ACCELERATED WHEAT PRODUCTION IN SEMI-ARID DEVELOPING REGIONS: ECONOMIC AND POLICY ISSUES

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Working Paper 80/2

ECONOMICS PROGRAM

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This paper focuses on wheat production in the semi-arid regions (SARs) of selected developing countries. It is divided into three main parts. We begin by providing a perspective on what has happened in wheat production in the recent past, particularly in SARs and follow with evidence on projected demand increases and the potential for increasing wheat production in these areas. The second section then analyses economic considerations affecting farmers' choice among alternative technologies again with particular reference to the SARs. We conclude by drawing some implications for agricultural research policy.

TRENDS IN WHEAT SUPPLY AND DEMAND

Trends in World Wheat Production and Prices -- The growth in world wheat production, yields, and international trade have exceeded world population growth over the past two decades (see Table 1). Similar data for maize and rice show changes in yield lagging well behind wheat. For maize, area changes have permitted production increases to keep pace with those of wheat. The price data of Table 2 show that wheat's real price (its dollar price adjusted for changes in the U.S. consumer price index) has declined since the first half of the 1960s.[1/] Related to the more rapid production increases in wheat, the price of rice relative to that of wheat has increased over the 1960s and 1970s. Interestingly, even though maize and wheat production changes were virtually identical over the period, the price of maize relative to that of wheat has risen markedly, from .69 to .84 or by some 20 percent. This is primarily a consequence of the large and growing demand for maize as an animal feed, as a consequence of rapid increases in the consumption of livestock products which have accompanied rising incomes in some countries.

For wheat, the inference from the price data is that production changes have exceeded changes in demand emanating from population increases, from income changes, and from changes in other prices. From the standpoint of the

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1/ Even in the face of wheat price increases in 1980, real prices of wheat in November, 1980 were below prices in the early 1960s.

TABLE 1: MEASURES OF WORLD AREA, YIELD AND PRODUCTION FOR WHEAT, MAIZE AND RICE (1961-1978)

	Area[a/]		Yield[a/]		Production[a/]		Trade[a/]		Annual Rate Change (1961-1978)			
	1961-65	74-78	1961-65	74-78	1961-65	74-78	1961-65	74-78	Area	Yield	Prod.	Trade
	(m. ha)		(t./ha)		(m. ton)		(m. ton)		(Percent/Year)			
Wheat	210.4	230.4	1.2	1.7	254.4	392.4	54.0	70.5	.7	2.7	3.4	2.3
Maize	99.7	116.2	2.2	2.9	216.4	332.7	20.4	57.8	1.2	2.1	3.4	8.4
Rice[b/]	123.6	142.2	2.0	2.5	253.2	355.4	7.3	9.2	1.1	1.5	2.6	1.8

a/ Data for five year averages

b/ Paddy

Source: FAO Production Yearbookds and FAO Trade Yearbooks from 1970 to 1978.

TABLE 2: SELECTED PRICES FOR WHEAT, MAIZE, AND RICE,[a/] 1961-1978. ($U.S./t)

	Current Dollars		Constant[b/] 1967 Dollars		Ratio of Price of Maize and Rice to Wheat Price	
	1961-65	1974-78	1961-65	1974-78	1961-65	1974-78
Wheat (No. 2 HRW Kansas City)	70.2	119.9	76.0	68.2		
Maize (No.2 Yellow Chicago)	49.0	102.1	52.7	57.3	.79	.84
Rice (Thai 5% broken Bangkok)	141.8	358.4	154.4	215.1	2.03	3.15

Source: Various issues of USDA Feed Situation and Wheat Situation

a/ Prices are five years averages centered on 1963 and 1976

b/ The U.S. CPI has been adjusted to reflect differences between calendar and crop years for maize and for wheat.

consumer, this reduction in real prices reflects well on the efforts of the wheat industry.

Trends in Wheat Production for Selected Countries and Regions -- Table 3 presents wheat production statistics for those developing countries which have more than 100,000 hectares planted to wheat. The data in Table 4, taken from Table 3, group developing countries in terms of progress they have made toward increasing yields. Countries with annual yield increases from 1961-78 of over three percent represent 72 percent of the wheat area. These include Bangladesh, China, India, Libya, Mexico, Pakistan, Tunisia, and Turkey - eight of the 26 developing countries analyzed. Several of these countries, India, Pakistan, Bangladesh and Mexico, have a high proportion of their area sown to High Yielding Varieties (HYVs). Area changes were most notable in South Asia where yield changes were also large.

There is, however, some 28 percent of the reported area where yield changes have not kept up with population increases. For the most part, this area is in the traditional wheat belt, much of it semi-arid, stretching from Morocco to Afghanistan.

The data in Table 3 on imports are another manifestation of further opportunity for progress. Twenty three of the 26 developing countries listed were net importers over the period from 1974-78. For 22 of these countries, net imports have increased from 1961-65. Indeed, for 15 of the 22 countries with complete data even relative dependence on imports (imports as a percent of total consumption) has increased (see Table 5).[1/] Only Turkey and, by 1978, India, two of the largest producers among the 26 developing countries of Table 3, have become self-sufficient, and have entered the list of developing country exporters.

Classification into Wheat Production Regions -- Focusing more sharply on production in the SARs of developing countries, attention is concentrated on developing countries from Morocco to Bangladesh which are significant producers of wheat. In the past, discussion of wheat production under various climatic

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1/ Some countries (Libya, Tunisia and Mexico) with yield increases above 3 percent per annum, have become more dependent on imports because of the effect of both rising incomes and population growth on the demand for wheat.

TABLE 3: SELECTED WHEAT STATISTICS FOR DEVELOPING COUNTRIES WITH OVER 100,000 HA WHEAT 1961-78

	AREA[a] 1961-65 (1000's ha)	AREA[a] 1974-78 (1000's ha)	YIELD[a] 1961-65 (t/ha)	YIELD[a] 1974-78 (t/ha)	Net Imports[a] 1961-65 (1000's t)	Net Imports[a] 1974-78 (1000's t)	Annual Rate of Change (Percent) Area	Yield	Production	(1961-78) Imports
North Africa	4700	5259	.66	.73	950	3876	.9	.8	1.7	11.4
Algeria	1971	2125	.64	.60	339	1747	.5	-.5	0	13.4
Libya	149	211	.25	.39	137	490	2.7	3.5	6.2	10.3
Morocco	1578	1843	.85	.95	322	1257	1.2	.9	2.1	11.0
Tunisia	1002	1080	.49	.72	152	382	.6	3.0	3.6	7.3
Other Africa	1615	1579	1.41	1.86	1872	4180	-.2	2.2	2.0	6.4
Egypt	557	568	2.62	3.35	1747	3893	.2	1.9	2.1	6.4
Ethiopia	928	636	.71	.89	22	77	-2.9	1.8	-1.1	10.1
Kenya	103	114	1.18	1.49	- 2	45	.8	1.8	2.6	d/
Sudan	27	261	1.31	1.13	105	165	19.1	-1.1	18.0	3.5
Middle East	16773	20270	.95	1.30	1244	2758	1.5	2.4	3.9	6.3
Afghanistan	2321	2345	.95	1.20	46	20	0.1	1.8	1.9	-6.2
Iran	3580	5585	.80	.99	193	1230	3.5	1.7	5.2	15.3
Iraq	1210	1288	.70	.79	156	709	.1	.9	1.0	12.4
Israel	58	106	1.54	2.11	257	440	4.7	2.5	7.2	4.2
Jordan	249	146	.72	.66	113	216	-4.0	-.7	-4.7	5.1
Syria	1396	1580	.78	.99	- 73	355	1.0	1.9	2.9	d/
Turkey	7959	9220	1.08	1.64	552	-212	1.1	3.3	4.4	d/
South Asia	18555	26466	.84	1.36	5774	6197	2.8	3.8	6.6	.5
Bangladesh	60	152	.61	1.38	na.	1419	7.4	6.5	13.9	na.
India	13402	19834	.84	1.36	4501	3540	3.1	3.8	6.9	-1.8
Nepal	109	324	1.24	1.12	0	41	8.7	-.8	7.9	d/
Pakistan	4984	6156	.83	1.35	1273	1197	1.6	3.8	5.4	na.
Latin America	7889	9856	1.46	1.48	-239	2116	1.7	.1	1.8	d/
Mexico	802	783	2.09	3.59	-265	382	-.2	4.2	4.0	d/
Argentina	4916	4914	1.53	1.58	-3227	-2908	0	.2	.2	-.8c/
Brazil	812	3021	.71	.83	2152	2981	10.6	1.2	11.8	2.5
Chile	753	633	1.44	1.55	190	922	-1.3	.6	-.7	12.9
Peru	153	131	.98	.89	406	766	-1.2	-.7	-1.9	5.0
Uruguay	453	374	1.03	.97	-25	-27	-1.5	-.5	-2.0	.6c/
China	25195	30601	.88	1.35	4477	5695	1.5	3.3	4.8	1.9
Selected Other										
U.S.S.R.	66622	61234	.96	1.50	10	3489	-.6	3.5	2.9	5.7
Major Exporters[b]	41568	50020	1.66	2.06	-39465	-59237	1.4	1.7	3.1	3.2c/

a/ Data are for five year averages for 1961-65 and 1974-78

b/ Includes Australia, Canada, France, U.S.A.

c/ Growth rate is for exports

d/ Growth rate not calculated because of change from importer to exporter or vice-versa

na. not available

Source: FAO Production Yearbook and FAO Trade Yearbooks from 1970-78

TABLE 4: AREA IN WHEAT FOR DEVELOPING COUNTRIES[a/] GROUPED BY RATES OF CHANGE IN YIELD OVER THE PERIOD 1961-1978.

