

Production of fall-planted cereals in Morocco and technology for its improvement

J. P. Shroyer,* J. Ryan, M. Abdel Monem, and M. El Mourid

ABSTRACT

Cereal production is of paramount importance in the national economies of Middle East-North African countries. High per capita consumption of cereal products along with rapid population growth underlies endeavors to achieve self-sufficiency. The purpose of this paper is to describe current cereal production, particularly, rainfed wheat (*Triticum* spp.), in Morocco, note agronomic research advancements, and discuss the potential for increased production. Wheat is Morocco's dominant cereal, the greater proportion being the hard or durum type (*Triticum turgidum* var. *durum* L.). At least 80% of production is rainfed, with about 40% in the semiarid (250 to 400 mm) rainfall zone. Production increases are plagued by recurring drought and stymied by low inputs of fertilizers and machinery and by diseases and crop pests, particularly Hessian fly (*Mayetiola destructor* Say). The past decade has witnessed a major research and development effort for dryland wheat production, embracing related physical and economic factors.

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Emphasis has been placed on training cereal scientists and improving the research infrastructure. Potential for yield increases has been shown using pest-resistant cultivars, combined with effective fertilizer use and improved practices. A network of on-farm trials has been the basis of cereal technology transfer efforts.

THOUGH WHEAT originated in the Middle East, countries of that region and North Africa, ironically and with few exceptions, are unable to produce it in adequate quantities for their burgeoning populations. Wheat consumption rates of some countries in this broad region are among the world's highest, averaging 225 kg per capita in 1981 (Briggle and Curtis, 1987). Despite geographical and climatic diversity, cereal production in the region has a number of common features: low average yields, i.e., 650 to 850 kg ha⁻¹; mostly rainfed, with durum wheat being most widely grown, especially in the 250- to 400-mm rainfall zones; fall planting to avail of winter rains; predominantly shallow soils; and a similar array of insect and fungal pests. The purpose of this paper is to describe current cereal production, particularly, rainfed wheat, in Morocco using a holistic approach, note agronomic research advancements, and discuss the potential for increased production. This requires that all features

of cereal production from edaphic and climatic limitations to economic restraints be considered. Only by understanding the playing field can researchers, extension personnel, and farmers identify needs of developing areas.

Morocco lies on the northwest corner of Africa, with nearly 1950 km of coastline on the Atlantic Ocean and the Mediterranean Sea (Fig. 1). It is the closest African country to Europe, separated only by the Strait of Gibraltar. Topographically, Morocco is sharply divided into an open, agriculturally rich plains area in the northwest, and economically poor mountains and plateaus in the eastern and southern part. The coastal plains and plateaus, fronting for some 560 km on the Atlantic Ocean, are cut off from the interior by encircling mountains. Peaks of the High Atlas and Middle Atlas ranges rise to 4150 m above sea level; peaks of the Rif Massif rise sharply from the coast to 2150 m. The coastal plains are the most densely populated and economically advanced, including nearly all of Morocco's major cities.

Beyond the mountains, eastern Morocco is a series of arid, rolling plateaus that form a continuation of the Algerian High Plateaus in the northeast, and gradually drop into the Sahara Desert in the south and southeast. Population in these areas is sparse. On the Atlantic side of the Atlas Mountains, the climate is semitropical; on the other side, dry steppes merge into the Sahara Desert. The Mediterranean coast has a mild, sunny climate. April through October are usually dry months.

The variable topography influences climate, soil type, and consequently, patterns of land use. Statistics presented in a World Bank report (1979), though somewhat dated, give an overview of Morocco's agriculture, which is essentially relevant today. At that time, the country had 7.7 million ha with soils and moisture suitable for cropping, and 2 million ha in semiarid or mountain regions suitable only for grazing and forests; some 720 000 ha were under permanent irrigation. About 5.3 million ha of agricultural land were cultivated each year; the remainder was planted to tree crops (0.4 million ha) or left fallow (2 million ha). About 4.3 million ha were planted to winter cereals; 500 000 ha to pulses; 140 000 ha to vegetables; 60 000 to sugarbeet (*Beta vulgaris* L.); and the remainder to oil-seed, cotton (*Gossypium hirsutum* L.), and forage crops. Data for 1982-1983 (Crawford and Purvis, 1986) indicated that the total cropped area had increased to 8.3 million ha, while winter cereals had increased to 4.7 million ha. The area of forest was put at 5.2 million ha.

