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THE ADOPTION OF HIGH YIELDING WHEATS IN TUNISIA

Malcolm J. Purvis

Since 1966 strenuous efforts have been made to introduce into Tunisia some of the new high yielding wheat varieties in order to accelerate cereals production. This paper seeks to analyze some of the data now available on the new wheats in Tunisia and to explore some of the economic problems of increased cereals production with these varieties.

The Cereals Project

During the early 1960's high yielding wheat varieties were developed in Mexico at CIMMYT (Centro International de Mejoramiento de Maiz y Trigo). These wheat varieties and the rice varieties developed by a sister institute in the Philippines, have been the basis for the much publicized "Green Revolution" which has had such an impact in recent years on cereals production in the developing countries, particularly in South and Southeast Asia (see 1; 2; 3). These new varieties are all short strawed "dwarf" cereals which respond well to fertilizer application. However, they were developed for irrigated conditions. In Tunisia, as in the rest of North Africa and large parts of the Middle East, wheat production is predominantly from dry land agriculture, i. e., relies entirely upon rainfall during the growing season. Much of these areas, and Tunisia is no exception, suffer not only from a rather sparse average annual rainfall but also from very marked inter- and intra-seasonal variability. [1/] As yet there is little experience with these high-yielding varieties in dry land conditions. Tunisia was one of the first countries to try and adapt the new genetic material from Mexico to rainfed agriculture.

Tunisia, once a net exporter of wheat, has over the last decade come to rely increasingly on imports to meet its growing internal consumption needs (Table 1). Wheat production during the sixties has not expanded and there has been some decline in total area planted to cereals in an effort to take marginal land out of cereal production and put it into other uses such as tree crop or permanent pasture. It was under these circumstances that the project was started by the Tunisian government in 1966 with the support and assistance of USAID, the Ford Foundation and CIMMYT. The project was based on the National Agricultural Research Institute (INRAT) which has a long history of plant breeding and agronomic research. Indeed, one of the main soft wheat varieties grown in Tunisia -- a variety called Florence Aurore -- had been developed thirty years ago at INRAT and was an important parent stock in the breeding work of CIMMYT. In 1966/67 the first field trials were made using seed imported from Mexico. Since that time there has been a rapid expansion of the research activities, of seed multiplication and testing and of field demonstrations of the new varieties, so that by 1970/71 just over 100,000 hectares were planted in the Mexican wheats (Table 2).

The results have been encouraging. Yields far in excess of the

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1/ For an analysis of rainfall variability and yield variability in Tunisia see 4.

Table 1. Tunisia: Production and Net Imports of Cereals, 1960-1970

(Thousand Metric Tons)

	Production				Net Imports
	Hard Wheat	Soft Wheat	Other Cereals[b/]	Total Cereals	
1960	443	79	187	709	-23
1961	247	42	74	363	424
1962	395	72	146	613	352
1963	650	123	353	1,126	40
1964	431	81	182	694	-25
1965	577	100	272	949	225
1966	432	49	135	616	108
1967	403	50	120	523	439
1968	425	73	200	698	524
1969	301	80	116	497	556
1970	369	150	207	726	(550)[a/]

Sources: Abdelmajid Sahnoun, "Indice de la Production Agricole 1964-70; base 1960-1964." Rapport de Recherche en Economie Agricole No. 8, (Ministère de l'Agriculture, Tunis, Avril 1971).
Abdelmajid Sahnoun, "Comptes Resources-Emplois (1964-69): Agriculture Sylviculture et Peche," Rapport de Recherche en Economie Agricole No. 6, (Ministère de l'Agriculture, Tunis, Fèvrier 1971).
John D. Hyslop, "Analayse de Politiques Possibles de Production Ceralière en Tunisie," Rapport de Recherche en Economie Agricole No. 5, (Ministère de l'Agriculture, Tunis, Juin 1971).

a/ Estimated

b/ Principally barley, but also includes very small amounts of corn and sorghums.

