than is variety use, as might be expected due to the greater investment at risk with fertilizer.

Conclusions

The adoption studies with which CIMMYT has been associated have shown that to a limited extent, differences in farmer adoption behavior can be explained by differences in information, in the availability of inputs, in market opportunities for the crop, and differences in farm size and farmer risk aversion or risk perception. The pattern of adoption among large and small farms is generally consistent with the proposition that small farms may lag behind larger farms in the early stages of adoption, but soon catch up. Our impression from these studies is that the most pervasive explanation of why some farmers don't adopt new varieties and fertilizer while others do, is that the expected increase in yield for some farmers is small or nil, while for others it is significant, due to differences (sometimes subtle) in soils, climate, water availability, or other biological factors.

Agricultural technology is more site-specific than we were led to believe by some of the early successes with wheat and rice varieties. The early high-yielding wheat varieties were adapted to extensive production areas and were widely adopted. It appears to us that these early successes will not be easily duplicated on such a scale. In the areas not already dominated by new varieties, the factors limiting yields are so disparate and complex as to make it unlikely that any single new variety can repeat the success of the early releases from international breeding programs.

Government policies to reduce the cost of information, the cost of inputs or the impact of risk could be expected to influence the decisions of those farmers whose expected yield increases are now marginal. But the experience in the areas of these studies suggests that these policies are not likely to have a large impact in increasing the number of farmers who adopt new technologies. Significant advances in adoption will not occur until significant advances are made in technologies which will increase yields in the agro-climatic environment of those farmers not presently adopting. This will require greater attention to the environment for which technologies are being developed than was necessary for the early successes in cereal breeding.

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