About one-third of agricultural production value is generated by the livestock subsector. Livestock raising is primarily extensive, based on grazing of natural pasture. Intensive livestock production, based on cultivated forage crops, barley (*Hordeum vulgare* L.), or industrial crop residues, is rapidly becoming important in irrigated and high-rainfall areas. Most industrial crops and forage crops, as well as vegetables and citrus fruits are grown under irrigation, as are almost all export crops. About 50% of Morocco's cultivable land receives about 350 mm or less rainfall and is generally cultivated under

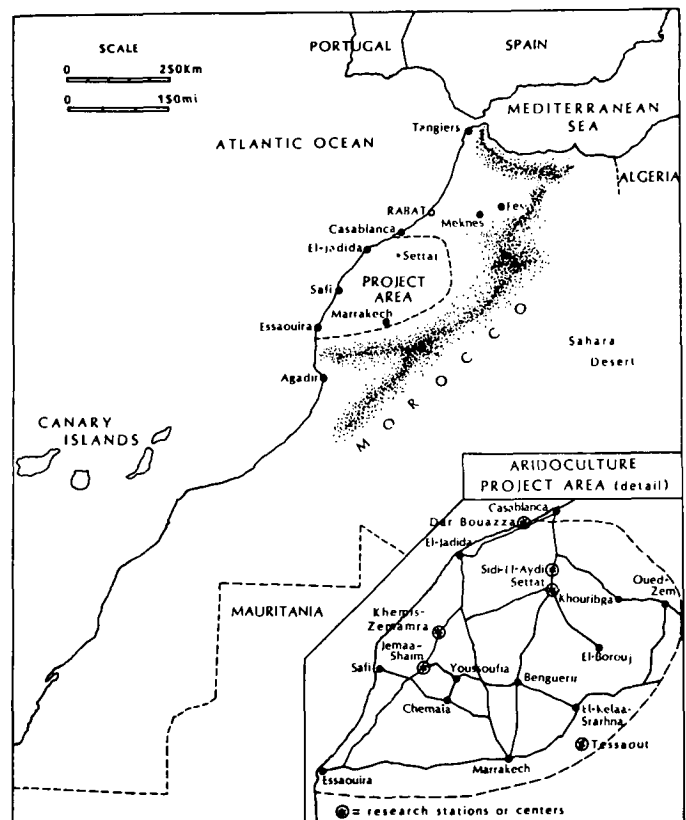


Fig. 1. Schematic map of Morocco.

a barley/fallow rotation. Most of Morocco's rainfed areas are characterized by traditional agricultural practices. Despite efforts undertaken since promulgation of the Agricultural Investment Code in 1969, limited use is made of fertilizers, pesticides, herbicides, high-yielding cultivars, and farm machinery. As a result, crop yields and livestock productivity are generally low.

CEREALS: POPULATION GROWTH AND DEMAND

From Neolithic times, cereals have been produced in the Maghrib area of North Africa; indeed during Roman occupation, wheat was exported from the region. Today, demographic changes underscore the national concern about cereals. The present population of about 26 million people, growing at 2.6% or more per year, is estimated to double within 27 yr. Though predominantly rural, the population is undergoing a dramatic shift towards urbanization—a feature characteristic of most developing countries. Data in Table 1 indicate projected growth between 1980 and the year 2000 relative to other country categories. The projected increase is 60% higher than for all wheat-growing countries considered to be developing and over six times higher than for developed countries. While some countries can meet the increased demand by expanding the crop area, Morocco cannot do so. With about 8 million ha that are potentially arable, the ratio of people to land is projected to increase from

Table 1. Estimated and projected population, and land-related parameters for Morocco in relation to stages of development of wheat-growing countries.†

Parameters	Morocco	All developing countries	All developed countries
Population			
1980 estimated, million	21	3283	1131
2000 projected, million	37	4884	1272
Increase to 2000, %	78	49	12
Land			
Arable ha, million	7.9	741	672
Persons/arable ha			
1980	3.0	4.4	1.7
2000	5.0	6.6	1.9

† Adapted from *Wheat in the Third World* (Hanson et al., 1982).

Table 2. Cultivated area, yield per hectare, and total grain production of fall-planted cereals in Morocco since 1961.

Crop	Period	Area		Yield Mg ha ⁻¹	Total production Mg × 10 ³
		Cultivated ha × 10 ³	Relative %		
Bread wheat	1961-1970	464	11	0.84	392
	1971-1980	482	11	0.93	451
	1981-1987	776	17	1.24	965
Durum wheat	1961-1970	1402	33	0.87	1215
	1971-1980	1371	31	1.01	1380
	1981-1987	1157	25	1.10	1268
Barley	1961-1970	1938	45	0.88	1697
	1971-1980	2088	48	1.00	2089
	1981-1987	2246	49	0.87	1950

3 to 5 per hectare by 2000. Again, these estimates reflect high pressures on land utilization, compared to developed countries with comparatively stabilized populations.

Cereals comprise about one-third of Morocco's agricultural production and occupy about 75% of the total cropland. However, production increases over the past three decades have been minimal; drought, escalating production costs, and limited opportunities for cropland expansion have been adverse factors. In the 1961-1987 period, the area planted to cereals increased from 4.3 to 4.6 million ha; corresponding figures for output were 3.7 to 4.4 million. Nevertheless, it is interesting to examine the changes in relative proportions of the major cereals.

