Durum wheat in WANA: Production, trade, and gains from technological change

A. Belaid
ICARDA, B.P. 435, El Menzeh 1, 1004 Tunis, Tunisia

SUMMARY – In the dryland environments of WANA durum wheat production is a major enterprise with important implications on the region economies. Five WANA countries (Algeria, Morocco, Syria, Tunisia, and Turkey) account for over one third of world annual durum area and production. World trade of durum wheat has increased considerably over the last few decades, largely due to the increasing import requirements of North Africa that more than doubled between the 1975/86 period (average of 1.4 million tons) and the 1988/97 period (average of 3.0 million tons). The durum world market has an oligopolistic structure, i.e., dominated by few sellers: Canada, USA, and the EU. In view of increasing durum demand in most WANA countries, durum production must increase significantly and very rapidly. This will have to be achieved through significant and sustained productivity growth, although evidence suggests that with the exception of Syria, durum research, undertaken over the past three decades, has had little impact on durum productivity. Nevertheless, the generation and efficient utilization of technology innovations will be critical in addressing current and future challenges confronting durum production in the region. The challenge is not only to spark productivity growth where new technology-induced gains have not been considerable, e.g., North Africa, but also to sustain the gains in the NARSs that have enjoyed significant productivity gains over the past few years, e.g., Syria. This is the challenge faced by researchers and policy makers alike at the dawn of the new millenium.

Key words: Durum, WANA, oligopolistic, demand, growth, productivity.

RESUME – *"Le blé dur dans la région AOAN : Production, commerce et progrès grâce aux changements technologiques". Dans les zones à faible pluviométrie d'Asie de l'Ouest et d'Afrique du Nord (AOAN) le blé dur représente une spéculation importante ayant des implications majeures sur les économies de la région. Cinq pays de la région (Algérie, Maroc, Syrie, Tunisie et Turquie) comptent pour plus du tiers de la superficie et de la production annuelles de blé dur dans le monde. Au cours de ces dernières décades, le commerce mondial du blé dur a beaucoup augmenté en volume, suite à l'augmentation des importations des pays d'Afrique du Nord qui ont plus que doublé entre les périodes 1975/86 (moyenne de 1,4 millions de tonnes) et 1988/97 (moyenne de 3,0 millions de tonnes). Le commerce mondial du blé dur a une structure oligopolistique, c'est-à-dire dominée par quelques vendeurs : Canada, USA et UE qui dominent le marché mondial d'exportation du blé dur. Considérant la demande croissante qui prévaut dans la plupart des pays de l'AOAN, la production de blé dur doit augmenter rapidement. Ceci doit se faire par le biais d'une croissance significative et durable de la productivité, bien que les résultats disponibles montrent que la recherche conduite ces trois dernières décades sur le blé dur n'a eu que peu d'impact sur l'amélioration de la productivité, à l'exception du cas de la Syrie. Malgré tout, le développement et l'utilisation efficiente d'innovations technologiques sera déterminante quant à une amélioration significative et durable de la production de blé dur dans la région. C'est là le défi auquel seront confrontés les chercheurs et les décideurs de la région à l'aube du nouveau millénaire.*

Mots-clés : *Blé dur, AOAN, oligopoliste, demande, croissance, productivité.*

Introduction

Although durum is grown in various regions of the world, the great bulk of durum area and production is concentrated in North America and the Mediterranean Basin. In West Asia and North Africa (WANA), durum is mainly grown under rainfed conditions characterized by low and highly variable rainfall and/or extreme temperatures with high probability of terminal stress (drought and heat), not to mention nutrient deficiencies and soil problems, e.g., alkalinity, boron toxicity, and zinc deficiency. Moreover, biotic stresses as a result of high occurrence of diseases, insects, and viruses, may also be particularly severe.

Five WANA countries (Algeria, Morocco, Syria, Tunisia, and Turkey) account for over one third of world annual durum area and production. These countries have the capacity to increase their durum production and meet domestic demand. However, in spite of the paramount importance of durum for their rural economies, these countries have not all succeeded in their (research and development) effort to

substantially improve durum productivity. The combination of increasing demand for durum and durum products, as a result of demographic pressure, and relatively low durum productivity partly due to abiotic stresses, mainly heat, cold, and moisture stresses, has changed many WANA countries, especially North African countries, from net exporters to net importers of durum.

Over the past few decades, most governments of the WANA region have enacted policies geared toward providing greater support to agricultural research in order to create a strong base for technological change. Although more efforts are still required to strengthen agricultural research, most national agricultural research systems of the region have succeeded in generating a significant stock of promising technologies that could significantly improve crop productivity. Paradoxically, however, the increasing supply of technology innovations has not always translated into increased productivity at the farm level as their widespread adoption and utilization by farmers lagged behind. This is particularly true in the case of resource-poor farmers who usually continue to apply dated technology, very often unaware of the availability of new and better performing technologies developed by research.

The purpose of this report is twofold: (i) provide a global overview of durum production trends in the world, with special emphasis on the five major dryland durum producing countries of WANA (Algeria, Morocco, Syria, Tunisia, and Turkey); and (ii) assess durum productivity changes brought about the adoption of modern durum varieties in these NARSs. It draws on two sources of information: (i) International Grains Council; and (ii) when available, official statistics from the five WANA countries (Algeria, Morocco, Syria, Tunisia, and Turkey). The report is organized into four sections:

(i) Section 1, which follows this introduction, provides an overview of durum wheat area, production, yields trends and trade in the world over a twenty four-year period (1973-1996)[1].

(ii) Section 2 compares national trends (area, production, and consumption) observed in the five countries.

(iii) Section 3 compares the five WANA countries in terms of technological change resulting from adoption and utilization of modern varieties.

(iv) Section 4 provides future prospects in light of the trends reviewed.

Durum wheat in the world

Durum wheat (*Triticum turgidum* var. *durum*) is a spring wheat mainly grown for human consumption. It is consumed under the form of pasta products, e.g., spaghetti and macaroni, couscous, bulgur, frike, flat breads, etc.[2].

Area and production trends

Worldwide, the area annually planted to durum is estimated to be around 17-18 million hectares, i.e., 8 percent of total wheat area, with a production averaging about 30 million tons annually, i.e., 5.5 percent of total wheat production. Although durum is grown in various regions of the world, the great bulk of durum area and production is concentrated in North America and the Mediterranean basin. Eight countries (Algeria, Canada, Italy, Morocco, Syria, Tunisia, Turkey, and USA) account for nearly two thirds (2/3) of world durum area and production.