Table 2. Tunisia: Area and Average Yield under Mexican Wheats, 1967/8-1970/1*

Year	Area	Estimated Average Yield
	Hectares	Quintals/Hectare
1967/8	800	27
1968/9	12,000	15
1969/70	53,600	20
1970/71	102,000	15

*Information supplied by the Cereals Project, Tunis.

national average have been obtained. Average yields for traditional soft wheats [2/] in Northern Tunisia have been about 8 quintals per hectare and for durum wheats only about 5 quintals (4 pp. 10, 16). In 1969/70 the wheat program was able to announce that some 6% of the wheat land (under Mexican wheats) had produced about 20 per cent of the national wheat production. Although the Cereals Project has run into some problems as the program expands, particularly in connection with seed multiplication, testing and distribution, the target for 1973/74 is to plant 520,000 hectares with the new varieties -- over one-third of the national wheat acreage.

To date the Mexican wheats have been grown largely by the "modern" sector of Tunisian agriculture -- either on large state or cooperative farms (which typically have 800-1,000 hectares of tillable land) or on the larger private farms of about 200 hectares or more. In both cases, the wheat is being produced using mechanical means of seed bed preparation, cultivation and harvesting. Wheeled tractors, caterpillars and combines are a regular part of wheat production in this modern sector.

In order to obtain some data on actual farm costs and yields of the Mexican and the other wheats a farm survey was carried out during the 1969/70 crop year. The results of this survey are described below.

The Survey

During 1969-70 crop year a survey was carried out on 27 cooperatives, precooperatives and state farms in order to assemble and analyse some

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2/ The Mexican wheats are also soft wheats. They are of rather lower quality than the established soft wheat varieties in Tunisia (5, p. 22).

information concerning the use and productivity of farm resources in Northern Tunisia. It is the first farm management survey of this type ever to have been carried out in Tunisia.

The principal difficulty in carrying out any farm management survey is having access to accurate information on the use of resources on the farm over the course of a full crop year. At the present time the farm management data systems in use on large scale farms of one kind or another in Tunisia are unworkable. The Bureau of Control, which was responsible for the cooperative farms in Northern Tunisia, set up a farm management record keeping system in 1968 which was completely redesigned in 1969. The Medjerda Valley Authority (OMVVM) had its own and different system, as did the Office of State Land (OTD). Other systems had been proposed by the Institute of Productivity and the School of Agriculture. None of these systems have worked because they are too complicated and the quantity of information to be collected far exceeds the capacity of the available staff to control, supervise and analyse the data. An essential element in farm management record keeping is also an understanding by the record keeper of the use to which these records are to be put. Due to the separation on large scale government farms in Tunisia of financial and technical control from the day to day operational control of the farm, this integration between data keeping and data using is difficult to achieve.

The principal problem facing the survey was therefore to find capable persons on large farm units who could keep management records on a regular and reasonably reliable basis. An opportunity was presented by the existence of the FAO Farm Management Training project which, in its second year of operation in 1970/71, had 50 trainees on 25 farms in Northern Tunisia. An agreement was made with the FAO project that the trainees would fill in simple farm management forms during their year's on-farm training during 1969/70. 3/

The farms on which the trainees were placed were a mixture of cooperatives, pre-cooperatives and farms of the OTD and the OMVVM and some few special farms, such as those used for vocational agricultural training, scattered throughout Northern Tunisia. The distribution of farms by organizational type was as follows:

Co-operatives	10
Pre-cooperatives 4/	10
Other 5/	7

During the year five of these farms were dropped from the survey for one reason or another. Obviously this sample of large scale farms in Northern Tunisia has no statistical basis. The farms were simply those on which the trainees were placed. In general these farms were chosen because of their capacity to accept the trainees and to offer accommodation for them. It is probable that these farms represent better than average farms since considerable effort was made by the FAO project to ensure that the trainees were located on farms where their year's farm experience

3/ Dr. Meijerman of the FAO project was of great assistance in initiating this survey and, until his departure, assisted materially in its control and execution. M. Henke and later M. Van der Flier also contributed in this activity. Their assistance is gratefully acknowledged.

4/ Under the guidance of the O.T.D.

