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RAIN-FED CROP PRODUCTION SYSTEMS OF UPLAND BALOCHISTAN
1. WHEAT (TRITICUM AESTIVUM)

by

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Short title: Rain-fed wheat in upland Balochistan

Rain-fed crop production systems of upland Balochistan

1. Wheat (*Triticum aestivum*).

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SUMMARY

This is the first in a series of articles evaluating crop production and its potential for improvement in upland Balochistan. The results of three years' trials on improved wheat management under rainfed conditions on farmers' fields are presented. Annual rainfall varied from 30 mm to over 350 mm with site and season.

The water use efficiency of the local wheat land-race was 8.7 kg ha^{-1} mm^{-1}, similar to other values reported for wheat. The wheat varieties recommended for irrigated conditions in upland Balochistan did not give substantially higher production than the local land-race, and in 1986/87 the "good" rainfall year, suffered considerable cold damage and gave substantially less yield.

Application of phosphate and potassium fertilisers had little effect on yields. In 1986/87 application of

nitrogen fertiliser increased straw and seed yields of the local land-race by 29% and 24%, respectively, but averaged over all trials the increased crop value was only 80 R ha^{-1} greater than the increased cost of production, and returns to labour were slightly reduced. Weeding also had little effect on crop yields.

Net returns for wheat production and returns for labour were low and variable, varying from negative values to 1042 R ha^{-1}, and from negative values to 12 R $hour^{-1}$, respectively, averaging only 304 R ha^{-1} and 2.3 R $hour^{-1}$.

In the arid conditions of upland Balochistan the economic net benefits and returns to labour of wheat production under rain-fed conditions are low and highly variable. Substantial improvements in wheat productivity are unlikely unless crop water availability can be increased on a sustainable basis. The case for encouraging a change to alternative crops is presented in the subsequent articles of this series.

INTRODUCTION

Wheat is a main component of the cropping systems of West Asia and North Africa, supplying 40% of calories and protein in the "average" diet (Oram, 1988) and an even higher proportion (72%, CIMMYT, 1989) in Pakistan. The introduction of high-yielding varieties, increased fertiliser use and better management practices have resulted in an increase in Pakistan's national wheat yields of 142% from 1966 to 1986 (CIMMYT, 1989).

Wheat is the major rain-fed crop grown in upland Balochistan, but yields are low and over 80% of the crop is consumed on-farm, indicating the primarily subsistence nature of dry-land farming in this area (Buzdar et al., 1989). The region has a semi-arid continental climate, with annual rainfall varying from 50 to 400 mm, cold winters and hot summers (Rafiq, 1976). The farmers expect three to five years out of ten to be poor for crop production, with yields of only 100 to 200 kg ha^{-1}, and even in "good" years (two to three years in ten) yield expectations are only 400 to 800 kg ha^{-1} (Rees et al., 1988). In this high-risk environment agricultural inputs are minimal, with only 50% of farmers using tractors for ploughing, no fertiliser use, the use of un-improved seed and the use of animal traction for planting and threshing (Buzdar et al., 1989).

The demand for increased crop production in West Asia and North Africa is expected to lead to increased cropping on marginal lands (Oram, 1988). Upland Balochistan is a typical example of large areas of Afghanistan, Iran and Pakistan where such cropping on marginal lands is currently practised and is expected to increase in the future.

The success of high yielding varieties and increased fertiliser use in other rain-fed areas of Pakistan, West Asia and North Africa has led to considerable interest in testing new varieties and fertiliser application even in the marginal environment of upland Balochistan (Government of Pakistan, 1988). This paper is the first in a series evaluating the potential for improved crop production in this area, and presents the results of trials carried out on farmers' fields from 1985 to 1988 examining the effects of variety and fertiliser on potential wheat production.

MATERIALS & METHODS

The trials were carried out on farmers' fields at a number of locations from 1985/86 to 1987/88 (Table 1) on fine textured valley bottom soils (yermosols), the main soil type used in agriculture in upland Balochistan (Government of Pakistan, 1978). Chemical and physical characteristics of the soils are shown in Table 1.

The local wheat land-race was compared with the recommended variety for autumn sowing in upland Balochistan in 1985/86 and 1986/87 (Zarghoon), and with the recommended variety for spring sowing in 1987/88 (Zamindar). These varieties are recommended principally for irrigated conditions. The varieties were compared with and without nitrogen fertiliser (40 kg ha^{-1} nitrogen applied as 26% ammonium nitrate, 10 kg ha^{-1} sown with the seed in the seed-bed, 30 kg ha^{-1} top-dressed at tillering), with and without phosphate (60 kg ha^{-1} phosphate applied as 46% triple super-phosphate sown with the seed in the seed-bed), with and without potassium (60 kg ha^{-1} applied as 22% potassium sulphate sown with the seed in the seed-bed), and with and without manual weeding (at tillering, booting and late-flowering stages), in a 2^5 factorial design with one replicate at each location. The trials were analysed separately, using second order and higher interactions as an error term (Petersen, 1985) and over locations for each year, treating locations as blocks.

In 1985/86 and 1987/88 the trials were planted at the bottom of furrows in ridged seed-beds (following farmer practise) using a tractor-drawn Oyjord plot-planter; in 1986/87 the trials were planted by farmers using the local camel-drawn single-row drill. Row spacing was 40 cm and seed-rate was 100 kg ha^{-1}, following local practise. The plot size was 12 by 2 meters and yield estimates were made by sampling the entire central two rows. In 1986/87, the "good" rainfall year, farmers in two areas (Dasht, Kovak) advised that the crops should be cut for green fodder in early December. Accordingly the trials in those areas were divided into two, with one half of each plot being cut by hand to a height of 5-10 cm above the ground. Data from the cut and un-cut portions were subsequently analyzed as separate trials.