Annual Yield Changes (1961-78)	Number of Countries in Group	Area, 1978 (m. ha)	Percent of Total Area
Over 3 percent	8	68.0	72
2 - 3 percent	1	1	-
1 - 2 percent	7	13.8	15
Under 1 percent	10	12.1	13
Total Selected Countries	26	94.1	100

Source: Calculated from Table 3.

a/ Developing countries with over 100,000 ha of wheat, including China.

TABLE 5: IMPORTS OF WHEAT AS A PROPORTION OF DISAPPEARANCE (PRODUCTION PLUS IMPORTS) FOR SELECTED COUNTRIES AND REGIONS, 1961-78[a/]

	Percent Imported 1961-65	Percent Imported 1974-78		Percent Imported 1961-65	Percent Imported 1974-78
North Africa	23	50	South Asia	27	15
Algeria	21	58	Bangladesh	na.	87
Libya	79	86	India	29	12
Morocco	19	42	Nepal	0	10
Tunisia	24	33	Pakistan	na.	13
Other Africa	45	59	China	17	12
Egypt	54	67	Latin America	b/	13
Ethiopia	03	12	Mexico	b/	12
Kenya	b/	21	Argentina	b/	b/
Sudan	75	36	Brazil	79	54
Middle East	07	09	Chile	15	48
Afghanistan	02	01	Peru	73	87
Iran	06	18	Uruguay	b/	b/
Iraq	16	41			
Israel	74	66			
Jordan	39	69			
Syria	b/	19			
Turkey	06	b/			

a/ Five year averages, 1961-65 and 1974-78.

b/ Self-sufficient or exporter

Source: Calculated from Table 3.

circumstances has been hampered by lack of data. For most countries, data have not been available for agro-climatic regions but only for political sub-divisions. In collaboration with national programs and others, CIMMYT has assembled a first rough measure of wheat producing regions classified on the basis of moisture conditions and type of wheat.

We asked national programs to identify major producing regions in their country for spring bread, winter bread and durum wheats based on characteristics such as irrigation, drought stress, disease, maturity and cold tolerance. From these data we have classified regions into three moisture regimes - irrigated, well-watered and semi-arid. In the irrigated areas, we presume that moisture is generally not limiting yields although we recognize that many irrigation systems deliver less than the required amount of water because of changing water supply conditions. The well-watered area generally receives a rainfall of at least 450-500 mm mostly during the growing season in a Mediterranean or Continental climate.[1/] The semi-arid category is characterized by moisture stress at some stage during the crop season most years and usually corresponds to wheat producing areas with less than 450 mm of rainfall.

These three categories are rough delineations of moisture regimes. A more precise classification would require more information on soil type, evaporation rates, topography and fallow practices. Nonetheless we believe they are a useful first approximation.

The countries considered include a substantial part of the semi-arid production in developing countries.[2/] Table 6 and 7 show that irrigated bread wheats account for a little over 40 percent of the area and well over half the production. Some 90 percent of this wheat is produced in South Asia -- Bangladesh, India, Pakistan and Nepal. The next large group are spring bread wheats produced

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[1/] The definition again is subjective. For example most non-irrigated wheat in Bangladesh is classified as well-watered although it is grown under residual moisture with very little growing season rainfall.

[2/] Our data do not yet extend to Latin America and China and Mongolia where there are substantial areas of semi-arid wheat production.

in semi-arid regions followed by semi-arid winter wheat and then by semi-arid durum wheats. Yields in these semi-arid regions apparently range from 0.6 to 1.0 t/ha. It is probable however that these estimates overstate current yields and we expect that continuing attempts to refine the country reports underlying Tables 6 and 7 will lead to yields of something like 0.5-0.6 t/ha in SARs.[1/]

Unfortunately we do not yet have a measure of the rates of changes in yields in these various producing regions. However we do know, that with the exception of Turkey, most HYVs are sown on irrigated or well-watered areas. One inference is that, for the most part, little change in yield has occurred in SARs.

Trends in Demand for Wheat -- Wheat is the basic staple for the countries of the Middle East and North Africa and a significant staple for much of South Asia (see per capita consumption figures of Table 8). Consumption of wheat is determined by three factors; change in population, change in incomes and prices, and the propensity to increase wheat consumption as incomes increase or prices are reduced. On the first of these, it is clear that over most of the region wheat demand will expand by 2.5 percent per year or more due simply to population changes. Moreover, consumer preferences for wheat are well known. For most of the countries, changes in consumption relative to income changes are high as shown by the income elasticities of demand in Table 9. Moreover, many countries, especially the oil producing countries, have experienced quite rapid rises in incomes.

Recent changes in wheat consumption reflect these forces. Estimated as the sum of wheat production plus imports, wheat consumption over the period 1961-78 has expanded by about 4 percent per annum in the Middle East countries and 5 percent per annum in the North African countries excluding Egypt. These consumption increases are largely being met from imports as shown in Table 6. By 1978, the Middle East/North African group of countries (excluding Egypt and Turkey) imported eleven million tons of wheat.[2/]

[1/] For some of the countries the area and average yield figures from Table 7 differ substantially from the FAO production figures presented in Table 3. To some extent this may be due to the use of data from different years. Nonetheless, national yield figures implied in Table 7 for India, Libya Tunisia and Jordan seem unrealistically high. The data in Table 7 (and also Table 3) should therefore be treated as approximations which we hope to refine by further exchanges with the national programs.

[2/] This includes also minor wheat producers such as Saudi Arabia. Including Egypt which produces all irrigated wheat, the region imported 16 million

TABLE 6: SELECTED WHEAT STATISTICS BY CLASS OF WHEAT AND MOISTURE REGIMES FOR SELECTED DEVELOPING COUNTRIES

	IRRIGATED						WELL-WATERED[a]						SEMI-ARID[b]					
	Spring Bread		Durum		Winter Bread		Spring Bread		Durum		Winter Bread		Spring Bread		Durum		Winter Bread	
Country	Area (1000ha)	Yield (t/ha)	Area (1000ha)	Yield (t/ha)	Area (1000ha)	Yield (t/ha)	Area (1000ha)	Yield (t/ha)	Area (1000ha)	Yield (t/ha)	Area (1000ha)	Yield (t/ha)	Area (1000ha)	Yield (t/ha)	Area (1000ha)	Yield (t/ha)	Area (1000ha)	Yield (t/ha)
Morocco	48	2.7	68	2.3			227	1.1	1143	.9			247	0.4	291	0.6		
Libya	15	2.0					20	1.0	30	1.0								
Sudan	245	1.4																
Egypt	535	3.1	19	3.3														
Jordan			5	1.5					18	1.0					130	0.7		
Syria	130	2.4	42	2.3			300	1.4	116	1.0			64	0.9	860	0.7		
Iraq	86	1.2	65	1.2			191	0.9	150	0.9			877	0.7	150	0.7		
Iran	375	2.4			1170	1.9	350	1.7	10	0.6	800	0.7	200	0.4	20	0.5	3000	0.5
Afghanistan	1125	1.8			125	1.7	65	1.1	10	0.6	135	0.7	40	0.4	200	.4	600	0.5
Pakistan	4948	1.6					252	1.1					1417	0.9				
India	14970	2.2					580	1.7					3710	1.0	1400	0.6		
Nepal	233	1.0					114	1.1										
Bangladesh	61	1.8					124	1.8										
Algeria							380	1.0	670	0.8			400	0.8	700	0.6		
Tunisia							80	1.2	586	1.0			20	0.8	585	0.8		
Ethiopia							40	1.2	335	1.0			10	0.7	115	0.7		
Kenya							108	1.2										
Turkey							1372	3.0	944[c]	1.6	1491	1.9	436	1.8	1295[c]	0.6	3488	1.5

[a] Areas which are not irrigated and which do not normally experience serious moisture stress and usually with at least 450-500 mm annual rainfall.

[b] Areas reported as subject to frequent moisture stress and usually with less than 450 mm annual rainfall.

[c] Both spring and winter durums are included

Source: CIMMYT survey of national wheat programs. Statistics reported were generally for the period 1976-1978.

Table 7: AREA AND YIELD OF WHEAT BY CLASS OF WHEAT AND MOISTURE REGIME

Moisture Regime	AREA Spring Bread	AREA Durum (m.ha)	AREA Winter Bread	AREA All	YIELD Spring Bread	YIELD Durum (t/ha)	YIELD Winter Bread	YIELD All
Irrigated	22.8	.2	1.3	24.3	2.1	2.0	1.9	2.5
Well-watered	4.3	4.0	2.4	10.7	1.9	1.1	1.4	1.5
Semi-arid	7.5	5.9	7.1	20.4	.9	.6	1.0	.9
Total	34.6	10.1	10.8	55.4				

Source: Calculated from Table 6.