5/ Agro-combinats of the OMVVM, rural youth training farms, etc.

would be as useful as possible.

The trainees were requested to fill in simple forms to record the physical use of resources by enterprise on a daily basis. Data were collected for the major activities of these farms, i.e., hard wheat, soft wheat and Mexican wheat as well as for forage crops and the sheep and cattle enterprises. Information was also recorded on total labor and tractor use on the farm. The forms permitted the recording of daily labour use, use of mechanical or animal power and of other inputs (seeds, fertilizer, sprays, etc.) as well as of final output (wheat, straw, etc).

It will be noted that all information was recorded in physical units. This approach was used because of the greater ease in appreciating and collecting information in physical terms and because of the previously mentioned separation of financial accounting from management control on large scale farms in Tunisia. Frequently even the farm director does not know the unit prices of inputs he is using. For the completion of the economic analysis these physical data were translated into monetary terms by the use of fixed prices for each input and product. These prices are shown in Table 3. The use of single valued prices even for farms geographically widely dispersed is not perhaps too serious a departure from reality since prices for most purchased inputs and major products are controlled and more or less standard throughout Northern Tunisia.

Results

The data collected in this manner were used to estimate partial budgets for the three wheat types. To the extent that these wheats are more or less perfect production substitutes (in respect to the use of

Table 3. Northern Tunisia: Unit Prices for Inputs and Outputs in Wheat Production

Item	Unit	Price in Dinars
Fertilizer		
Super 16	Quintal	1.576
Super 45	Quintal	3.950
Ammonium nitrate 22	Quintal	3.300
Ammonium nitrate 33	Quintal	4.600
Seed[a/]		
Hard wheat	Quintal	6.940
Soft wheat	Quintal	6.320
Mexican wheat	Quintal	6.150
2-4 D	Litre	0.450
Cost per day:		
Unskilled labor[b/]		0.550
Wheeled tractor[c/]		4.000
Caterpillar tractor[c/]		5.150
Combine harvester[c/]		8.100
Draft animals (mules etc.)[c/]		0.600
Products		
Hard wheat	Quintal	4.195
Soft wheat	Quintal	3.734
Mexican wheat	Quintal	3.734

a/ Prices of central seed cooperative (COSEM); ordinary seed could be cheaper but the cost of seed preparation and dusting would have to be added. The COSEM prices include these costs.

b/ Variable costs -- excludes overhead costs such as social security, supplying television or social centers for the workers.

c/ Operating costs (fuel, oil, maintenance) and including driver's wage.

d/ Prices after payment of taxes but without adjustment for possible premiums or discounts due to grain quality and purity.

fixed resources, particularly land and machinery) partial budgets are useful. In the absence of adequate whole farm accounts no attempt has been made to estimate these fixed costs. The number of observations (N) for each type of wheat is less than the total number of production units included in the survey because not all farms sowed all three wheats:

	N
Hard wheat	18
Soft wheat	15
Mexican wheat	17

The results of the partial budget analysis are shown in Tables 4 and 5. In general the physical use of resources is not far different from the planning norms in general use in the Ministry of Agriculture. Labor inputs are slightly higher. However, tractor use (especially for wheeled tractors) are rather less.

Some of the post harvest cultivations (ploughing, disking of stubble or deep tillage) or of first-step seed bed preparation (in the case of an 18 month stubble fallow rotation) carried out in the preceding August may not have been counted. To the extent that these operations are carried out equally for all three wheats any underestimation is not so important in making comparisons between them. 6/

Although the average use of 2-4 D is of the same order of magnitude

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6/ However, hard wheat and Mexican wheats are typically given first place in the grain-grain-forage fallow rotation recommended for Northern Tunisia.

Table 4. Northern Tunisia: Utilization of Inputs and Production per Hectare of Wheat, 1969/70.