[1] Reliable world statistics on durum are not readily available. For example, FAO wheat statistics (production data) do not differentiate between durum and bread wheat. Worldwide, durum area and production are usually estimated to represent about less than 10% and 5% of the world's wheat area and production, respectively. As indicated above, for the purpose of this report, four sources are used: 1) 1973-1986: World Wheat Statistics 1987, International Wheat Council; 2) 1987-1996: World Grain Statistics 1996/97, International Grains Council; 3) when available, official statistics from the five WANA countries (Algeria, Morocco, Syria, Tunisia, and Turkey); and 4) data from farm surveys undertaken in all five countries in 1997 and 1998.

[2] In some regions of the world, poor quality durum is used for feed.

In developing countries, the total area devoted to durum is estimated at about 8-9 million hectares, i.e., about 50 percent of world area, the bulk of which is concentrated in five WANA countries of the Mediterranean basin: Turkey, Algeria, Morocco, Syria, and Tunisia. However, because durum yields are much lower in developing countries, their share in durum world production does not exceed 35 percent.

Over the past two decades (1977-1986 and 1987-1996), world durum area has slightly declined while production increased as a result of yield increase (Table 1). Over the same period, the top six countries with the largest durum area are Turkey (average of 2.904 million hectares per year), Canada (1.672 million), Italy (1.657 million), USA (1.421 million), Morocco (1.208 million), and Algeria (1.193 million). Over the two decades considered, durum area declined in most durum producing countries except in Spain, Greece, and Canada. The most dramatic increase in durum area was observed in Spain where durum area has nearly increased by four fold, reaching an average of 0.407 million hectares over the 1987/96 period versus 0.116 million hectares over the 1977-1986 period. Spain has now become one of the major durum producing country of the EU after Italy and Greece. Over the same period, durum area has nearly doubled in Greece, while in Canada it increased by 43 percent (Table 1).

Table 1. Average durum area, yields, and production in selected major durum-producing countries and in (1973-1996)

NARS	Area (000ha)				Yields (t/ha)				Production (000t)			
	Mean 73/96	Mean 77/86	Mean 87/96	Change (%)†	Mean 73/96	Mean 77/86	Mean 87/96	Change (%)†	Mean 73/96	Mean 77/86	Mean 87/96	Change (%)†
Algeria	1193	1135	1077	-5.1	0.71	0.67	0.90	35.0	835	738	977	32.0
Morocco	1208	1211	1127	-7.0	1.15	1.07	1.29	21.0	1382	1286	1482	15.0
Syria	800	834	694	-17.0	1.59	0.97	2.47	155.0	1252	821	1814	121.0
Tunisia	755	800	663	-17.0	0.97	0.81	1.23	51.0	742	647	887	37.0
Turkey	2904	2932	2955	0.8	1.62	1.78	1.52	-15.0	4719	5236	4500	-14.0
WANA††	6826	6913	6516	-5.7	1.20	1.26	1.48	17.4	8917	8728	9660	10.7
USA	1421	1511	1242	-18.0	2.01	2.07	2.07	0	2838	3114	2559	-18.0
Canada	1672	1446	2067	43.0	1.79	1.70	1.94	14.0	3012	2462	3931	60.0
Italy	1657	1686	1660	-1.5	2.20	2.04	2.49	22.0	3646	3474	4090	18.0
Spain	238	116	407	251.0	2.00	2.05	2.27	11.0	459	245	800	227.0
Greece	394	294	571	94.0	2.33	2.21	2.58	16.0	947	663	1451	119.0
World	17800	17680	17480	-1.1	1.48	1.39	1.68	21.0	26309	24590	29451	20.0

Source: Adapted from World Wheat Statistics 1987 (International Wheat Council and World Grain Statistics 1996/97 (World Grains Council).

†Average change between 1977/86 and 1987/96 periods.

††The figures relate to the five countries only. Other durum producing countries from WANA are not included.

Table 1 also shows that the top six producing countries are Turkey (average of 4.7 million tons per year), Italy (3.64 million), Canada (3.01 million), the United States (2.84 million), Morocco (1.40 million), and Syria (1.25 million)[3]. Regarding productivity per unit area, several points are worth mentioning:

(i) Yields have increased in all major durum-producing countries over the second decade (1987/96) except in Turkey where a decline is observed and in USA where they remained unchanged.

(ii) Based on 1987/96 averages, Greece, Italy, and Syria are the top ranking countries with an average yield of 2.5 tons per hectare, while Algeria is ranked last with an average yield below one ton per hectare.

[3] Although not shown in Table 2, average annual durum production in Russia is estimated to be around 2 million tons.

(iii) Looking at the evolution of wheat yields over time in Syria, the sudden and sharp increase appears to have paralleled the widespread reliance on supplemental irrigation that started in the late 1980s.

Table 2 presents data on growth rates of durum area, production, and yields of the 8 major durum producing countries, over 3 different time periods (1973-96, 1973-84, and 1985-96). Several trends can be observed across the selected countries.

Table 2. Growth rates (%) of durum area, yields, and production in 8 major durum producing countries

NARS	Area			Yields			Production		
	1973-96	1973-84	1985-96	1973-96	1973-84	1985-96	1973-96	1973-84	1985-96
Algeria	-1.34[a]	-3.32[a]	-1.47	4.68[a]	6.33[a]	4.93[b]	3.32[a]	2.96	3.44
Morocco	-1.58[b]	-2.24[b]	-2.28	1.43[a]	0.41	-1.46	-0.15	-1.82	-3.73
Syria	-1.77[b]	-3.00[b]	2.56	6.50[a]	0.28	11.50[a]	4.74[a]	-2.72	14.02[a]
Tunisia	-1.77[c]	-0.37	2.00	3.55[a]	1.75	3.07	1.69	1.38	5.07
Turkey	0.27	1.35[a]	-1.11[c]	-0.20	3.43[a]	-3.07[b]	0.07	4.84[a]	-4.18[a]
USA	-1.65[b]	-0.57	-0.31	1.09[c]	2.32[c]	1.51	-0.56	1.75	1.20
Canada	3.16[a]	3.54[c]	-0.02	1.16[c]	0.50	4.92[b]	4.32[a]	4.04	4.90[c]
Italy	0.17	1.55[b]	-1.78[b]	1.84[a]	1.32	2.07	2.01[a]	2.87[c]	0.29

Source: Computed based on data from International Wheat Council (World Wheat Statistics 1987) and International Grains Council (World Grain Statistics 1996/97).

[a] = Significant at 1% level; [b] = Significant at 5% level; [c] = Significant at 10% level.

Note: Growth rates are calculated using the semilog trend function: $\ln Y = \beta_0 + \beta_1 T + \varepsilon$ ($\ln Y$ is natural log of the variable being considered, i.e., area, yield, production, β_0 is a constant, β_1 is the growth rate of Y, T is time, and ε is a disturbance term).