Barley, which is the dominant cereal, increased from 45 to 49% of the cropped area, with no change in yield per hectare (Table 2). At the same time, bread wheat (*Triticum aestivum* L.) increased in area and yield, and consequently, output, mainly in the last decade. Both of these increases occurred at the expense of durum wheat in terms of area cultivated. However, durum wheat yields tended to increase over the period, with total production remaining constant. Maize (*Zea mays* L.), the remaining cereal of any major importance, occupied about 10% of the cropped area but tended to decrease in both area and yield. It must be borne in mind that cereal production is subject to large annual variations, e.g., total grain production ranged from a low of 2 million t in the drought year of 1980-1981 to a high of 7.7 million t in 1985-1986.

While barley, which is noted for drought tolerance and Hessian fly resistance, is largely used as animal feed, the

Table 3. Total Moroccan wheat imports and per capita comparison of in-country production vs. imports since 1971.

Year	Wheat			Per capita			
	Bread	Durum	Total	Im-ports	Pro-duction	Total	Im-ports
	Mg × 10 ³			kg yr ⁻¹			
1971-1973	663	1	664	42	125	167	25
1974-1979	1296	27	1323	74	100	174	43
1980-1986	1843	18	1861	87	99	186	48

focus of public policy has been to increase wheat production. This is understandable in view of the importance of wheat as a staple diet for most Moroccans. Their per capita consumption of cereals is about 2.5 times that of the average European. Although bread wheat is a ubiquitous item in the daily diet of Moroccans, especially the less well-off in rural and urban areas, durum wheat is also used for bread, as well as couscous and pastries. This pattern of consumption is common to the entire region. Domestic grain production has not kept pace with the country's population or net demand, with consequent need for imports. Selected data for the 1971-1986 period (Table 3) show that a substantial increase occurred in the importation of bread wheat—mostly from the USA. On a per capita basis, the increasing dependence on imports was more obvious, with the imported proportion increasing from 25 to 48%. The per capita consumption available from in-country production of all cereals declined 7% during that period. Efforts to achieve a marked expansion in wheat production in Morocco have to be based on an evaluation of the country's resources for producing wheat, scrutiny of existing production methods, and a consideration of the complex interrelationships between wheat and other cereals and animal production systems.

PRESENT PRODUCTION AND RESOURCES

Rainfall and Temperature

Rainfall and its distribution pattern dictate cereal cropping in Morocco. As a consequence of topography, virtually all production is confined to the coastal plains and plateaus west of the Atlas mountains and south of the Rif mountains. Rainfall ranges from essentially nothing in the Sahara to >1000 mm in high elevations in the mountains. The climate is arid to semiarid, with moderate winters and dry hot summers. Although the mean annual temperature is 17°C, it ranges from 11°C in the coldest month, January, to 27°C in July, the hottest month. Precipitation occurs between October and April, with an average of 6 to 8 rain-days during that period. In the absence of irrigation, cropping occurs at this time, when evaporation rates are low and moisture adequate. Rainfall in the Atlantic plains ranges from 200 to 400 mm yr⁻¹ in the southern half and above 400 mm yr⁻¹ in the northern part, but considerable fluctuation around the long-term mean is the norm. Barley tends to dominate the 200- to 300-mm rainfall zone, but with <200 mm,

Table 4. Comparative production for irrigated and rainfed cereals in Morocco since 1976.

Cereal	Year	Irrigated			Rainfed		
		Area ha × 10 ³	Yield Mg ha ⁻¹	Production Mg × 10 ⁵	Area ha × 10 ³	Yield Mg ha ⁻¹	Production Mg × 10 ⁵
Bread wheat	1976-1979	60.5	1.9	1.17	158	1.4	2.15
	1980-1984	98.6	2.3	2.31	240	0.6	1.41
Durum wheat	1976-1979	67.5	1.7	1.18	2460	1.3	30.07
	1980-1984	54.1	1.8	0.97	2550	0.6	14.30
Barley	1976-1979	65.6	1.6	1.02	2075	1.0	21.20
	1980-1984	48	1.5	0.75	2814	0.5	13.90
All grains	1976-1979	211	1.7	3.61	6707	1.2	78.40
	1980-1984	222	2.0	4.41	8424	0.5	45.30

little grain can be grown without irrigation. Highly variable total rainfall and patterns of rainfall have recently been documented (Watts and El Mourid, 1988) for the semiarid zone. Such a database is necessary for long-term cereal production strategies. As in all semiarid areas, the potential contribution from irrigation and rainfed land has to be assessed in any economic development plan.