Item	Hard Wheat	Soft Wheat	Mexican Wheat	Norms[c/]
Labor	7.55	5.60	8.34	5.52
Wheeled tractor (days)	0.82	0.70	0.73	1.79
Caterpillar tractor (days)	0.48	0.53	0.30	0.55
Combine harvester (days)	0.15	0.19	0.23	0.14
Seed (quintal)	0.90	1.12	1.00	1.00
Ammonium nitrate 33[a/] (quintal)	0.90	0.86	1.38	1.33[d/]
Super 45 [a/] (quintal)	0.67	1.06	0.91	1.00-08
2-4 D (litres)	0.59	0.44	0.47	0.60
Wheat harvested (quintal)	10.08	12.81	17.17	--
Straw [b/] (bales)	37	12	17	--

a/ Or equivalent in other fertilizer.

b/ Incomplete -- in several cases straw was not baled or was sold on the field.

c/ From Rep. Tunisienne, SEPEN, S/SEA, Direction de la Production Agricole <u>Norms UCP du Nord 1969</u>, March 1969. Note: The use of other production inputs such as mules, pesticides or other weedkillers was negligible.

d/ 2, 3 or more quintals for the Mexican wheats depending on the pre and post planting rainfall.

Table 5. Northern Tunisia: Costs, Receipts and Gross Margins in Wheat Production, 1969-70*

(Dinars)

Item	Hard Wheat	Soft Wheat	Mexican Wheat
Labor	4.152	3.080	4.587
Wheeled tractors	3.280	2.800	2.920
Caterpillar tractors	2.472	2.730	1.545
Combine harvester	1.215	1.539	1.863
Seed	6.246	7.078	6.150
Ammonium nitrate	4.140	3.956	6.348
Super phosphate	2.646	4.187	3.594
2-4 D	0.266	0.198	0.212
Direct total cost	24.417	25.568	27.219
Wheat	42.286	47.832	64.113
Straw	3.700	1.200	1.700
Total receipts	45.986	49.032	65.813
Gross margin	21.569	23.464	38.594

* Based on Tables 3 and 4.

as the norms, it should be noted that there was enormous variability in individual farm use of herbicides. For example, for the Mexican wheats three farms used no 2-4 D and four used more than twice the recommended dose. Similarly the use of nitrogenous fertilizer on the Mexican wheats, although larger than for the hard wheats, is still far from the 2-3 quintals (33%) recommended by the Cereals Project.

The overall similarity in the resource use for the three wheats is obvious. The Mexican wheats showed a rather greater use of nitrogenous fertilizer and slightly higher labor use than did the other wheats. Clearly, the three wheats are almost perfect substitutes in production. Production costs for the three wheats were very similar (Table 5). It should be noted that seed and fertilizer account for over half the total production costs and labor for less than one-fifth. However, due to the difference in yield levels the gross margins for Mexican wheat are substantially greater than for the hard and soft wheats -- the additional 4.1 quintals of Mexican wheat over the soft wheats increase the total receipts by nearly sixteen dinars, at an additional cost of only 1.6 dinars. Thus, the Mexican wheats with a yield differential of only slightly over 30 percent produce an increase in the gross margin of 64 percent.

Some Problems

The high average yields obtained during the first few years of the Cereals Project and the distinctly higher profitability of the Mexican wheats shown above are encouraging. However, there is danger in underestimating the difficulties faced by Tunisia in obtaining significant and continued productivity gains in the cereals sector from the new varieties.

The relatively high yields obtained from the Mexican wheats have been compared to the average yields for soft wheat in Northern Tunisia. This needs careful interpretation. There is substantial evidence to suggest that under comparable conditions of soft "fertility" and management the Mexican wheats are perhaps no more than 30 percent more productive than existing wheats and certainly not 300 percent more productive. It will have been noted that in our survey the average yield for the traditional soft wheats was 12.8 quintals as against 17.17 quintals for the Mexican wheats -- a difference of only 34 percent. The wheat yield obtained by the Cereals Project's demonstration farms in 1967/68 and 1968/69 showed a similar difference (Tables 6 and 7), and so do the results obtained from the FAO experimental farm at Beja over a three year period 1967/68-1970/71 (Table 8). In brief, the existing local varieties, well adapted to Tunisian conditions and in widespread use over a long period of time, are also capable of almost as high yield levels as are the Mexican wheats.

