THE MART/AZR PROJECT

HIGH ELEVATION RESEARCH IN PAKISTAN

Pakistan Agricultural Research Council

ARID ZONE RESEARCH INSTITUTE

Brewery Road, Quetta, Pakistan.

No. 24

BARLEY PRODUCTION UNDER SUBOPTIMAL CONDITIONS IN UPLAND BALUCHISTAN: AGRONOMIC AND SOCIO-ECONOMIC CONSIDERATIONS

by

D.J. Rees, F. Rehman, A. Samiullah
J.G. Nagy, G.F. Sabir,
J.D.H. Keatinge and S.H. Raza

1989

MART / AZR PROJECT RESEARCH REPORTS

This research report series is issued by the Management of Research and Technology Project/Arid Zone Research Component (MART/AZR). This project is financially sponsored by the Mission to Pakistan of the United States Agency for International Development (USAID).

The project contract is implemented by the International Center for Agricultural Research in the Dry Areas (ICARDA) and Colorado State University (CSU) at the Pakistan Agricultural Research Council's Arid Zone Research Institute (AZRI).

This institute has responsibility for undertaking dryland agricultural research in all provinces in Pakistan through its headquarters in Quetta, Baluchistan and its sub-stations at D.I. Khan (NWFP), Umerkot (Sind) and Bahawalpur (Punjab)

The principal objective of the MART/AZR Project is the Institutional support and development of AZRI in the period 1985-1989. This series of research reports outlines the joint research findings of the MART/AZR project and AZRI. They will encompass a broad range of subjects within the sphere of dryland agricultural research and are aimed at researchers, extension workers and agricultural policy-makers concerned with the development of the resource-poor, arid areas of West Asia and the Middle East.

Libraries, individuals and institutions may obtain single copies of this research report series free of charge and may request their names be placed on a mailing list for periodic notifications of published papers by writing to the MART/AZR project office, P.O. Box 362, Quetta, Pakistan.

BARLEY PRODUCTION UNDER SUBOPTIMAL CONDITIONS IN UPLAND BALUCHISTAN: AGRONOMIC AND SOCIO-ECONOMIC CONSIDERATIONS.

Rees, D. J.[1], Rehman, F.[2], Samiullah, A.[2], Nagy, J. G.[1], Sabir, G. F[2]., Keatinge, J. D. H.[1] and Raza, S. H.[2]

[1] International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 362, Quetta, Pakistan.

[2] Arid Zone Research Institute, Brewery Road, Quetta, Pakistan.

Paper to be presented at the Symposium on "The agrometeorology of Rainfed barley-based farming systems" at Tunis, 6-10 March 1989, sponsored by the International Center for Agricultural research in Dry Areas (ICARDA) and the World Meteorological Organization.

Abstract

The main dryland agricultural activity in upland Baluchistan is sheep and goat production using rangeland grazing as the main source of feed supply. Barley is grown as a supplementary feed on rainfed and "water-harvesting land" but the area planted to wheat is much greater than that for barley.

Annual rainfall varies from 150 to 350 mm, and the exceedence probability of receiving 300 mm varies from 10 to 30% for most of upland Baluchistan. Rainfall during the grain-filling period is usually low resulting in frequent and severe crop water stress.

Air temperatures vary considerably with elevation, with periods of frost ranging from a few days to over three months in winter, and summer temperatures varying from 35 to 40 C.

The agricultural soils are generally fine textured, highly calcareous, low in nitrogen, phosphate and organic matter.

The results of a series of surveys of farmers' practices, yield expectations and production problems are presented. Barley is perceived as a lower-yielding crop than wheat, but the main reason for sowing more wheat than barley is for food security.

The results of a multi-locational barley variety/ fertilizer trial conducted on farmers' fields over three years are presented. Crop water use efficiencies varied from 9 to 14 kg $ha^{-1}mm^{-1}$. Application of fertilizer increased biological yield and crop water use efficiencies, but not enough to pay for the fertilizer, even in a "wet" year. The variety "Arabic abiad" from Syria demonstrated a consistent increase in "environmental stability" and water use efficiency compared to the local check, resulting in an overall increase in economic gross benefit of 20%.

Even with full adoption of the new barley variety it is unlikely that farmers will increase the area sown to barley at the expense of land sown to wheat. Changes and improvements to the whole crop-livestock system will be probably be required before the farmers will make any major shift away from growing poor crops of wheat for subsistence to growing better yielding crops of barley for improved livestock production. The nature of some of these changes are outlined.

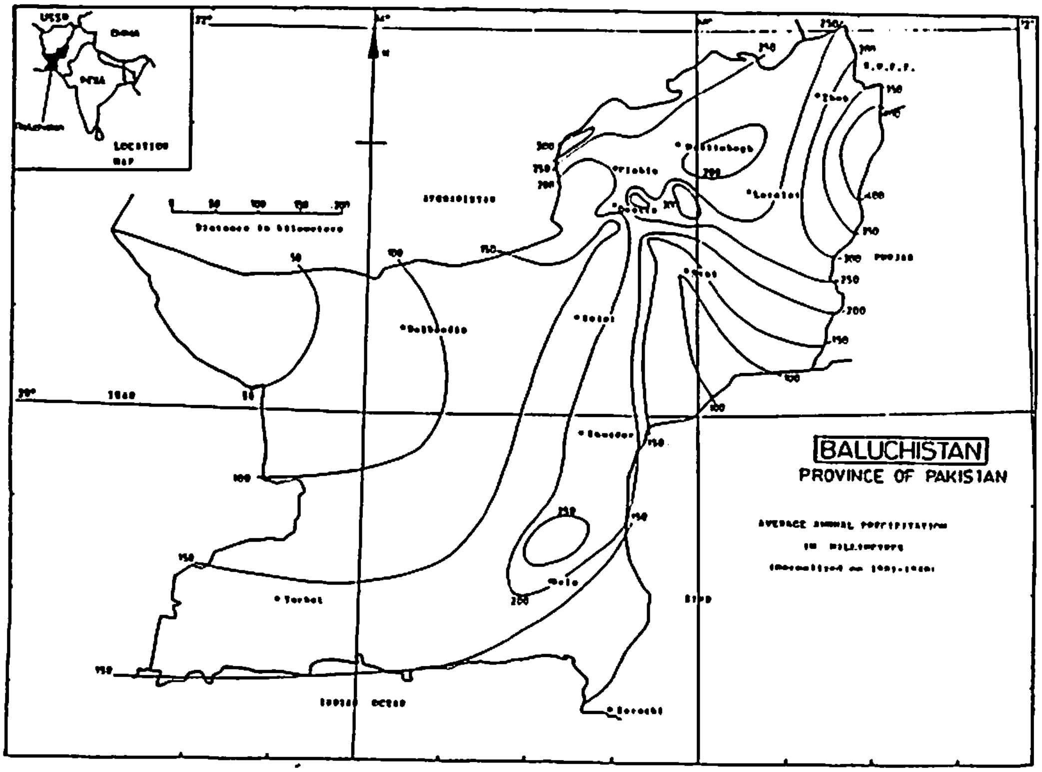

Figure 1. Baluchistan annual average rainfall (mm), from Kidd et al. (1988). Location of places mentioned in text: Zhob 31°12'N 69°20'E; Loralai 30°23'N 68°34'E; Maslakh 30°20'N 66°40'E; Tomagh 30°12'N 68°09'E; Quetta 30°13'N 66°57'E; Dasht 29°58'N 66°52'E; Mastung 29°48'N 66°50'E; Kovak 29°28'N 66° 47'E; Kalat 29°06'N 66°33'E; Khuzdar 27°47'N; 66°23'E.

1. Introduction

In 1985 ICARDA, in cooperation with the Arid Zone Research Institute, instituted a multi-disciplinary research program on dryland agriculture in upland Baluchistan, encompassing collection and analysis of climatic data, socio-economic surveys of farmers involved in dryland agriculture, range-livestock management and improved crop production, emphasizing fodder crops such as barley and vetches. The salient features of farmer practises and ideas about livestock and crop production were known (ICARDA 1987) and so research on crop and livestock production was initiated simultaneously with the socio-economic research. This paper summarizes key points of the climatic analyses, socio-economic information about the farmers, particularly in relation to barley, and the results of a multi-locational barley trial conducted over three years, a "normal", a "wet" and a "dry" year.