Irrigation: Potential for Cropland

Irrigation accounts for about 90% of water use in Morocco, with the remainder for domestic use and industry (Crawford and Purvis, 1986). However, irrigated agriculture, which accounts for only 10% of Morocco's arable land, contributes about 45% of the agricultural production and produces 65% of the agricultural exports. Average yields in irrigated areas have risen steadily because of increased use of improved cultivars, fertilizers, and other inputs. These higher yields, together with more use of irrigated land, have resulted in substantial increases in the production of major irrigated crops. Output from irrigated areas grew at about 8% per year between 1960 and 1983. Such trends are illustrated in Table 4 for the major cereals. Though only 12% of the total bread wheat-growing area was irrigated, that area contributed 24% to total bread wheat output. During the period considered (average values for 1976-1979 vs. 1980-1984), there was a substantial increase in irrigated bread wheat, with increases in per hectare yield, i.e., from 1.9 to 2.3 t ha⁻¹. Though the area of rainfed wheat increased in the same period, from 158 000 to 240 000 ha, yields per hectare dropped dramatically because of the disastrous drought of 1980-1984. Thus, variability in overall production is closely related to rainfed conditions. The area planted to irrigated durum wheat, barley, and corn was even less than that for bread wheat but production was higher than from rainfed cropping. Overall, the area cropped to irrigated grains was 9%, contributing 19% of total grain output. Thus, given the fact that rainfed cropping is dominant in Morocco's agriculture and will continue to be in the foreseeable future, major emphasis was placed on improving the efficiency of that sector.

Rainfed Cropping

The potential technical and economic feasibility of rainfed projects relative to irrigated ones was considered

in the previously cited World Bank report (1979). This indicated that rainfed production could be increased, given the elimination of certain constraints, e.g., problems associated with land tenure, inefficient farming practices, insufficient use of agricultural credit and inputs, and inadequate infrastructure. Compared with large-scale irrigation projects, rainfed cropping has lower costs per hectare and per family, and a higher economic rate of return. Projected economic rates of return for rainfed projects were estimated by the International Bank for Reconstruction and Development (IBRD) to be about 20%, compared to 7 to 12% for large-scale irrigation projects. The most viable option to reduce the deficit in cereals is for intensification of rainfed agriculture, starting with the more favorable zones. The social benefit of rainfed cropping derives from the fact that the rural poor live mostly in areas with little irrigation potential.

Soils, Land Use, and Fertility

Given the great diversity in the distribution of factors of soil formation, i.e., parent material, climate, vegetation, and topography, similar variation exists in soil types. These, in turn, influence land use and cropping systems. Soils are predominantly calcareous and inherently fertile. Only about 8.5 million ha (12%) of Morocco's 69 million ha of land (excluding the Sahara) have adequate soils with sufficient rainfall for crop production. Soils of Morocco have been described in maps with degrees of intensity ranging from FAO-UNESCO's Soil Map of the World to detailed maps at a scale of 1/20 000. The diversity of soils is illustrated in the FAO-UNESCO map according to distribution: Xerosol, Chromic Luvisol, Calcic Cambisol, Calcic Kastanozen, Rendzina, Calcic Xerosol, Calcaric Fluvisol, and Vertisol. Mapping has occurred in high use-intensity areas, i.e., irrigated areas and project zones. As yet, only a small proportion of rainfed agricultural soils are mapped. Accurate documentation of soil type distribution is fundamental to transfer of technology from representative soil types.

Mapping is carried out by the National Institute of Agricultural Research (INRA), and according to the French system of classification, Special projects have used the U.S. system of classification, i.e., *Soil Taxonomy*, as a basis for technology transfer. In a recent study of N mineralization in the mapped area of Chaouia in the lower rainfall zone, El Gharous (1987) used 14 soil types

and identified their equivalence in terms of *Soil Taxonomy*; dominant soils were Chromoxererts, Typic Rendolls, Typic Eutrochrepts, Halploxerolls, and Xerochrepts. Most of these soils had free CaCO_3 , were heavy textured, and had organic matter ranging from about 10 to 50 g kg^{-1} . In view of their widespread distribution in both the low and high rainfall zones and their high potential productivity, the vertisols of Morocco have received considerable attention (Wilbert, 1965).

Cereal production, as is all cropping, is influenced by farm size and patterns of land holdings. Private ownership accounts for about 75% of all cropland; however, most of the range or grazing land is collectively held (Crawford and Purvis, 1986). Many farmers do not have clear title to the land they own. Average farm size is 4.9 ha, which is considered, at most, about half of the threshold for viability in rainfed agriculture. As in most countries, farm size distribution is unequal, with 11% of the households owning 55% of the land. The inevitable consequence of such a preponderance of small holdings is a traditional form of subsistence agriculture with low output.

However, because of sharecropping and renting, Crawford and Purvis (1986) suggest that a distinction should be made between land ownership and land use. Land inheritance patterns have contributed to the distribution of small parcels to numerous heirs. Thus, the land effectively controlled in relation to size may be underestimated. A further contributing factor to data unreliability was the fact that their statistics were taken from tax records. Nevertheless, Crawford and Purvis's (1986) data showed close agreement with a survey of Primov et al. (1987) in the Abda region. Here, 84% of farms were < 10 ha and accounted for 44% of the total land. Indeed, 97% of all farms were < 25 ha.

