Durum Wheats:

Challenges and Opportunities

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S. Rajaram
E.E. Saari
G.P. Hettel
Editors

International Maize and Wheat Improvement Center
(CIMMYT)

IMPACT OF DURUM WHEAT BREEDING IN DEVELOPING COUNTRIES: A DILEMMA FOR THE FUTURE

D. Byerlee
CIMMYT Economics Program

Note: Paper presented by R.A. Fischer

Durum Wheat in the Developing World

No reliable global statistics on durum wheat are available, but from various sources we can gain a general picture of durum wheat production. Durum wheat is grown on a total of about 17 million hectares in the world, producing about 26 million tons (Mt) annually (International Wheat Council 1987). In developing countries, some 7-8 million ha of durums are grown, but because of lower yields, only about 35% of global production is grown in developing countries. Previous estimates place durum wheat area at 12 million ha in developing countries (Srivastava 1984), but this appears to be a considerable overestimate. The latest IWC publication (Jan. 1992) states 1989-1992 durum production averaged 30 Mt with 14 Mt from the Soviet Union and developing countries. This suggests an area of closer to 9-10 million ha for developing countries. Presently, about 5% of wheat production in developing countries is from durums. However, durums generally receive a price premium (averaging 15% in international markets), which increases their share of the total value of wheat production. In addition, the developing world imports another 3 Mt of durum wheat annually (over half of which is imported by Algeria).

Overall, area and production of durums have expanded more slowly than for bread wheats. In fact, there is probably a long-term tendency for the total area under durums to decrease. For example, 50 years ago over half of the black soil area of Central and Southern India was sown to durums (Howell 1909), but durums now occupy only an estimated 22% of the wheat area in this region (Byerlee 1992). Further evidence will be presented later that this downward trend in durum wheat area is likely to continue, because of substitution of durum by bread wheats in consumption patterns.

Durum wheat area is largely concentrated in regions of low rainfall (Table 1). However, because of the low yields in these regions, about half of all durum wheat is produced in higher rainfall or irrigated areas. The great bulk of durum wheat area in developing countries is grown in West Asia and North Africa (WANA) between the 300 and 450 mm annual rainfall isohyets (Srivastava 1984). Another 1.0-1.5 million ha are grown under hot, dry conditions in Central and Southern India in what is termed mega-environment 4C. Finally, some area of durum wheat is scattered under varying environments in Ethiopia, Mexico, Argentina, and Peru. These data exclude the durum wheat area of 1.5-2.0 million ha in the former Soviet Union, which may soon fall under CIMMYT's mandate. Nearly half of this durum wheat is produced in Kazakhstan.

Release and Adoption of Improved Varieties

Released durum varieties

The CIMMYT database on varietal releases indicates that some 135 durum wheat varieties have been released by developing countries since 1965, nearly all of them spring durums. The bulk of these releases have occurred in the WANA region (Table 2). From 1965 when the first semidwarf durum variety was released in Mexico, the proportion of releases that are semidwarfs has increased rapidly, so that by the 1980s almost all

releases were semidwarfs (Figure 1). This reflects the steadily increasing use of CIMMYT germplasm in varietal releases. By the 1980s, over 70% of releases were directly from CIMMYT crosses, and another 10% of releases carried CIMMYT germplasm with one or more of the parents being CIMMYT lines. Most of the remaining varieties were released for Central and Southern India, where improved tall varieties have been developed by the Indian national program (see below).

By far, the most popular CIMMYT crosses have been Bittern, Stork, Cisne, Albatross, and Frigate, which together account for 36 of the 85 releases from CIMMYT crosses in the 1966-90 period (Table 3). However, there is often a considerable time lag between the release of a variety outside of Mexico and its first release in Mexico (Table 3).

The above data, of course, only include varietal releases in developing countries. Durum varieties containing CIMMYT germplasm, or based directly on CIMMYT crosses, have also been widely released in developed countries, including the USA, Spain, Italy, and Australia. Because CIMMYT's mandate is specifically to work with developing countries, our database does not include releases in developed countries.

Adoption of improved varieties

An estimated 4 million ha of durum wheat area are now sown to improved varieties. This represents just over half of the estimated 7.5 million ha of durum wheat in the developing world. Of the 4 million ha sown to improved varieties, some 2.5 are sown to varieties derived from CIMMYT (or CIMMYT/ICARDA) crosses. The most widely grown crosses have been Cisne, Frigate, and Bittern that each cover more than 0.5 million ha (Table 3). Another 0.35 million ha of durum wheat, mostly in India, are sown to varieties with a CIMMYT parent. Although adoption of improved durum varieties still lags that of bread wheats in every region (Table 4), the data at hand suggest considerable progress in the short space of 25 years in which CIMMYT has had an active durum wheat breeding program.

Nonetheless, a closer examination of the adoption of improved durum varieties shows that adoption has been uneven (Tables 5 and 6). The highest adoption rate has been in Latin America followed by WANA. Adoption in Asia (largely India) and in sub-Saharan Africa has been minimal. In general, adoption has taken place in irrigated and higher rainfall environments, and most of the durum area in these environments is now sown to semidwarfs (Table 7). By contrast, only about one-third of dryland durum area is sown to semidwarfs. This is despite the fact that a considerable proportion of the released varieties have been targeted to dryland areas (Figure 2).

This is seen most clearly for India where semidwarfs have generally performed poorly under dryland conditions. Only one semidwarf has been released for rainfed conditions in India, whereas nearly all the releases for irrigated conditions (Table 8) have been semidwarfs, and most of the irrigated durum area has been planted to these varieties compared to only 10% of the dryland durum area that is planted to improved varieties (nearly all tall varieties) released since 1966.

Impacts of Improved Varieties on Yield and Quality

Gains in yield potential

The release of semidwarf varieties has had a spectacular effect on yield potential in spring durums. This has been well documented in northwestern Mexico where, under irrigated conditions, yield potential of durums released since 1965 has increased by an annual rate of 1.7-2.5% per year (Figure 3--Waddington et al. 1987, Sayre et al. pers. comm.), considerably faster than the equivalent progress in bread wheats. Likewise, yield

potential of durums released for irrigated areas in northwest India has increased by 1.4% per annum, since the first improved durum variety (Raj 911) for irrigated areas was released in 1974 (calculated from data provided by K.B.L. Jain). Part of the reason for these rapid yield gains has been success in overcoming sterility in the first generation of semidwarfs.

In dryland areas, gains in yield potential have generally been much smaller and in many cases, negligible. The most comprehensive evidence comes from India (mega-environment 4C, with production on residual moisture) where no gains in yield potential of durum varieties released for dryland Central and Southern India have been recorded over the past 25 years (Figure 4). The situation in dryland areas of WANA (mega-environment 4A with production on growing season moisture) is probably somewhat better, but to date, comprehensive data from dryland areas on yield of varieties of different vintages are unavailable from that region. These differences in rates of gain in yield by environment undoubtedly explain the contrasting adoption rates experienced in each environment.

Gains in quality

Quality is probably a more important factor in varietal acceptance for durums than in bread wheats. In many areas, and especially in dry areas, high quality durums are grown as a speciality crop that is marketed at a price premium. In Central and Southern India, this premium may be is as much as twice the price for bread wheats.