The principal dryland agricultural activity in upland Baluchistan is the production of sheep and goats, using rangeland grazing as the main source of feed. Cereal crops are also grown, of which wheat and barley are the most important. However wheat hectarage is twenty times greater than that of barley in upland Baluchistan (GOB). Annual rainfall varies from 200 to 350 mm suggesting that barley is a much more appropriate crop for rainfed farming in upland Baluchistan, and experimental results have demonstrated that barley yields, although low, average 20% higher than wheat under dryland conditions (ICARDA 1988, 1989). The purpose of this paper is to discuss the prospects for increased productivity through the introduction of improved barley varieties, in the context of the local crop-livestock system.

2. Climate, soils and land use.

The climate of upland Baluchistan has been described as continental semi-arid Mediterranean (Rafiq, 1976), characterized by low rainfall (200-350 mm), low humidity, dry winds, cold winters and hot summers. Figure 1 taken from Kidd et al. (1988) shows rainfall isohyets for the whole of Baluchistan; upland Baluchistan can be roughly equated with the 150 mm and above rainfall zones. Figure 2 maps the probability of receiving 300 mm or more rainfall in Baluchistan (gamma distributions were fitted to rainfall records for 104 stations standardized on the period 1901 to 1940). These exceedence probabilities are greater than 0.5 only in the north-east corner of Baluchistan; for most of upland Baluchistan the probabilities are between 0.1 and 0.3 (Kidd et al. 1988). Assuming that 300 mm represents the annual rainfall in a Mediterranean climate required to grow a reasonable crop of barley, this figure clearly illustrates the suboptimal nature of the climate of Baluchistan for

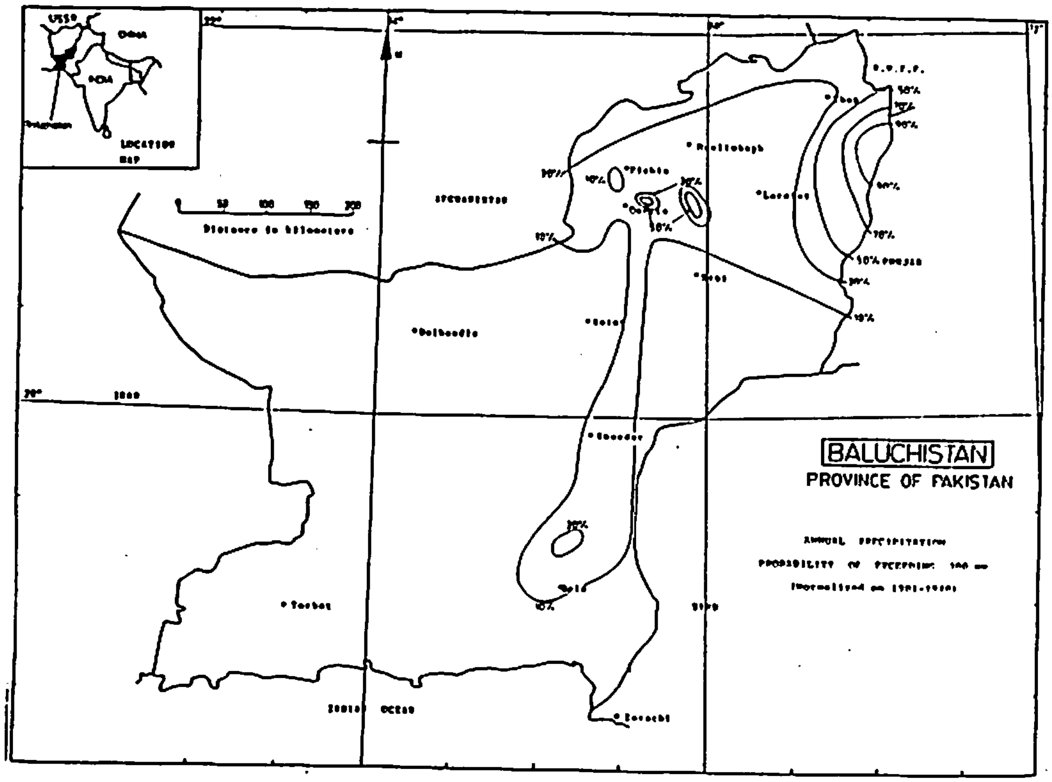

Figure 2. Probability of exceeding 300 mm annual average rainfall in Baluchistan, from Kidd et al. (1988).

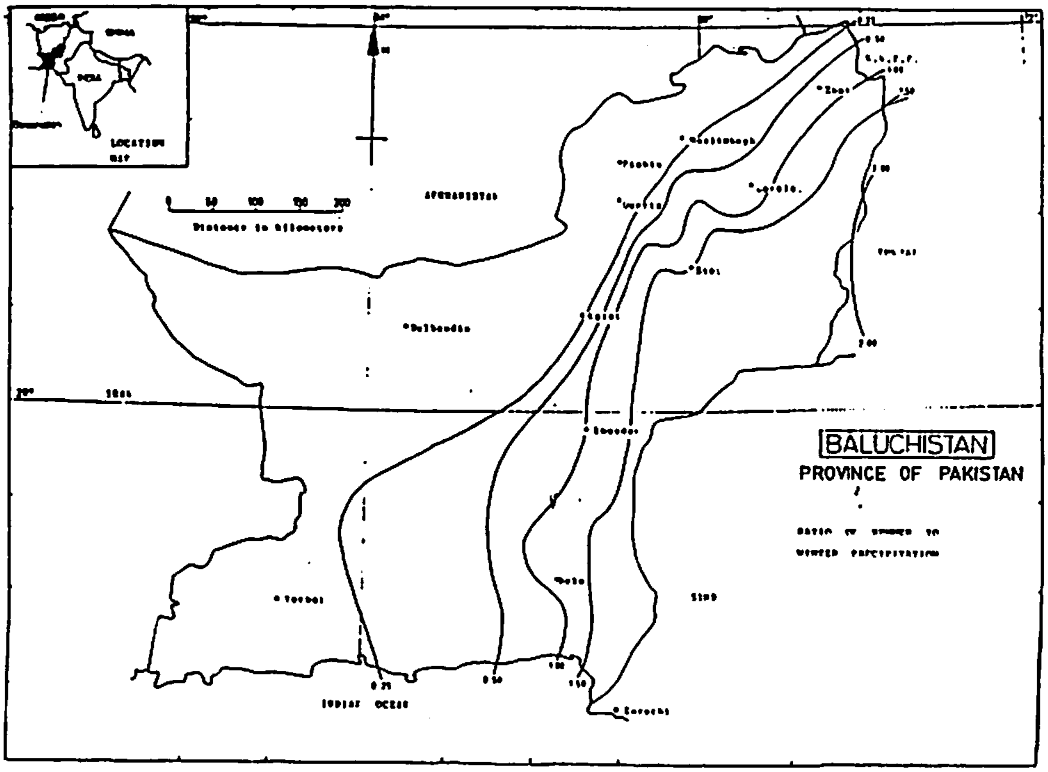

Figure 3. Ratio of summer to winter rainfall in Baluchistan, from Kidd et al. (1988).

barley or wheat production, with good crop yields likely only one to three years in ten.

The ratio of summer to winter rainfall in Baluchistan is mapped in Figure 3 (Kidd et al. 1988). The proportion of rain received during the summer months increases on a roughly north-east to south-west transect over a very narrow geographic range corresponding to the zone of increasing altitude. At Khuzdar, for instance, the median rainfall for summer and winter periods are 77 and 84 mm respectively, whereas at Quetta the corresponding figures are 16 and 185 mm. If summer rainfall occurs in July or August the dryland farmers delay planting until mid-September at high elevations (eg Quetta) and mid-October at lower elevations (eg Khuzdar) when average temperatures are 20-25 C. If no summer rainfall occurs the same local varieties are either planted into dry soil in October/November or planted after rain in early February, with harvest in May/June in both cases. As indicated above the probability of sufficient rainfall for autumn sowing is low over much of upland Baluchistan, for the Muslimbagh-Quetta-Kalat region autumn sowing can be expected 1 to 3 years in ten; whereas for the Loralai-Khuzdar region autumn sowing may occur 7 to 8 years in ten (Kidd et al. 1988).