(i) First, over the first decade (1973-1984), durum area declined in the WANA region, with the exception of Turkey where it significantly expanded at an annual rate of 1.35 percent. The largest, and significant, decline in durum area is registered in Algeria, Syria, and Morocco (-3.32, -3.0, and -2.24 percent annual growth rate, respectively) while in Tunisia it decreased slightly, although not significantly, as indicated by the negative growth rate of 0.37 percent. In contrast, a substantial and significant expansion of durum area is registered in Canada (3.54 percent) and in Italy (1.55 percent) while a slight non-significant decline is observed in USA. It must be noted that in several WANA countries, this period coincided with a period of aggressive policy aiming at expanding bread wheat area very often at the expense of durum. Morocco is a case in point. The declining trend in durum area continued during the second decade (1985-1996) in Algeria and Morocco. In Syria and Tunisia, however, positive growth rates are observed (2.56 and 2.00 percent, respectively). However, neither the decline (Algeria and morocco) nor the expansion (Syria and Tunisia) of durum area was statistically significant. During this second period, a significant decline is registered in Turkey (-1.11 percent growth rate). A slight, non-significant, declining trend is observed in USA and Canada. In Italy, however, the decline was not only more pronounced but also highly significant. Looking at the entire 24-year period, durum area has declined in all major producing countries or remained unchanged, e.g., Turkey and Italy, with the exception of Canada where it grew at an annual rate of 3.16 percent.

(ii) Second, in terms of production, the most remarkable change has occurred in Syria where durum production grew at an unprecedented annual rate of 14 percent during the last decade (1985-1996) after a decline (2.72 percent) during the preceding period. Over the same period, relatively high positive growth rates were also registered in Tunisia (5.07 percent), Canada (4.9 percent), and Algeria (3.44 percent). However, the upward trend of durum production was significant only in Syria (1 percent level) and Canada (10 percent level). Over the same period, durum production declined in Turkey at a highly significant growth rate of -4.18 percent and Morocco at a growth rate of -3.73 percent, although not statistically significant. Throughout the 24-year period, durum production was characterized by positive annual growth rates in all countries except in Morocco where it declined slightly (-0.15 percent) and in the USA where it declined at an annual growth rate -0.56 percent. The overall upward trend in durum production was highly significant in all of Algeria, Syria, Canada, and Italy.

(iii) Third, overall durum production growth, over the period considered, is primarily due to rising yields as area planted to durum appears to have leveled off, if not gradually declining. This is particularly the case in Syria, Algeria, and Tunisia where durum yield demonstrated a strong, highly significant, and steady growth over the 1973-1996 period. The growth rates shown in Table 2, however, convey little information on yield level discrepancies that exist between countries. For example, while durum yields grew steadily at a rate of 4.68 percent a year from 1973 to 1996 in Algeria, they remain the lowest of the major durum producing countries with an average of 0.9 ton per hectare (Table 1). In spite of a negative growth rate during the last decade, durum yields recorded in Morocco are nearly 45 percent higher than those recorded in Algeria. The same observation applies in the case of Turkey where in spite of a decline during 1985-1996, average durum yield is around 1.5 ton per hectare, i.e., much higher than yield average of Algeria and Tunisia.

(iv) Fourth, it appears that a sort of equilibrium has been reached in the land use pattern of cereals in all 5 WANA countries. Therefore, it is unlikely that durum area expansion will be an important source of growth of durum production[4]. Future growth will necessarily have to come from higher yields.

Durum trade

The durum world market has an oligopolistic structure, i.e., dominated by few sellers. Canada, the United States, and the EU dominate the world export market of durum wheat. Together they account for nearly all durum exports[5]. During the mid-1970s to mid-1980s period (1975-1986), the world market share of the United States and Canada averaged 43.1% and 50.1%, respectively (Table 3). In the second period (1987/88 to 1996/97) Canada remained the major durum exporting country with an export share of 48%. However, the market share of the United Stated was halved (averaging 20%) over the same period[6].

World trade in durum wheat has increased considerably over the last few decades, rising to an average of 6.2 million tons during the 1990s (Table 4) – approximately 20% of world durum wheat production – (compared to about 17% in the case of bread wheat), from an average of less than 2 million tons during the 1960s[7]. The increase in durum trade is largely due to the increasing import requirements of North Africa that more than doubled between the 1975/86 period (average of 1.4 million tons) and the 1988/97 period (average of 3.0 million tons)[8].

Towards the late 1980s, the EU's Common Agricultural Policy (CAP) has given significant incentives to durum producing countries of the Union for increasing production of durum. This policy has had a significant impact on durum and durum products trade within the EU. One such impact has been the spectacular increase of the EU's durum world market share from an average of less than 3% for the 1975-1986 period to over 26% for the 1988-1997 period. However, the EU's market share suddenly plummeted again in 1995/96 and 1996/97 with 4 and 7%, respectively (Table 3).

Durum wheat in WANA

Durum is a major crop in WANA. It is mainly grown under rainfed conditions in environments characterized by relatively low, between 250 to 450 mm, and uncertain rainfall usually falling between the months of December and March[9]. The prevailing highly variable precipitation causes large inter-annual fluctuations in dryland durum production. Moreover, abiotic stresses, e.g., drought, terminal heat, and cold, represent a common feature of durum production environments of WANA. These are frequently exacerbated by biotic stresses, e.g., diseases and insects, that may severely inhibit crop growth.

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[4] In spite of the finite effective supply of land, durum area could, however, be raised by reducing the fallow area which is still significant in most WANA countries. Reducing fallow, however, may lead to mono-cropping which in turn may adversely affect crop productivity.

[5] As durum production is concentrated in North Dakota in the US and in Manitoba in Canada, most of durum exports move through the Great Lakes.

[6] Canada's share ranged from a low of 35% in 1988/89 to a high of 64% in 1996/97. Over the same period, the US share ranged from a low of 9% in 1988/89 to a high of 39% in 1991/92.

[7] Including semolina.

[8] Over three-quarters (77.4%) of North Africa durum imports during the 1988/97 period went to Algeria.

[9] Use of supplemental irrigation in durum wheat production is becoming more common, however, in some countries, e.g., Syria.