For irrigated durums, rapid progress has been made in transforming the first varieties, which generally had low quality for pasta making, to varieties released in the 1980s, which easily meet international market standards for pasta (Figure 5). Indeed, Mexican varieties provide the basis for the production of durums in western USA--quality durum wheat produced under irrigation for export--southern California and Arizona. There are also examples of durums for dryland areas which have been quite successful because of their high quality for local foods. In Gujrat, India, the variety GW 1 released in 1980 has been fairly widely accepted by farmers under the harsh dryland conditions of that state. Although this variety provided little yield advantage over the previously grown variety, A206 released in 1954, it commanded a price premium for its high quality grain (Byerlee 1992). Likewise, acceptance of improved durums by small farmers in Ethiopia was in part because of quality characteristics of these varieties (for local food preparations (Negatu et al. 1992). This suggests that, for durum wheat, breeders may have to pay as much attention to quality for the various food preparations as to yields (Varughese 1975).

Considerations for the Future

The data presented above on impacts of durum wheat breeding clearly point to considerable success, both by CIMMYT and our national program collaborators, in developing and diffusing improved varieties in many countries of the developing world. Despite a late start, the release and adoption of improved durums, and especially semidwarfs, now rival those of spring bread wheats. Nonetheless, the gains have been uneven, with the largest impacts clearly occurring in the irrigated and well watered areas.

In closing, I want to raise two issues that are important in mapping our strategy for the future: 1) the dominance of CIMMYT crosses in varietal releases and 2) the appropriate emphasis in the future on developing durum varieties for favorable versus unfavorable environments.

Dominance of CIMMYT crosses

As in the case of spring bread wheats, CIMMYT is clearly the main supplier of improved germplasm for durum wheat in the developing world. However, there is an important distinction. For spring bread wheats, large national programs tend to use our materials as parents in their crossing programs, with crosses generally occurring between CIMMYT lines and locally developed materials. In the case of durums, however, CIMMYT germplasm is generally released directly, and only in India is it widely used as a parent in local crossing programs. In the 1980s, 70% of the released durum varieties were derived directly from CIMMYT crosses, and only six varieties were released from national program crosses with a CIMMYT parent. This excludes some varieties released from third country crosses, such as the variety, Gerardo, developed in Italy with one CIMMYT parent, and subsequently released in a number of developing countries. This presumably reflects the fact that few national programs have sufficient resources to run a full crossing program for durum wheats.

This implies that CIMMYT germplasm is largely being used as a finished product. Hence to be successful, we will have to pay particular attention to those characteristics that are important to farmers, including grain and straw quality. The varietal characteristics desired by farmers vary according to local farmers' circumstances. Hence we should consider in-depth studies of the type conducted in Ethiopia (Negatu et al. 1992), on the uses and preferences of farmers for durum wheats in selected durum-growing regions, in order to have a clear sense of the characteristics we should be emphasizing. In the Ethiopian study, it is clear (Table 9) that the semidwarf durums grown by farmers are very acceptable in terms of grain and straw quality, but that their adaptation would be realized by more emphasis on biotic and abiotic stresses (although the improved durums had better disease resistance than the local varieties that they replaced). We also need to be concerned about ensuring sufficient genetic diversity in our program, given that we are the major "gene mixers" for spring durums.

Priority to well watered vs. dryland areas?

An important dilemma for our future strategy is the extent to which we should emphasize durum wheats for well watered or dryland regions in the future. There are two important considerations in making this decision.

Future of durum wheats in dry areas--In general, there is a long-term tendency for the area of durum wheat to decline relative to that of bread wheat. This, in part, reflects the spread of irrigation and the availability at an earlier date of semidwarf bread wheat varieties, as in India. It also reflects the much faster growth of consumption of bread wheats, promoted by urbanization (see the example of Tunisia in Figure 6 where consumption of durum wheat in large cities is less than half of that in rural areas). In some countries, government policies have also promoted this substitution through consumer subsidies on bread wheat at the expense of durums (e.g., as in Morocco). However, there is a tendency for the remaining area of durums to be concentrated in the driest zones. For example, the proportion of the national durum area that occurs in the drier Central Zone of Tunisia has increased from 23% in the 1960s to 36% in the 1980s.

Negative spillover effects on dryland producers--An unintended effect of success in breeding high-quality durum wheats for favored areas is the possible negative price effects for dryland producers. In general, durum wheat producers have received a considerable and increasing price premium over bread wheats. This dilemma is most apparent in India. As irrigation and semidwarf bread wheats have spread over the past 25 years, durum wheat production was reduced to the driest and hottest environments. The reduction in durum wheat supply meant that producers in these environments were able to command a growing price premium for durum wheats, which increased from 25% in

the 1960s to 50% percent in the 1980s (Byerlee 1992). However, since 1975, India has established a wheat breeding program for irrigated durums (Figure 7), which by 1990 had released nine varieties. These varieties are being steadily adopted--for example in the irrigated Punjab--and the supply of good quality durums from irrigated areas now competes with durum production in dryland areas. The consequences for the price premium on durums has not been analyzed but it is logical that dryland producers of durum wheats are now worse off than they would have been in the absence of an irrigated durum wheat program.

Taken together, the evidence suggests that the case for expanding resources to durum wheats is not strong, given their long-term downward decline in area relative to bread wheats. However, given the considerable and growing proportion of the durum area that is grown under dryland conditions and the availability of suitable bread wheats for the wetter areas, I would argue that most of CIMMYT's efforts in durum wheats in the future should be targeted at the drier areas. In fact, our effort on dryland durum wheats could constitute the bulk of our total effort in breeding for dryland areas, since it seems clear that in the case of bread wheats, the highest payoffs will come from concentrating on mega-environment 1.

In formulating our strategy for the future, we should ensure that we have the best information available. In particular, we need to update our mega-environment database and analyze shifting trends in the environments in which durum wheat is grown. Secondly, we need to understand the preferences and experiences of small farmers in dry areas for improved varieties of durum wheats. Recent work initiated by CIMMYT and ICARDA to analyze adoption patterns in dry areas of Tunisia and Morocco is an important start in this direction.

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Discussion Notes

Varughese: In durums, CIMMYT-ICARDA lines dominate compared to bread wheat. National programs do not have their own durum wheat programs--a reflection of their weakness.

Fischer: Byerlee does not mention if the national programs should be strengthened. Should they be?
Rajaram: Look at the Indian Durum Program in Central and Southern India--semidwarfs are not necessarily needed.
Fischer: That is a good point; we don't necessarily have to think semidwarfs for that part of the world.

Nachit: Durum wheat is coming back into the highlands of Morocco, so the trend into 1991 is not what is stated by Byerlee.
Fischer: If you think trends are changing, keep us informed.

Table 1. Distribution of durum wheat area and production by mega-environment, 1980.[a]

Mega-environment	Area (000ha)	Production (000t)	Yield (t/ha)	Percent of Area	Percent of Production
ME1 Irrigated	376	1082	2.9	3.6	7.9
ME2 High rainfall	2370	4629	2.0	23.0	33,6
ME4A Dryland winter rainfall	4703	4408	0.9	45.6	32.0
ME4C Dryland residual moisture	1500	1200	0.8	14.5	8.7
ME6C Winter wheat-high rainfall	165	765	4.6	1.6	5.6
ME6D Winter wheat-dryland	1210	1694	1.4	11.7	12.3
	10324	13778	1.3	100	100
Total dryland (ME4A, 4C, 6D)	7413	7302	1.0	71.8	53.0

[a] The data reported here appear to be overestimates of durum wheat area and production. This is in part because the data are for the late 1970s, and, in part, because durum area in some countries, especially Turkey and India, was overestimated.