Thus, even though the Mexican wheats may be more productive, the problems to be overcome in realizing high average yields are not to be solved only by the introduction of the new varieties but obviously require simultaneously the use of a whole set of modern production techniques. The high yields obtained on the experimental and demonstration farms as well as by private and state farms is also in part a reflection of the superior natural resource endowment of these farms. 7/ It must

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7/ The process by which the better wheat land in Northern Tunisia has become concentrated in the hands of the large scale modern state and private farms and the dualism between it and the traditional smallholder sector is sketched out in 6, pp. 92-96.

Table 6. Tunisia: Comparison of Wheat Yields, 1967-68, on 27 Farms

Variety	Yield Average as per cent of Florence Aurore	Average Yield	Range High	Range Low
		Qx/ha		
Local soft wheats				
Florence Aurore	100.0	17.6	37.3	10.8
Ariana 66	122.4	21.4	45.1	11.8
Mexican wheats				
Sonora 63	133.3	23.0	50.3	12.9
Inia 66	153.7	26.4	52.4	15.2
Jaral 66	122.7	21.0	43.4	8.8
Tobari 66	129.7	22.4	42.6	10.1

Source: Resultats des Demonstrations de Production de Ble de la Campagne 1967-68 avec le Secretariat d' Etat à l'Agriculture de Tunisie et la Mission Speciale de Cooperation Economique et Technique des Etats-Unis d' Amerique.

Table 7. Tunisia: Comparison of Wheat Yields, 1968-69, on 22 Farms

Variety	Yield Average as per cent of Florence Aurore	Average Yield	Range High	Range Low
		Qx/ha		
<u>Local soft wheats</u>				
Florence Aurore	100	13.55	24.6	0.9
Ariana 66	120	16.24	39.8	1.6
<u>Mexican wheats</u>				
Sonora 63	117	15.90	42.4	2.4
Inia 66	147	19.96	39.2	2.0
Jaral 66	106	14.30	31.8	2.2
Tobari 66	131	17.82	43.0	1.6

Source: Rep. Tunisia, Sec. State for Agriculture, Accelerated Cereals Production Project, <u>Farm Experience with Short Stemmed Mexican Bread Wheat Varieties During 1968-1969</u>,

Table 8. Tunisia: Results from FAO Experimental Farm for Mexican and Local Wheats, 1967/68-1969/70.

Variety	1967-68	1968-69	1969-70	Average Gross Margin [a]
		Qx/ha		Dinars
Local soft wheats				
Florence Aurore	23.2	20.8	28.2	65
BT 2123	22.2	32.2	31.2	78
Mexican wheats				
Tobari 66	21.9	32.3	35.1	85
Sonora 63	25.5	26.1	27.5	70
Inia 66	17.4	34.9	24.6	73
Jaral 66	17.1	28.5	27.1	60
Hard wheats				
BD D117	22.1	--	--	--
D5825	--	36.1	29.7	116
Rainfall (mm.)	409	582	878	

a/ Gross revenue less seed, fertilizer, labor and tractor costs.

Source: FAO, Experimentation et Demonstration sur Certaines Productions Forrageres et Animales, Tunisie: Production de Ble dans les Centres d' El Afareg et de Bou Rebia, Rome, 1971 [AGS: SF/TUN 17 Rapport Technique 5].

be expected that as the new varieties replace the old varieties on larger and larger areas, average yields will decline somewhat. However, it is the thesis of the remainder of this paper that it is the use of variable or controllable inputs which influence wheat yields to a far greater extent than differences in natural resources. This is not to say that soils, topography or rainfall are not important but that it is only through the careful application of production technology that their effects can be overcome.[8/]

The hypothesis can be advanced that the Mexican wheats are far more sensitive to "control" variables. By control variables is meant those factors which affect plant growth and yields and which lie within the control of the farmer. By contrast, "non-control" variables are those outside the control of the farmer; examples are rainfall, disease epidemics,[9/] wind and hail damage. It seems reasonable to presume that plant breeding has been directed to the selection of plants which are perhaps less affected by non-control variables and more responsive to control variables. Selection for disease resistance and straw stiffness has been a major

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8/ It should be noted that increases in national cereal production will have to be attained primarily through increased yields. There are no reserves of uncultivated arable land which can be developed in Tunisia or major possibilities for substitution of land from other uses to wheat production. It is an objective of agricultural development policy to decrease total arable acreage and to use marginal arable land for tree crops or permanent pasture (7, pp. 16-21).