Fragmentation of farms is another adverse land use factor; the average farm has six separate holdings, with an average size of 0.64 ha per parcel. Crawford and Purvis (1986) attributed fragmentation to adherence to laws and customs regarding inheritance, large family sizes, and people's desire to maintain a rural foothold for sake of economic survival, regardless of the actual worth of the land. In addition, a number of widely scattered plots enables a farmer to spread the risk of crop loss over various microclimatic zones. However, farming such scattered parcels of land increases operation costs and reduces efficiency. It also contributes to soil erosion; gully and sheet erosion are common occurrences. Where land is sloping, fragmentation occurs with the slope so that each person has some good and some poor land. Cultivation of such parcels is usually up and down the slope. Such a situation is not conducive to soil conservation practices. However, public awareness of the adverse effects of fragmentation exists, and various initiatives at the administrative level have been taken to redress this trend.

Although drought is the major limiting factor in cereal production in Morocco, yields vary substantially with soil type—specifically with respect to fertility and soil depth, which, in turn, influence water-holding capacity. This is

illustrated in a recent soil test calibration study, which showed that with similar rainfall, cultivars, and cultural practices, unfertilized cereals yielded over twice as much from a vertisol as from a shallow (< 35 mm) soil, rendoll (Abdel Monem et al., 1988a). The high nutrient-supplying capacity of deep clay soils at an experimental station was also shown by these workers (Abdel Monem et al., 1988b); over a 3-yr period, little or no responses occurred for wheat with either N or P application.

On the contrary, in research plots on farmers' fields encompassing different soil types, responses to applied N were observed, especially following cereals, maize, or fallow. Data for a vertisol typical of the project region (Fig. 1) over a 2-yr period of varying rainfall illustrate this point (Fig. 2). In most cases, applied N as low as 40 kg ha^{-1} had a marked effect on yield. However, there was little evidence of any consistent response to P. This lack of response to applied P was in accord with the observation of Abdel Monem et al. (1988c) that banding was no different from broadcasting. These crop response data were recently corroborated by soil test summaries of $\text{NaHCO}_3\text{-P}$ values from cereal fields from the major soil types in the Chaouia region. Some soils were adequate in soil P, whereas others showed various degrees of deficiency based on a critical level of 5 to 7 mg kg^{-1} P. Research results to date stress the need to consider soil types in fertilizer P recommendation and, in the case of N, previous cropping history.

As with most soils of semiarid areas, few instances of K deficiency have been observed. In addition, cereals tend to have a low demand for soil K. Similarly, because of the calcareous nature of most soils and the low leaching environment, responses to either Mg or S are unlikely. Though micronutrient deficiencies are common to calcareous soils, little or no information on these elements with respect to cereals is available in Morocco. Though cereals are not very responsive to soil micronutrients, legumes, which constitute an integral part of the cereal rotation system, are sensitive to Fe and Zn.

Cultural Practices and Inputs

As is characteristic of developing countries, crop production in rainfed areas of Morocco follows a time-honored traditional pattern with high labor input and few

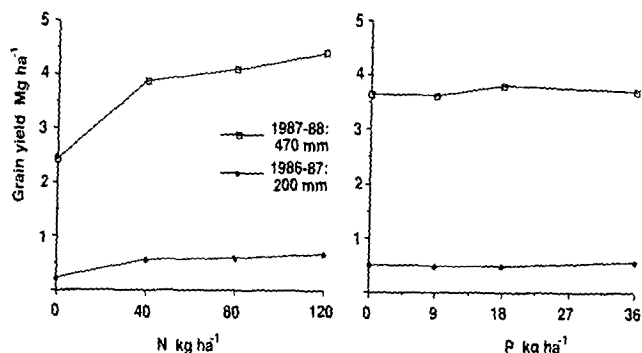


Fig. 2. Wheat response to applied N and P on a Vertisol over two growing seasons.

farm chemicals. The system of cereal production has evolved to take advantage of soil moisture, integrated with other field crops. Fallowing is widely practiced, especially in drier areas; with shallower soils, at any one time, about 50% of cereal land in such areas is fallow. Such land is not idle, however, because winter rains produce a vigorous stand of weeds, which are used for animal pasture. Such weedy fallow frequently contains N-fixing legumes, e.g., medics (*Medicago* sp.). Weedy fallow tends to be practiced by smaller farmers who cannot afford to leave the land idle; they do not have the resources for clean tillage in the fallow season and need forage for their livestock. However, cropping with weeds reduces or eliminates any carry-over effect of soil moisture to the following cereal crop. With increasing land pressure, the proportion of fallowed land has gradually declined.

Rainfall dictates whether cereals are grown successively or in rotation. Continuously cropped cereals, especially bread wheat, is common in the more favorable northern part of the country, whereas many farmers in the 250- to 400-mm zone practice a maize/cereal/food legume rotation. Maize is grown in deeper soils as a forage crop and is indirectly used to control weeds as the soil is subject to several cultivations. Lentil (*Lens esculenta* Moench. J.) and chickpea (*Cicer arietinum* L.) are common legumes used to enhance residual N for the succeeding crop. A recent study involving rotations on three soil types, i.e., deep (Chromoxerert), medium (Calcixeroll), and shallow (Rendoll), showed that carry-over N from legumes may be adequate for the succeeding cereal crop (Abdel Monem et al., 1988a). However, this depends on type of legume and how it is managed. There is little or no intercropping or multiple cropping with cereals.