TABLE 8: PER CAPITA WHEAT CONSUMPTION AND VARIABLES AFFECTING THE GROWTH CONSUMPTION FOR SELECTED COUNTRIES

	Per Capita Wheat Consumption a/ (kg/person)	Population Growth Rate, 1970-78 (% year)	Income/ Capita ($US, 1978)	Rate of Growth of Per Capita Incomes 1960-78 (% year)	Income Elasticity for Wheat b/
North Africa					
Morocco	88	2.9	670	2.5	.4
Algeria	88	3.2	1260	2.3	.6
Tunisia	125	2.0	950	4.8	.4
Libya	84	4.1	6910	6.2	.4
Middle East					
Afghanistan	115	2.2	240	0.4	.4
Iran	104	2.9	2160	7.9	.3
Iraq	83	3.3	1860	4.1	.4
Jordan	120	3.3	1050	1.8	.2
Syria	125	3.2	930	3.8	.2
Turkey	140	2.5	1200	4.0	-.2
Other Producers					
Argentina	96	1.3	1910	2.6	-.1
India	29	2.0	180	1.4	.5
Mexico	21	3.3	1290	2.7	.4
Pakistan	41	3.1	230	2.8	.4
U.S.A.	53	.8	9590	2.4	-.3
U.S.S.R.	122	.9	3700	4.3	-.1

a/ Estimated for 1975

b/ The percentage change in wheat consumption per capita for a one percent change in per capita income. Negative elasticities imply declining wheat consumption with increasing incomes.

Source: Population and per capita incomes from World Bank (1980): Income elasticities and per capita consumption from FAO (1971)

The Potential for Yield Increases in SARs -- An immediate question concerns the scope for increasing yields in SARs. One source of evidence is from SARs of developed countries. Table 9 shows average yield trends over recent years in South Australia, Nebraska and Central Oregon, all SARs but all following a wheat fallow rotation. These data clearly show that yield increases are feasible in SARs even on the basis of already relatively high yields at the beginning of the period. In fact, the annual percent changes reported for Nebraska compare well with those from India. While improved varieties have played a role the dominant contributions have come from improved husbandry, leading to better moisture conservation and the use of fertilizers.

TABLE 9: AVERAGE FARMERS' YIELDS AND YIELD INCREASES FOR SELECTED SEMI-ARID REGIONS OF DEVELOPED COUNTRIES

South Australia		Nebraska		Central Oregon	
	(t/ha)		(t/ha)		(t/ha)
1945-49	.83	1954-64	1.38	1964-66	2.03
1974-78	1.13	1966-76	2.01	1974-76	2.60
Annual Rate Change (%)	1.0		3.2		2.5

Source: South Australia, Australian Statistical Yearbooks; Nebraska, Barker, Gabler and Winkelmann (1978); Central Oregon, Oregon State University (1979).

Another measure of yield potential is the difference between yields researchers obtain in farmers' fields and those obtained by farmers. Evidence on this difference for SARs is summarized in Table 10. Results from experiments and demonstrations in farmers' fields regularly show a potential to increase yields by 50 to 100 percent even in the driest areas. As further evidence, a survey of national wheat programs for the Fifth Regional Wheat Workshop in Algiers in 1979 estimated that wheat yields in low rainfall areas were only 31 percent of potential yields.

TABLE 10. COMPARISON OF FARMERS' YIELDS WITH YIELDS OBTAINED FROM DEMONSTRATIONS AND EXPERIMENTS IN FARMERS' FIELDS IN SEMI-ARID REGIONS.

	Farmers' Yield	Average Yield Obtained in Demonstrations/Experiments in Farmers' Fields	Percent Increase Over Farmers' Yields
Syria - Demonstrations with Durum Wheat			
a. 350 + mm rainfall	1.9	3.0	58
b. 250 - 350 mm rainfall	1.2	1.9	58
Jordan - 500 Demonstrations			
a. Amman Governorate (350 mm rainfall)	1.2	2.0	67
b. Kerak Governorate (270 mm)	0.9	1.5	67
c. Irbid Governorate (250 mm)	0.8	1.3	63
Tunisia - Durums			
a. Inland Plateau - Variety trials	0.9	2.7	300
b. Inland Plateau - Demonstrations	0.9	2.0	222

Sources: Syria - Average results of 45 demonstrations reported in ICARDA (1978); Jordan - Average results of 500 demonstrations reported in Schmisseur (1976); Tunisia - Average results of unknown number of demonstrations over 5 years obtained by personal communication with Country Wheat Research Program.

In summary, then, the countries from Morocco to Bangladesh include much of the wheat grown under semi-arid conditions in developing countries. Some 20 million hectares of wheat are grown in the SARs of these countries, over one-third of their total wheat area. Demand for wheat is strong and growing as evidenced by increasing reliance on imports. While yield increases have been attained, most of this was probably on irrigated and well-watered lands. There is scope for increasing yields and production in SARs and notable advantages from doing so. The remainder of this paper is focused on some of the issues which will be confronted in pursuing those higher yields.

ECONOMICS OF IMPROVED WHEAT PRODUCTION PRACTICES AT THE FARM LEVEL

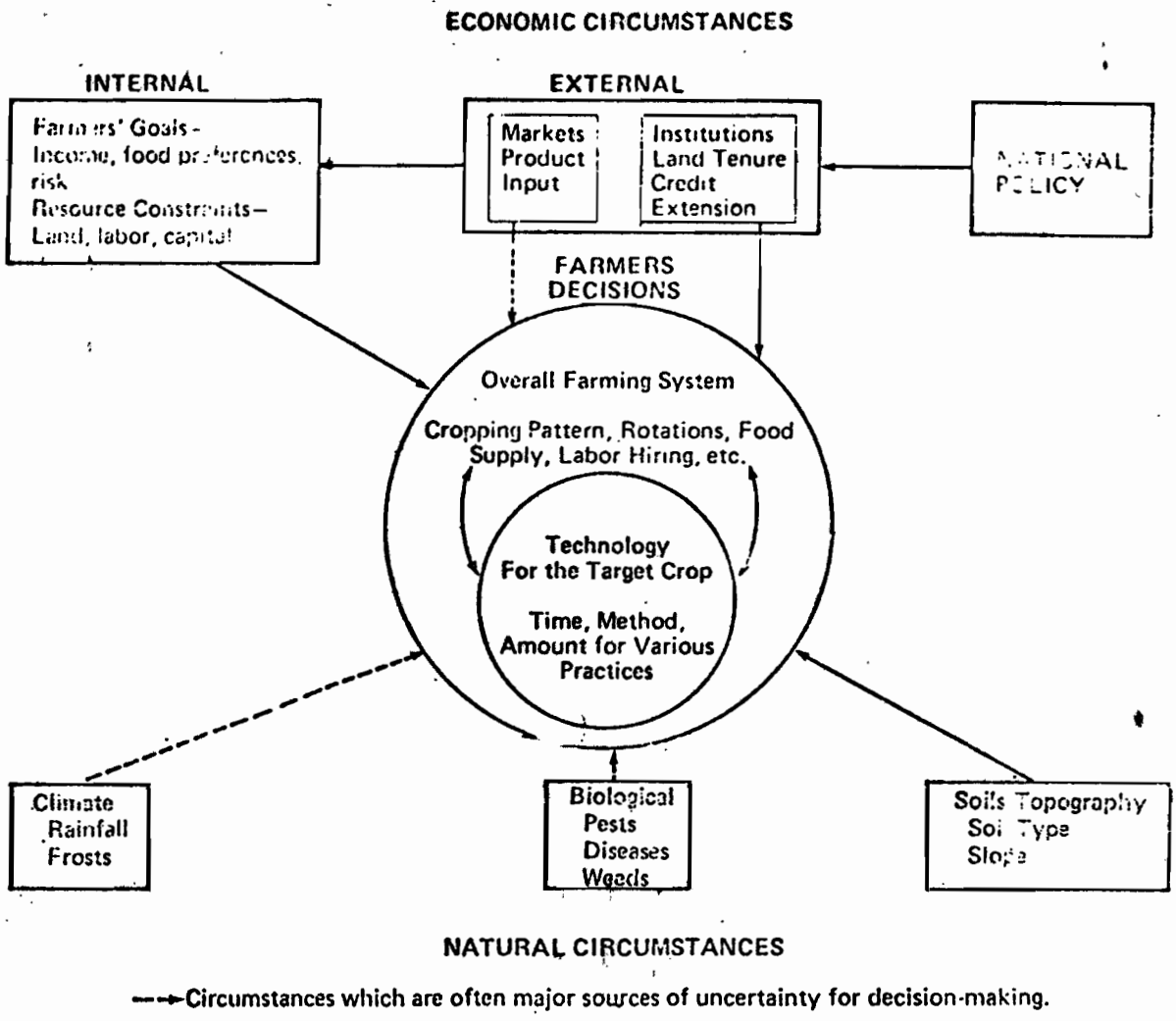
Farmer Decision Making in Semi-Arid Environments -- We now turn to an evaluation of wheat technologies at the farm level with emphasis on semi-arid areas. This evaluation must take into account the factors that condition farmers' decision-making. These factors are presented schematically in Figure 1. The farmer is depicted as having an intimate knowledge of a given natural and economic environment in which he allocates his scarce resources of land, labor and capital to meet certain goals.

Individual farmers may have quite specific goals but three goals predominate among small farmers. First, there is now overwhelming evidence that farmers seek to increase incomes. Experience from many countries has shown that when farmers are presented with new technologies that offer opportunities for significantly increased incomes within the resources available to them, these technologies are widely adopted (Perrin and Winkelmann, 1976). Second, farmers will modify their income-seeking objective to some extent, to avoid risks arising from weather or market uncertainties which may incur undue hardship to the farm business or farm family. In semi-arid areas the risks associated with variable rainfall are likely to be especially important in conditioning the environment in which farmers make decisions. For example, in the semi-arid areas of Eastern Oregon, the coefficient of variation of annual wheat yields is 43 percent (Oregon State University, 1979) compared to only 10 percent in the irrigated wheat area of northwest Mexico (Barker, Gabler and Winkelmann (1980)).