Source: CIMMYT mega-environment database.

Table 2. Number of durum wheat varieties released in developing countries by period and region, 1966-1990.[a]

Region	1965-69	1970-79	1980-90	Total
Sub-Saharan Africa	2	3 (1)	2 (1)	7 (2)
WANA	6	36 (24)	38 (26)	80 (50)
Asia	4	9 (4)	8 (4)	21 (8)
Latin America	2 (2)	8 (8)	17 (15)	27 (25)
Total	14 (2)	56 (37)	65 (46)	135 (85)

[a] Numbers in parentheses are CIMMYT or CIMMYT/ICARDA crosses.

Table 3. Popular CIMMYT and CIMMYT/ICARDA durum crosses.

Cross	Name of variety released in Mexico	Year released in Mexico	Average year released other countries	Total number of releases	Area 1990 (000 ha)
Bittern	Yavaros	1979	1985	10	576
Stork	Mexicali	1975	1981	9	74
Cisne	Cocorit	1971	1974	8	674
Albatros	Jori	1969	1974	6	277
Frigate		na	na	5	560
Gallareta	Altar	1984	_	2	85
Others				45	262
Total				85	2508

na = Not released in Mexico.

Table 4. Percent of area under durums and adoption of semidwarf varieties by region 1990.

Region	Percent wheat area in durums	Percent durum area sown to semidwarfs	Percent spring bread wheat area sown to semidwarfs
Subsaharan Africa	39	18	62
WANA	23	51	72
Asia	3	28	89
Latin America	2	65	82
Developing countries	8	46	85

Table 5. Percent of durum wheat area sown to varieties classified by origin, 1990.

Semidwarfs	CIMMYT cross	CIMMYT parent	Non-CIMMYT Released since 1966	Non-CIMMYT Released prior to to 1966	Total
			(Percent of area)		
Subsaharan Africa	11	0	7	82	100
WANA	46	1	20	33	100
Asia	0	28	0	72	100
Latin America	65	-	0	35	100
All developing countries	39	5	9	41	100

Source: CIMMYT Wheat Variety Database.

Table 6. Composition of durum wheat area planted to varieties released since 1966.

	Percent of area under recent releases				Percent area planted to releases since 1966
	CIMMYT cross	CIMMYT parent	Non-CIMMYT	Total	
Subsaharan Africa	60	0	40	100	18
WANA	70	2	28	100	67
Asia	0	100	0	100	28
Latin America	100	0	0	100	65
All LDCs	66	8	26	100	59

Table 7. Percentage of wheat area under semidwarfs by moisture regime, 1990.

Wheat type	Well-watered[a]	Dryland[a]
Spring bread	99	62
Spring durum	87	33
Winter bread	94	9
Winter durum	100	0

a Based on ecological niche recommended for each variety.

Table 8. Composition of durum wheat releases in India, 1960-90.

	Percent for Irrigated	Dryland	Total
1960-69	0	100	100
1970-79	50	50	100
1980-89	63	37	100
All	39	61	100
Origin of durum wheat releases in India, 1960-90			
Percent releases from:			
CIMMYT cross	78	0	32
CIMMYT parent	22	14	14
Non-CIMMYT	0	86	55
	100	100	100
Percent semidwarf	88	14	41
Percent successful	57	49	52

Table 9. Index of farmers' rating of semidwarfs durums and tall bread wheats for several characteristics, Central Ethiopia, 1991.

Type of characteristic[a]	Semidwarf durums Boohai	Cocorit	Gerardo	Tall bread wheats Enkoy	Israel
Yield	2.4	2.6	2.4	2.5	2.7
Straw characteristics	2.4	2.2	2.4	1.9	2.5
Resistance to abiotic stress	1.8	2.0	2.0	2.1	2.3
Resistance to biotic stress	1.9	2.2	2.1	2.0	2.6
Grain type	2.5	2.5	2.4	1.6	2.2
Food quality	2.6	2.6	2.6	1.6	2.4
Storage and marketability	2.3	1.9	2.0	1.6	2.2

[a] The index for each type of characteristic is a composite of farmers' rating of several characteristics. For example for food quality, farmers rated each variety for five local foods.

Source: Data provided by Wilfred Mwangi.

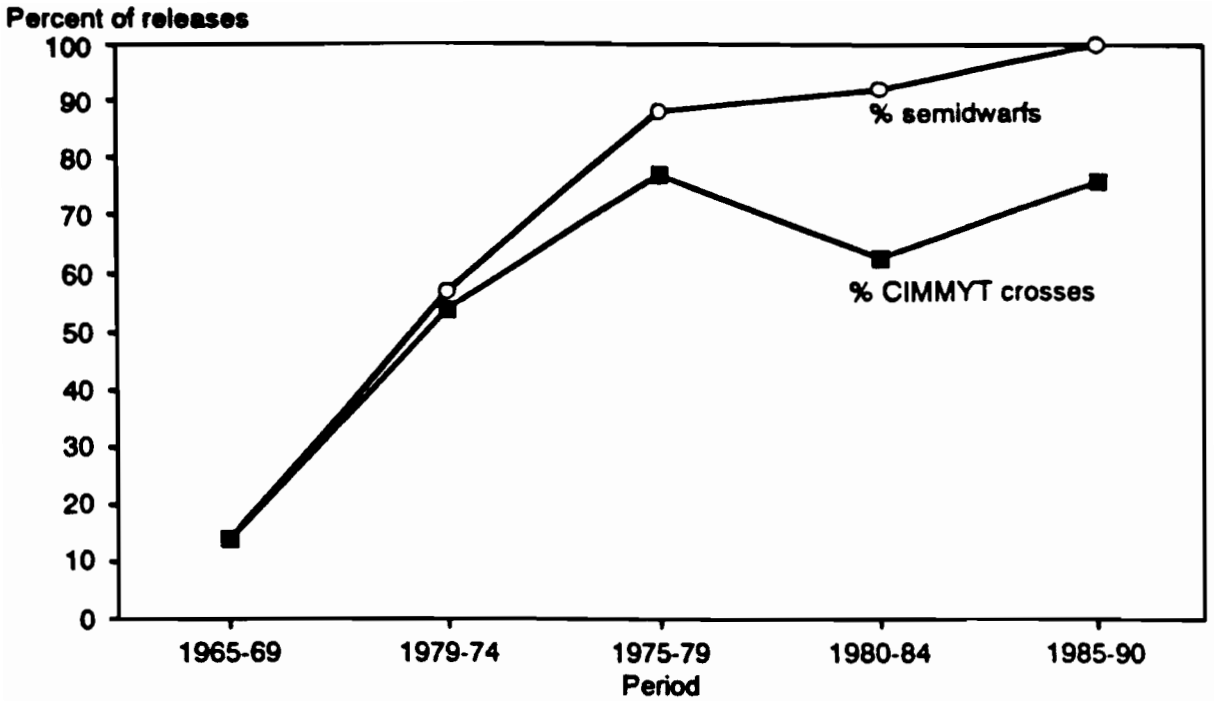

Figure 1. Percent of durum releases in developing countries as semidwarfs and percent from CIMMYT crosses, 1965-90

