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ADOPTION OF UNLIKE HIGH YIELDING WHEAT VARIETIES IN TUNISIA

by

Salem Gafsi and Terry Roe*

This paper presents an analysis of the effects of introducing high yielding durum wheat varieties developed from Tunisian genetic material versus high yielding bread wheat varieties developed from Mexican genetic material. While previous studies have tended to focus on the factors affecting the adoption of a single high yielding variety or a rather homogenous group of high yielding varieties, this study focuses on the diverse effects on adoption of two dissimilar high yielding varieties. The difference in the genetic background of the high yielding durum and bread wheat varieties provides a unique opportunity to obtain insights into the importance of developing domestic and/or otherwise introducing foreign varieties that appear suited to local agroclimatic conditions but which are technically and palatably (taste) dissimilar to the older familiar varieties.

While the results of this study are generally consistent with the results obtained by others for the case of a single or homogenous group of varieties, the results distinguish between varieties and suggest that farmers' acceptance of the new varieties is conditioned by the extent of the technological and palatability differences with the old familiar varieties. A common genetic background between

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the high yielding and old durum wheat varieties is found to be consistent with the production surface of the new durum wheat varieties that is technically neutral in inputs relative to the old durum wheat variety. However, substantial differences are found to exist between the production surfaces of the new and old bread wheat varieties which do not share a common genetic background and which appears to inhibit their acceptance.

This study is based on a field survey of 375 Tunisian farms. The sample was stratified to reflect two different rainfall zones, hill and valley land and farm size. The plan of the paper is first to provide insights into the issues involved in this study by discussing the background to the introduction of high yielding varieties in Tunisia and summarizing the previous research which bears on these issues. Then, differences in farmers' acceptance of the high yielding bread versus the high yielding durum wheat varieties are analyzed by regressing the proportion of land area planted to the various high yielding varieties on a series of firm level explanatory variables. These results serve to identify the diverse effects of factors associated with farmers' behavior in planting the bread versus durum wheat varieties. They also serve to suggest and focus attention to the underlying technological differences between the varieties. The technological characteristics of the varieties are presented in the next section of the paper where production functions are estimated for each variety and the implications of their technological differences are related to farmers' acceptance of the varieties.

BACKGROUND

Virtually all of Tunisia's bread wheat was in a single variety, Florence Aurore, at the inception of the CIMMYT sponsored wheat project in Tunisia. In launching the program, bread wheat varieties developed in Mexico were tested in the Tunisian environment. Those bread wheat varieties that were adopted to Tunisian agroclimatic conditions were multipled and released to farmers in 1969-70.[1/] However, high yielding durum wheat varieties were developed in a different manner. The durum wheat varieties, referred to as INAT 69 and BEDI, were developed from Tunisian genetic material and released in 1971. Even though the bread wheat varieties were released at an earlier date, their adoption lagged the adoption of the high yielding durum wheat. Two years after the release of these varieties a larger percentage of farmers reported the use of high yielding durum wheat (DWHYV) than high yielding bread wheat (BWHYV), irrespective of farm size and region (Table 1).

Differences in production surfaces between the old familiar varieties and the new varieties, producer skills in receiving and decoding new information, firm level endowments (land quality and type and agroclimatic conditions) and palatability (taste) differences between varieties are felt to be among the important variables influencing demand for high yielding variety seeds. Among the studies giving these issues perspective are those of Heibert (6), Sidhu (10) for the Indian Punjab, Wolgen's (14) study of the influence risk and several studies (1, 2, 3, 4, 12) sponsored by CIMMYT.

Table 1: Proportion of All Farms by Size Category Reporting Use of High Yielding Seeds in Northern Tunisia

	Farm Size					
	(0-15) ha.		(>15-40) ha.		(>40-) ha.	
	Region I	Region II	Region I	Region II	Region I	Region II
Average Size of Farm	9.1	8.9	25.4	24.3	144	120.5
Number of Farms Surveyed	52	91	65	74	58	35
Percent Reporting use of BWHYV	3.8	6.6	9.2	17.0	15.5	48.6
Percent Reporting use of DWHYV	11.5	9.9	16.2	29.3	53.3	57.1

Source: Field Survey Data: Region I is normally a lower rainfall area and includes the regions of Bou Salem while Region II includes the regions of Jendouba and Pont du Fahs. Both regions are in the northern wheat producing area of the country.