Figure 4 shows the seasonal variability in rainfall at these two contrasting locations in upland Baluchistan, Quetta and Khuzdar. The 10-day total rainfalls are of very low dependability at both sites, but particularly at Khuzdar, emphasizing the skewed nature of the rainfall distribution - relatively few large rainfall events make up a considerable proportion of the total rainfall record. At both locations rainfall expectations are very low during the grain-fill period (April at Khuzdar, May at Quetta).

Temperature is highly dependent upon elevation; Figure 5 contrasts Khuzdar (1200 m above sea level) where frosts rarely occur, and Quetta (1650 m) where minimum temperatures can be expected to be below 0 C for up to three months of the year.

The soils of upland Baluchistan can be divided into two broad groups: the fine textured valley bottom soils (yermosols in the FAO system) and skeletal gravelly soils (lithosols) on the slopes of the hills and mountains. Table 1 presents chemical and physical data for selected valley bottom sites. All the soils are strongly calcareous with lime contents between 15 and 30%, low in organic matter, nitrogen and phosphate. The soils are predominantly loamy, silty and clayey, with textures ranging from sandy loams to silty clays. The more finely textured soils (ie. silt loams to clay loams) suffer from surface sealing when wet,

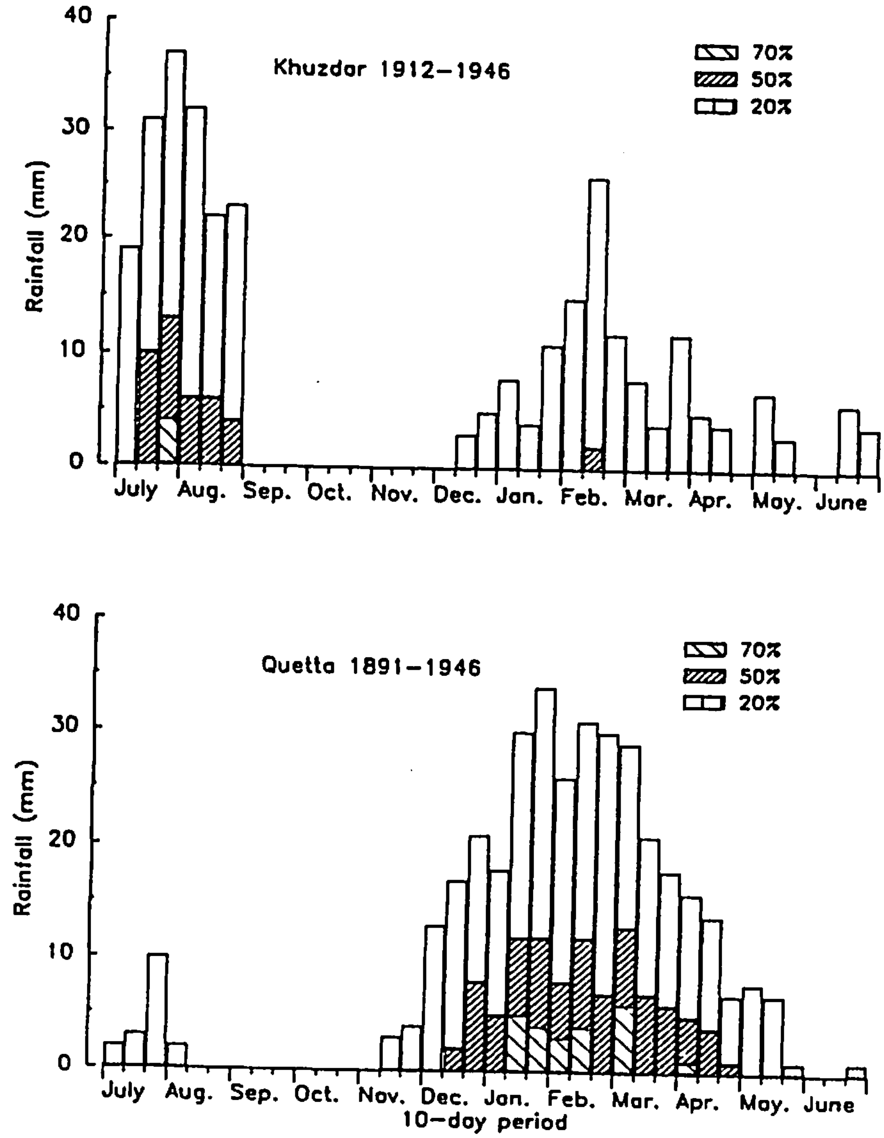

Figure 4. Ten day rainfall totals at 70%, 50% and 20% exceedence probabilities, Quetta and Khuzdar

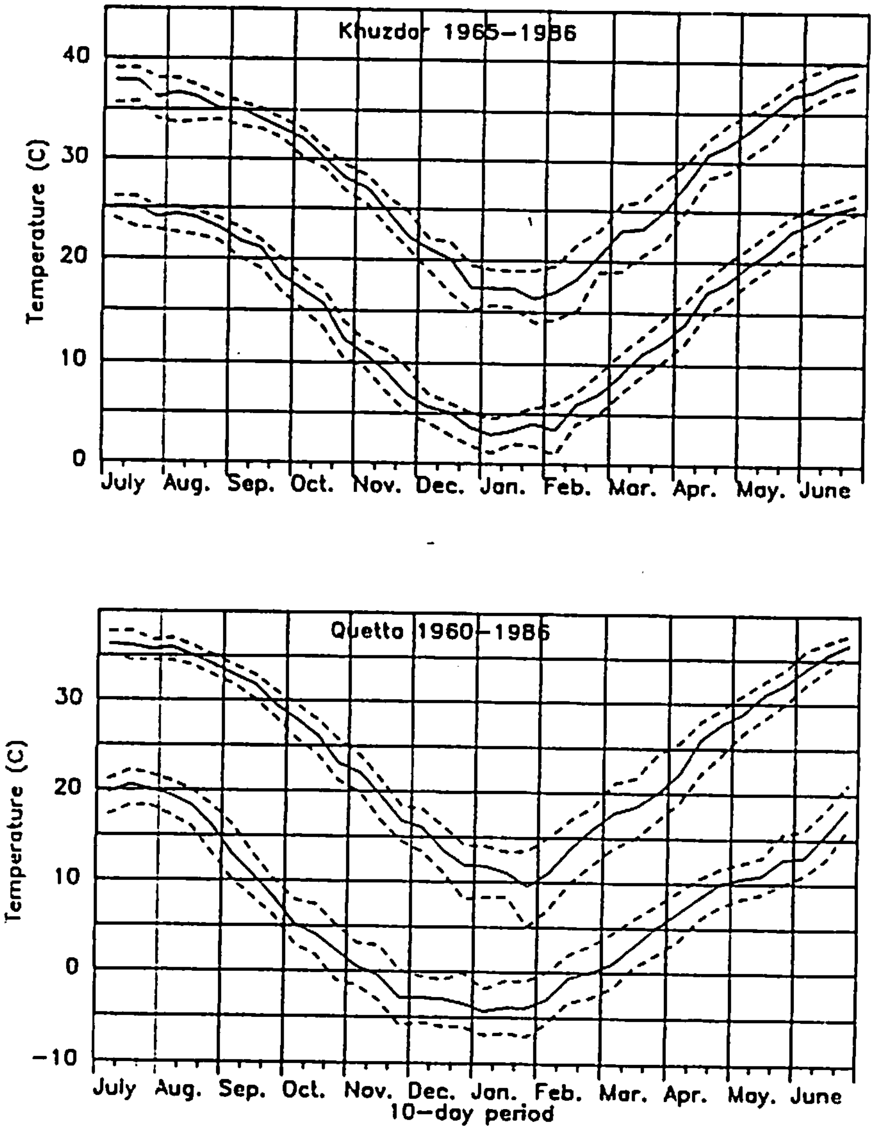

Figure 5. 25,50 and 75% maiximum and minimum 10-day temperatures, Quetta and Khuzdar.