Though cereal cultivation is becoming increasingly mechanized, much work is still done by hand. With the advent of the rainy season in October, planting is done by broadcasting seed by hand, following prior tillage with a tractor-drawn disc harrow or cover crop or by an animal-drawn plow, usually horses (*Equus caballus*), mules (*E. asinus* × *E. caballus*), donkeys (*E. asinus*), or camels (*Camelus dromedarius*), or a paired combination. The amount of tillage depends on soil type, the farmer's financial resources, and whether he owns a tractor. Currently, it is estimated that there are about 40 000 tractors and 5000 combine harvesters in Morocco, with numbers increasing because of increased credit and elimination of taxes on farm equipment. Drills are rare and found only on larger farms. Stubble mulch tillage or direct drilling is not practiced. Lack of machinery and the vagaries of the weather contribute to late planting by many farmers, a factor that significantly reduces yield. Broadcast rates for bread and durum wheat are 100 to 125 kg ha⁻¹, whereas barley is seeded at 140 to 160 kg ha⁻¹ (Primov et al., 1987). These rates could be reduced and a more even stand established by drilling. Most of the bread wheat used is improved cultivars, whereas about 50% of the durum wheat and only 10% of the barley cultivars are improved.

Herbicides are used sparingly and primarily on large

farms. Most herbicide applications are made by single-nozzle backpack units but are too late for optimum results. Women and children have a major role in hand-weeding cereal fields and carrying weeds home for livestock. Bread and durum wheat receive preferential weeding. Despite possible beneficial effects on livestock, weeds compete with cereals for scarce moisture, and consequently reduce yield and water-use efficiency (Tanji et al., 1987). The major weeds in cereals are wild jujube [*Ziziphus lotus* (L.) Lam.], dwarf thesium (*Thesium humile* Vahl), wild oat (*Avena sterilis* L.), silverleaf nightshade (*Solanum elaeagnifolium* Cav.), and rigid ryegrass (*Colium rigidum* Gaudin).

Given the humid conditions of growth, it is not surprising to find a range of plant diseases, although low-yielding landraces tend to be resistant to various degrees. The most important diseases of bread and durum wheat are leaf rust (*Puccinia recondita* f. sp. *tritici*), stem rust (*P. graminis* f. sp. *tritici*), speckled leaf blotch (*Septoria tritici*), tan spot (*Pyrenophora trichostoma*), and root rots (*Fusarium* and *Helminthosporium* spp.). Important barley diseases are net blotch (*Helminthosporium teres*), barley stripe (*H. graminieum*), covered smut (*Ustilago hordei*), and powdery mildew (*Erysiphe graminis*). These diseases are prevalent in most years but vary in their severity.

While weeds may not always be perceived by the farmer as harmful to cereal production, no such ambivalence exists about insect pests, which can, in some years, be devastating for Moroccan agriculture. The Hessian fly is the principal culprit. A survey by Hatchett et al. (1984) showed moderate to heavy infestations in sampled fields. Hessian fly can reduce grain yields to zero with severe infestations. However, damage is normally not that severe and depends on location, cultivar, and planting date. Its effect on cereals can be mitigated by pesticides. Carbofuran [2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate] (Furadan) has been shown to effectively control the pest when applied with the seed in experimental trials. However, it is not used commercially in dryland cereal farming. The sawfly (*Cephusis* sp.) is another insect pest of importance for cereals (El Bouhsini et al., 1987). Farmer use of pesticides for cereals is limited; what materials are used are mainly in irrigated agriculture, where microclimates encourage pests and where crop value warrants the expense involved.

In contrast to pest control chemicals, fertilizers play a greater role in crop production. Although Morocco's fertilizer consumption is higher than for other North African countries, it is low by comparison with developed countries. Application rates tend to be adequate for irrigated cash crops but less for cereals, legumes, and forages. According to Crawford and Purvis (1986), only 35% of the area under cereals is fertilized and at less than half the recommended rate; they estimated that a mere 5% of cereals in the low rainfall zone is fertilized. Risk of losing this investment in fertilizers because of crop failure resulting from drought, as well as unreliable and erratic supplies, are factors contributing to low levels of input for dryland cereals.

Nevertheless, fertilizer consumption data for the past few decades suggest a greater rate of fertilizer use in the future. Mouline (1979) showed that from 1956 to 1978, total fertilizer consumption increased ninefold, though admittedly from a low base of 23 540 t. Consumption of N and K increased slowly to 1965 and thereafter at 13% per year; P increased at 2800 t yr⁻¹ over the same period. Data for 1983 show consumption of N, P₂O₅, and K₂O to be 11 500, 95 800, and 38 700 t, respectively (IFDC, 1985). The increase in cereal production attributed to fertilizers ranged from 0.3 to 0.7 t ha⁻¹, depending on climatic zone. Fertilizer use is expected to increase at 6% per year to the year 2000 (Crawford and Purvis, 1986).