Major differences between the production surfaces of the old and new varieties may, as Heibert (6, p. 765) suggests, contribute to risk because of imperfect information as to the nature of these differences and the possibility of committing alternative errors. Welch (13) and others (8) have emphasized the role of information and producer skills in the adoption process, the importance of which increases as the technical differences between the old and new varieties increase. However, technical differences between production surfaces have generally appeared to be neutral. For instance, Sidhu (10 p. 225) concluded that the introduction of Mexican wheat in the Indian Punjab increased technical efficiency by approximately 25 percent while apparently showing technical neutrality in inputs. This conclusion is consistent with our results for the durum wheats but not for the new bread wheats.

The importance of endowment, such as land quality, type and agroclimatic conditions, were found by Gerhart (4) to be the single most important variable explaining the adoption of high yielding maize varieties in Kenya. His results also appear to suggest that risk is a significant factor influencing the rate of adoption while a formal education, knowledge, availability of credit and extension visits were found to be positively, though not significantly, correlated with adoption.[2/] This is consistent with Wolgen's (13) results which imply that risk plays an important role in multi-cropping by Kenyan farmers. Insights into the diverse effects of these factors on farmers behavior in planting the high yielding durum and bread wheat varieties are presented in the next section, the results of which serve to suggest and focus attention to the underlying technological differences between the varieties which are considered in a later section.

FARMERS' ACCEPTANCE OF HIGH YIELDING VARIETIES

Two equations are specified to reflect firm level demand for high yielding variety seeds relative to ordinary variety seeds. One equation is specified for each of the bread and durum wheat varieties where a linear functional form was selected based on its fit to the data. The dependent variables are the percentage of total bread (durum) wheat area planted to high yielding bread (durum) wheat varieties at the firm level.[3/] The independent variables are defined in Table 2 along with the expected sign of the coefficients. The independent variables relate to profitability (variables 1 to 3) variety palatability (variable 4), information (variables 5 to 8) and variables relating to firm level endowments (variables 9 to 14), access to seeds (variable 15), credit (variable 16) and non farm sources of income (variable 17). While the majority of variables are expected to have similar directional effects on both high yielding varieties, the palatability and profitability variables are expected to have differential effects.

The high yielding bread wheats are expected to be less desirable to the Tunisian palate than the old bread wheats because they are not composed of Tunisian genetic material. Consequently, as the proportion of wheat produced for family consumption (variable 4)

Table 2. Results from regressing the percentage of ~~bread~~ wheat area and durum wheat area planted to new bread and durum wheat varieties on various farm level variables.

Variable No.	Description	Expected Sign	Bread Wheat Regression a/ I	Bread Wheat Regression a/ II	Durum Wheat Regression b/ I	Durum Wheat Regression b/ II
	Constant		52.01	34.58	-66.02	86.59
1	Ratio: price of relevant ordinary wheat in tolerated market to its price in legal market	-bread, +durum.	-12.22**	-12.53**	-35.32**	-47.5**
2	Ratio: quantity of relevant ordinary wheat sold in tolerated to sold in legal market	-bread, +/-durum	-1.05**	-.98**	-.32	
3	Yield of relevant ordinary variety in qx/ha.	-	-.42**	-.405**	-.63	
4	Proportion of wheat produced for family consumption	-	-.22*	-.23**	-.10**	-.19**
5	Interaction with other farmers	+	.52		1.87	
6	Years of schooling for farmer	+	-2.42		-5.20	
7	Years of farming experience	+/-	-.20**	-.18**	-.15	
8	Years of experience with HYV's	+	-.92		2.31	
9	Topography, 1 = valley, 0 = otherwise	+	71.03**	69.62**	9.10**	8.33**
10	Region 1 = high rainfall region, 0 = otherwise	+	.16		-15.38	
11	Potential family labor available	+	.01		.03	
12	Tractor for plowing, 1=tractor, 0=otherwise	+	1.84		4.93	
13	Land under farmers' control in hectares	+	-.04**	-.024**	.32	
14	Distance to normal market	-	0.09		.14*	.21*
15	Difficulties in acquiring HYV seeds 1 = difficulties were encountered, 0 = otherwise	-	-.83		-3.48*	-7.14*
16	Production credit obtained in 1973	+	1.80		12.02*	9.42*
17	Income from non-farm sources	+	.09		.13	
	R^2		89.21	88.9	80.53	79.5