Table 1. Soil chemical and physical characteristics from selected valley bottom soils of upland Baluchistan.

Location	pH (1:1)	Lime (%)	Olsen P (ppm)	O.M. (%)	Kjeld. N	Clay (%)	Silt (%)	Sand (%)	Text.
Maslakh	8.8	19.1	4.4	0.4	320	15.6	39.4	42.9	SL
Quetta	8.7	32.1	6.0	0.6	415	21.3	57.2	19.6	SiL
Dasht	8.4	21.9	6.6	0.7	595	30.0	59.2	9.7	SiCL
Mastung	8.9	22.9	4.4	0.4	262	14.2	51.9	32.1	SiL
Kovak	8.4	25.7	6.8	0.8	538	13.3	59.8	24.6	SiL
Khuzdar	8.4	25.7	6.4	0.5	417	28.4	44.7	25.2	CL

S - Sand; Si - Silt; L - Loam; C - Clay

resulting in low infiltration rates which can give rise to reduced crop emergence and waterlogging damage, particularly in fields which receive additional runon water.

Two types of dryland farming are distinguished by the farmers: 1. Farming pure rainfed land ("kushkaba" land); and 2. Farming land that receives runon water as well as rainfall ("sailaba" land). The additional runon water usually comes from ephemeral streams, but runon water from rock outcrops, roads, etc is also utilized.

3. Characteristics of dryland farmers of upland Baluchistan.

Tables 2 to 5 summarize some of the results of farmer surveys conducted by the Arid Zone Research Institute from 1986 to 1988 in key locations in upland Baluchistan where dryland agriculture is the predominant activity. All surveys were conducted with written questionnaires; the questionnaires were prepared in English but administered in the local languages of Brahui or Pashto. No attempt was made to contact the same farmers in different surveys.

It can be seen in Table 2 that rainfed land is the major land type owned or rented by the farmers, with much smaller holdings of the more productive "runon" land, and some access to irrigated land (mainly planted to orchards). Domestic and livestock water supplies are frequently at some distance from villages, up to 16 km away. Most farmers practice some form of storage of crop products for fodder, and barley straw, where grown, is predominantly stored for fodder. On average three quarters of the farmers use draft animals (camels or bullocks) for some or all of their plowing, and almost all farmers use draft animals for both planting and threshing. Most farmers own some sheep or goats, with overall average flock sizes of 22 sheep and 16 goats. The major feed source for their animals is rangeland grazing, of which over half is tribal, or communal land, and only 9% is privately owned. Most farmers classify rangeland as poor quality land which cannot be usefully cropped. Half of the sampled farmers migrate with their animals away from the upland areas during Winter to the lowland plains of Sibi and Kacchi, for the stated reasons of "no vegetation for grazing and low temperatures." Over half of the farmers own land in the lowland areas, but almost all stated that they would keep their livestock in the upland areas if there were better feed and water supplies.

The quality of herd management is fairly poor, with little or no control of rangeland grazing, considerable mortality and morbidity losses from diseases and pests, poor flock management and poor infrastructure (ICARDA 1989).

Table 3 shows the results of a survey where farmers were asked to classify years into "Good", "Normal" or "Poor" agricultural years, and describe their cropping practices in such years. Only two out of ten years were classified as "Good". This is in reasonable agreement with the probability estimates of annual rainfall exceeding 300 mm, which vary from one to three years in ten for the survey area (Kidd et al. 1988). Even in "Good" years average yield estimates of the farmers were only 300 to 400 kg ha^{-1}. As would be expected the area of land farmed decreased with decreasing year quality, and the farmers stated that they decreased the area of rainfed land planted to wheat, and increased the area planted to barley as year quality decreased. There was however no consistent pattern in their farming of "runon" land . Farmers' yield estimates from "runon" land were twice those from rainfed land, but interestingly the farmers apparently perceive barley as a poorer-yielding crop than wheat. This has not been supported by agronomic experiments conducted by the Arid Zone Research Institute on farmers' fields using the local wheat and barley varieties (ICARDA 1988, 1989); indeed the reverse has been found with the local barley yielding roughly 20% more than the local wheat. Farmers' estimates of the proportion of their income that comes from activities other than dryland agriculture increased from an average of 12% in "Good" years to over 50% in "Poor" years.

Table 2. Characteristics of dryland farmers of upland Baluchistan. (200 farmers interviewed in Khuzdar, Kalat, Kovak, Dasht and Tomagh valleys, 1987.) From Nagy and Sabir (1988).

	Ave.	S.D.	Range
Area of upland land owned (ha)			
Rainfed	16	33	1-280
"Runon" land	2	2	0-4
Irrigated	1	4	0-24
Area of upland land rented in (ha)			
Rainfed	23	48	0-324
"Runon" land	0	0	0
Irrigated	2	2	0-6
Distance to water (km)	9	48	0-16
Percentage of farmers who:			
Store crops for fodder every year	80	-	59-100
Store barley grain for fodder	15	-	10-23
Store barley straw for fodder	64	-	37-75
Store wheat straw for fodder	13	-	3-45
Percentage of farmers who:			
Use tractors for plowing	36	-	13-63
Use draft animals for plowing	76	-	23-100
No. of sheep owned	22	33	0-210
No. of goats owned	16	33	0-290
Control of rangeland (%):			
State	4	-	0-22
Tribal	57	-	19-79
Private	9	-	0-19
Farmers perception of rangeland (%):			
Good	12	-	0-22
Poor/Uncultivable	87	-	41-100
Farmers who move livestock to lowlands in winter	47	-	16-75
Reason for moving livestock (%):			
No vegetation	33	-	3-59
Too cold	10	-	0-20
Both	50	-	23-77
Would keep livestock in uplands if sufficient feed and water	97	-	92-100
Farmers who own land in lowland areas	64	-	50-100

Table 3. Farmers' perceptions of area planted, yields and off-farm income by type of year. (80 farmers interviewed from Dasht, Mastung, Kalat and Khuzdar valleys). From Rees et al. (1988).

	Good	Normal	Poor
Good, normal or poor agricultural years in ten	2	4	4
Total land cropped (ha)	13	11	5
Rainfed land planted to wheat (%)	73	70	64
Rainfed land planted to barley (%)	21	24	31
"Runon" land planted to wheat (%)	78	76	84
"Runon" land planted to barley (%)	14	16	16
Rainfed land wheat yields (t ha^{-1})	0.4	0.3	0.1
Rainfed land barley yields (t ha^{-1})	0.3	0.3	0.0
"Runon" land wheat yields (t ha^{-1})	0.8	0.6	0.3
"Runon" land barley yields (t ha^{-1})	0.5	0.4	0.2
Off-farm income (%)	12	30	55

Nearly all farmers interviewed listed rust disease as a major problem for wheat and barley (Table 4) probably because there have been two major epidemics of Yellow Rust (Puccinia striiformis) in the last decade. Bird and insect pests were the other two major problems listed. In general most farmers considered that these production problems were slightly less important in barley than wheat.

Table 5 describes farmer practices of grazing or cutting barley and wheat for green fodder in the vegetative stage (November/ December), grazing or cutting for hay or green fodder after flowering (April/ May), or harvesting the seed and straw of the mature crops. Well over half the farmers interviewed stated that they cut/ grazed both crops at the vegetative phase, but few cut/ grazed wheat after flowering. A higher proportion (28%) stated that they cut barley after flowering. Note that over all three years only 73% stated that they were able to harvest a mature wheat crop, and only 50% say that they were able to harvest a mature barley crop. In almost all cases the crops were cut for animal fodder; only 6% stated that they sold the cut crop products in the market.

Table 4. Farmers perceptions of production problems with wheat and barley. (31 farmers in Khuzdar, Quetta, Pishin, Loralai and Zhob districts). From Nagy et al. (1989).

Problem	Wheat	Barley
Rust	94	77
Birds	81	74
Insects	70	65
Smut	65	27
Other *	33	27
Emergence	19	19
Lodging	0	0

* Other - Porcupine, mouse, hare, etc.