Table 3. Durum export shares (% of world trade) of Canada, USA, and the EU (1975-1986; 1988-1997)

Year	Canada share	USA share	EU share	Total share
1974/75	48	45	0	93
1975/76	45	49	1	95
1976/77	48	38	2	88
1977/78	50	42	0	92
1978/79	44	55	1	100
1979/80	37	52	1	90
1980/81	52	38	2	92
1981/82	49	47	3	99
1982/83	61	32	5	98
1983/84	61	36	2	99
1984/85	56	40	3	99
1985/86	43	41	15	99
Mean 1975/1986	50	43	3	95
1987/88	39	22	30	91
1988/89	35	9	48	92
1989/90	43	19	35	97
1990/91	48	17	34	99
1991/92	39	39	20	98
1992/93	40	18	40	98
1993/94	51	23	21	95
1994/95	57	16	23	96
1995/96	62	17	4	83
1996/97*	64	17	7	88
Mean 1988/1997	48	20	26	94

Source: 1974/75-1985/86: Adapted from World Wheat Statistics 1987 (International Wheat Council).
1987/88-1996/97: Adapted from World Grain Statistics 1996/97 (International Grains Council).

Table 4. World durum exports† (000 tons of wheat equivalent) and origin (1987/88 to 1996/97)

Origin	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97
Canada	2616	2040	2819	2994	2620	2603	2797	3907	3307	3885
USA	1478	510	1261	1075	1357	1155	1270	1082	914	1050
EU	1965	2796	2274	2111	2567	2642	1171	1578	235	400
SubTotal	6059	5345	6353	6180	6544	6400	5238	6566	4456	5335
Argentina	–	33	–	15	–	–	–	–	–	–
Mexico	51	170	50	–	–	–	50	100	250	220
Turkey	501	188	–	–	–	–	–	–	T*	T*
Others	20	43	78	85	120	150	232	162	621	545
World	6631	5778	6481	6280	6664	6550	5520	6828	5327	6100

Source: International Grains Council 1996/97.
†– Negligible; *Less than 500 tons.

The five major durum-producing countries of the WANA region account for over one third of world annual durum area and 34% of production (Table 1). All 5 countries have the capacity to produce considerably larger quantities of durum. However, because of relatively higher risks of abiotic stresses, mainly heat and moisture stresses, the yields recorded under rainfed conditions are low, compared to yields recorded in the other major durum producing regions, i.e., North-America and European Union countries.

Macro-level trends in durum area, yield, and production

In the five NARSs, durum production is distributed across a wide range of production environments. The latter span both well watered zones, e.g., bour favorable (Morocco), northern zone (Tunisia), zones along the Mediterranean coast (Algeria and Turkey), production zones 1 and 2 (Syria), and less favorable environments, e.g., bour défavorable (Morocco), high plateaus (Algeria), Anatolian plateau (Turkey), Central zone (Tunisia). Circumstantial evidence from the region suggests that over the past few decades the spread of modern durum varieties combined with associated crop management practices have had significant gains in durum productivity, especially in favorable environments[10].

On a regional basis, durum area remained relatively stable at around 7 million hectares annually. Production on the other hand, exhibited a steady increase from around 7.5 million tons annually in the 1970s to 10 million tons annually in the 1990s (Table 1). A steady increase of production while cultivated area remained unchanged implies a steady growth of durum yields, which reached an average of 1.5 tons per hectare. However, as indicated above, these regional data conceal major differences between the five WANA countries. First, Turkey dominates durum production and accounts for nearly 45% of total durum area cultivated in the 5 countries. Second, a very sharp yield increase is registered in Syria starting in the late 1980s. This remarkable burst in durum productivity levels seems to have paralleled the extensive reliance on supplemental irrigation. Third, Algeria and Tunisia appear to exhibit significant yield increases over the past decade with, however, important year to year fluctuations. Turkey reveals a steadily decreasing trend in durum yields since the early 1980s. Fourth, in the case of Morocco, durum yields first increased starting in the mid 1980s and then began to fall in the early 1990s, most probably as a result of recurring severe drought spells.

Marked differences are observed across the five countries, especially in durum yields. These yield differentials are assumed to reflect primarily differential occurrences of abiotic stresses, mainly drought and cold, differential rates of adoption of new technology, mainly modern varieties and fertilizers, and management differentials, especially use of supplemental or full irrigation. Pronounced differences in durum productivity levels are reflected in these production trends. For example, whereas durum yields have rocketed in Syria over the past decade, reaching nearly 3 tons per hectare, they barely reach 1 ton per hectare in Algeria. The high productivity levels achieved through the provision of new water supply (supplemental irrigation) have encouraged the extensive substitution of irrigated durum for rainfed durum in Syria[11]. In contrast, the other NARSs, especially in North Africa, the quasi totality of cultivated durum area is rainfed.

The review of national trends of durum production points to the existence of large differences among the five WANA countries. Perhaps the two most important aspects emerging from the review are: (i) the remarkable improvement of durum productivity achieved by Syria; and (ii) the magnitude of durum production shortfalls experienced annually by Algeria. Production per capita can be an illuminating indicator in comparing the performance of WANA countries over time. Using FAO population data and production data used from International Wheat Council and international Grains Council, durum production per capita was computed for each country over three time periods, 1985/88, 1989/92, and 1993/96 (Fig. 1). The results are noteworthy in several respects:

(i) Algeria has the lowest production per capita, regardless of the time period. Despite a steady improvement over time, which implies that production has been growing at a higher rate than population, durum production per capita does not exceed 41 kg.

(ii) A steady decline in production per capita is observed in Morocco and Turkey. In the former, production per capita declined from 67 kg in 1985/88 to 62 kg in 1989/92 then to 53 kg in 1993/96, i.e., a 21 percent decline, in absolute term, between the first and the last period. In Turkey, the decline is even sharper as production per capita declined by nearly 37 percent between 1985/88 (101 kg) and 1993/96 (64 kg). While Turkey achieved the highest production per capita in the first period with 101 kg, it ranked third in the third period, behind Syria and Tunisia, with 64 kg.

[10] Compared to favorable environments, however, the productivity effect of modern durum varieties has been less dramatic, in absolute terms, in dryland environments.
[11] The spurt of expansion of supplemental irrigation, rather than full irrigation, started in the late 1980s and continued at a rapid pace in the 1990s.

(iii) Tunisia has succeeded in keeping its production per capita at a relatively high level, especially in the second period when it surpassed not only Algeria and Morocco, but also Syria and Turkey with an average of production 121 kg per capita. Although a decline is noted in the last period, it ranks second behind Syria.

(iv) Owing to an unprecedented durum production growth, at an annual rate of 14%, during the 1985-1996 period (Table 5), Syria has increased its production per capita by over two folds reaching nearly 200 kg per capita[12].