**Statistically significant at the 95 percent level or more using the F test. *Statistically significant at the 90 percent level or more using the F test.

a/ The dependent variable is the percentage of total bread wheat area planted to new varieties of bread wheat.

b/ The dependent variable is the percentage of total durum wheat area planted to new varieties of durum wheat.

increases the percentage area planted to high yielding bread wheats should decrease. This is not expected to be the case for the durum wheats since they are derived from domestic Tunisian genetic material. The price ratio variable (variable 2) reflects conditions in the two alternative markets for wheat in Tunisia. Wheat prices are fixed in the government operated legal market. The tolerated market refers to the traditional private market which exists in most villages and, based on the sample data, accounts for approximately 30 percent of all wheat sold. The tolerated market is dominated by operators of small traditional technology farms and wheat is traded in this market primarily for household consumption purposes. No farmers in the sample reported selling the high yielding bread wheat variety in the tolerated market. Consequently, higher relative prices for ordinary bread wheat in the tolerated market should decrease the demand for high yielding bread wheat variety seeds. This relationship is not expected for the new durum wheat variety since, as pointed out earlier, they are composed of domestic genetic material and are expected to be indistinguishable from ordinary durum wheat varieties.

The ratio of the quantity of bread (durum) wheats sold in the tolerated market to the quantity sold in the legal market (variable 3) is included to reflect the tendency for small farms to rely on the tolerated market. The more reliance the farmer has on this market the less incentive he might have to adopt the new bread wheat varieties. This should not be the case for durum if the new durum wheats are indistinguishable from the old variety.

The variables expected to be positively correlated with the demand for the high yielding bread and durum wheats are the information related variables, namely: the average weekly frequency a farmer recalls discussing new varieties and related farming practices with other farmers (variable 5), years of schooling (variable 6), and years of experience in raising high yielding varieties (variable 7). Years of farming experience (variable 8) may or may not be positively correlated with the use of high yielding varieties since experience may be associated with the inertia of traditional practices and higher levels of risk aversion. On the other hand, experience may be associated with knowledge repertoire and enable a quicker and more accurate decoding of new information.

Perferences for high yielding varieties relative to ordinary varieties are also expected to be positively correlated with variables representing the firm level endowments of valley land versus hill land (variable 9), rainfall (variable 10), the availability of family labor (variable 11), the use of mechanical versus animal traction (variable 12) and farm size (variable 13). However, farm size is often found (4, 5) to not be significantly correlated with the use of high yielding varieties. Yet, a positive correlation is hypothesized here because farm size is expected to be correlated with access to markets and offers possibilities for risk diversification. The availability of production credit (variable 15) and nonfarm sources of income (variable 17) are expected to be positively correlated with the use of high yielding seeds.

A negative correlation is expected between the dependent variable and the yield of the old varieties (variable 3) which is included to reflect the opportunity cost of the competing variety. Spatial costs, which are reflected in variable (14), and the shortage of seeds, which is reflected by the difficulties farmers reported in acquiring seeds (variable 15), are also expected to be negatively correlated with the use of high yielding varieties.

The results suggest that six of the 17 variables are statistically significant and account for over 78 percent of the variation in the percentage of area planted to new varieties of durum wheat while 7 variables are significant and explained approximately 87 percent of the variation in the case of bread wheats. Results obtained after purging the insignificant explanatory variables from the regression equations are reported in column II of Table 2. Overall, considerable agreement appears to exist between the results obtained here and those obtained from studies cited earlier, in particular those of Gerhart (4). Important similarities exist in the importance of land topography (variable 9), the importance of domestic varieties (variable 3), access to credit (variable 16) and the proportion of wheat produced and consumed by the household (variable 4).