Table 5. Percentage of farmers who cut/graze wheat or barley crops in Nov/Dec (vegetative stage); cut/graze in April/May (flowering to milk-dough stage); or harvest the mature crops. (31 farmers in Khuzdar, Quetta, Pishin, Loralai and Zhob districts). From Nagy et al. (1989).

	1987/8		1986/7		1985/6		Average	
	W	B	W	B	W	B	W	B
Nov/Dec green fodder	61	52	97	81	65	55	74	63
April/May hay	0	16	3	39	7	29	3	28
May/June harvest	65	39	94	92	61	23	73	51

	Animal fodder	Market sale
Reason for cutting crops	94	6

	Sick	Young	Pregnant	All
Animals receiving fodder	3	7	0	90

Wheat grain and straw generally attracts a slightly higher price than barley. "Farm-gate" prices of wheat and barley seed as stated by the farmers in 1988 were R 238 and R 235 per 100 kg respectively, and prices of wheat and barley straw were R 200 and R 175 per 100 kg respectively (Nagy et al. 1989). (December 1988 conversion rate is US$ 1 = R 18.6.) 1987/88 was an extremely poor agricultural year, and these prices are much higher than those stated in the previous, good agricultural year: R 200 and 175 per 100 kg seed of wheat and barley respectively; and R 50 per 100 kg of straw for both crops (ICARDA 1988). When asked why they did not grow more barley farmers stated: 1. They used their resources to grow wheat for food security; 2. The market for barley is poor in terms of their ability to sell their product; and 3. Most of the available land resources are used in the production of wheat (Nagy et al. 1989). Farmers were also asked how big an increase a new barley variety would have to provide, or how much the barley price would have to be increased by, before they would expand the area planted to barley at the expense of wheat; the majority answer was between 50 and 100% (Nagy et al. 1989). Little accuracy can be attributed to these figures, but they certainly indicate that farmers are unlikely to increase barley hectarage at the expense of wheat in the foreseeable future.

The data presented above indicates that farming in upland Baluchistan comprises a fairly diverse range of activities including dryland field crop, livestock and some irrigated fruit/horticulture. The level of management in all these activities is fairly low, a reflection of the low expected returns. Clearly there is considerable scope for improvement in all these activities. For barley in particular there are a number of ways in which production could be improved: 1. Identification of a higher-yielding general purpose variety; 2. identification of a drought-resistant short season variety suitable for spring planting; 3. Incorporation of rust resistance into the "improved" varieties. The potential for improved growth by fertilizer addition does not seem high for rainfed crops, but may have some role on "runon" land. The claim that barley yields less than wheat in an environment apparently better suited to barley emphasizes the need for an accurate base-line data set on barley growth in upland Baluchistan under realistic, but carefully monitored conditions on farmers' fields.

4. The performance of the local and "best-bet" barley variety introductions in upland Baluchistan.

The farmers of upland Baluchistan clearly prefer to grow wheat rather than barley, and actually perceive it is as a poorer-yielding crop than wheat. With this in mind a barley production trial on farmers' fields was initiated with the objectives of: 1. Providing a reliable base-line data set of barley growth and yield under farmer conditions; and 2. Simultaneously evaluating the possibility of increased barley production by the introduction of new varieties and/or the use of fertilizer.

Tables 6 to 8 and Figures 6 to 9 summarize the results of the trial conducted on farmers' fields at multiple locations in upland Baluchistan (Dasht, Mastung, Kovak, Kalat,

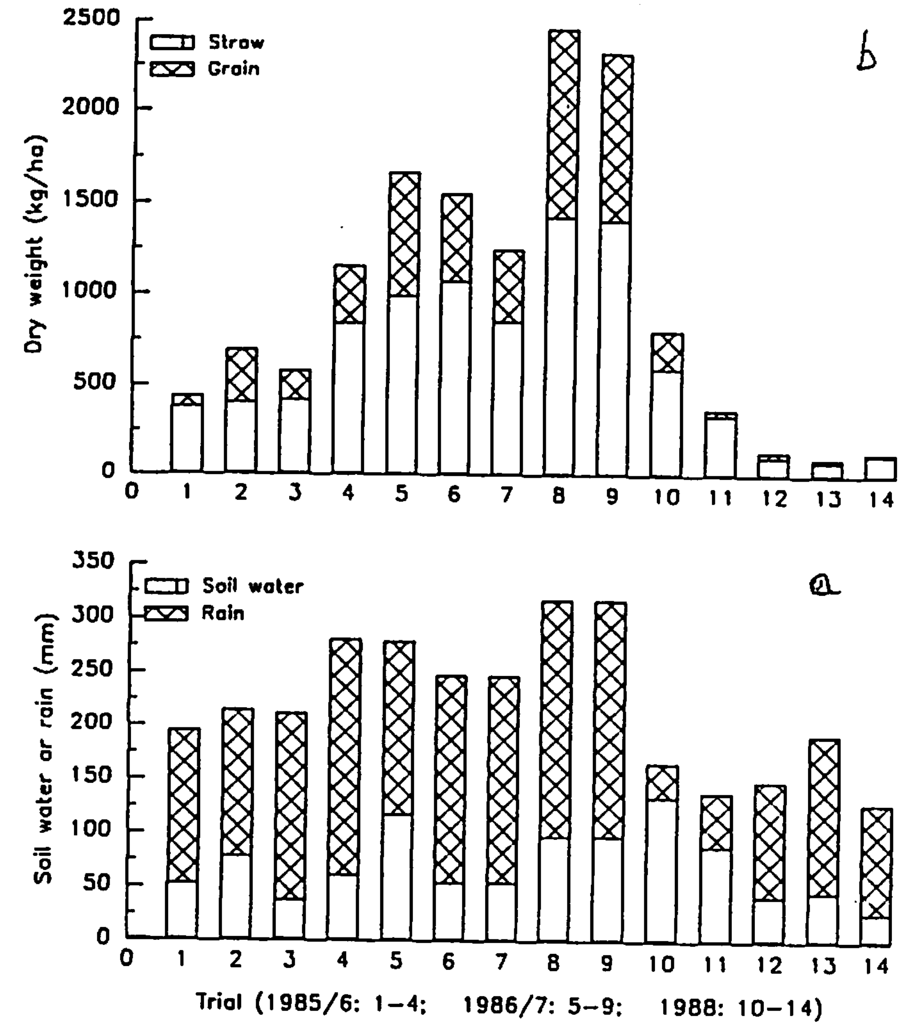

Figure 6 a. Soil water to 1m depth at planting and total rainfall during growing season; b. Trial mean straw and grain dry weights.

Khuzdar) from 1985/86 to 1987/88 (ICARDA 1988, 1989). In Dasht the trial was repeated on both rainfed and "runon" land in 1985/86 and in 1987/88. Summer rainfall did not occur in 1985/86 and the trials were dry-planted in October 1985. In 1986/ 87 crops were sown into moist soil in September and in the Dasht and Kovak trials half of each plot was cut in early December, to evaluate the effects of this local farmer practice on final yields. 1987/88 was an extremely dry year throughout Baluchistan and a pre-planting irrigation was applied at two locations where some irrigation water was available (Khuzdar and Kalat). This practice is fairly common amongst farmers who have access to sufficient water for irrigation. Trials were sown in early February. Plot size was 12x2 m; the seed rate was 90 kg ha^{-1}; and the local row spacing of 35 to 40 cm was used.

In each location the barley variety local to that area was used as a control. All experiments were planted as 2-factor factorial randomized complete blocks with three replicates at each location. 10 kg ha^{-1} of N and 60 kg ha^{-1} of phosphate were sown with the seed at planting, and a further 30 kg ha^{-1} N was top-dressed at tillering. Fertilizers used were ammonium nitrate (26% N) and triple super-phosphate (46% phosphate). Soil water at planting was sampled gravimetrically at 6 locations in each trial to 1 m depth. Bulk densities were sampled at three positions in each location and found to average 1.4 g cm^{-3}, with little difference between locations (ICARDA 1989). Rainfall was recorded at each location.

Potential hay production was estimated by measuring total above ground dry weight at the milk-grain stage from two 1 m row samples from each plot. Final straw and grain yields were estimated by sampling the two center rows in their entirety.