Finally, small farmers, because of market risks and marketing costs, usually produce their own basic food staples. To some extent, then, preferences for different grain types and suitability for home processing will enter as a goal in small farmers' decision-making, particularly with respect to varietal choice.

Wheat production in semi-arid areas cannot be analyzed in isolation from other farm-enterprises. In particular, wheat in semi-arid areas is usually produced as part of an integrated cereal-livestock system. Livestock serve various functions such as provision of a ready source of cash and a reduction of income variation in dry years. Especially important in evaluating wheat technologies is the use of the fallow cycle and crop residues as sources for livestock feed.

Figure 1 Various Circumstances Affecting Farmers' Choice of a Crop Technology



→ Circumstances which are often major sources of uncertainty for decision-making.

Source: Byerlee, Collinson et al (1980)

The farmer will use improved production practices if; a) they fit the particular natural and economic circumstances, b) adequate information is available on the new practices, and c) the necessary inputs are available. However, rarely will a farmer accept a "complete" package of practices at one time, both because of the initial capital required and of the risk of the unknown in using a completely new production system. Typically farmers adopt new practices individually or in clusters (Mann, 1975) in a sequential manner beginning with those practices which give highest return to scarce resources when added to farmers' existing practices.

In semi-arid areas, moisture availability is usually the overwhelming constraint. Following Bolton (1979), improved management practices in these conditions may act a) to increase the amount of water stored in the soil and reduce evaporation losses or b) to use stored water and growing season rainfall more efficiently. In the short run, it is the latter type of improvement which offers the greatest potential. Moisture conservation dependent on tillage technique usually requires additional power and appropriate implements which may require a longer period for full adoption. Hence Bolton sees a sequential adoption process as follows: a) chemical weed control, b) stand establishment, c) fertilizer, d) improved varieties, and e) tillage and moisture conservation. Here we present evidence on the economics at the farm level on two of the priority factors - chemical weed control and fertilizer use - and briefly discuss some constraints on tillage practices in semi-arid environments.

Budgets for Evaluating the Impact of New Technologies on Farm Incomes -- Before considering the economics of improved inputs, we digress briefly to discuss some concepts important in constructing sound farm budgets for evaluating the impact of improved practices on farm income. Although the evaluation of a new technology in terms of its impact on farmers income is not conceptually difficult, we have found that most studies substantially underestimate costs and benefits.

The added costs of using a new input can be summarized as follows (Perrin et al, 1976).

1. Purchase price of input
2. Cost of the transport of input to the farm
3. Cost of labor to apply the input
4. Cost of equipment to apply the input
5. Cost of operating capital spent on the input
6. Cost of harvesting, threshing and transporting extra yield produced by the input.

Typically budgets on input use ignore many of these costs, some of which are quite substantial. Transport costs for bulky inputs such as fertilizer typically add at least 10 percent to the cost of the input at the farm level. Small farmers are usually constrained by capital scarcity and the cost of capital may be quite high. To be attractive to capital-short small farmers we consider than an input should return at least 50 percent annually on operating capital invested. This rate of return is of course reflected in the informal capital market where interest rates are often 50 to 100 percent or more. In the analysis below we assume that a rate of return of 50 percent over the production cycle is necessary to induce small farmers to rapidly adopt a new technique.[1/]

Costs of harvesting, threshing and transporting of the extra yield are usually ignored in budget calculations. Because these costs vary with the level of yield, we prefer to calculate a field price of output which the market price minus cost of harvesting, threshing and transportation. As a rule of thumb this field price is about 20 percent less than the market price for output for hand harvesting.[2/]

In evaluating added benefits from using an input, two factors are usually overlooked. First, caution must be used in applying yield increases obtained in experiments, even experiments on farmers' fields, to farmers who operate larger areas under different management conditions. Experiences suggest that average farmers yields will only be 70-90 percent of experimental yields for the same technology (Davidson (1962). Second, in countries of the Middle East and North Africa, livestock is an important part of the farming

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[1/] For an eight month production cycle (input purchase to grain sales) this is equivalent to an annual interest charge of 75 percent.

[2/] Costs of machine harvesting usually do not vary greatly with yield.

system and wheat straw and (sometimes weeds) are often an important component of total crop output.

Weed Control -- Losses due to weeds in wheat production in the Middle East/ North African region have been estimated at 20 percent (Basler, 1979). Moreover weed competition for moisture becomes critically important in semi-arid areas. Improved weed control is one of the greatest potential sources of improved water use efficiency and higher yields in these areas.

There is now ample evidence that use of herbicides to control broadleaf weeds in wheat, particularly 2-4, D is economically attractive to small farmers and is one of the first inputs widely adopted when made available to them. The total cost of 2-4,D application including costs of capital and equipment is usually equivalent to the value of 100 kg wheat as shown for various situations in Table 11.[1/] The budgets for Turkey and Tunisia have been adjusted to include costs omitted in the original sources. Also in Tunisia, where herbicides are subsidized by 50 percent, the unsubsidized price reflects the real national cost of herbicide use. Although farmers applying herbicide for the first time may have to incur a substantial initial cost for the sprayer, in many areas a rental market for hand sprayers exists and/or herbicides is applied by contractors. In areas where weeds are extracted by hand and fed to animals, other costs (value of weeds fed to animals) and benefits (saving of labor for hand weeding) of herbicide need to be considered. Also, in other areas where wheat is a commercial crop, an additional benefit of herbicide use is the reduction of price discounts due to weed seed impurities.

Evidence from on-farm experiments shows that yield increases from application of 2-4, D alone without any other changes in management are usually much higher than 100 kg/ha. In Turkey results of 18 experiments in the dry Anatolian Plateau showed average yield increases of 280 kg/ha which even discounted by 20 percent to reflect farmers' yields would easily cover the costs (Mann, 1975). In Tunisia, average returns on fields with average weed populations were barely enough to cover subsidized costs (Ben Zaid, 1975) but this may reflect the additional pre-sowing tillage of experimental plots

[1/] These budgets do not consider the value of additional straw produced which will reduce costs further if the value of the extra straw exceeds the forage value of the weeds killed.

TABLE 11: APPROXIMATE COST OF APPLICATION OF 2-4, D HERBICIDE TO SMALL GRAINS IN VARIOUS SEMI-ARID REGIONS.

	WHEAT IN TUNISIA		WHEAT IN TURKEY (ANATOLIAN PLATEAU)	BARLEY IN MEXICO (HIGH PLATEAU	
	With 50% Subsidy	Without Subsidy		Recommended Dosage	Farmers' Dosage
Dosage Commercial Product	1.3 lt/ha	1.3 lt/ha	2.0 lt/ha	2.0 lt/ha	0.5 lt/ha
Product Price[a/]	D 0.7/lt	D 1.4/lt	TL 161/lt	P 120/lt	P 120/lt
Application Cost[b/]	D 1.25/ha	D 1.25/ha	TL 40/ha	P 130/ha	P 130/ha
Cost Herb. + Application	D 2.26/ha	D 3.1/ha	TL 162/ha	P 370/ha	P 190/ha
Cost with 50% Cost of Cap.	D 3.3/ha	D 4.6/ha	TL 243/ha	P 555/ha	P 285/ha
Market Price Wheat/Barley	D 0.62/kg	D 0.62/kg	TL 255/kg	P 3.0/kg	P 3.0/kg
Field Price Wheat/Barley	D 0.05/kg	D 0.05/kg	TL 205/kg	P 2.4/kg	P 2.4/kg
Total Cost of 2-4 D in kg Grain	66 kg	92 kg	119 kg	230 kg	110 kg

[a/] Prices in local currencies; Tunisian Dinar (D), Turkish Lire (TL), Mexico Peso (P)

[b/] Calculated from the contract rate in Turkey; cost of hand sprayer plus labor for Mexico. Method of application not stated for Tunisia.

Source: Tunisia - Republic of Tunisia, (1975); Turkey - Mann (1975); Mexico - Byerlee, et al (1980)

(Republic of Tunisia, 1972).[1/] Also the economic risk of chemical weed control of broadleaf weeds is minimal since yield losses are relatively more important in drier years and there may be little interactions of absolute yield losses and moisture stress (Ben Zaid, 1975). In the dry Anatolian Plateau, use of 2-4, D weed control was unprofitable in only one of eighteen sites (Mann, 1975).

The rapid spread in recent years of herbicide use for broadleaf weed control in semi-arid wheat producing areas in some countries is further proof of the profitability of the practice. In Turkey, the percent of wheat area treated apparently increased from 12 percent in 1975 (Mann, 1975) to 50 percent in 1977/78 (Basler, 1979) in response to increased supplies of the input. In the dry altiplano of Mexico, use of 2-4, D herbicide increased from 20 percent to over 70 percent of barley farmers over a six year period as shown in the adoption curve of Figure 2. Particularly important in this area of Mexico was the ability of farmers to adopt herbicides independently of tractor availability since most herbicides are applied by hand sprayers, even by farmers with over 100 ha of barley. Herbicides are now applied by practically all farmers in the area, many of whom have less than 10 hectares planted to barley.