9/ Some diseases, particularly seed borne disease, could be considered as controllable factors since they can be eliminated by seed treatment and selection. Others can be diminished in importance by cultural practices. However, endemic or epidemic disease (e.g., rust and wheat blights) is often outside the control of the individual farmer.

feature of the Mexican wheat breeding program. 10/ However, the plant breeder by deliberately selecting material which is responsive to control inputs, such as nitrogenous fertilizer, probably selects plants which are more sensitive to the absence of proper control.

Clearly in Tunisia the non-control variables weigh heavily against the ability of dryland farmers to consistently obtain the high yields of which the plants are genetically capable. The paucity and irregularity of rainfall, the occurrence of storms and heavy winds and the soils and topography of Tunisia make wheat farming a precarious undertaking. The effectiveness of control variables becomes even more critical under these conditions. When the non-control variables are less important as in the case of irrigated wheat, it becomes much easier to determine and recommend to farmers what optimal degree of "control" is necessary and economically profitable. When risk and uncertainty are reduced farmers are more likely to adopt new practices. 11/

Thus, in dryland wheat areas a greater responsiveness of the Mexican wheats to control variables might be expected. The four years experience of the Cereals Project have time and again demonstrated the importance of seed bed preparation, seeding rates, date of planting, rate and timing of fertilizer and weed control. 12/ If all these things are done properly

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10/ The elimination of photosensitivity (day length) was an additional key element in the rice breeding program at IRRI.

11/ For discussions of adoption of new wheat varieties see 8, 9, 10. It may also be argued that prior to the green revolution, wheat farmers of the Punjab and rice farmers of the Mekon had already developed a more intensive form of cereal culture than is feasible on dryland conditions, making adoption of new varieties relatively easier.

12/ These factors have been repeatedly stressed in the reports of the Cereals Project (11, 12, 13).

the Mexican and local wheats both give high yields -- but the Mexican wheats are appreciably more responsive to such carefully exercised control. However, at low yield levels, i.e., when no control is exercised over some of these variables, the local wheats may actually outyield the Mexican wheats.

This hypothesis is supported by evidence from two sources. First, the demonstration farm data of 1967/68 and 1968/69 of the wheat project reported yields of the Mexican wheats and of Florence Aurore grown on the same farms and under equivalent conditions of "control." The yields of Mexican wheats are positively correlated with the yields of Florence Aurore. The slopes of the linear regression of Mexican wheats yields on Florence Aurore yields are greater than one and for 1968/69 the intercept is negative (Table 9). In other words, at low yields the superiority of the Mexican wheats is less in absolute terms than at high yield levels and may even (in the case of 1968/69) be negative. The 1968/69 data suggest that when Florence Aurore yields 5 quintals or less then the Mexican wheats will be even less productive.

Secondly, data from the 1969/70 survey were used to show that Mexican wheat yields are more responsive to control variables than are the traditional varieties. 13/ This was done by regression analysis of yields against (1) Total cost of production 14/ and (2) an Index of control

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13/ An analysis of nitrogen and rainfall on wheat yields for the demonstration farm data also found that a proxy variable for management was more significant, especially in the case of the Mexican wheats (14).

14/ Defined as the sum of the cost of variable inputs; excludes overhead costs.

Table 9. Tunisia: Yield of Mexican Wheat as a Function of Yield of Florence Aurore, Demonstration Farms 1967/8 and 1968/9.*

Year	Intercept	Slope	R^2
1967/8	6.621	1.123 (.216)	.52
1968/9	-3.759	1.751 (.149)	.87

*Calculated from data in annual reports of Cereals Project

Table 10. Tunisia: Regression Analysis of Wheat Yield, Survey 1969/70.