Annual rainfall totals varied with site from 138 to 206 mm in 1985/86, 254 to 780 mm in 1986/87, and 32 to 147 mm in 1987/88. Figure 6a shows the measured soil water to 1 m depth at planting and rainfall recorded during plant growth for all trials. Soil water at planting varied from 26 to 133 mm. Rainfall during crop growth varied from 32 to 220 mm. Figure 6b shows the trial mean straw and grain dry weights for all varieties without fertilizer for all 14 trials, which varied from 79 to 1400 kg ha^{-1} for straw, and from 17 to 1000 kg ha^{-1} for grain.

Table 6 summarizes crop production over all 14 trials. Using the 1986/87 fertilizer cost of 516 R ha^{-1} it is clear that although fertilizer increased all aspects of biological yield, the increases were not sufficient to pay for the fertilizer. In 1986/87, the high rainfall year (return period of such a high rainfall year is about 1 in 15 years), straw and seed yields were increased by 245 (19%) and 128

(16%) kg ha^{-1} respectively. Even in this year the increased gross benefits (347 R ha^{-1}) were not sufficient to pay for the fertilizer applied. It is apparent that at the moisture levels to be expected in dryland agriculture in upland Baluchistan barley responses to fertilizer are unlikely to be economic.

Table 6. Average crop production over all trials.

A. Without fertilizer.

Variety	Hay dry weight (kg/ha)	Straw dry weight (kg/ha)	Grain dry weight (kg/ha)	Total dry weight (kg/ha)	Gross benefits (R/ha)
LB7	1108 b	629 a	324 ab	953 ab	882 ab
W.Hassa	1215 ab	563 a	324 ab	887 b	848 b
Tadmor	1121 b	585 a	348 ab	933 ab	902 ab
A.Aswad	1237 ab	577 a	334 ab	911 ab	873 ab
A.abiad	1594 a	754 a	378 a	1132 a	1039 a
Local	1369 ab	736 a	289 b	1025 ab	874 ab
Mean	1274	641	333	974	903
SE.	124	63.2	24.8	71.0	57.1

B. With fertilizer.

Variety	Hay dry weight (kg/ha)	Straw dry weight (kg/ha)	Grain dry weight (kg/ha)	Total dry weight (kg/ha)	Gross benefits (R/ha)
LB7	1360 a	712 c	417 a	1129 ab	1086 a
W.Hassa	1198 a	633 c	381 ab	1014 b	983 a
Tadmor	1488 a	741 bc	406 ab	1147 ab	1082 a
A.Aswad	1364 a	696 c	382 ab	1078 ab	1016 a
A.abiad	1606 a	878 ab	363 ab	1241 a	1074 a
Local	1327 a	922 a	311 a	1233 ab	1005 a
Mean	1390	764	377	1140	1041
SE.	152	55.8	32.8	70.6	69.1

Hay dry weight - above ground biomass at "milk grain" stage.
Total dry weight - above ground weight at crop maturity.
Gross benefit - calculated using 1986/87 prices of R 1.75 per kg grain and 0.5 R per kg straw.

a,b,c - means with different letters differ significantly at $P < 0.05$ (Duncan's multiple range test).

Total above ground dry weight at maturity averaged 30% less than total above ground dry weight at the milk-grain stage, a reflection of the rainfall pattern and frequent water stress during the grain-filling stages discussed above (Figure 5). All the exotic varieties produced higher seed yields overall than the local, but only in the case of "Arabic abiad" without fertilizer were the differences statistically significant (Table 6). Comparing varieties without fertilizer addition, only "Arabic abiad" produced greater total above ground dry weight at maturity than the local check - all the other varieties produced less straw than the local. Similarly "Arabic abiad" produced 20% more "hay" than the local check, whereas the other varieties all produced less than the local.

Figure 7 shows modified "stability analyses" after Eberhardt and Russell (1966): the trial mean value of total dry weight, seed yield etc is taken to be an "environmental index" against which values of each variety can be plotted using least-squares linear regression. Low trial mean values are assumed to reflect a harsh environment, whilst high values are taken to indicate good environments. Figure 7 shows examples in which gross benefits have been used as a convenient way in which to add grain and straw together in an appropriately weighted fashion, and the trial means of the treatments without fertilizer have been used as "environmental indices". It can be seen that the regression line for "Arabic abiad" exceeds that of the local for all "environments" greater than 160 R ha^{-1}, ie. all except the most extreme in which crop failure would be assured. Figure 7b shows that the line for "Arabic aswad" hardly differs from that of the local check - the greater grain production is offset by the lesser straw production.

Similar graphs were produced for all crop yield parameters with and without fertilizer and Table 7 presents a summary of the regression analyses for selected yield parameters. Considering the treatments without fertilizer, only "Arabic abiad" produced a slope significantly greater than that of the local check for gross benefits or for "hay" production. Fertilizer addition increased slopes in almost all cases; interestingly the increase in slope was greater for the local than for "Arabic abiad" indicating a greater fertilizer response (see Table 6 also). When fertilizer was added the slopes for the varieties "LB7" and "Tadmor" were significantly greater than the local, but the Y-axis intercept for "LB7" was also considerably reduced. The data indicate that when fertilizer is applied "LB7" will produce higher gross benefits only when the "environmental index" is greater than 684 R ha^{-1}, whereas "Tadmor" will produce higher gross benefits than the local when the "environmental index" is greater than 57 R ha^{-1}. As fertilizer application is not economic this information is of academic interest only, but may be of use if other interventions, aimed at

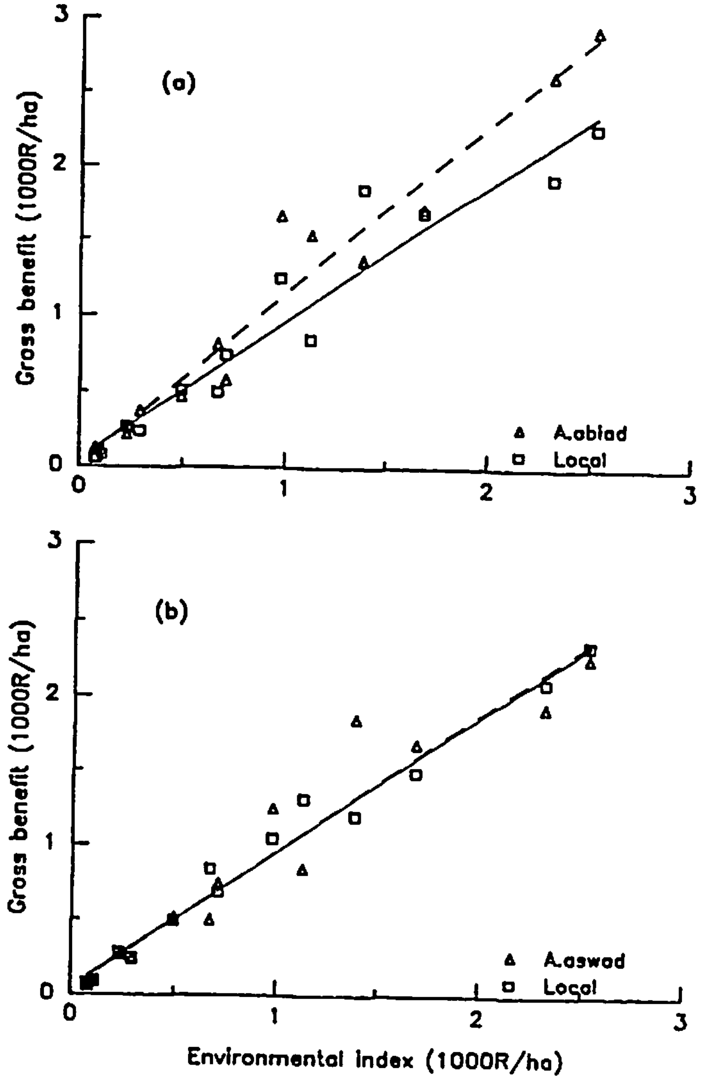

Figure 7. Relationships between individual variety gross benefit and trial mean gross benefit ("environmental index").

improving water harvesting efficiency, prove to be successful and acceptable to farmers (ICARDA 1989).