Herbicide control of grassy weeds is considerably more expensive. For example, herbicides such as Suffix to control wild oats need to increase yields by about 350-500 kg/ha to cover all costs.[2/] Availability of these herbicides at subsidized prices in Tunisia and Algeria requires yield increases of 250-350 kg/ha of wheat (Ben Zaid, 1975 and Nelson, 1980). In Algeria, the response to Suffix application over 16 trials averaged 480 kg/ha (Nelson, 1979). In Tunisia the yield response in average fields was 300 kg/ha but this increased to 630 kg/ha in heavily infested fields and was even higher in years with wet winters followed by a dry spring (Ben Zaid, 1976). In semi-arid areas, where yield responses are likely to be lower, the cost and risk associated with use of herbicides for grassy weeds will prevent rapid adoption in the near future.

[1/] Since it is a common practice to perform extra tillage operations before planting an on-farm experiment, experimental yield response to weed control may actually be less than for farmers.

[2/] This discussion abstracts from the possibility of residual benefits from weed control over time.

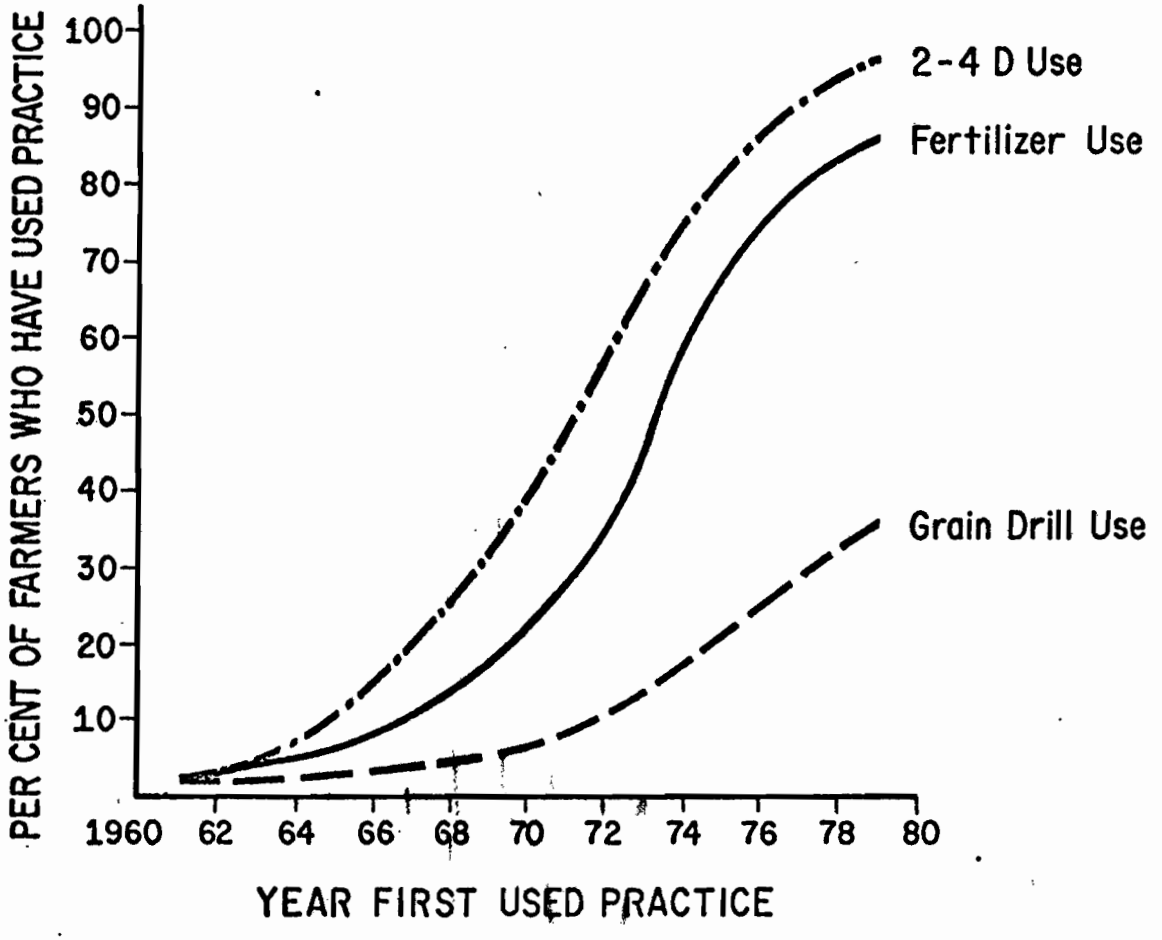

Figure 2. Adoption for Various Barley Production Practices, Central Plateau, Mexico.

Source: Unpublished Survey Data.

However, with effective control of broadleaf weeds, grassy weeds will increase in importance.

Fertilizer Use -- Nitrogen fertilizer use offers potential for increased wheat yields in semi-arid areas. However, the profitability of nitrogen use is strongly influenced by moisture supply and unlike 2-4, D herbicide use, risk becomes a critical factor in farmers' decisions on fertilizer use.

First let us examine the profitability of nitrogen fertilizer use. As with weed control many of the costs and benefits of fertilizer use are overlooked in analyzing fertilizer experimental data. Typically the market price of nitrogen fertilizer is divided by the market price of wheat to obtain the number of kilograms of wheat needed to pay for one kilogram of nitrogen. This is useful for international comparisons but substantially underestimates the costs faced by farmers. Budgets for nitrogen use in Turkey and Mexico are shown in Table 12 were straw yields are assumed to respond to nitrogen in the same ratio as grain. These figures show that a yield response of 4 kg and 5 kg of wheat in Turkey and Mexico respectively was necessary to pay the cost of one kg of nitrogen, over double the crude nitrogen/wheat price ratios.

One of the most comprehensive studies of nitrogen response in semi-arid wheat production was conducted by Russell (1967, 1968) in South Australia. Experiments were sown in farmers' fields at 16 widely scattered locations with average annual rainfall from 285 mm to 500 mm to give 52 site-season combinations. Agroclimatically this region is representative of the Mediterranean areas of North Africa and Middle East although the nitrogen response is probably somewhat lower in South Australia because of the medicago-ley fallow rotation system employed in wheat producing areas of South Australia and because the studies were conducted before the introduction of semi-dwarf wheat varieties. A nitrogen-moisture response function developed by Byerlee and Anderson (1969) was used to construct Figure 3 which shows the combinations of nitrogen-wheat price ratios and annual rainfall at which it becomes profitable to use fertilizer.[1/] The area identified by the dotted

[1/] In constructing this figure we have taken into account that there is a fixed cost of fertilizer application regardless of the level applied. The fixed cost application is assumed to be 33 kg/ha of wheat roughly the cost of hand broadcasting in Mexico or machine application in Algeria.

TABLE 12. APPROXIMATE COSTS OF APPLYING NITROGEN FERTILIZER TO SMALL GRAINS IN SEMI-ARID AREAS OF TURKEY AND MEXICO.

	WHEAT IN TURKEY (ANATOLIAN PLATEAU)	BARLEY IN MEXICO (HIGH PLATEAU)
Product	Ammonium Nitrate (26%N)	Urea (46%N)
Method of Application	Machine	Broadcast
Market Price of Product[a/]	TL 1.5/kg	P 3.2/kg
Cost of Transport	n.a.	.2/kg
Field Price of Nitrogen (includes transport)	TL 5.8/kg	P 7.4/kg
Cost of Application[b/]	TL 200 per 50kgN	P 50 per 50kgN
Cost of Fertilizer + Application	TL 9.8/kgN	P 8.4/kgN
Total Cost with 50 percent cost of capital	TL 14.7/kgN	P 12.6/kgN
Market Price of Wheat/Barley	TL 2.75/kg	P 3.0/kg
Field Price of Wheat/Barley (20 percent less for harvesting, threshing transport)	TL 2.2/kg	P 2.4/kg
Field Price of Straw	TL 0.7/kg	P 0.1/kg
Field Price of Grain + Straw (Grain Price + Twice Straw Price)	3.6	2.5
Crude Price Ratio (Market Price N/Market Price Wheat)	2.1	2.3
Actual Price Ratio (Total Cost N Applied/Field Price Wheat + Straw)	4.1	5.0

[a/] Expressed in local currencies - Turkish Lire (TL), Mexican Peso (P)