The results also suggest that a considerable difference exists between the factors affecting farmers acceptance of the high yielding bread versus the high yielding durum wheat varieties. Difficulty in obtaining high yielding durum wheat seeds (variable 15) and the importance of production credit (variable 16) together suggest a strong and perhaps excess demand for high yielding durum wheat seeds.

This is apparently not the case for bread wheats. The area planted to new varieties of durum wheat are seemingly not sensitive to the yield of old durum wheat varieties (variable 3) which is also not the case for new bread wheat varieties. This difference may suggest and support the verbal comments made by farmers during the data survey that the new varieties of durum wheats are similar to domestic varieties in terms of yield variability due to local climatic, disease and pest conditions, while the new bread wheat varieties are more sensitive to variations in these local conditions. In other words, new bread wheat varieties may be relatively riskier than the new durum wheat varieties.

Higher prices in the tolerated market relative to the legal market (variable 1) appear to have a strong negative impact on the area planted to high yielding varieties. While this direction of causation was expected in the case of bread wheats it came as a surprise in the case of durum wheat. These results suggest that traditional bread and durum wheat varieties are preferred in the tolerated market. This influence is also supported by the significance of household consumption needs (variable 4). However, the significance of variable 3 for the bread wheat case only implies that the tolerated market is more sensitive to the new bread wheat varieties than to the new durum wheat varieties.

An unexpected result in the bread wheat equation is the negative relationship between farm size (variable 13) and the percent of area planted to new bread wheat varieties. This negative relationship implies that as farm size increases a smaller percentage of their bread wheat hectarage is planted to the new bread wheat variety. In light of the fact that more large farms reported the use of high yielding bread wheat varieties than small farms (Table 1), this result may suggest that larger farmers are also unwilling to commit proportionately more hectarage to the high yielding varieties because of risk.

A rationalization for the unexpected positive rather than negative effect of distance to market as a measure of spatial cost is not obvious. However, in retrospect, a positive correlation may result because farmers in the same geographic location appear to patronize different markets depending on their means of transportation. Farmers with access to modern transportation appear to patronize larger metropolitan markets, particulary Tunis, which may provide a better access to information and inputs, particularly credit which is positively correlated with the dependent variable.

The analysis presented in this section identified some of the major variables affecting the percentage of land area planted to high yielding varieties and suggests that farmers tend to prefer the high yielding durum to the high yielding bread wheat varieties. However, it does not identify the technological characteristics underlying the new varieties or their relationships to the older domestic varieties. These issues and their implications to adoption are considered in the next section where the results suggest that the high yielding durum wheat varieties are technologically identical to the old durum varieties except in the scale parameter of the production function, while the high yielding bread wheat varieties are technologically different from the domestic bread wheats.

TECHNOLOGICAL DIFFERENCES BETWEEN ORDINARY AND HIGH YIELDING VARIETIES

Technological differences between the high yielding and ordinary yielding varieties are assessed by estimating production functions for each variety and testing for structural differences between the functions for the relevant high yielding and ordinary yielding varieties. The Cobb-Douglas functional form:

$$Y_{ij} = e^{a_{01j} + a_{02j}T_{ij} + a_{03j}V_{ij} + a_{04j}W_{ij}} N_{ij}^{a_{1j}} P_{ij}^{a_{2j}} L_{ij}^{a_{3j}} \varepsilon_{ij}$$

is specified for each of the four varieties of high yielding durum wheats (DWHYV), ordinary yielding durum wheats (DWOV), high yielding bread wheats (BWHYV), and ordinary yielding bread wheats (BWOV): where i, j denote the observation on the i-th farm, j-th wheat variety. The a's are coefficients and--

Y = wheat harvested in quintals per hectarage;

T = 1 if mechanical traction, = 0 otherwise;

V = 1 if Valley land, = 0 otherwise;

W = 1 if chemical weeding, = 0 otherwise;

N = Nitrogen fertilizer in kg/ha of pure nitrogen

P = Phosphate fertilizer in kg/ha of P_2O_5;

L = Number of land preparation operations per hectare;

ε_{ij} = random disturbance, assumed to be log normally distributed with a unit mean and constant variance.