Variety (Yield in Quintals)	Intercept	Total Cost (dinars)	Index	Rainfall (millimetres)	R^2
Total Cost					
Ble dur	-19.58	.313 (.335)	-	.037** (.018)	.32
Ble tendre	- 1.467	.495* (.317)	-	.025* (.015)	.39
Ble Mexican	-12.995	.843*** (.234)	-	.011 (.018)	.61
Index					
Ble dur	-11.793	-	3.674* (2.625)	.011 (.018)	.21
Ble tendre	- 2.451	-	2.665** (1.133)	.010 (.012)	.54
Ble Mexican	-37.974	-	5.839*** (2.206)	.039** (.021)	.40

* Significant at 90 percent level.
** Significant at 95 percent level.
*** Significant at 99 percent level.

variables. Total costs of production are a measure of the degree of control being exercised. The greater the amount of tillage, seed used or of chemical inputs the higher the total cost of production per hectare. However, total cost is not a very good measure of the quality of control, hence an index was constructed to try and better measure the degree of control being exercised.

This control index was made up of the following variables (all measured on a per hectare basis):

Tractor hours in seedbed preparation
Date of planting
Seed rate
Amount of phosphatic fertilizer applied
Amount of chemical weed killer used
Amount of nitrogenous fertilizer applied
Timing of nitrogen application (date and whether as single or split-level application)

In addition, rainfall (a non-control factor) was included in the analysis but as a separate variable.

Each variable was standardised so that it had a mean value of 1.0 and a lower bound of zero. The index was constructed by simple addition of the values for each variable. In the case of the data for time of planting the variable was measured by the weeks away from the dates recommended by the Cereals Project.

The results of this analysis are shown in Table 10. Although the R^2 are not high and not all the slope coefficients are statistically significant, [15/] they exhibit some stability and lend support to our hypothesis that control is a major factor in obtaining high yields from the Mexican wheats.

Demand Limitation

The Tunisian wheat project has put its primary emphasis on the development of imported varieties of soft wheat to Tunisian conditions. Given the availability of genetic material at the time the program started and the rising levels of bread wheat imports into Tunisia, which during the last few years have reached annual levels of 300-500 thousand tons or more [16/] (see Table 1), this strategy was not inappropriate. Moreover, bread wheat production is largely in the hands of those "modern" farmers in Northern Tunisia who were equipped to handle the new wheats.

However, by far the larger acreages, production and consumption of cereals in Tunisia are of hard wheats and barley. The former is a preferred commodity and the latter an inferior substitute for wheat. [17/] There has been a rapid increase in soft wheat consumption during the 1960's -- associated with urbanization, increased availability through work relief programs and as a result of blending with milled hard wheat

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15/ Not all of the rainfall coefficients are significantly different from zero. The range of rainfall in the sample observations was from 490 to 720 millimeters; these are substantially higher than average rainfall in Northern Tunisia due to the exceptionally high rainfall in September and October 1969. In years of lower total rainfall, rainfall would probably be more important.

16/ Tunisia wheat imports, whether on concessional or commercial terms, are almost exclusively of soft wheats.

17/ Barley is predominantly grown in the marginal cereal areas of central and southern Tunisia on a "catch-as-catch-can" basis, depending on rainfall. In some years no harvest is taken. Barley is also used as an animal feed.

by the national cereals monopoly (Office of Cereals). With hard wheat production more or less stagnant during the last decade the rising demand for wheat from both population and income increase has been met by (imported) soft wheats. However, hard wheats are at least twice as important as soft wheats in total consumption even though controlled prices are higher. Moreover, less than half of national durum production enters the controlled market -- the remainder is consumed at home or sold on the "parallel market" at substantial premiums over the contracted price. 18/ Prices of 8 or 9 dinars per quintal, as against the farm price of 4.2 dinars (after tax), at which the Office of Cereals stands ready to purchase any hard wheat delivered to it, are quite common. Quality differences and preferences for particular wheats are also important -- for top quality milled durum wheat the "parallel" market price may reach 11 dinars. Obviously no official statistics are available on the operation of the 'black' market, but the market size and the premium prices paid in it are indicative of the strong consumer demand for durum wheat.