[b/] Machine contractor in Turkey and in Mexico

Source: Turkey -

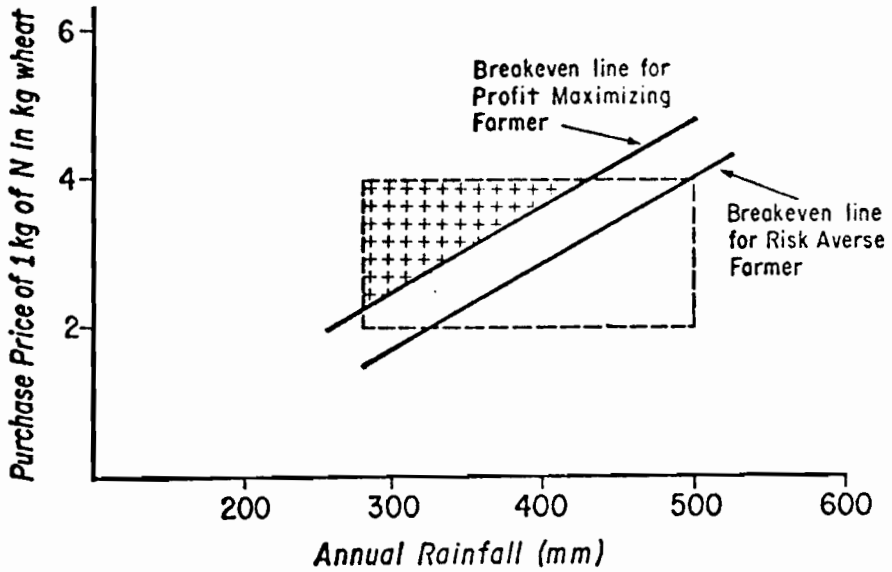

Figure 3a

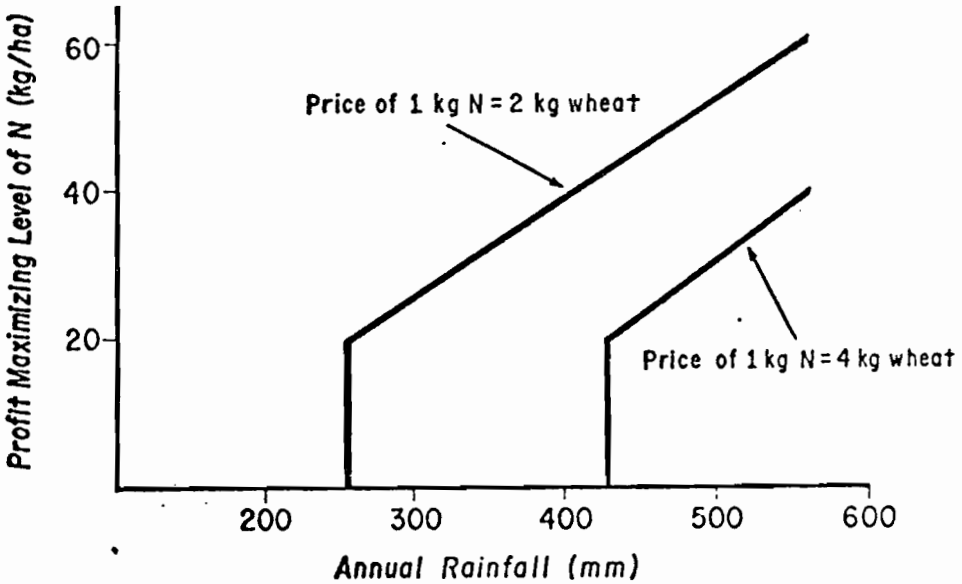

Figure 3b

Figure 3. Predicted Effect of Rainfall and Price of Nitrogen on Nitrogen Use in South Australia. Figure 3a. The solid lines are breakeven lines for profit-maximizing and risk averse farmers. That is for combinations of price of nitrogen and rainfall to the right of these lines farmers would use nitrogen. The box shown by the dotted line shows relevant combinations of prices and rainfall for SAR's. Figure 3b. Shows the optimal level of N for varying rainfall for two prices of nitrogen. Farmers need to apply about 20 kg of nitrogen to cover a fixed cost of application of 33 kg wheat.

line in Figure 3a represents the rainfall and nitrogen cost combinations commonly found in semi-arid wheat areas. To the right of the solid lines are combinations of rainfall and nitrogen prices at which it is profitable to apply nitrogen. Significantly, at a low rainfall and with favorable nitrogen prices, it is still profitable to apply nitrogen under favorable nitrogen prices. With unfavorable nitrogen prices, rainfall must increase to at least 430 mm before nitrogen application becomes profitable. These figures then support the fact that farmers' decisions on whether to use nitrogen in semi-arid areas will be quite sensitive to the prevailing wheat/nitrogen price ratios and to average annual rainfall.

However, the above analysis considers only profitability and ignores risk. Most fertilizer studies show a strong positive interaction between rainfall and nitrogen response. In the extensive South Australia studies presented above, nitrogen response in dry years was negligible and in some years and sites with a hot spring, grain yields were depressed by nitrogen application (Russell, 1968).[1/]

We predicted that farmers with average risk aversion would use about 25 percent less nitrogen than a profit maximizing farmer in lower rainfall areas.[2/] Moreover as shown in Figure 3a, the set of rainfall and nitrogen wheat price ratios in which farmers would use nitrogen is reduced substantially and risk averse farmers in the lowest rainfall areas would no longer apply nitrogen fertilizer even at the more favorable prices for nitrogen.

Results from scattered fertilizer experiments elsewhere also indicate the substantial risk in applying nitrogen to wheat. In the last ten years of fertilizer experiments on dryland wheat in Jordan, reported in Duwayri and Saket (1978), less than half of the experiments seem to show an economic response to nitrogen. Data from areas of Tunisia with less than 500mm annual rainfall and with a total cost of one kg of nitrogen equivalent to 5 kg wheat indicate on average an economic response to nitrogen upto 66 kg/ha. However, in two out of the five years, represented in the data, farmers would be better off by applying only 44 kg/ha of nitrogen. The possibility that

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1/ However, straw yields were not adversely affected which lessens risk in areas where straw has a high economic value as forage.

2/ Risk aversion is often measured by farmers' willingness to trade-off expected profits with a measure of risk, usually standard deviation of profits (Anderson et al, 1977). We used a value of 0.5 which has been derived in several studies in LDC's (e.g. Scandizzo and Dillon (1978)).

farmers would lose money from nitrogen application in dry years represents a significant risk to farmers. We calculated from the South Australian data that even at favorable nitrogen prices (1 kgN costing 2 kg wheat) farmers would lose money one year in three from nitrogen use in the low rainfall areas (less than 300 mm annual rainfall) but only one year in seven in the higher rainfall areas (500 mm annual rainfall).[1/]

Farmers, and especially smaller farmers, generally attempt to follow mangement strategies which reduce risks even if these strategies imply lower expected profits. In this case, to some extent, farmers can avoid risks by splitting nitrogen application with perhaps a moderate dose applied at planting and a second application applied depending on stand establishment and available soil moisture. Also phosphorous application is considerably less risky since it may give a response even in dry years (Russell, 1968) and residual phosphorous can be carried over to the next season.

In summary, fertilizer use and particularly nitrogen use, given current farmer prices for fertilizer seems to be profitable even in the lowest rainfall wheat areas although risk may be a severe deterrent to nitrogen use in these areas. Moreover fertilizer can be broadcast by hand independently of machine availability and is therefore particularly appropriate to small farmers. While fertilizer use has increased rapidly in some SARs (e.g. the Anatolian Plateau of Turkey), average rates of use both nitrogen and phosphorous are usually below 10 kg nutrients per hectare in the countries of the SARs (FAO, 1978).

Tillage Practices -- Tillage practices are important in moisture conservation, weed control, and stand establishment. Extensive experimentation in the Anatolian Plateau of Turkey has demonstrated a substantial yield advantage of over 500 kg/ha from early tillage followed by a clean fallow to conserve summer moisture. However, the use of weedy fallow for livestock and the high price of forage resulted in only 27 percent of farmers adopting this practice in 1975/76 compared to 58 percent who were using herbicides (Mann, 1977). The partial budget in Table 13 shows that when the forage value of weed and straw is taken into account, the benefits of early tillage were negligible at that time. However, after 1975 adoption of other elements of the technological

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1/ These risks are somewhat lower if only risks of losing cash costs of nitrogen use are considered.

TABLE 13. ADDED BENEFITS AND COSTS OF EARLY TILLAGE IN TURKEY IN 1975[a/]

Added Benefits	
Added yield in experiments	0.60 tons/ha
Added yield in farmers fields (90% experimental yield)	0.54 tons/ha
Added straw yield (twice grain yield)	1.08 tons/ha
Market price of wheat	TL 2.75/kg
Field price of wheat (less 20 percent for harvest costs)	TL 2.20/kg
Field price of straw	TL .90/kg
TOTAL ADDED BENEFITS	TL 2,160/ha

Added Costs	
Weed Yield foregone (dry matter)	2.00 tons/ha
Price for weeds (approximate)	TL 1.00 /kg
Foregone value of weeds	TL 2,000/ha
Extra cultivation to clean fallow	TL 150/ha
TOTAL ADDED COSTS	TL 2,150/ha

[a/] Monetary units are Turkish Lire (TL)

Source: Mann (1980)

package and the use of bailersto conserve straw has apparently increased the value of early tillage and led to widespread adoption of this practice.

A second difficulty with improved tillage operations in the short run is the need for additional power to be available in a timely fashion. A recent survey in the semi-arid barley area of Mexico's high plateau shows substantial differences in tillage practices among owners and renters of tractors. As shown in Table 14, tractor owners plough earlier, harrow more frequently and plant earlier than tractor renters. To some extent the later ploughing of tractor renters reflects the fact that many small farmers (who are largely tractor renters) graze straw residues while large farmers bale straw to sell. But even allowing for this difference, tractor renters have difficulty obtaining tractor services in the short time when moisture is suitable for either primary or secondary tillage; on average there was a 12-day lag from time services were requested until delivered. However, there is evidence that with increasing numbers of tractors in the area (and virtual disappearance of animal power) the timing and intensity of tillage operations among tractor renters is improving.

TABLE 14. COMPARISON OF TILLAGE PRACTICES OF BARLEY PRODUCERS WHO RENT TRACTORS AND WHO OWN TRACTORS IN THE CENTRAL VALLEY, MEXICO.