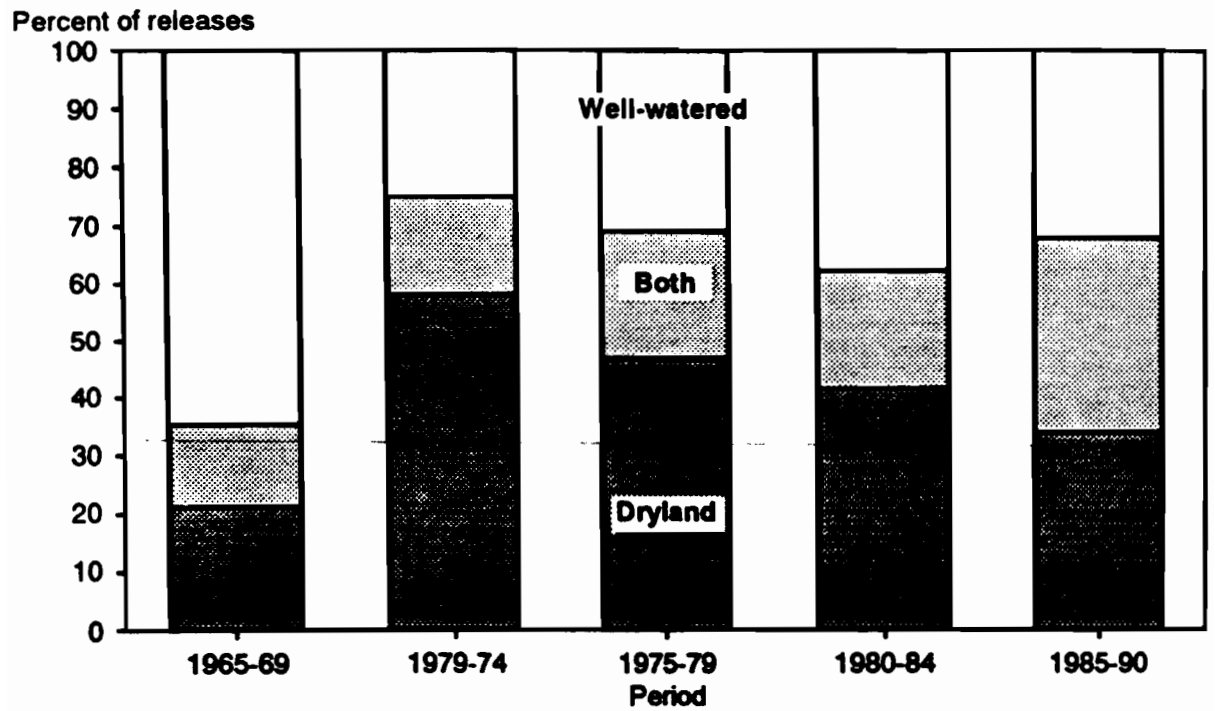

Figure 2. Ecological niche of released durums by period, 1965-90

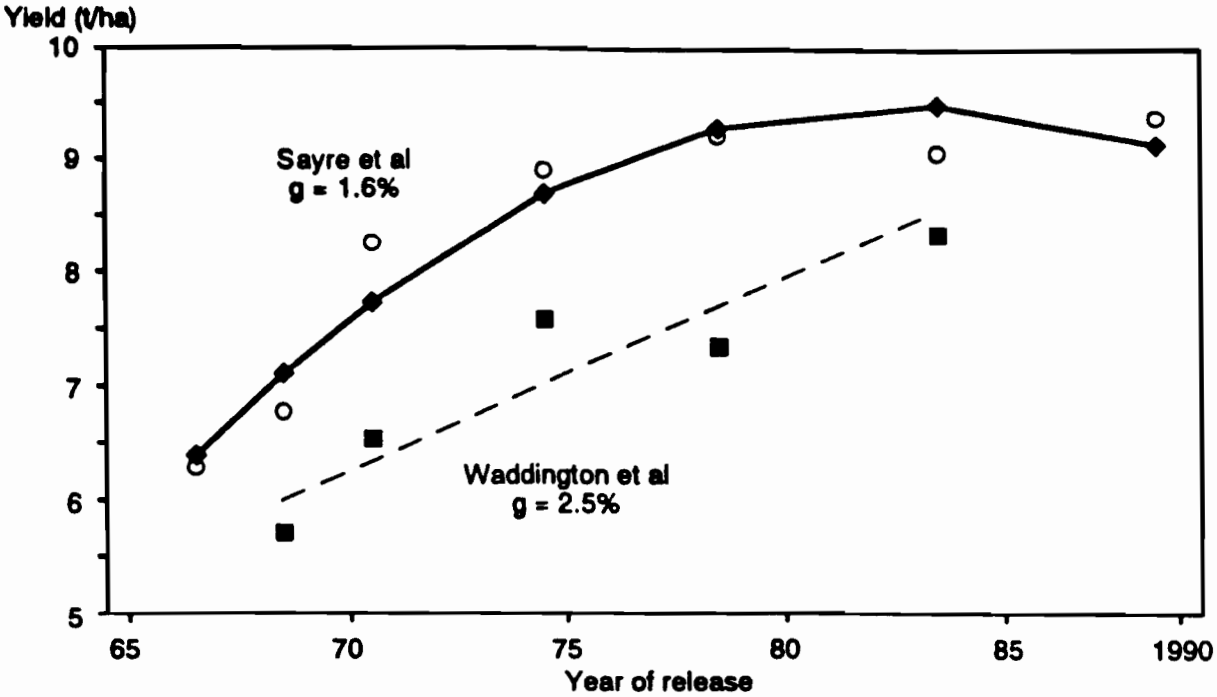

Figure 3. Yield potential of durum varieties, Mexico, 1967-89.

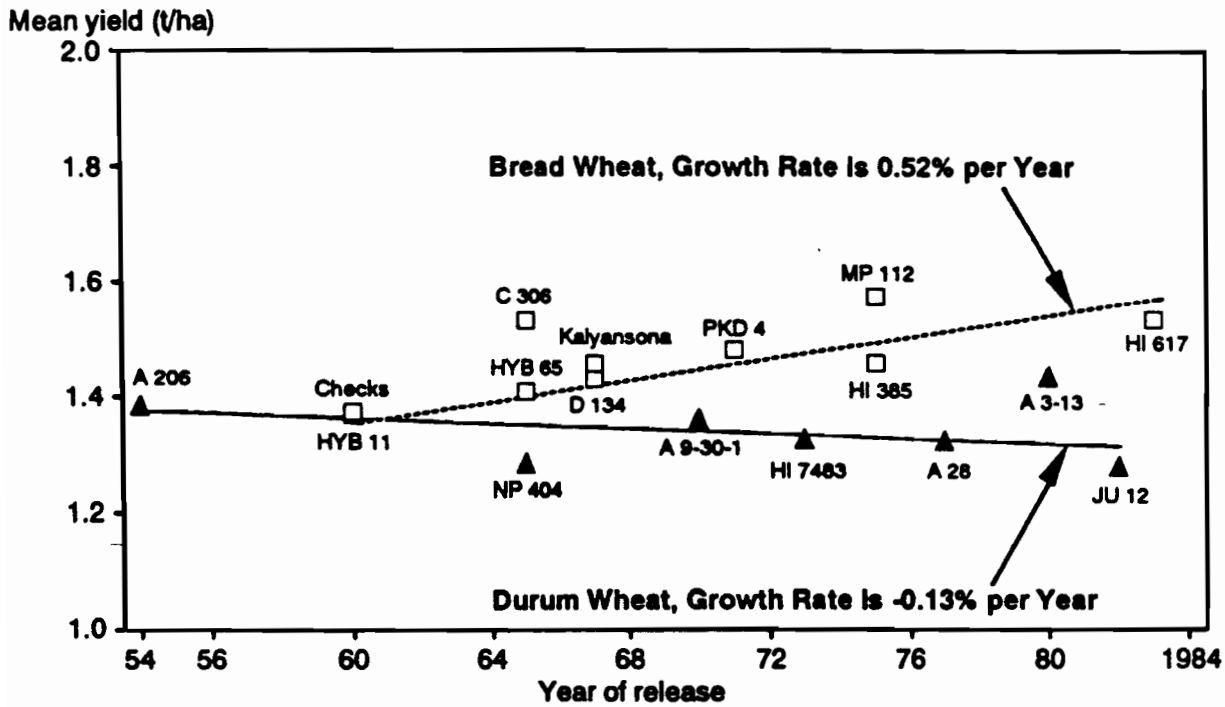

Figure 4. Yield gains in bread and durum wheat varietes released for the Central Zone, India: rainfed, timely sown condition, 1954-83.
Source: K. B. L. Jain.