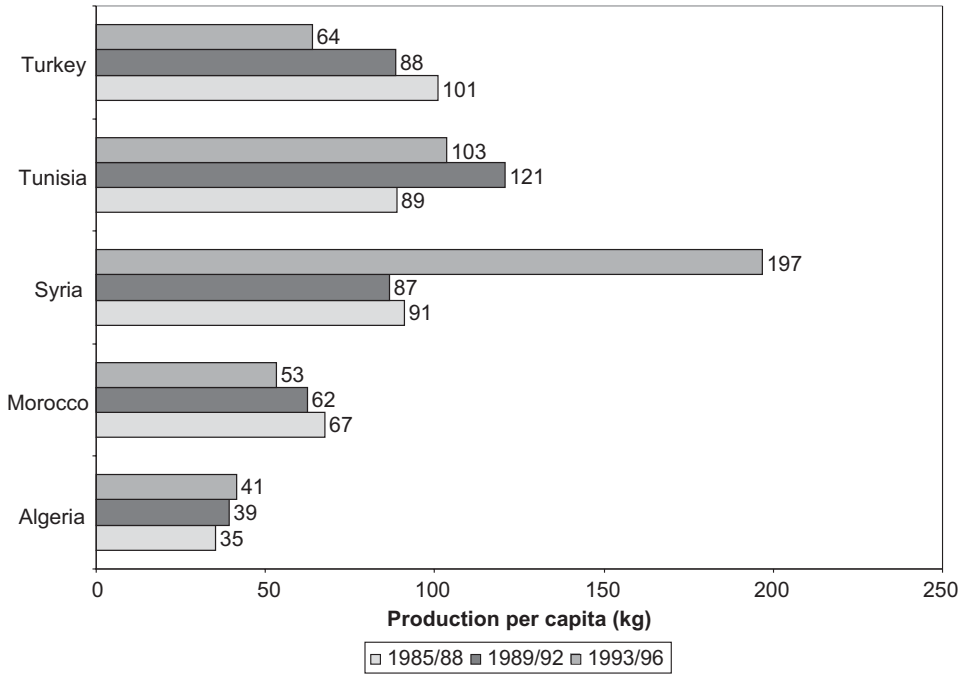

Fig. 1. Durum production per capita (kg) in Algeria, Morocco, Syria, Tunisia, and Turkey over three time periods (1985/88, 1989/92, and 1993/96).

Table 5. Major macroeconomic indicators of the 5 WANA countries[†]

	Population				GNP per capita 1992[e]	GNP growth (%)	
	1992[a]	2020[b]	Growth[c]	Rural[d]		70/80	81/90
Algeria	26.3	44.3	2.4	46.0	1840	6.1	3.3
Morocco	26.2	40.8	2.0	53.0	1030	5.5	3.7
Syria	13.0	30.4	3.3	49.0	1160	9.1	3.4
Tunisia	08.4	13.4	1.9	43.0	1720	7.5	3.8
Turkey	58.5	88.0	1.9	36.0	1980	5.2	5.4
Total	132.4	216.9					

Source: Adapted from Rodrigez (1995).

[†a]In million; [b]Projections in millions; [c]In %; [d]In % of total population; [e]In US$.

[12] Syrian population increased from 11.03 millions 1985/88 to 14.16 millions in 1993/96.

Trends in durum consumption and trade in the 5 WANA countries

For the past few decades, the demand for food in general, and wheat and wheat products in particular, has been mainly driven by the particularly high population growth that characterizes the region. The demand for food will probably continue to grow, as the regional population growth rate, estimated at 2.8% per year, does not appear to be slowing down. For example, in less than three decades, early 1960s to late 1980s, total wheat consumption in WANA more than doubled, raising from 25 million tons to nearly 55 million tons (Belaid and Morris, 1991).

Durum consumption is mainly concentrated in countries of the Mediterranean Basin considered as the most significant import market for durum. Together Turkey, Algeria, Morocco, Tunisia, and Syria account for more than one third of durum world consumption. In Tunisia, for example, per capita annual consumption of durum has increased from 89 kg in 1966 to 130 kg in 1990 (Ben Salem *et al.,* 1995). In the past two decades some governments of the region, e.g., Morocco, have implemented policies aimed at promoting the use of bread wheat as a substitute to durum, mainly through consumer subsidies. In Morocco, for example, within a few years, this substitution policy led to a marked decline of the share of durum in cereal per capita annual consumption of wheat, from nearly two thirds in 1971 to less than one fourth in 1985 (Ouassou, 1995)[13]. However, in spite of these policies per capita annual consumption of durum has remained by far the highest in the world.

Population is projected to reach nearly 220 million people in the five WANA countries by the year 2020, i.e., an increase of 64% in comparison with 1992 (Table 6). As a result of a particularly high population growth rate of 3.3% per year, the population of Syria is projected to reach 30 million, i.e., more than double the 1992 level of 13 million. Although population growth rates differ greatly by country, they are all above average growth rate of developing countries estimated at 1.7% a year (Rosegrant *et al.,* 1995)[14]. No major declines in population growth rates are foreseen in the coming decades. These population trends will most probably exert tremendous pressure on demand for food, especially cereals, and thus worsen the prevailing production/consumption gap.

Table 6. Importance of agriculture in the 5 WANA countries[†]. Source: Adapted from Rodrigez (1995)

NARS	GDP 1992[a]	Agriculture (% of GDP)	Agric. Labor (% of labor force)	Female employment[b]	Female in agriculture[c]
Algeria	35,674	15	18	4	4
Morocco	28,401	15	46	26	31
Syria	17,236	30	23	18	41
Tunisia	13,854	18	26	21	22
Turkey	99,696	15	47	31	69

[†a]In million US$; [b]Percentage of total labor force; [c]Percentage of female labor force.

In the 60s, the population of the 5 WANA countries was mostly rural. However, as a result of a high rate of urbanization and high population growth in the urban areas, more than half of the population resides in the urban areas (except in Morocco). In Turkey, for example, the rural population represents only slightly over one third of the total population. These new demographic patterns that characterize the region have significant effects on food demand structures.

In the 1970/80 period, the 5 WANA countries have registered high growth rates of Gross National Product (GNP). The latter ranged from 9.1% in Syria to 5.2% in Turkey (Table 6). However, with the exception of Turkey, these WANA countries experienced drastic declines in GNP growth the following

[13] According to the figures provided by Ouassou (1995), per capita annual durum consumption decreased from 86 kg in 1971 to 41 kg in 1985. This is a very low figure by regional standards. For bread wheat per capita annual consumption rose from 45 kg in 1971 to 131 kg in 1985.
[14] Population in the developed countries is projected to grow at 0.4%. On the other hand, population will continue to increase at a rate of 2.9% a year in Sub-Saharan Africa (Rosegrant, *et al., op cit*).

decade, especially Syria. Over the last few years various initiatives of market reforms have been enacted to help improve investment (foreign and domestic) and boost the economy.