Perhaps a brief justification for including the number of land preparation operations per hectare (L) in the above specification rather than units of labor and/or machinery is in order. It became apparent during the survey that farmers, especially on smaller farms, could not accurately recall the number of hours or days allocated to the production of wheat, let alone the various varieties of wheat. However, their recall of the number of land preparations appeared to be accurate. This observation seems justified when poor results were obtained when units of labor and/or machinery were substituted for (L) in the specification, although the parameter estimates of fertilizer (N, P) were only slightly affected. Since a dummy variable is specified to account for the type of traction and since a fairly constant ratio between the quantity of labor and machinery exists, a pragmatic approach seemed to suggest and support this specification.

Employing the assumptions of Zellner et. al. (15) ordinary least squares is used to fit the above function to the survey data (Table 3). While alternative functional forms and specifications were fit to the data, the above appeared to produce the best fit.

Inspection of the results suggests that technological differences exist among and between varieties. Differences among bread wheat varieties appear to exist in the efficiency of the technology, i.e., the BWOV intercept appears larger than the intercept of the BWHYV, and the parameters associated with the input variables (N, P, L) appear larger for the BWHYV than for BWOV. Furthermore, the ratios of the input variable parameters of the BWHYV appear different than the

Table 3. Production function estimates for wheats for wheats grown in 1972-73 in Northern Tunisia.

	Constant	T	V	W	HYV	N	P	L	R^2	Obs.
DWHYV	1.417 (.188) **	.213 (.124) *	.159 (.069) **	.092 (.066)		.059 (.026) **	.051 (.022) **	.555 (.138) **	0.513	92
DWOV	1.334 (.079) **	.167 (.069) **	.249 (.048) **	.118 (.069) *		.061 (.017) **	.066 (.016) **	.441 (.080) **	.500	344
DW	1.323 (.069) **	.170 (.050) **	.235 (.041) **	.105 (.053) **	.164 (.047) **	.061 (.014) **	.064 (.013) **	.461 (.069) **	.570	436
BWHYV	1.016 (.299) **	a/	0.299 (.138) **	0.032 (.093)		0.162 (.061) **	0.117 (.048) **	0.548 (.196) **	.593	50
BWOV	1.431 (.128) **	.198 (.079) **	.194 (.065) **	.148 (.083) *		.047 (.023) **	.085 (.023) **	.405 (.114) **	.460	174

Notes: The regressions are linear in logarithms. The dependent variables are outputs in quintals per hectare of durum wheats high yielding varieties (DWHYV), ordinary varieties (DWOY), bread wheats high yielding varieties (BWHYV) and ordinary varieties (BWOV). The dummy variables T, V, W and HYV represent types of traction, topography, weeding and seeds, respectively, while N, P and L refer to the logarithms of the rates of application of nitrogen fertilizer, phosphate fertilizer, and land preparation operations per hectare. The numbers in parentheses are the standard errors of coefficients. **Statistically significant at the 95 percent level or more, using the F test. *Statistically significant at the 90 percent level or more, using the F test.

a/ The traction variable was not included in the specification of BWHYV because all 50 observations reported the use of either owned or rented mechanical traction in seed bed preparation.

ratios of the corresponding parameters of the BWOV, suggesting non-neutral technological differences among these two varieties. The primary differences among the durum wheats appear in the intercept parameters while the response to fertilizer is nearly identical, thus suggesting a neutral technological difference.

The statistical procedure used to test for the structural differences between the estimated equations follows Theil (11).[4/] The procedure is to first test for the equality of the slope coefficients and then to test for the equality of the intercept coefficients using the F test statistic at the 95 percent level of confidence in both cases. Application of this test to the durum wheat equations, DWHYV and DWOV (Table 3), suggests the acceptance of the hypothesis that the slope coefficients are not statistically different. However, the test leads to a rejection of the hypothesis that the intercepts are equal. Consequently, the durum wheat data can be pooled where a dummy variable (HYV) is specified to represent DWHYV seeds. The results from the pooled durum wheat data appear as equation DW in Table 3. These results imply that the use of DWHYV seeds are equivalent to a neutral upward shift in the durum wheat production function equivalent to about a 16 percent increase in yield per hectare. Perhaps this similarity is not surprising since, as mentioned earlier, the new variety is a product of domestic varieties. This similarity has the important implication that producers need not acquire new knowledge or experience in order to produce a given output at least cost since the least cost combination (ratio) of inputs is identical for both varieties. This should encourage adoption of the new variety by lowering the cost of new knowledge and reducing the risk of committing allocation erors in producing the new variety. The results reported in Table 1 and 2 appear generally consistent with these inferences, in particular, the existence of an excess demand for high yielding durum wheat seeds.