	Tractor Renters	Tractor Owners
Percent plough immediately after harvest	17	32
Percent plough on intermittent dry season rainfall	49	57
Percent plough after beginning of rainy season	34	11
Percent do zero or one pre-planting cultivation.	68	38
Percent do two or more pre-planting cultivations.	32	62

Source: Byerlee et. al. (1980)

Farmers Adoption of Improved Production Packages -- We hypothesized at the beginning of this section that farmers in SARs would generally follow an adoption sequence initially emphasizing divisible inputs - chemical weed control followed by fertilizer use and variety - accompanied by gradual improvement of practices such as tillage methods which are dependent on increased availability of power and machinery.

In fact evidence from semi-arid areas in which rapid technological change has taken place support this type of adoption sequence. Table 15 shows that for the Turkish Anatolian Plateau in 1975/76 the rates of adoption were highest for seed treatment followed in descending order by drilling and phosphorous use, herbicide application, spring nitrogen application, early plowing and additional tillage. It is likely that the number of herbicide users would have been higher had there not been a shortage of herbicides. The cross-tabulation of practices used shows where important interactions occur. It is significant that nearly all farmers who used nitrogen fertilizer also applied herbicide but only 20 percent of nitrogen were growing high yielding varieties which were not widely available at the time.

TABLE 15: ADOPTION OF SELECTED PRACTICES IN WHEAT PRODUCTION IN ANKARA PROVINCE, TURKEY, 1975-76.

	Practice					
	Treated Seed	Herbicide	Drilling (and phosphorous use)	Plough early	Nitrogen	High Yielding Variety
	(Percent farmers who use practices)					
All farmers	92	58	70	27	43	12
Farmers applying nitrogen	97	84	71	37	100	20
Farmers ploughing early	100	65	93	100	60	24
Farmers using HYV	100	84	100	56	68	100

Source: Mann (1977)

Evidence from other SARs also shows that herbicide is likely to be adopted before nitrogen fertilizer. In the semi-arid upper plateau of Mexico the adoption of 2-4, D herbicide use, fertilizer (mostly nitrogen), and planting with a grain drill are shown in Figure 2. Use of 2-4, D rose very rapidly from 1968-1975 closely followed by nitrogen fertilizer use. Adoption of grain drilling has been much more gradual and was only used by 40 percent of farmers in 1979.

Cases of non-adoption of practices are usually associated with unprofitability, risk or lack of availability of relevant inputs. After an extensive demonstration program over seven years in semi-arid wheat areas of Jordan (250-400 mm rainfall) adoption of the 'package' was low. The package consisting of four operations for land preparation to provide clean fallow, drilling, nitrogen and phosphorous application and 2-4, D use, raised yields by an average of 650 kg/ha or 50-70 percent over farmers practices (Schmisseur, 1976). However, the yield increase required to cover cost is close to 700 kg/ha[1/] and this was only achieved in 6 of 23 villages in five seasons in which the demonstrations were made. However, in the somewhat better rainfall areas, the use of 2-4, D combined with nitrogen and phosphorous application was profitable in almost all cases[2/] (Gotsch, 1980). This experience shows the need to disaggregate "technological packages" on the basis of on-farm agronomic research prior to reaching the demonstration stage.

RESEARCH AND POLICY ISSUES

Increased wheat production in semi-arid areas will come about through applied research to develop technologies appropriate to farmers in the area, combined with availability of inputs and price incentives to implement these technologies. In this section we offer some evidence and recommendations for each component.

1/ These results are somewhat more negative than found by Schmisseur (1976) because we have used a higher cost of capital (25 percent) and included harvesting costs (10 percent). The forage value of weedy fallow was not considered by Schmisseur.

2/ These demonstrations were conducted under improved land preparation so the response to fertilizer use may be somewhat higher than farmers would obtain.

Agricultural Research -- We have already emphasized the importance of management in increasing wheat yields in semi-arid regions. While we have made some generalizations about the type of technologies and sequences of adoption of technologies in semi-arid areas, we stress that much research is needed to adapt these technologies to the specific climatic, soils and economic circumstances found in each semi-arid areas.

Our review of agronomic research in the SARs of the Middle-East and North Africa indicates that, with few exceptions such as Turkey, there has been very little agronomic research and in particular agronomic research aimed at representative farmers. Much of the agronomic research has been conducted on experiment stations which usually do not represent conditions in farmers' fields, and even where research has been conducted in farmers' fields we have the impression that it has not been aimed at representative farmers - often the small resource-poor farmer. For example, in Algeria, extensive fertilizer trails were conducted in farmers' fields in the early 1970s' In the dry upper plateaus of Algeria, the average yield in the check plot without fertilizer over five years of trials was over 2 t/ha (FAO, 1976) in a region where farmers average yields are 0.5 t/ha or less, indicating that either nonrepresentative fields were used or that the underlying agronomic practices were very different to what farmers are likely to use in the immediate future.

In addition, there is also a shortage of farm-level economic studies in the region to provide a knowledge and understanding of farmers' existing system. As a result there is a serious lack of information on such questions as constraints on improved tillage operations, operation of tractor hire schemes, crop-livestock interactions, farmers' cash flows in relation to needed inputs and farmers' perception of risk and the influence of risk on their choice of management practices.

We believe an important means of increasing the relevance of research to farmers is through programs of area-specific on-farm research. We have elsewhere described procedures developed by CIMMYT for conducting such research and only summarize its main elements here.[1/] As shown in Figure 4, on-farm research emphasizes the collaboration of agronomists and economists to identify and understand the circumstances of farmers through farm surveys

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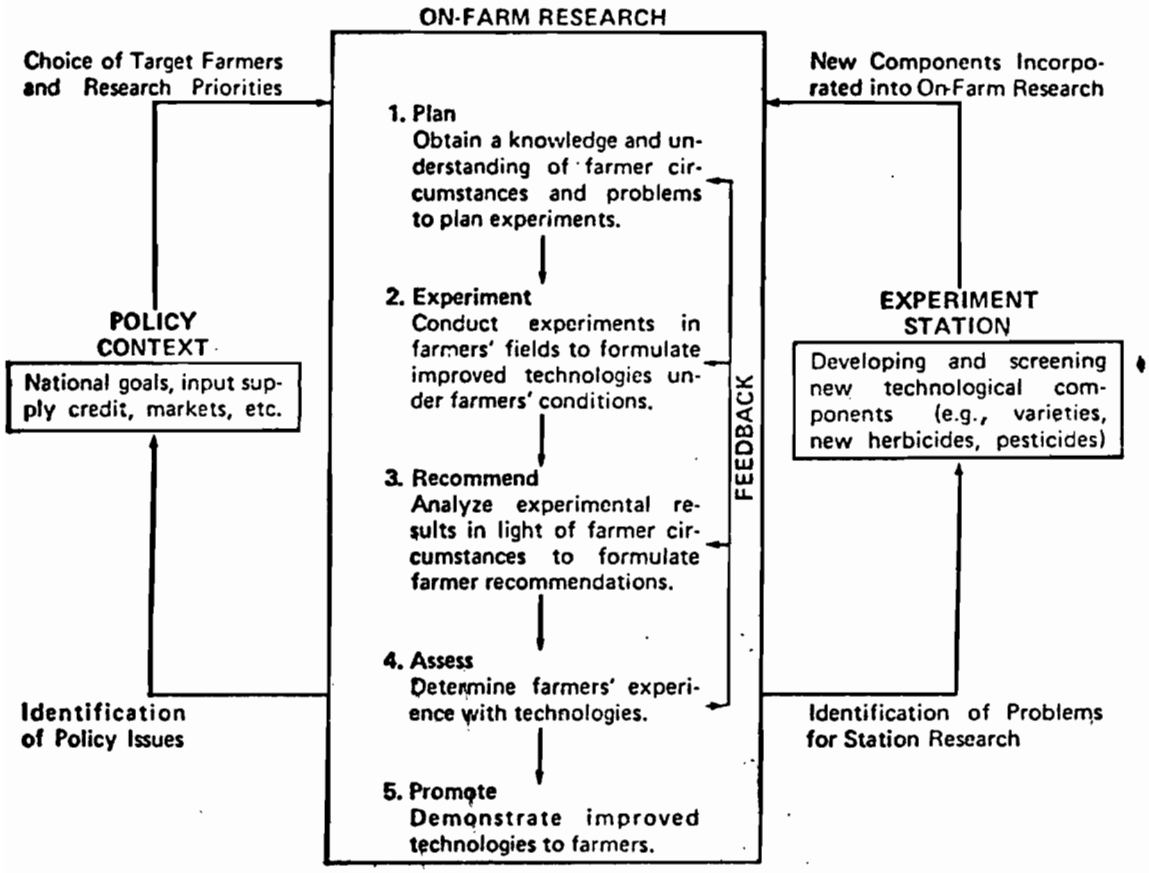
[1/] See Winkelmann and Moscardi (1979), Byerlee, Collinson et al (1980), and CIMMYT Wheat Training (1979).

Figure 1. Overview of an Integrated Research Program



and/or informal interviews with farmers who are the target of the research. This helps to more clearly focus experiments in farmers' fields by identifying key constraints to increased production as well as those technologies for overcoming these constraints which best fit farmers' goals and resources. Although on-farm research usually has an immediate objective the formulation of recommendations appropriate to farmers, we are increasingly finding that the process of working in farmers fields in communication with farmers provides valuable guidance to experiment station research and to policy formulation.