Despite urban-biased policies, which were the norm in the recent past, agriculture has emerged as a leading economic sector in most countries of the region. As Table 6 shows, the share of the population that is active in agriculture is substantial, especially in Morocco and Turkey where agricultural labor still represents nearly 50% of the labor force, in spite of the rapid growth in mechanization. Further, female employment in agriculture is quite important, especially in Turkey where agriculture provides employment to more than two thirds of the total female labor force. In Algeria, on the other hand, female labor force represents less than 5% of the total labor force and female labor force is negligible (4%).

The combination of increasing demand for durum and durum products, driven mainly by high demographic and income growth, and relatively low durum productivity has changed many of WANA countries, essentially North African countries, from net exporters to net importers of durum. As a result of demographic pressure, and still insufficient improvement of durum productivity per unit area, the consumption/production gap has considerably worsened in some WANA countries, leading to greater reliance on imports. A case in point is Algeria that has become the world-leading importer of durum with nearly 2.5 million tons per year during the past decade (average 1987-1996), i.e., over 40% of total durum imports.

In Algeria, the durum production-to-consumption ratio has declined at an average annual growth rate of nearly 2% over the last two decades (Fig. 2)[15]. Even during record production years, e.g., 1996, the ratio is just slightly over the 50% level, while during bad production years, e.g., 1987, it may fall to less than 15%, meaning that domestic production covers only 15% of domestic demand for durum and durum products[16]. To overcome such a wide production-consumption gap, Algeria has opted, over the past two decades, for an “import substitution” strategy that led to an unacceptable foreign exchange drain.

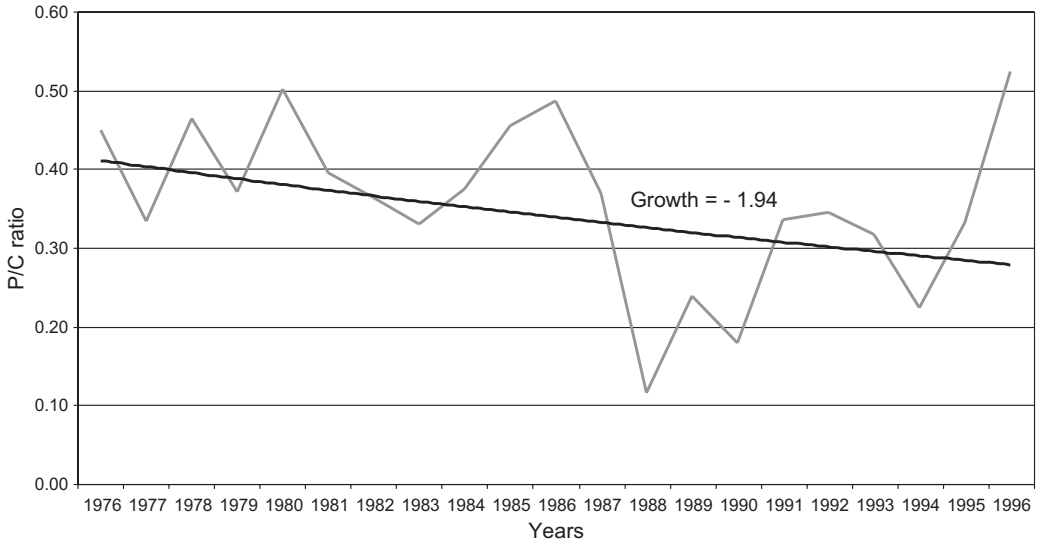

Fig. 2. Durum production to consumption (P/C) ratio in Algeria overtime (1976-1996).

Based on data shown in Table 7, Algeria imported an average of 80 kg/capita of durum annually over the 1990-1997 period. This strong growth in the demand for wheat and wheat products has placed increasing pressure on the agricultural sector to raise wheat production in order to reduce the supply-consumption gap and reliance on imports. Given the large quantities imported, this food procurement

[15] The decline of the production-to-consumption ratio occurred in spite of the fact that the growth of durum production has accelerated from about 3.2 percent a year during 1973-1984 to about 4.4 percent a year during 1985-1996.
[16] A rough estimate of domestic consumption is used in this report. Domestic durum consumption is estimated as the difference between the sum of domestic production and imports, and exports. Consumption includes durum used for food, durum used for seed, etc.

strategy is neither sustainable nor economically sound. This policy raises serious concern as to the ability of Algeria to achieve the food security objective in grain production[17].

Table 7. Durum imports (000 mt) in WANA and in the world (1975-1997)

Years	Algeria (A)	Morocco	Tunisia	Turkey	WANA (B)*	World (C)	A/B (%)	A/C (%)	B/C (%)
1975	1224	–	–	–	1259	3053	97.20	40.09	41.20
1976	998	–	–	–	1073	3425	93.00	29.14	31.30
1977	751	60	67	–	909	2785	82.60	26.97	32.60
1978	1022	24	235	–	1294	3883	78.00	26.32	33.30
1979	774	–	150	–	924	3277	83.77	23.62	28.20
1980	1190	–	401	–	1596	4221	74.50	28.19	37.80
1981	1054	92	217	–	1391	4138	75.80	25.47	33.60
1982	1325	19	102	–	1476	4768	89.80	27.79	31.00
1983	1325	–	160	–	1546	4619	85.80	28.69	33.50
1984	1286	–	349	–	1768	4019	72.70	32.00	44.00
1985	1000	7	252	–	1382	3455	72.30	28.94	40.00
1986	1324	–	114	–	1557	3297	85.00	40.16	47.22
Mean 1975/86	1106	17	205	–	1339	3745	82.60	29.8	35.6
1988	3164	8	270	–	3567	6631	88.70	47.72	53.80
1989	2725	5	445	–	3295	5778	82.70	47.16	57.00
1990	2640	2	320	200	3282	6473	80.40	40.78	50.70
1991	2485	59	144	9	2817	6206	88.10	40.04	45.40
1992	2481	44	22	36	2703	6664	91.80	37.23	40.60
1993	2381	260	12	190	2983	6550	79.80	36.35	45.50
1994	2265	292	33	198	2888	5520	78.40	41.03	52.20
1995	3523	55	516	17	4111	6828	85.70	51.60	60.20
1996	1457	337	449	169	2412	5327	58.00	27.35	47.20
1997	1750	350	130	90	2420	6100	72.30	28.69	39.70
Mean 1988/97	2487	141	234	91	3058	6208	80.60	39.80	49.23

It must be pointed out, however, that with the exception of Algeria and Tunisia, to a certain extent, the other three countries reveal acceptable durum self-sufficiency levels as domestic durum production covers over 90 percent of domestic consumption (Table 8). What is particularly worrying is that in the case of Algeria, in the 1990s, the quantities of durum imported remained nearly double the volume of domestic production.