The test for the equality of the slope coefficients and then the intercept coefficients between the two bread wheat varieties leads to a rejection of the intercept equality and slope equality hypotheses in both cases. The dissimilarity between the two bread wheat varieties is shown in Figure 1a where the production surface of the BWHYV intersects the BWOV surface from below (denoted ABC). Consequently, the old variety out-yields the new variety at low levels of fertilization or at high levels of nitrogen (phosphorus) and low levels of phosphorus (nitrogen) fertilization. Furthermore, since the ratios of slope coefficients of these varieties are reversed, the least cost combination of inputs for the high yielding variety is different than the least cost combination of inputs for the ordinary variety. This is depicted in Figure 1a by $(N/P)_{BWHYV}$ and $(N/P)_{BWOV}$.

Before the implications of these different production surfaces on adoption of the high yielding variety are discussed, it should be pointed out that the intersection of the two production surfaces results in a discontinuity in the least cost input-output space in the vicinity of (about) the intersection of the two surfaces. This is depicted by the use of Figure 1b. where the total variable cost functions of the two varieties are derived in the normal manner from their respective expansion paths, e.g., $(N/P)_{BWHYV}$ and $(N/P)_{BWHYV}$ of

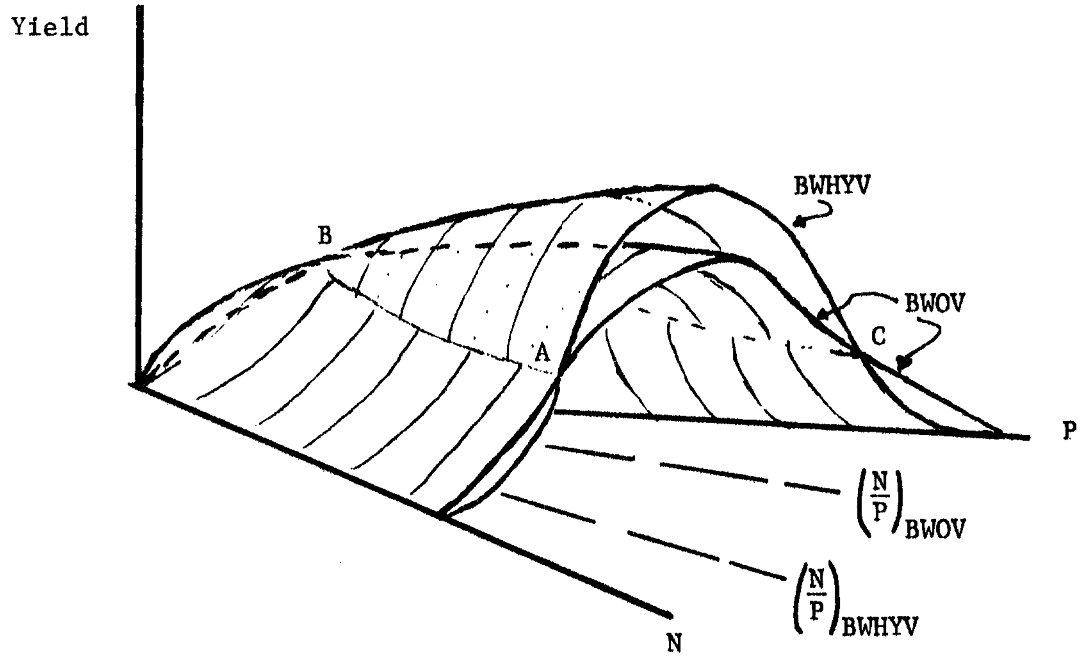

FIGURE 1a. Yield of high and ordinary yielding bread wheats expressed as a function of N and P.