Although this preference for durum wheat will change with time 19/ and can be modified by increased availability of soft wheats at lower prices, it must be expected that it will change rather slowly. Demand adjustments are therefore additional restraints on the rate and pace at which the new soft wheats can be expected to spread in Tunisia. Although Tunisia will do well to replace current import levels (for which demand

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18/ In effect at the lower control price the Office of Cereals has been rationing hard wheats; demand has been satisfied with the more available soft wheats.

19/ For some estimations of effects of urbanization and population changes on demand see 15.

already exists) by domestically produced soft wheats, this will require some acreage adjustment in favor of the soft wheats. It is in these adjustments that the "demand pull" of the durum wheats will be felt, for at a black market price of 9 dinars the quintal, the durum wheats are more profitable even at yields of less than half those of the Mexican wheats.

Conclusions

The implications of this analysis are not very encouraging. Although high yields from the new wheats can be obtained under dry land conditions, even with rather modest rainfall, this requires a great degree of control in their cultivation, in seed bed preparation, planting and harvesting. [20/] It is in this aspect that constraints will be felt in spreading the Mexican wheats. Control depends upon two factors: (1) education and the knowledge of what to do and (2) the means by which to achieve it.

The first condition implies that a massive production education program will be needed. Extension education is still very rudimentary in Tunisia [21/] and modern production knowledge is not very widespread <u>even though the traditional wheats</u> also respond well to these management inputs. The second condition implies very substantial investment, with a very high foreign exchange component, in mechanical power and equipment. We have seen that on the large state farm tractor costs were a high

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20/ A similar observation was made by Cownie, Johnston and Duff in relation to irrigated wheats in West Pakistan (16, p. 65).

21/ The wheat program has developed its own extension staff for this purpose, but it is still very limited in size.

proportion of variable costs (inputs). Moreover, there seems to be little substitute for this mechanical input if similar or better levels of control are to be achieved. Not only is mechanical cultivation one way of assuring that cultivation operations are properly executed but the control variables all have a very important element of timeliness -- in preparation, planting, fertilizer and herbicide applications and harvesting. Because of the dependence on natural rainfall the time periods in which these operations have to be carried out and can be performed, even using mechanical power, are very limited. For example, the period between the onset of the rains and the time when it is too late or impossible to continue cultivation because of waterlogging of soils is frequently very short. Similarly at harvest time there is a risk of delaying harvest due to sirocco winds causing lodging and shattering.

These observations are well appreciated in Tunisia and the wheat program has concentrated its attention almost exclusively on the modern sector, i.e., that part of Tunisian agriculture which is equipped with mechanical power. However, this rather small modern sector has now adopted the new wheats. If Tunisia is to realize continued growth of wheat productivity through the new varieties then very substantial new investments will be required to make this possible. Although investment has also been important in Asia during the Green Revolution, production increases were largely obtained using existing resources combined with large increases in variable inputs (notably fertilizer). In other words the Green Revolution in Tunisia must be expected to be slower, more costly and less dramatic than in the irrigated wheat and rice producing areas. The possibility for sustained productivity gains depends not only on continued Tunisian research and development of better varieties (more disease resistance, higher maximum yields, etc.) but also upon the ability and determination to carry out at public expense a large scale extension education program and to make available the necessary capital production inputs.

The alternative is to both reorientate research towards the hard wheats and barleys grown by the bulk of the Tunisian peasant farmers, and to eliminate the need for high levels of expensive (in terms of material and human capital) control. This can be done as has been demonstrated by the Puebla Project in Mexico (17; 18). However, it will only be achieved if researchers and administrators can be persuaded to put their confidence in the ability of Tunisian small farmers to adopt new technology (suited to their needs) and to provide the major gains in productivity and output so badly needed from the agricultural sector.

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