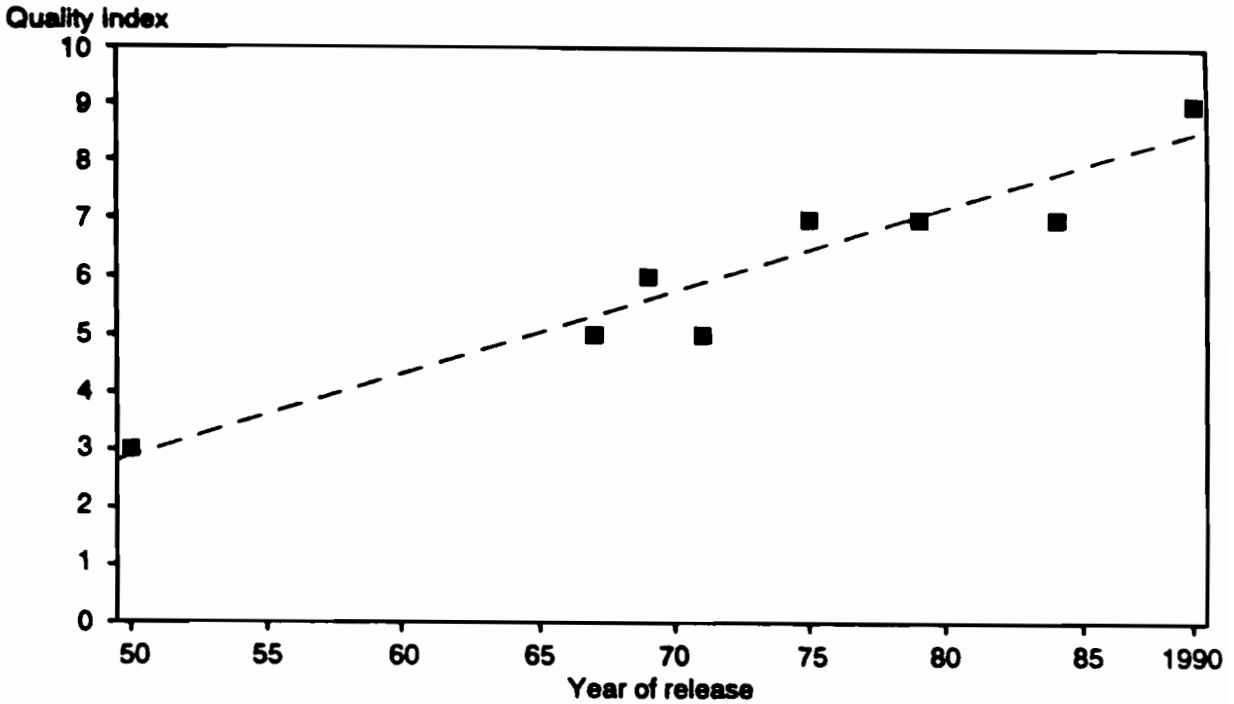

Figure 5. Quality index for durum wheat varietes Mexico, 1950-89.
Source: A. Amaya & J. Peña (pers. com.). Based on yellow pigment (ppm) and SDS-sedimentation (mR). Maximum quality score is 10.

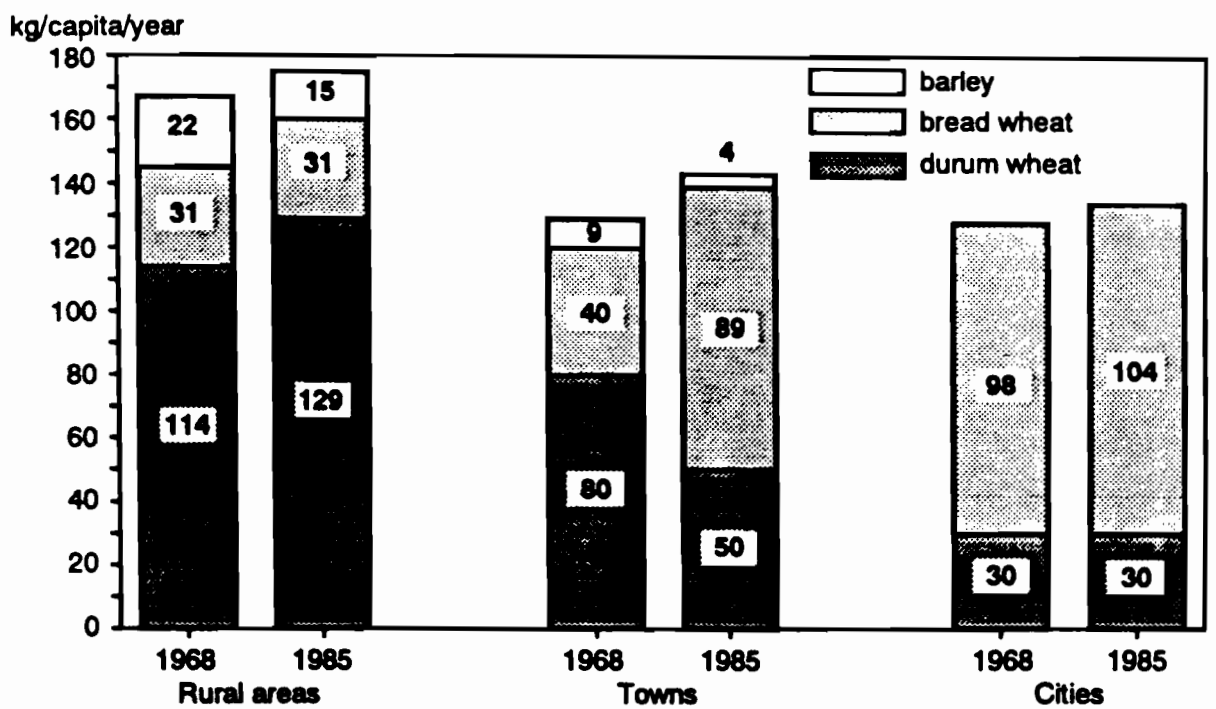

Figure 6. Changes in cereal food consumption patterns in Tunisia, 1968-85.
Source: Perisse and Kamoun (1987), and Johnson et al. (1983).