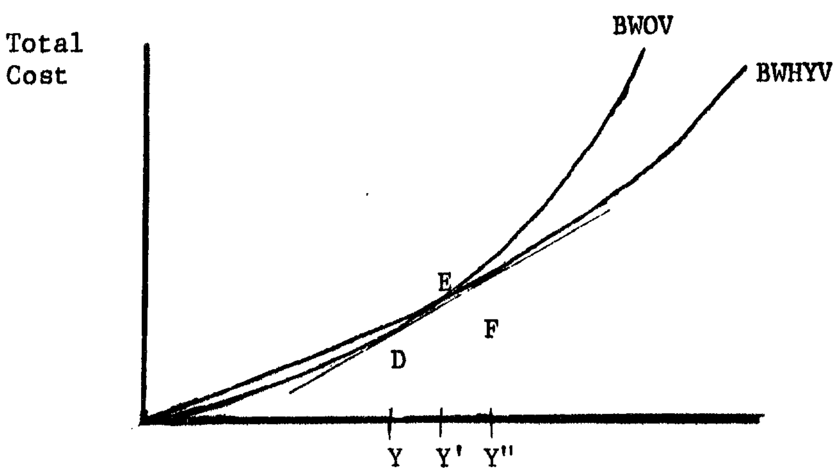

FIGURE 1b. Total variable cost per hectare of producing high and ordinary yielding bread wheats.

Figure 1a. The tangencies at Points D and F imply equality of the marginal cost at output levels Y and Y" of BWOV and BWHYV respectively, and therefore, a discontinuity in the firm's supply function between these output levels.

These yield intersection and tangency points of the two bread wheat varieties are determined for the least cost levels of fertilizer (N, P) based on the observed levels of other variables in the production function (T, V, W, L) and government fertilizer prices (Table 4). The discontinuity occurs between yield levels of 9.75 qx./ha. and 12.63 qx/ha. and corresponding fertilizer input levels (Table 4). This discontinuity implies that it is not optimal for the profit maximizing firm in a competitive riskless environment to "move up" the old variety production surface to the point of intersection (11.22 qx/ha) of the two surfaces (Y') and then switch to the new variety. Rather, it is optimal to "move up" the surface of the old variety (consistent with $(N/P)_{BWOV}$) to output level Y (9.75 qx./ha.) and then switch to the new variety and begin production at output level Y" (12.63 qx./ha.) and input ratios $(N/P)_{BWHYV}$. Note that this upper tangency point is only about one qx/ha below the observed mean yield of 13.7 qx/ha for the BWOV.

The implication of the BWHYV technology to the rate of adoption lies in the firm's resource endowments, in particular traction and hill or valley land, as these variables affect the point of intersection of the two production surfaces and the firm's access to input and product markets since this influences firm level input and product prices and therefore the nature of the firm level supply function. Dissimilarities in least cost input combination imply that additional knowledge and

Table 4. Observed Bread Wheat Yield and Input Levels Compared to Estimated Yield and Input Levels at Supply Surface Intersection and Tangency Points

	Bread Wheat High Yielding Variety				Bread Wheat Ordinary Yielding Variety			
	Yield Qx/Ha	Elemental Nitrogen Kg/Ha.	Elemental Phosphorous Kg/Ha.	Land Preparation No./Ha.	Yield Qx/Ha	Elemental Nitrogen Kg./Ha.	Elemental Phosphorous Kg./Ha.	Land Preparation No./Ha
Observed Mean	21.25	35.53	34.6	4.14	13.70	17.72	21.18	3.63
Intersection	11.22[a/]	3.30	4.35	4.14	11.22[a/]	1.99	6.58	3.63
Tangency Point A					9.75[b/]	.68	2.26	3.63
Point B	12.63 [b/]	4.96	6.55	4.10				

a/ This yield corresponds to point E Figure 1b.

b/ Yields correspond to points D and F Figure 1b. The tangency points are determined given the observed levels of T, V, W and L for each variety. The tangency at point D for BWOV is given by

$$Y = \left(\frac{Ab}{Ba}\right)^{\frac{ab}{a-b}} \left(\frac{b-1}{a-1}\right)^{\frac{(1-a)b}{a-b}}$$

while the tangency at F for BWHYV is given by

$$Y'' = \left(\frac{B}{A}\right)^{\frac{ab}{b-a}} \left(\frac{a-1}{b-1}\right)^{\frac{(1-b)a}{b-a}}$$

where A,B denote the intercept coefficients of the total cost function and, a, b denotes the sum of the fertilizer coefficients of BWHYV and BWOV respectively.

experience must be acquired if allocative error is to be minimized in producing the new bread wheats. If some cost is associated with the acquiring of this knowledge and/or experience, and if some uncertainty exists as to the shape of the new varieties production surface, then the firm will likely not switch from the old familar variety at Y and adopt the new unfamiliar variety at point Y".