Morocco is fortunate in being one of the world's leading sources of rock phosphate. As a result, about 50% of the fertilizer consumed in Morocco is from domestic sources and imported raw materials (e.g., NH₃, K, and S). The balance is in the form of imported finished products (Crawford and Purvis, 1986). The principal N fertilizers are urea, ammonium nitrate, and ammonium sulfate, whereas P is supplied as ammonium phosphate, triple superphosphate, and an array of fertilizer formulations. Potassium chloride and sulfate are the standard sources of K on the market.

It is estimated that 85% of all cereals are mechanically harvested. A larger percentage of bread wheat is combine harvested than barley (Primov et al., 1987). After harvest, the straw is baled and stacked. If the field is mechanically harvested, women and children will often cut the remaining stubble with hand sickles and carry the straw home. Hand harvest is slower and more expensive than mechanical harvest, and the majority of the labor rests on family members. Rafsnider and Laamari (1988) estimated mechanical harvest costs for fall-planted cereals to be 150 to 210 dirhams (\$1 = 8 dh) per ha, and Primov et al. (1987) reported that hand harvest required 10 to 20 man-days per ha at a cost of 30 to 45 dh per worker per day. Straw with grain intact is stacked in fields, later to be carried to a central threshing point. Animals walk over the straw, threshing the grain, and then grain is winnowed from the straw. After harvest, sheep (*Ovis aries*), and goats (*Capra hircus*) are allowed to graze stubble fields. Although no reliable estimates of grain losses from harvest operations in the field exist, they appear to be significant, as evidenced by the volunteer growth in such fields in the fall. Methods of grain storage range from underground matmoras or silos to aboveground stone enclosures and sacked grain. Storage losses are estimated to be about 10%.

Research Infrastructure and Cultivar Development

The INRA is primarily responsible for all phases of cereal research. Its scientists are either graduates of the Ecole Nationale d'Agriculture (ENA) in Meknes or from the Institut Agronomique et Veterinaire, Hassan II University (IAV), Rabat, Morocco. Staff at both institutions also conduct cereal-related research. The INRA network involves eight regional centers and 19 research

stations. Until recently, most cereal research was conducted on small plots at the various stations. However, there has been an increase in on-farm trials and demonstrations. A major catalyst for dryland cereal research has been the establishment of the Aridoculture Center in Settati in 1980 (see Project area in Fig. 1). This is based on collaborative endeavors of scientists from INRA and from the MidAmerica International Agricultural Consortium (MIAC) with funding from the U.S. Agency for International Development. A major component has been the training of Moroccan scientists in the USA, primarily through higher degree programs. Research at the center focuses on all aspects of dryland cereal production.

A major thrust has been the development of spring cereal cultivars. Since 1956, INRA has released 4 durum wheat, 13 bread wheat, and 12 barley cultivars, with most being released during the 1980s. Within the next 2 yr, INRA will release a total of 10 durum and 5 bread wheat cultivars, and 4 barley cultivars. Prior to 1979 there was little emphasis on cultivar development. Then only one person was in the national breeding program, and cereal agronomists were responsible for making selections. There now are six breeders, who have been responsible for this large number of releases. Presently, there is one breeder conducting anther culture work and another using embryo rescue techniques with interspecific crosses. There is no work on mutation breeding or hybrid development.

Emphasis is on conventional breeding, using a modified pedigree method with F₂ selection and multisite testing. In the last 2 yr of testing, candidates for release are placed in eight locations of the national catalog test. The national release committee makes final approval on all releases. The INRA increases foundation seed to G₃. A semistate body, the Societe Nationale de Commercialisation des Semences (SONACOS), is charged with certified seed production, distribution, and marketing. The SONACOS contracts G₃ seed production with state companies such as the Societe de Gestion des Terres Agricoles (SOGETA). Both R₁ and R₂ seed production is by state companies and contract farmers through SONACOS, which then cleans, treats, bags, and sells the seed.

Morocco has made steps to preserve its germplasm in local cultivar and landrace collections throughout the country. The INRA has shared its responsibility in maintaining this collection with the International Center for Research in Dry Areas (ICARDA) in Aleppo, Syria, and the International Board for Preservation of Germplasm Resources (IBPGR), Rome. The INRA shares germplasm with other national cereal programs in North Africa and Mediterranean regions and international centers, such as ICARDA in Syria. This cooperation has proven to be beneficial and is necessary for realizing future improvements.

High grain yields in both high- and low-yield environments are emphasized. These are achieved by selecting early maturing, disease- and insect-resistant lines. This is necessary in all of Morocco to avoid heat and lack of moisture during grain-filling. Therefore, consideration is given to selection for drought and heat resistance. Older cultivars and landraces are later maturing. Farmers har-

vest a grain crop 2 out of 4 yr in some regions. In drought years, straw is harvested to salvage a crop and provide feed for livestock. Therefore, breeders have not placed total emphasis on short-statured cultivars, since farmers need and want straw production with a grain crop. This is especially true with durum wheat and barley.