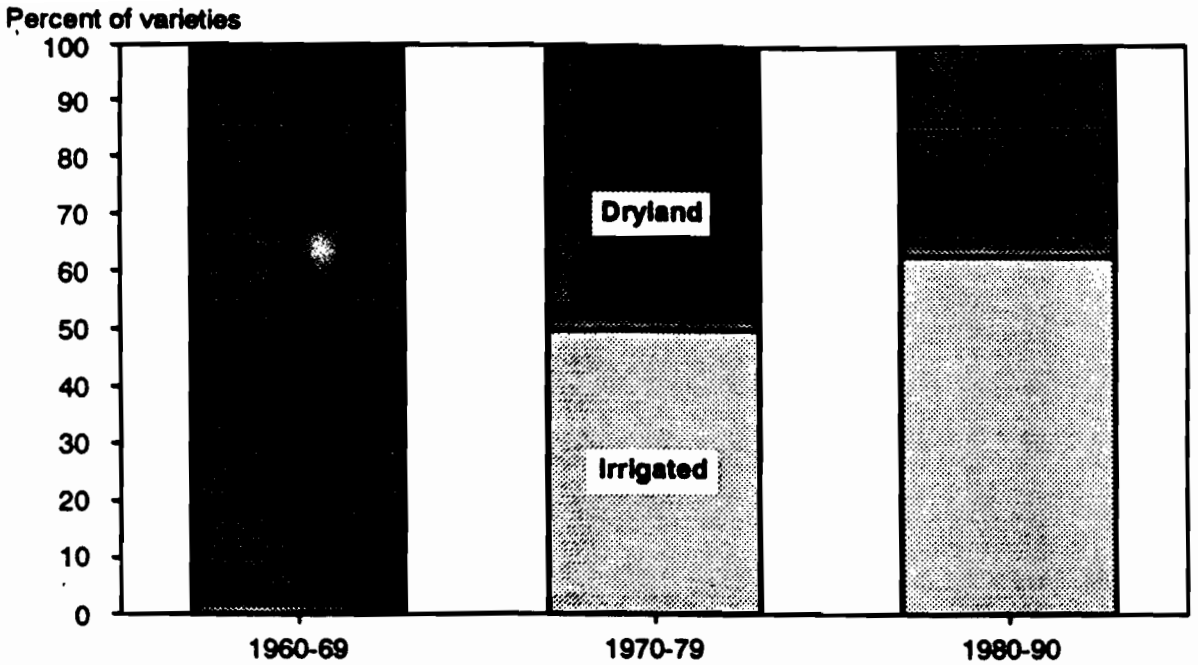

Figure 7. Composition of durum variety releases in India, 1960-90.
Source: K.B.L. Jain.

Annex A.

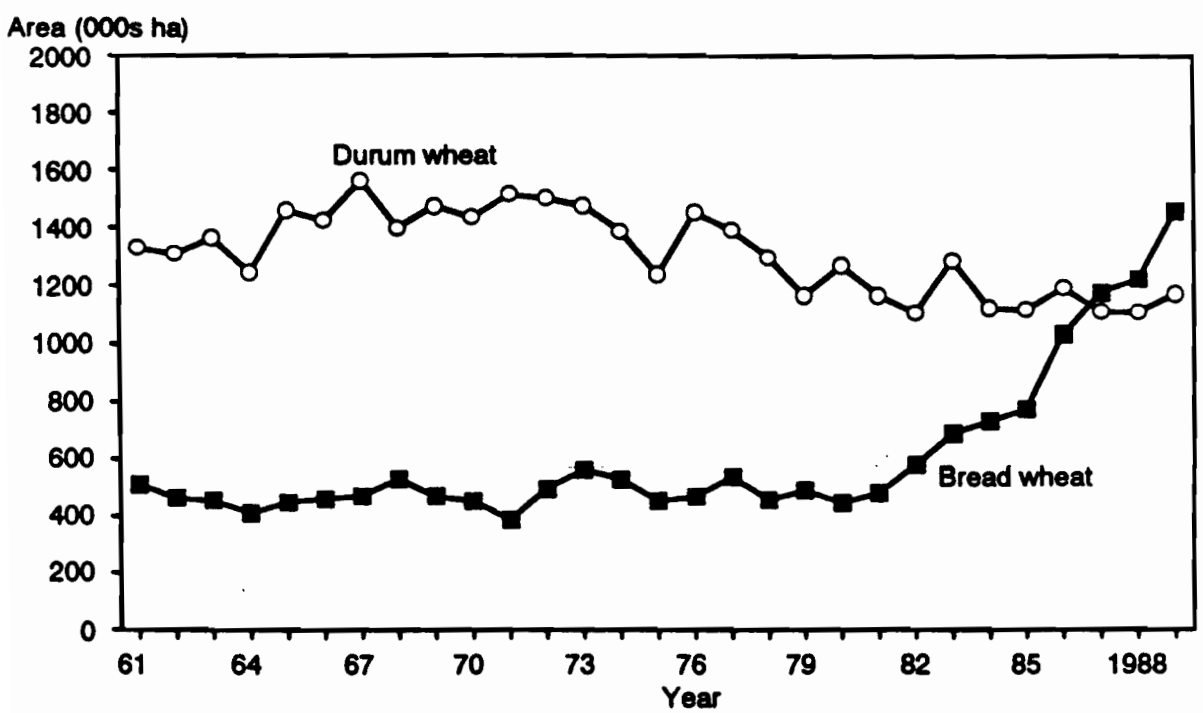

Figure 1. Area of durum and bread wheat, Morocco, 1961-89.

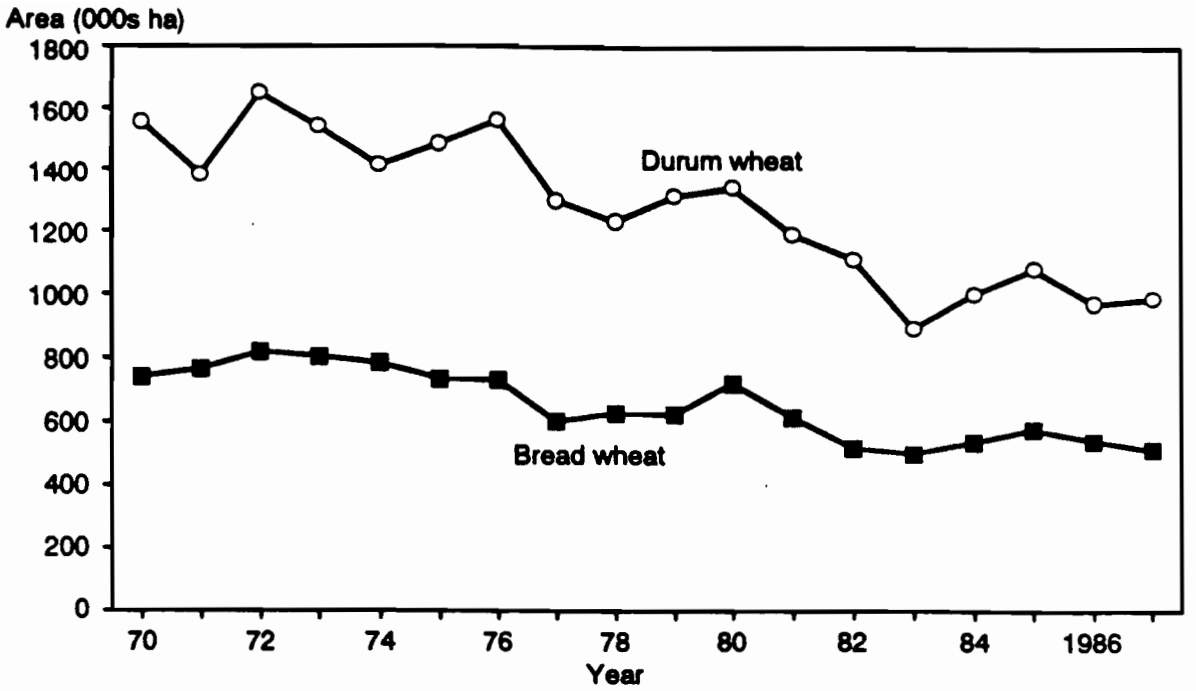

Figure 2. Area of durum and bread wheat, Algeria, 1970-87.