Implementation of effective on-farm research programs in the region will require greater resources for agronomic research and involvement of economists in the early stages of research design. This implies some restructuring of agricultural research institutes, (many do not currently employ economists), and appropriate incentives to ensure the implementation of such farmer-oriented research.

It might be argued that payoffs to scarce research resources may be higher if invested in higher rainfall areas than semi-arid areas. To some extent this is true. Yields in the better rainfall coastal areas of Turkey increased by 4-7 percent from 1961-76 compared to 2-3 percent in the semi-arid central plateau. In Algeria the experimentation/farmer yield gap in 1979 in drier areas was a little over one ton/ha compared to a gap of over 2 tons/ha in higher rainfall areas. However the very size of the semi-arid wheat area and the number of people dependent on wheat in these areas is alone justification for research aimed at these areas. In many cases it may also be possible to allocate research resources so that there are spinoffs to semi-arid areas. For example, a research strategy focused on the intermediate rainfall areas of North Africa may have high payoffs to those areas as well as significant spinoffs for the semi-arid areas. On the other hand research aimed at higher rainfall areas may have little relevance to the semi-arid areas.

Finally, increased research efforts must be accompanied by expanded demonstration and extension programs to make research results available to farmers. This is particularly the case for the introduction of chemical

inputs such as fertilizer and herbicides which require considerable knowledge on type of product, dosage and method and time of application in relation to climatic conditions.

Price Incentives for Wheat Production in Semi-Arid Areas -- From several sources (including our own observations) we have assembled in Table 16 some producer prices which seem to be consistent across various sources. Prices of wheat are quite variable by country. Assuming that over the last five years, it has cost from US $150-200/ton to land imported wheat in North Africa/Middle East, domestic wheat prices are somewhat lower than world prices in some countries such as Tunisia and much higher in others such as Algeria.

TABLE 16: APPROXIMATE PRICES RECEIVED BY FARMERS FOR WHEAT AND PAID BY FARMERS FOR NITROGEN FERTILIZER BY COUNTRY

Country	Year	Price of Wheat $US/ton.	Price of Nitrogen $US/Ton N	Ratio Price of Nitrogen to Wheat
Middle East/North Africa				
Algeria	1980	345	345	1.0
Tunisia	1977	135	350	2.6
Jordan	1979	330	465	1.4
Syria	1977	182	496	2.7
Turkey	1979	125	270	2.2
Afghanistan	1978	130	420	3.2
Iran	1978	200	300	1.5
Other Countries				
India	1979	154	400	2.6
Pakistan	1979	114	333	2.9
Australia	1980	159	632	4.0
U.S.A.	1980	154	406	2.6

Sources: Assembled from USDA (1979), FAO (1978) and our own personal interview with farmers in various countries.

Relative prices are more useful than absolute prices in comparing incentives for wheat production. On the one hand input-output price ratios are indicative of incentives for more intensive management. In Table 16 we show price ratios of nitrogen fertilizer to wheat. Significantly, for most Middle East/North Africa countries, price incentives for nitrogen use are quite strong relative to irrigated wheat areas such as India and Pakistan and especially strong when compared to large wheat producers such as Australia and the U.S.A.

The cost of nitrogen in terms of wheat is kept low by high support prices for wheat (e.g. Algeria) and/or government subsidies on fertilizer prices. Subsidies in 1976/77 for nitrogen fertilizers were 40-50 percent of farm gate prices in Iran, Syria and Turkey in 1976 and 20 percent of farmgate prices in Tunisia (FAO, 1978). Subsidies on fertilizer can be justified for various reasons. Purely on an economic efficiency criterion, subsidies may be used to induce farmers facing risks and capital scarcity to use fertilizer at levels nearer to socially optimum levels than they could otherwise use. For example, using the nitrogen response data of Figure 3, a subsidy of 50 percent would be needed to induce risk averse farmers to use fertilizer at a socially optimum level that maximizes profits (regardless of risks) at a social cost of capital of 20 percent. Moreover, a subsidy program is usually more efficient and easier to administer than a credit program to overcome capital scarcity, or a crop insurance program to counter risks.

The second set of price relation keeps affecting wheat production is the relationship between the price of wheat and competing farm activities. In the semi-arid areas, the main competing activity is livestock, especially sheep. Evidence on meat/wheat price ratios is very scanty. Roughly we have estimated that at the farm level one kg of live mutton is valued at about 55 kg of wheat in Tunisia, 45 kg of wheat in Algeria and about 15 kg of wheat in South Australia. That is, in countries of the Middle East and North Africa the price of mutton relative to wheat is three times as high as in Australia.

Partly because of oil and gas production, the North Africa/Middle East area is on the whole, a region of rapidly rising per capita incomes. It is also

a region of high population growth rates relative to other regions at comparable stages of development. Increasing incomes and population are likely to increase the price of meat relative to wheat. A recent Oregon State University report estimates that the demand for meat in the North Africa/Middle East is growing at 8 percent per annum because of a high propensity to increase meat consumption with rising income. At the same time, meat production is rising at only 3 percent per annum leading to upward pressure on meat prices. Of course wheat demand is also outstripping supply, but as we have seen this is being met by large increases in wheat imports. On the other hand, transportation and handling costs for meat imports are much higher. Even so, meat imports to North Africa and the Middle East have increased in recent years, particularly from Australia and New Zealand. These crop-livestock interactions add considerable complexity to policy decisions on increased wheat production that demands a thorough analysis of alternative strategies of domestic forage production, medic-ley farming and imports of feed grains and meat to relieve pressure on meat prices.

Input Availability -- In addition to price incentives, reliable and accessible product and input markets are needed to induce increased wheat production. Our impression is that in the case of wheat, reliable product markets are usually less of a problem than input distribution problems. This impression is reinforced by contrasting the experience of Algeria with that of Tunisia. Price policies apparently are more favorable to Algerian wheat, e.g. nitrogen costs in Tunisia are roughly 2.5 kg wheat and 1.0 kg wheat in Algeria while the cost of sheep, in terms of wheat, is lower in Algeria than in Tunisia. Even so, the annual change in yield in Tunisia is notably larger than for Algeria.

The problem with input distribution varies. Fertilizer often suffers from a limited number of distribution points, particularly if distribution is handled by the public sector. For the small farmer, the transport cost of bringing the fertilizer to the farm may be a severe deterrent to fertilizer use. Herbicide, on the other hand, is not a very bulky item. However, sprayers -- either tractor or backpack -- as well as the herbicide must be available for herbicide application.

Availability of machinery to small farmers usually depends on the establishment of a rental market. In Turkey and the upper plateau of Mexico this has largely been established by the private sector - entrepreneurs specialized in machinery rental or medium to larger farmers who rent machinery to small farmers after completion of work on their own farms. In both cases the levels of mechanization even on small farms has risen very rapidly. For example the number of tractors in operation in Turkey more than doubled from 1968-1976. Research too can help rationalize machinery import policy. For example, in Algeria Nelson (1980) has shown that heavier combination drill-cultivators from Australia give substantially superior results to those of conventional European models.

CONCLUSIONS

From Morocco to Bangladesh, wheat production under semi-arid conditions accounts for a significant proportion of the wheat sown. Average yields in these areas are low. In most of the countries with large semi-arid areas yield increases have generally lagged well behind population growth rates. Moreover, with expanding population and income, the demand for wheat, the staple for food cereal, is increasing at 4 to 5 percent per annum, a large part of which is being met by imports. For the Middle East and North Africa (excluding Turkey, and Egypt) wheat imports had risen to 11 million tons by 1978 or from 14 percent of total consumption in 1963 to 31 percent in 1978. However, experience of yield increases in SARs of developed countries, and some SARs of developing countries such as Turkey, and results from on-farm experiments and demonstrations show the potential for increasing yields by 50 to 100 percent or more in most SARs.

There is ample evidence that farmers in SARs will rapidly adopt improved technologies that fit their particular natural circumstances (soils and climate) and economic circumstances (goals of increased income and risk aversion as well as resource availability). There are relatively few farmer-level economic studies on wheat technologies in SARs and most ignore important costs and benefits. Most also ignore the crop-livestock interactions that influence farmers' decisions. Nonetheless we have shown that some technologies such as broadleaf weed control and fertilizer use are often appropriate to farmers - particularly resource poor farmers in SARs - since they can be applied by hand methods independently

of tractor availability. Some inputs such as nitrogen, are somewhat more risky, but even these inputs seem to be appropriate except perhaps in the lowest rainfall areas. Improved land preparation and moisture conversation also show promise of increased yields but improvement may be slower if increased power and machinery is required or weedy fallow is highly valued for livestock feed.

Increased farm-level agronomic and economic research at the local level is needed to establish improved practices appropriate to farmers in each SAR. This requires additional resources expenditures by national agricultural research programs for on-farm research, early involvement of applied economists in this research and appropriate incentives to orient research to farmers. Research also needs to be supported by strong demonstration and extension programs.

At the policy level, it appears that incentives to use improved management practices are usually provided at least in terms of input/output price ratios. However, expanded wheat area or use of wheat production practices such as early tillage which compete with livestock are constrained by policies which keep wheat prices low relative to livestock. Obviously, price incentives for input use have little effect unless inputs are made available to a wide number of distribution points in a timely way. It is in the area of management of input acquisition and distribution that policy can play the largest role in improving wheat production in SARs in the near future.

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