In view of the severity of Hessian fly as a cereal pest, the breeding program has stressed selection of resistant cultivars (El Bouhssini et al., 1986). Similar screening approaches for other cereal pests are being adopted in the region (Miller, 1987). Moroccan scientists have identified genes for Hessian fly resistance that may ultimately impact on wheat production in the USA—technology transfer in reverse. Of the cultivars of bread wheat, 'Saada' (a line from the South Dakota, USA, breeding program that carries the H5 resistance gene), has been shown to be resistant, in contrast to the more common cultivars 'Nesma' and 'Potam'. Saada is currently being studied with respect to other agronomic traits. Durum wheat cultivars are more tolerant to the fly than bread wheat cultivars, but they also can have severe infestations.

POTENTIAL FOR DEVELOPMENT

As with most countries in the process of development, the potential of Morocco's agriculture is far from being realized. Although the many factors that hamper increased output are complex, they are by no means insurmountable. Substantial increases are possible in rainfed cereal production with minimum inputs and improved management. This was evident from Crawford and Purvis's data (1986), which showed that, for instance, the bread wheat yield from better farmers was 2.0 t ha^{-1} as opposed to average yields of 1.0 t ha^{-1} . Indeed, yields increased to 2.4 t ha^{-1} on demonstration farms. A more startling disparity was apparent when yields of up to 4.4 t ha^{-1} were achieved on research-managed plots on farmers fields on a deep clay soil (Abdel Monem et al., 1988a). In view of the limited possibility of increasing the area of cereal land, potential production increases must be realized from increased yields. The primary goal is to achieve production increases within the short term; however, factors that contribute to sustained increases in the future need to be considered.

Improved technology of cereal production will have to come from well-trained scientists who have the wherewithal to generate improved technology and transmit it to farmers. The international cooperative Dryland Agriculture Project involving the USA and Morocco will result in a substantial cadre of highly trained scientists that will have an inevitable impact on cereal production in both the short and long terms. A major focus of this training has been on technology transfer; improved practices are identified through diagnostic and verification trials in coordination with agents of the national extension agricultural systems, i.e., Centres de Travail.

A number of improved practices can be readily implemented with immediate benefit. Chief among these is the use of fertilizer, which is currently low and inadequate. Yield increases reported by Abdel Monem et al.

(1988a) were achieved primarily by the addition of 120 kg N h^{-1} ; weed and Hessian fly control, along with drilling of the seed, were the other components of the improved package. Where N levels were low, increments of as little as 40 kg ha^{-1} more than doubled yields. However, fertilizer N could be reduced or eliminated where the previous crop was a legume. In practice, fertilizer application is fairly arbitrary and is not based on soil nutrient levels. Consequently, an effort has been made to promote soil test calibration and soil analysis as a basis for fertilizer recommendations. Numerous field trials have shown no response to P or K. Considerable savings could be achieved by omitting these inputs in such situations.

Although cereal breeding is normally a long-term process, selection has already identified the Hessian fly-resistant wheat cultivar, Saada. This promises immediate benefit to farmers. The process of combining favorable agronomic characteristics with such resistance will be a continuing challenge.

Given the current, low-input state of cereal growing in Morocco, yield increases in the foreseeable future will depend on how efficiently these resources are used. Low-level mechanization is seen as an effective means of increasing crop production, with animals being more cost-effective than tractors. Studies are in progress on draft animal power. Initial work of Bansal and El Gharras (1987) indicated that a five-row animal-drawn prototype drill held considerable promise; not only should this achieve a more uniform cereal stand, but it would help reduce seeding rates and effectively band-place fertilizer at the same time, thereby reducing seed costs and labor for broadcasting.

Altering the system of soil management may contribute to increased yield without additional input. It is apparent that modifications such as contour cultivation would reduce runoff and soil loss and increase soil moisture retention and, consequently, crop yield. The introduction of medics as annual forage and a substitute for weedy fallow may reduce fertilizer N requirement for the cereal crop and reduce the need to maintain weeds in cereals as annual fodder. This would emphasize the need for weed control; back-pack spraying would be a cheap input, effectively contributing to increased yields. These practices, along with insecticide use, are currently being evaluated and economically assessed on farmers' fields.

Research productivity of Moroccan scientists can be optimized only by effective collaboration at the national, as well as regional and international levels. Currently, close links have been established with ICARDA, whose mandate covers the West Asia-North Africa region. Similarly, there is an involvement with CIMMYT in Mexico in the area of cereal breeding. The International Center for Research in the Semi-Arid Tropics (ICRISAT) has been involved in the animal traction aspect of cereal research in Morocco.

Although any one improved cereal growing practice can contribute to increased yield, sustained output necessary to approach self-sufficiency can be achieved only by adoption of a series of improved practices. Government

officials must also provide incentives, such as farm credits, tax breaks for equipment, price supports, and an infrastructure to move and maintain quality grain before a majority of farmers accept already proven results. The future of increased cereal production in Morocco depends on an integrated approach by all concerned: policy-makers, researchers, extension personnel, and, of course, the farmer.

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