One weakness of the above analysis is that the "environmental index" is not completely independent of the individual variety values. Figure 8 shows an alternative: a very good linear relationship between a "water availability index" (calculated as the sum of the soil water available at planting plus the rainfall received during crop growth) versus total above ground dry weight at crop maturity was found. This "water availability" can be used as an independent estimator of environmental variability. The total water calculated in this way is not all available to the crop, as some of the soil water will be held at tensions

Table 7. "Stability analyses" after Eberhardt and Russell (1966) - linear regressions of individual variety parameters against overall site means of treatments without fertilizer.

		- Fertilizer			+ Fertilizer		
Above-ground dry weight at maturity (kg ha^{-1})							
Variety	N	r	b	a	r	b	a
LB7	14	0.94	0.99	-7	0.95	1.33	-164
Wadi Hassa	14	0.97	0.90	6	0.93	1.03	16
Tadmor	14	0.96	1.05	87	0.98	1.26	-81
Arabic aswad	14	0.93	0.84	95**	0.97	1.04	66**
Arabic abiad	14	0.96	1.17	-4	0.99	1.29	-19
Local	14	0.99	1.06	-4	0.98	1.26	7
Hay (biomass at milk-grain stage) dry weight (kg ha^{-1})							
Variety	N	r	b	a	r	b	a
LB7	14	0.94	0.85	21	0.96	1.01	80
Wadi Hassa	14	0.96	1.01	-69	0.91	0.75	248
Tadmor	14	0.96	0.94	-76	0.93	1.44	-334
Arabic aswad	14	0.96	0.90	93	0.97	0.91	204
Arabic abiad	14	0.97	1.48**	-292	0.95	1.34**	-100
Local	14	0.85	0.82	327	0.73	0.70	436
Gross benefit (R ha^{-1})							
Variety	N	r	b	a	r	b	a
LB7	14	0.97	1.01	-26	0.96	1.44**	-210
Wadi Hassa	14	0.99	0.94	-4	0.94	1.08	11
Tadmor	14	0.97	1.09	-79**	0.98	1.28**	-76
Arabic aswad	14	0.96	0.92	41	0.98	1.11	18
Arabic abiad	14	0.98	1.13**	16**	0.99	1.23	33
Local	14	0.99	0.91	52	0.97	1.06	50

** - Linear regressions for each variety were compared with those for the local variety (control). Slopes (b) and X-axis intercepts (Xo) marked with ** differ significantly from the control values at $P < 5\%$.

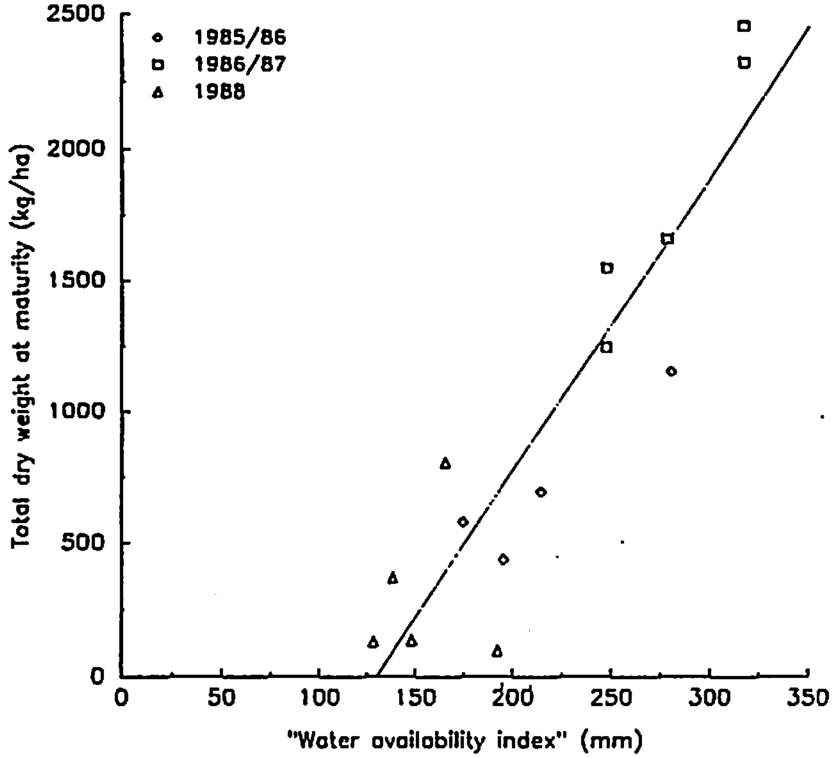

Figure 8. Relation between trial mean total dry weight at maturity (-fertilizer treatments) and "water availability". $y = 11.2(x-130)$ $r = 0.915$

below -1.5 MPa, and some of the rain would evaporate before the crop could use it. However the slope of the line, 11.2 kg $ha^{-1}mm^{-1}$, does represent the water use efficiency of the crop. Cooper et al. (1987) quote water use efficiencies for unfertilized barley of 14 to 20 kg $ha^{-1}mm^{-1}$ in northern Syria, but they subtracted estimates of soil evaporation during the crop season from the total water use to arrive at these values. Cooper, Keatinge & Hughes (1983) show that for the environments of northern Syria soil evaporation could be 38% of total evapotranspiration for barley and even higher for wheat. Reducing their values by 0.38 gives values of 9 to 14 kg $ha^{-1}mm^{-1}$, in good agreement with the value of 11.2 calculated for upland Baluchistan.

Figure 9 shows examples of the relations between "water availability" and gross benefit. Table 8 summarizes regression analyses for selected yield parameters versus the "water availability index". Crop water use efficiencies for total dry weight for the different varieties varied from 9 to 14 kg $ha^{-1}mm^{-1}$; for grain production from 3 to 7 kg $ha^{-1}mm^{-1}$ and for hay from 11 to 20 kg $ha^{-1}mm^{-1}$. The slope of the relationship between gross benefit and "water availability" varied from 10 to 16 R $ha^{-1}mm^{-1}$. The slope for "Arabic abiad" was consistently higher than that for the local for all attributes. Addition of fertilizer generally increased water use efficiencies as reported by Cooper et al. (1988).

The X-axis intercepts (Xo) can be interpreted as the minimum "water availability" below which no grain, straw, gross benefit, etc will be produced. None of the differences in intercepts between varieties were statistically significant, but note that the average intercept for total dry weight at maturity is 127 mm compared to 147 mm for grain, indicating that some straw may be produced at very low water availabilities, but an additional 20 mm is required before any grain may be produced.

5. Discussion

The results presented here show that in initial trials in a "Normal", a "Wet" and a "Dry" year in upland Baluchistan fertilizer use (nitrogen and phosphate) increased crop yields but not sufficiently to pay for the fertilizer, even in a "wet" year. Without fertilizer the variety "Arabic abiad" demonstrated a greater "environmental stability" and a greater water use efficiency than the local check, resulting in an overall 30% increase in grain production, without any loss in straw production (19% increase in gross benefits). This variety also produced 16% greater "hay" production if the crop was cut at milk-grain stage.

Above-ground dry weights generally decreased from flowering to maturity, a result of the rainfall pattern in upland Baluchistan, suggesting that productivity could be improved if the crops were grown for hay rather than for seed and straw. Only about 28% of farmers cut barley in this way, and only 3% cut wheat, and very few sell the cut crops, so it is difficult to find a "farm-gate" price that accurately represents the comparative value of barley hay as opposed to seed and straw. However, 1986/87 market prices

Table 8. Linear regressions of individual variety parameters against "water availability index" (see text): y = b(X−Xo).