Achieving sustainable food security has been and still is a fundamental objective of most developing countries. In WANA, maybe more than any other region, food security is closely linked to grain production, especially durum production knowing that durum consumption per capita is amongst the highest in the world. The increased reliance on imports to meet domestic durum production shortfalls is inflicting considerable damage to national economies of the region, especially in Algeria, resulting in an illusive food security and an unacceptable drain of badly needed foreign exchange.

In order to alleviate food insecurity, Algeria, for example, must increase production significantly and very rapidly. Unless more effective strategies can be devised to improve durum productivity in a significant and sustainable manner, the attainment of food security will remain an elusive objective.[18] Although the

[17] It must be pointed out that in addition to durum, Algeria also imports large quantities of bread wheat. On an annual basis, Algeria imports about 5 million tons of wheat (durum and bread wheat), which represents about 167 kg/capita (based on a population of 30 million people). This in turn points to the magnitude of the wheat production shortfalls experienced annually by Algeria.

[18] It is clear, however, that achieving sustainable food security will require more than just improving crop productivity at the farm level.

opportunities for further area expansion do not seem to be totally exhausted, considering the importance of fallow area, which represents nearly 40 percent of annually cultivated area, sustained expansion in domestic output growth will not be achieved without significant productivity growth.

Technological change and impact of modern varieties

It has long been argued that the generation and widespread adoption of modern varieties was the root cause of green revolution changes in wheat productivity throughout the world. To assess the impact of durum modern varieties released by the five NARSs on the growth of durum production time series covering the 1973-1996 period was analyzed. The series has been divided into two sub-periods: 1973-1985 and 1986-1996; the hypothesis being that in all five NARSs, 1973-1985 corresponds to a period of development, on-farm testing, release, and early diffusion of first generation modern durum varieties, whereas 1986-1996 to a period of large adoption of these first generation durum modern varieties by farmers of the region[19].

Table 8. Annual average durum area, production, imports, total supply, per capita consumption, and self-sufficiency levels in the five WANA countries over 4 different periods (1973-1996)

	NARS	Area (000 ha)	Production (000 mt)	Yield (mt/ha)	Imports† (000 mt)	Exports (000 mt)	Domestic supply†† (000 mt)	Per capita consumption (kg)†††	Self-sufficiency (%)†††††
1973-1978	Algeria	1358	618	0.46	999	–	1617	101	38.2
	Morocco	1384	1327	0.96	21	–	1348	78	98.4
	Syria††††	1000	937	0.94	–	–	937	126	100.0
	Tunisia	853	576	0.67	76	–	652	116	88.3
	Turkey	2738	4167	1.52	–	–	4167	104	100.0
1979-1984	Algeria	1137	701	0.62	1159	–	1860	100	37.7
	Morocco	1186	1177	0.99	19	–	1196	62	98.4
	Syria††††	812	813	1.00	–	–	813	92	100.0
	Tunisia	843	673	0.80	230	–	903	141	74.5
	Turkey	2954	5293	1.79	–	–	5293	119	100.0
1985-1990	Algeria	1062	773	0.73	2171	–	2944	132.5	26.3
	Morocco	1154	1600	1.40	5	–	1605	71.5	99.7
	Syria††††	633	953	1.51	–	–	953	87.5	100.0
	Tunisia	588	652	1.11	280	–	932	127	70.0
	Turkey	3192	5333	1.67	40	138	5235	104	101.9
1991-1996	Algeria	1075	1192	1.11	2265	–	3457	125	34.5
	Morocco	1109	1522	1.37	175	–	1697	62	89.7
	Syria††††	758	2307	3.04	–	–	2307	177.5	100.0
	Tunisia	736	1070	1.45	196	–	1266	144.5	84.5
	Turkey	2800	4083	1.46	103	–	4186	71.5	97.5

†Including semolina (in wheat equivalent).
††Domestic supply corresponds to total domestic disappearance, i.e., [(production + imports) – exports]. It includes food, feed, seed, stocks, and waste.
†††Per capita consumption is calculated as the ratio of domestic supply to average population.
††††No durum export figures are available for Syria, hence domestic supply is assumed to equal production.
†††††Calculated as the ratio of production to domestic supply.

[19] Prior to the 1970s, durum breeding research was modest, except maybe in Turkey, as most research resources were devoted to bread wheat. Durum research initiated in the region by CIMMYT was considerably reinforced after the establishment of ICARDA in 1977. This 1986-1996 period also corresponds to the development, testing, and release of second generation modern durum varieties.

The following log linear trend equation was estimated using OLS techniques to test whether the growth of durum productivity has accelerated during the second sub-period as a result of adoption of durum modern varieties by farmers.

$LnY = a_0 + a_1D + b_0T + b_1DT + u,$

Where:

LnY = natural logarithm of the variable durum yield.
D = intercept-shifting dummy variable taking value of 1 for sub-period 1986-1996 and 0 otherwise.
T = time (1973 = 1, 1974 = 2, etc).
U = error term.

The rate of growth for sub-period 1973-1985 is given by the regression coefficient b_0 and that for sub-period 1986-1996 by $(b_0 + b_1)$. The sign of b_1 indicates whether an acceleration (if positive) or a deceleration (if negative) of growth has taken place in the second sub-period (1986-1996)[20]. The regression coefficient of the dummy variable (a_1) indicates whether any adjustment has been made in the time series since 1985. The estimated equations are shown below (standard errors in parenthesis).

Algeria:	LnY = -1.04 + 0.06T – 0.002D – 0.011DT (0.19)[a] (0.019)[a] (0.35) (0.026)	2^2 = 0.69; F = 17.3
Morocco:	LnY = -1.091 + 0.015T + 0.270D – 0.0069DT (0.104) (0.014) (0.287) (0.020)	2^2 = 0.47; F = 7.73
Syria:	LnY = -0.92 + 0.0012T – 1.311D + 0.113DT (0.137) (0.019) (0.377)[a] (0.026)[a]	2^2 = 0.83; F = 38.36
Tunisia:	LnY = -0.466 + 0.0208T + 0.036D + 0.0098DT (0.168)[b] (0.023) (0.461) (0.032)	2^2 = 0.42; F = 6.73
Turkey:	LnY = 0.270 + 0.034T + 0.748D – 0.065DT (0.069)[a] (0.009)[a] (0.190)[a] (0.013)[a]	2^2 = 0.48; F = 8.25

[a] = Significant at 1% level; [b] = Significant at 5% level.

The results show that[21]:

(i) Following the release and utilization of modern varieties, the growth of durum yields has accelerated in Syria, and Tunisia. However, the acceleration was significant only in Syria where the growth of durum productivity has accelerated from 0.12 percent in the first period to nearly 11.50 percent in the second period. Although this impressive performance cannot be solely attributed to adoption of modern varieties, breeding advances made in durum must have played a key role, nevertheless.