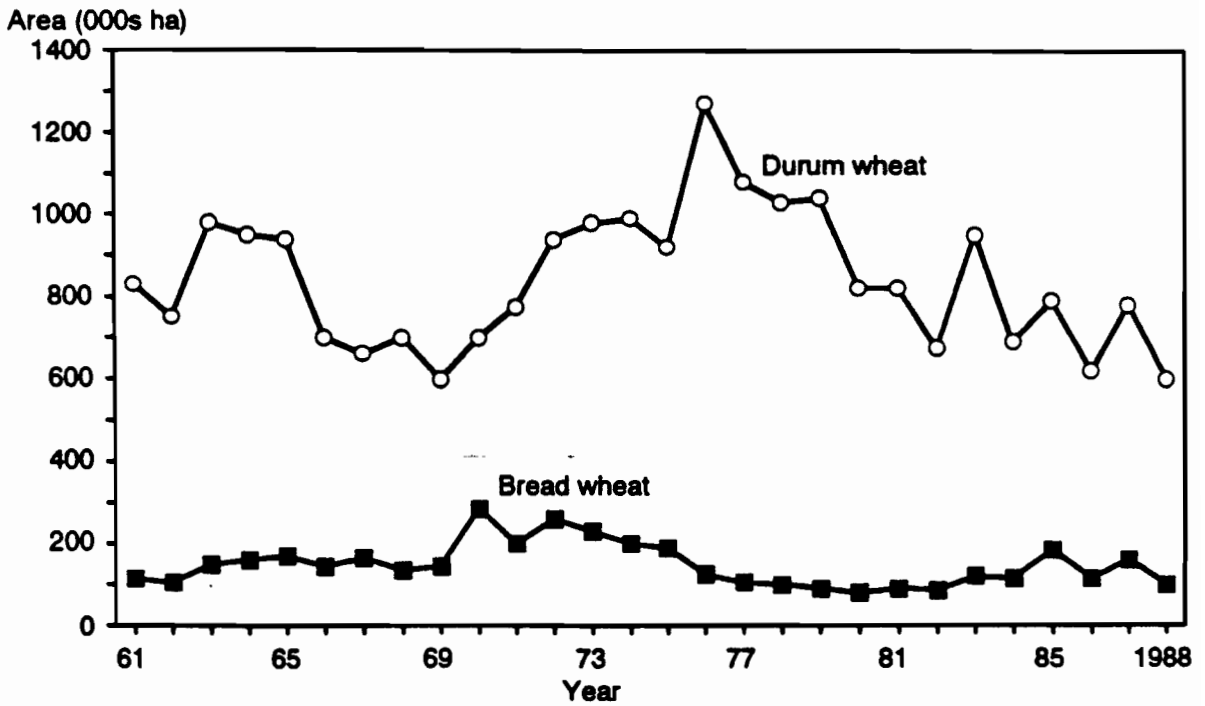

Figure 3. Area of durum and bread wheat, Tunisia, 1961-88.

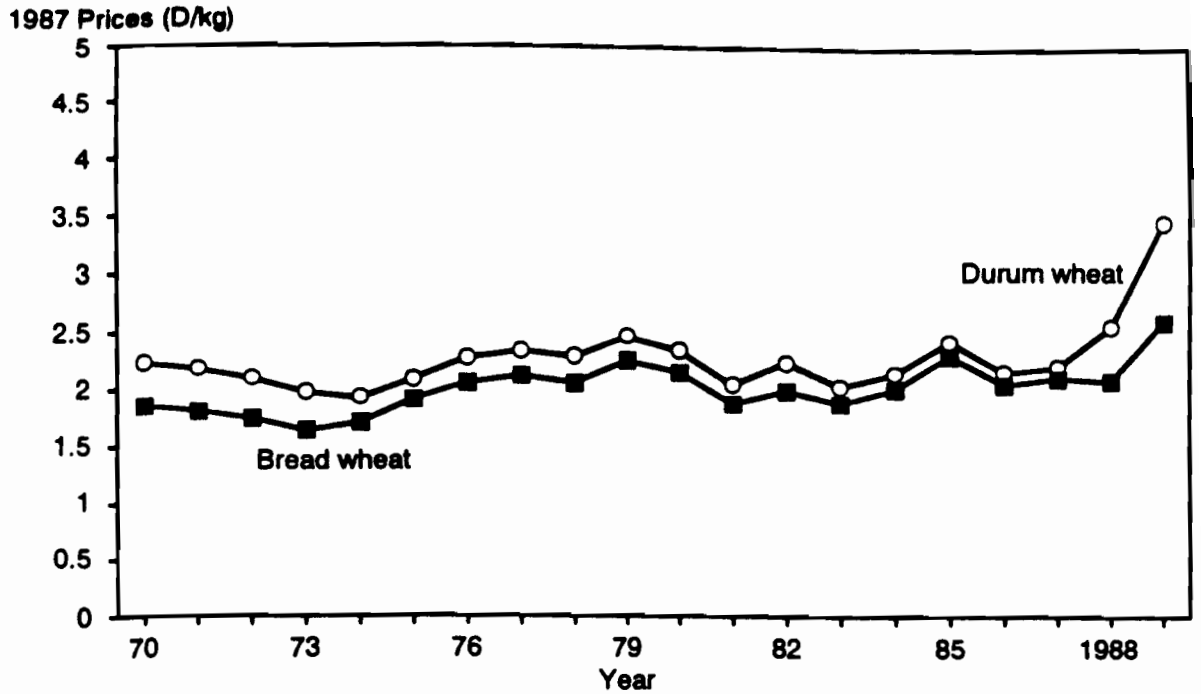

Figure 1. Real producer price of wheat, Algeria, 1970-89.