These inferences support those drawn in the previous section and provide additional insights for explaining farmers preference for the high yielding durum wheat varieties. Essentially, the technical nature of the new bread wheat varieties relative to the old varieties is likely to inhibit its overall rate of adoption. The non-neutral nature of the new bread wheat varieties should make their acceptance sensitive to the yields obtained from the old bread wheat varieties. This is supported by the significance of yield (variable 3, Table 2) on the percentage of area planted to the new bread wheat varieties. Since small farms are generally disadvantaged relative to large farms in terms of relative factor endowments, input and output prices, they can be expected to lag the larger farms in adopting the new bread wheats compared to their adoption rate for the new durum wheats. This problem is compounded if, as suggested in the previous section, the new bread wheats are not as palatable as the old variety and if small farms are more risk averse than larger farms.

SUMMARY AND CONCLUSION

This study focused on the effects of introducing high yielding varieties of bread and durum wheats which have different genetic backgrounds. High yielding durum wheats were developed from domestic genetic material while the bread wheats were derived from Mexican genetic material. Similarities in the factors affecting the area planted to high yielding varieties appeared to be palatability preferences for the old varieties sold in the tolerated (traditional) markets and consumed by the household. Dissimilarities suggested that an excess demand exists for the high yielding durum wheat seeds and that the adoption of the bread wheats is more sensitive to risk and farm level conditions than are the durum wheats. The underlying reasons for these dissimilarieties were supported and extended when the technical characteristics of the new durum wheat varieties were found to be substantially different from the technical characteristics of the new bread wheat varieties. The new durum wheats increased technical efficiency by about 16 percent while maintaining technical neutrality in inputs. Contrarily, the new bread wheats were found to be inferior to the old bread wheats at low levels of fertilization and to be technically biased in inputs. The relative differences in the new and old bread wheat varieties suggests that the adoption of the new bread wheats is more sensitive to farm level factor endowments, input and output prices and knowledge and experience as it relates to discovering the nature of the relative differences in the production surface of these varieties.

The results of this study imply that if the rapid adoption of new varieties is desirable, then the new varieties should be technically neutral in inputs. Otherwise, the variety must be technically superior to the technically neutral varieties and its introduction should be accompanied by information relating to the nature of its production surface relative to the production surface of an old familiar variety. If in addition the new variety is inferior to the old variety at low levels of input use, various input-output price policies might be considered to encourage adoption. In any case, farms with relatively less advantageous factor endowments and aversion to risk can be expected to lag other farms in adoption to a greater extent than in the case of a technically neutral variety.

FOOTNOTES

*/ Salem Gafsi, a former graduate student at the University of Minnesota, is employed by the World Bank and Terry Roe is an associate professor in the Department of Agricultural and Applied Economics, University of Minnesota, St. Paul, Minnesota. This research was supported in part by CIMMYT and and the Economic Development Center, University of Minnesota. Helpful comments by Lee Martin, Willis Peterson, Benjamin Sexauer and Mathew Shane on earlier drafts are acknowledged.

1/ A breeding program has since been initiated which focuses on developing bread wheat better suited to local conditions. These varieties have been introduced since the date of this study.

2/ The other studies supported by CIMMYT and cited above arrived at conclusions similar to those of Gerhart though perhaps less encompassing. These studies have been summarized by Perrin and Winkelman in [9].

3/ This dependent variable specification is used rather than the quantities of seeds because the farmers do not generally recall the amount of seeds used and often responded by multiplying the seeding rate of 1.1 quintals per hectare by the number of hectares planted. This seeding rate appeared uniformally constant over varieties and farms.

4/ For a clear statement of the formula for the F test, see Kmenta, p. 373.

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