(ii) In Algeria and Morocco, the growth of durum yield has decelerated in the second period, although not significantly. In both countries the deceleration rate is lower than the growth rate of the first period, implying a decreasing but positive growth rate in the second period.

(iii) The most significant deceleration took place in Turkey at a rate nearly twice as fast than the growth rate of the first period hence leading to a significant and negative average growth rate of -3.1 percent per year in 1986-1996.

These results are insightful and potentially policy relevant. They show that the development and diffusion of MVs have had highly contrasting effects. For example, while in Syria a significant and

[20] D is a dummy variable that measures the shift of the production function overtime (intercept-shifting) while the other coefficients remain constant. DT, on the other hand, measures the change of the slope of the production function overtime (slope-shifting), i.e., it captures a change in the parameters of the production function.
[21] It must be clear, however, that the following changes in durum yields not only reflect changes in yield potential of new varieties used by farmers, but also changes in input use and management.

considerable growth in durum productivity has been achieved, a significant downward trend in durum productivity is observed in Turkey, over the same time period[22]. The results also show that the diffusion of durum MVs has had but a modest impact on durum productivity in North Africa, especially in Morocco. Several possible causes explaining the lack of impact of durum MVs in these countries may be suggested:

(i) Given that durum production is mostly rainfed, the prevalent abiotic stresses may have severely hampered durum yields at the farm level.

(ii) The level of investment in research (both breeding and crop management) targeted at rainfed areas is lagging.

(iii) Poor targeting of extension programs and inadequate seed production capacity may have limited the productivity gains expected from MVs as the newer germplasm developed does not reach farmers until after a long time lag.

In North Africa, the lack of significant progress in raising durum productivity is very likely for reasons which are not only related to lack of research effort in the past, but also, and maybe more importantly, to poor targeting of extension effort and inadequate seed production and distribution capacity when modern varieties have become available. This in turn implies that in order to achieve significant productivity gains, NARSs should not only initiate (or reinforce) strong research efforts that specifically target drought-prone environments, but, in parallel, should also establish efficient extension programs and seed multiplication and distribution systems.

The process of development (by national research programs) and adoption (by farmers) of new durum germplasm is a continuum running from the experimental station to early adopters of new technology (mainly through technology transfer activities) and ultimately reaching the whole farmer community (laggards). Everything being equal, as the proportion of area planted to modern varieties increases, aggregate durum yields, hence production, are expected to increase. However, the evidence reviewed suggests that with the exception of Syria, durum research, undertaken over the last three decades, has had little impact on durum productivity as average aggregate yields remain low and have even declined in some NARSs, e.g., Turkey.

Conclusion

Durum wheat has historically been a very important commodity in much of WANA countries. Less than 50 years ago, countries such as Algeria and Morocco, for example, experienced durum surpluses. The situation has changed dramatically since then. Based on recent trends, it is difficult to be overly optimistic about the future of durum wheat in drought-prone environments of WANA. Mainly as a result of strong demographic pressure, Algeria, for example, has been experiencing a widening consumption-production gap and has now become the leading durum importer of the world. Given the magnitude of current population growth and past trends of durum production, it is unlikely that Algeria will succeed in closing this gap in the very near future, in spite of the fact that large potentials for production increases exist.

For WANA countries of the Mediterranean Basin, more than in any other countries, food security is closely linked to wheat production, in general, and durum production in particular, given that durum consumption per capita is amongst the highest in the world. Therefore, the research effort should not be confined to the sole objective of improving productivity per se. It should rather target the broader objective of achieving a sustainable food security. In all five WANA countries reviewed, the supply of arable land is finite. This implies that increases in cereal production, in general, and durum production, in particular, will have to come from higher productivity per unit area.

The evidence from the region indicates that research has been generally successful in developing new durum varieties with high yield potential and desired characteristics such as resistance/tolerance to main biotic and abiotic stresses prevailing in the region as well as better quality traits. It is clear that the

[22] As already pointed out, care must be taken in attributing changes in crop productivity, whether positive (Syria) or negative (Turkey), solely to MVs. Crop management, price policy and institutional policy may play a transcendent role as well.

generation of technological innovations alone is not sufficient to induce crop productivity growth. The widespread adoption of existing technologies by farmers, which could be significantly accelerated by appropriate technology transfer and extension programs, is also necessary. However, widespread adoption of new technologies will lead to productivity growth only if farmers use them efficiently. Throughout the region, however, there is evidence showing a persisting gap between the exploitable yield potential and farmers' yield. This could be taken as an indication that the most binding constraint to productivity growth is probably not imposed, at least for now, by the current technology frontier but rather by farmers' inability to exploit the genetic potential of existing germplasm as a result of inefficient use of available inputs. At least two factors have contributed to perpetuating input use inefficiency in the region: (i) contrary to crop improvement, which has been the focus of most research programs, fewer achievements have been accomplished in the area of crop management research that could enable farmers to exploit the potential allowed by increasingly performing germplasm; and (ii) the quasi exclusive focus of transfer of technology and extension programs on input intensification with little consideration, if any, to the efficiency with which the inputs are used by farmers. A greater focus on improving the efficiency with which farmers use agricultural inputs and existing technologies is likely to provide new opportunities for: (i) increasing crop productivity, hence food production; (ii) alleviating poverty and distributional inequities; and (iii) reducing the risks of environmental degradation, a growing and serious concern in the region.

The combination of relatively high population growth, negative trade balance, and growing food deficits are exerting an increasingly unbearable pressure on ailing government treasuries, hence precipitating the need to increase crop production, especially wheat production. In the coming decades, agricultural development and food production in WANA will be confronted to immense challenges. The latter must be met within the context of major technological, social, and economic changes stemming from the global opening of markets.

Sustained productivity growth is a *sine qua non* to national efforts aimed to increase domestic food supply to meet escalating demand. Regardless of the policy course followed by individual WANA countries, the generation and efficient utilization of technological innovations is likely to be critical in addressing current and future challenges confronting crop production in the region. The challenge is not only to spark productivity growth in the NARSs where the new technology-induced gains have not been considerable, e.g., North Africa, but also to sustain the gains in the NARSs, which have enjoyed significant productivity gains over the past few years, e.g., Syria. For at least the next two decades, public research and extension will continue to be critical to the development, refinement, and transfer of technology innovations that translate into higher and sustainable productivity growth at the farm level. Investment in agricultural research and extension should, therefore, be increased or at least not curtailed. This crucial investment need has come at a time of economic difficulties that have already led to cuts in domestic research budgets. Moreover, external research funding has significantly declined over the past decade. If allowed to continue, these funding trends will likely exacerbate the difficulties faced by WANA countries in overcoming current obstacles to productivity growth, with the very serious risk of widening the demand-supply food gap in the region.

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