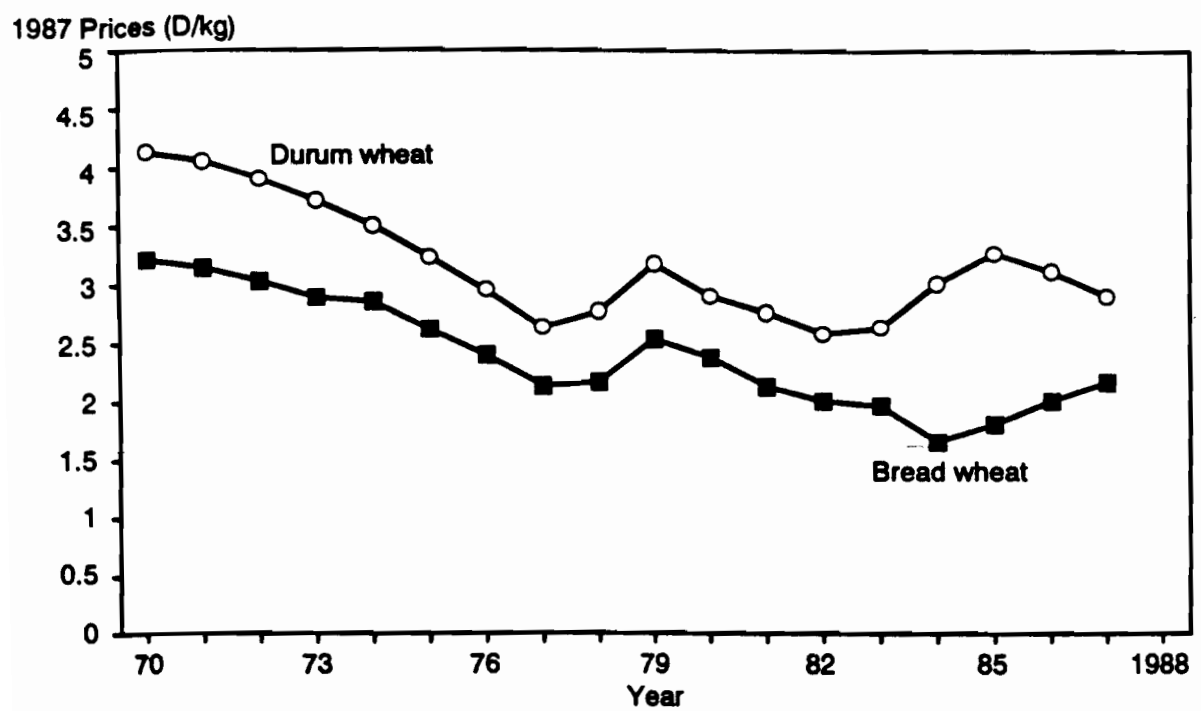

Figure 2. Real consumer price of wheat, Algeria, 1970-87.

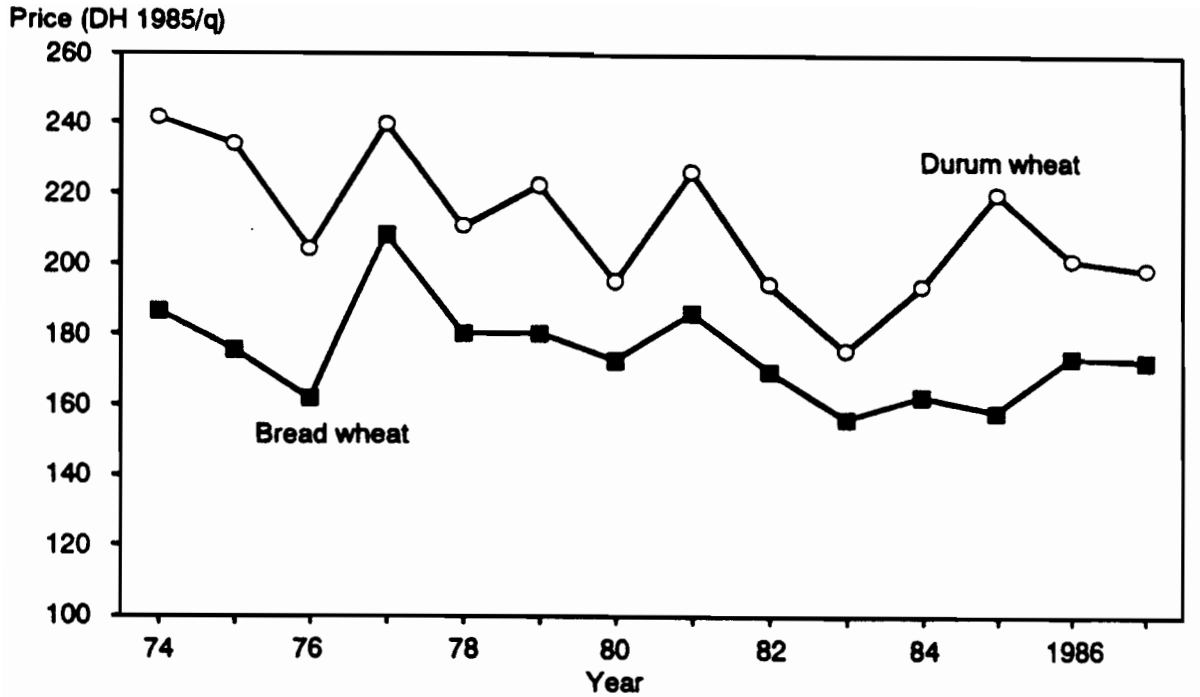

Figure 3. Market price to producers for bread and durum wheat in Morocco, 1974-87.

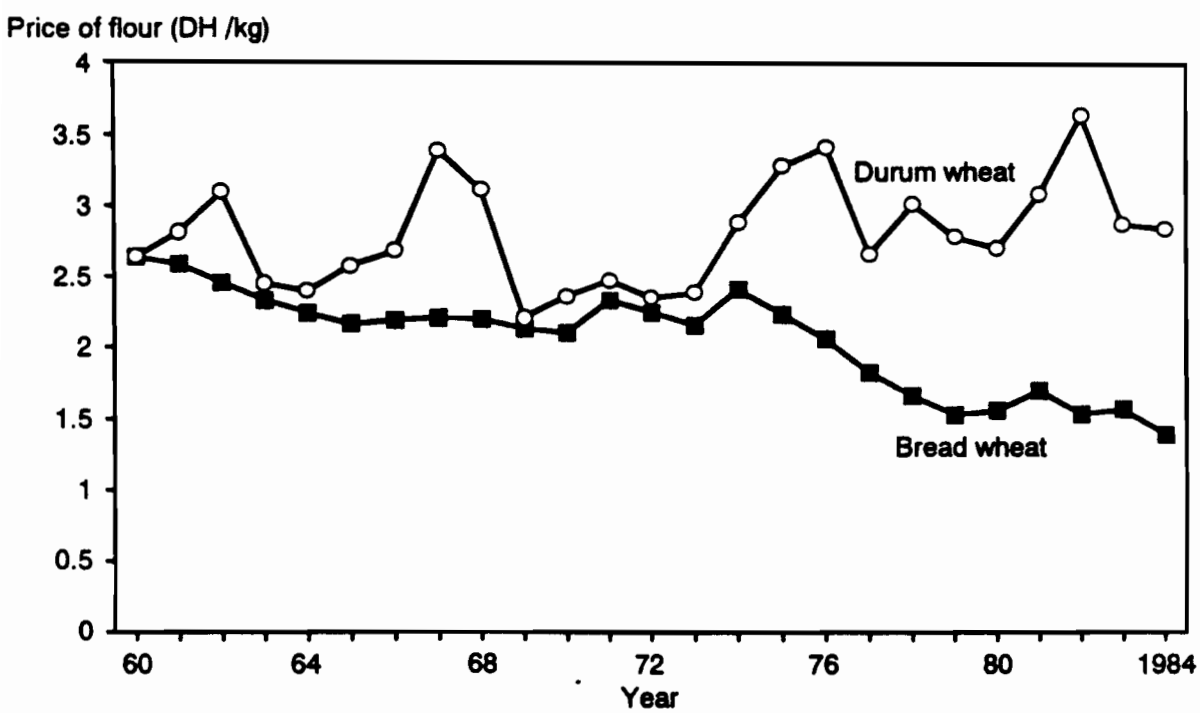

Figure 4. Consumer prices of bread and durum wheat in Morocco, 1960-84.