		− Fertilizer			+ Fertilizer		
Above-ground dry weight at maturity (kg ha^{-1})							
Variety	N	r	b	Xo	r	b	Xo
LB7	14	0.84	10.1	125	0.87	14.1	139
Wadi Hassa	14	0.91	9.8	129	0.78	9.9	117
Tadmor	14	0.85	10.7	132	0.87	12.9	130
Arabic aswad	14	0.90	9.3	121	0.90	11.0	122
Arabic abiad	14	0.94	13.1	133	0.92	13.3	127
Local	14	0.90	11.1	121	0.90	13.3	127
Grain dry weight (kg ha^{-1})							
Variety	N	r	b	Xo	r	b	Xo
LB7	14	0.89	4.54	148	0.86	6.73**	157
Wadi Hassa	14	0.88	4.35	145	0.78	4.75	139
Tadmor	14	0.86	4.91	149	0.85	5.65	147
Arabic aswad	14	0.89	4.59	146	0.85	5.07	144
Arabic abiad	14	0.94	5.20**	147	0.86	5.07	148
Local	14	0.91	3.61	139	0.82	3.71	136
Hay (biomass at milk-grain stage) dry weight (kg ha^{-1})							
Variety	N	r	b	Xo	r	b	Xo
LB7	14	0.85	11.5	123	0.84	13.1	116
Wadi Hassa	14	0.81	12.7	123	0.74	9.1	88
Tadmor	14	0.80	11.8	124	0.77	17.8	136
Arabic aswad	14	0.85	11.9	115	0.82	11.4	100
Arabic abiad	14	0.88	20.0**	140	0.80	16.8	124
Local	14	0.80	11.4	99	0.79	11.3	102
Gross benefit (R ha^{-1})							
Variety	N	r	b	Xo	r	b	Xo
LB7	14	0.88	10.7	137	0.87	15.5	149
Wadi Hassa	14	0.91	10.3	137	0.80	10.9	129
Tadmor	14	0.86	11.5	141	0.87	13.5	139
Arabic aswad	14	0.91	10.4	135	0.89	11.9	134
Arabic abiad	14	0.95	13.1*	140	0.90	13.2	138
Local	14	0.92	10.0	132	0.87	11.3	130

** − Linear regressions for each variety were compared with those for the local variety (control). Slopes (b) and X-axis intercepts (Xo) marked with * differ significantly from the control values at P < 10% and with ** at P < 5%.

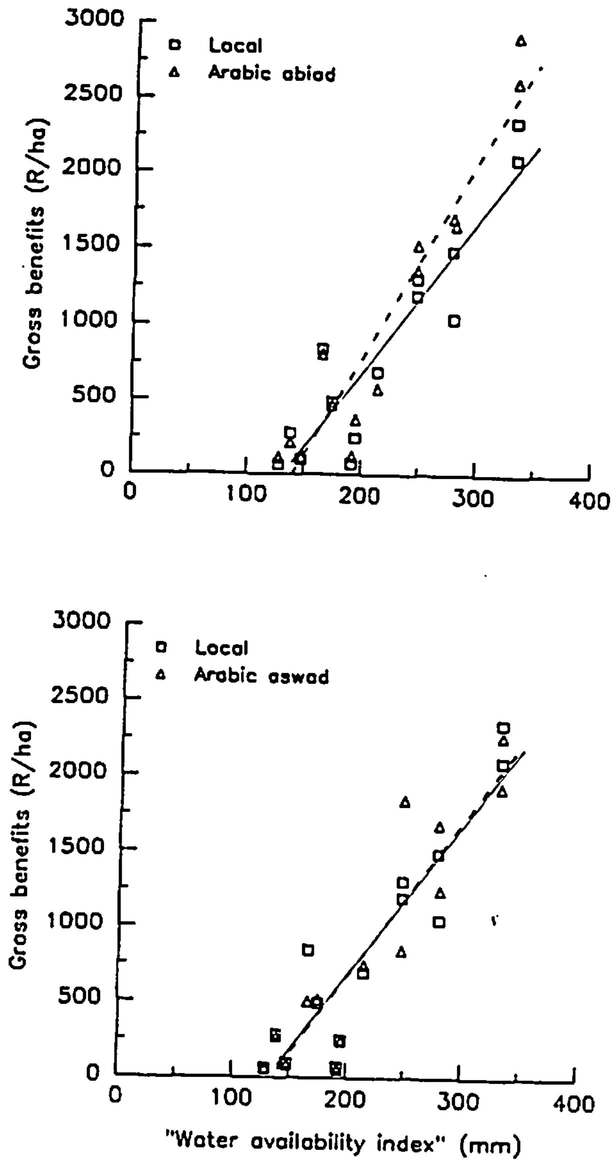

Figure 9. Relations between variety mean gross benefits and "water availability index" (soil water at planting + total rainfall during crop growth).

for green fodder (sold for transport draft animals) were 1 R kg^{-1} for fresh material, compared to 2.5 and 1 R kg^{-1} for barley seed and straw. Assuming a moisture content of 60% this gives a value of 2.5 R kg^{-1} dry weight for hay, giving a potential gross benefit of over 3000 R ha^{-1}, more than 3 times that for seed and straw. This is of course speculative as farmers do not currently sell their dryland crop-cuts, but does suggest that growing barley for hay may improve farmers' incomes.

The variety "Arabic abiad" may be more resistant to rust disease than the local but this has not been conclusively demonstrated. More extensive testing of "Arabic abiad" seems warranted, with a view to encouraging farmers to use it in place of the local material; but clearly there is still scope for considerable improvement by the identification of both general purpose and spring-planting drought resistant varieties that also incorporate resistance to rust disease. The use of fertilizer does not seem justified at this time, but if current research on improved water harvesting techniques proves successful and acceptable to farmers (ICARDA 1988, 1989) and the amount of water available to crops is increased, fertilizer responses may also be increased.

Government of Baluchistan statistics indicate that the area of land sown to wheat is more than 20 times that sown to barley. Farmers apparently perceive barley as a poorer yielding crop than wheat, but the principal reason that they grow wheat is for food security. The improved seed yield and gross benefits of "Arabic abiad" are unlikely to encourage many farmers to switch from dryland wheat to barley production even though barley consistently outyields wheat in agronomic trials. If "Arabic abiad" continues to do better than the local in more extensive trials it is to be hoped that this variety will be adopted in place of the local barley, but this will not have a large impact on overall productivity. Better barley production may encourage some change to better managed feeding regimes with a greater emphasis on crop products, but other changes to the whole crop-livestock system, such as improved water harvesting techniques, development of water resources, prophylactic animal health care to enable animals to utilize feed more efficiently, better flock management, etc, will be almost certainly be required before the farmers will make any major shift away from growing poor crops of wheat for subsistence to growing better yielding crops of barley for improved livestock production. ICARDA and the Arid Zone Research Institute are currently involved in research on all these topics and a reasonable potential for profitable change has been demonstrated (ICARDA 1989), as demonstrated here for the case of barley.

References

Cooper, P. J. M., Keatinge, J. D. H. and Hughes, G. 1983. "Crop evapotranspiration - A technique for calculation of its components by field measurements." Field Crops Research 7, 299-312.

Cooper, P. J. M., Gregory, P. J., Tully, D. and Harris, H. C. (1987). "Improving water use efficiency of annual crops in the rainfed farming systems of West Asia and North Africa." Experimental Agriculture 23, 113-158.

Eberhart, S. A. and Russell, W. A. (1966). "Stability parameters for cropping varieties." Crop Science 6, 36-40.

Government of Baluchistan (GOB). Various years. "Agricultural Statistics of Baluchistan." Directorate General of Agriculture Department, Quetta.

ICARDA (1987). "High-elevation research in Pakistan: The MART/AZRI project. Annual report for 1986." Research Report 110, ICARDA, Aleppo. 26 pages.

ICARDA (1988). "High-elevation research in Pakistan: The MART/AZR Project. Annual report for 1987." Research Report 127, ICARDA, Aleppo, Syria. 103 pages.

ICARDA (1989). "Small ruminant production and its sustained improvement in upland Baluchistan. Ann. Report for 1988." Research Report XXX, ICARDA, Aleppo. 83 pages.

Kidd, C. H. R., Rees, D. J., Keatinge, J. D. H., Rehman, F., Samiullah, A. and Raza, S. H. (1988). "Meteorological data analysis of Baluchistan." MART/AZR Research Report 19, ICARDA, Quetta. 60 pages.

Nagy, J. G., Sabir, G. F., Khan, S., Shah, N. A. and Afzal, M. (1989). "Barley in the rainfed farming system of upland Baluchistan." MART/AZR Research Report XXX, ICARDA, Quetta. 24 pages.

Rafiq, M. (1976). "Crop ecological zones of nine countries of the Near East region." FAO, Rome.