Rainfall, maximum and minimum air temperatures were measured near to each site by farmers. Soil water at planting was measured gravimetrically at six replicate positions in each trial to one meter depth and converted to mm water per m of soil using bulk densities of 1.4 to 1.6 g cm^{-3} (ICARDA, 1987, 1988). Soil chemical and physical characteristics were determined at the ICARDA soil laboratory at Aleppo from six 0-30 cm soil samples per site.

The following "farm-gate" prices were used for partial budgeting: grain 2 R kg^{-1} (fixed by government), straw 0.5, 0.6 and 1.0 R kg^{-1} in 1986, 1987 and 1988, respectively; cost of camel hire for plowing, planting and threshing 5.5 R $hour^{-1}$; time for plowing and planting 24.8 hours ha^{-1}; time for harvesting and threshing 38.5 and 95 hours $tonne^{-1}$, respectively; cost of 40 kg ha^{-1} nitrogen fertiliser in 1986/87 262 R ha^{-1} (in 1988 R18 = US$1).

RESULTS

1985/86

The rainfall distribution over the three years are shown in Figure 1 for one site, Dasht. Total annual rainfall varied with location from 138 to 204 mm, representative of a "normal" rainfall year in upland Balochistan. Summer rainfall did not occur at the locations selected in 1985/86 and the trials were planted into dry soil at the end of October. The December rainfall occurred when temperatures were too low for germination, which was consequently delayed until February. The crops thus did not experience severe cold stresses, with only 31 to 37 frost days during the growth period (Table 2). Rainfall was rather low but well distributed during March and April, resulting in reasonable crop growth, but considerable water stress was observed during May and June, and final yields were low (Table 3). The recommended variety, Zarghoon, produced more straw than the local land-race at all locations, a result that was statistically significant at two locations, and statistically significant when averaged over all locations. Seed yields were not significantly different, however. At three of the five locations crop failure occurred, i.e. seed yields were less than the sowing rate. At the other two locations application of phosphate fertiliser increased both straw and seed yields, but this was not statistically significant at either site. The application of nitrogen and potassium fertilisers had little effect, as did weeding.

1986/87

In 1986/87 rainfall was much higher, with annual totals varying with location from 254 to 724 mm (Khuzdar, 380 mm of which occurred before sowing), representative of a "good" rainfall year. The July/August rains were sufficient to permit sowing into moist soil in September (October in Khuzdar), following the farmer practise of placing the seed in moist soil at the bottom of 10 cm furrows. At two locations the crops were cut for green fodder in December, yielding 91 kg ha^{-1} dry weight at Dasht (main effects standard error 9.1 kg ha^{-1}) and 54 kg ha^{-1} at Kovak (main effects standard error 6.0 kg ha^{-1}), with no significant differences between treatments. The recommended variety, Zarghoon, entered the booting stage by the end of December and subsequently suffered severe cold damage, even at

Khuzdar, where only five days with air temperatures below zero occurred. This variety recovered well later in the season, but not sufficiently to yield comparably with the local land-race (Table 4), resulting in significant reductions in straw and seed yield in four of the five trials. Nitrogen fertiliser increased straw and seed yields in all trials, resulting in statistically significant 23% and 28% increases in straw and seed averaged over all locations. Phosphate and potassium fertilisers, and weeding had little effect on final yields. Crop-cutting at the tillering stage had little overall effect on yields, with the local land-race showing small increases in seed yield.

1987/88

In 1987/88 rainfall was low, with annual totals varying from 32 to 147 mm, representative of a "poor" rainfall year. At two of the sites where some irrigation water was available, Khuzdar and Kalat, pre-planting irrigation was applied at the farmers' insistence. The crops were sown into moist soil in the middle of February, resulting in a short growing season, exposure to cold stress at juvenile stages which caused negligible crop damage, and severe water stress. Yields were extremely low at all sites except Khuzdar (Table 5). The recommended variety for spring-sowing, Zamindar, gave increased seed yields at two sites, but reduced straw yields at all sites except one. The various fertilisers, and weeding, had little effect on yields in this dry year.

Relation between yield and water availability.

Figure 2 shows a high linear correlation between total dry weight at maturity of the local land-race without fertiliser and the sum of soil water at planting to 1 m depth plus rainfall during crop growth. The slope of the line, 8.69 kg ha^{-1} mm^{-1}, represents the change in yield per unit water, or the water use efficiency of the crop. A similar analysis for the local land-race with nitrogen fertiliser gave the relation: $y = 11.09(x - 134)$; suggesting that the application of nitrogen fertiliser increased crop water use efficiency, but the differences between the regressions for this relatively small data set were not statistically significant ($P < 0.24$).

Economics of wheat production

Season averages of partial budgets for the local wheat land-race are presented in Table 6. In 1985/86, a "normal" rainfall year, costs exceeded gross benefits in three of the five trials, resulting in a very low mean net benefit and a return to labour of only 1 R $hour^{-1}$. In 1986/87 yields were much higher and costs were accordingly increased as a result of the extra time for threshing; but these were more than offset by the increased value of the crops, resulting in net benefits ranging from 750 to 1550 R ha^{-1}, and returns to labour ranging from 9 to 16 R ha^{-1}. In 1987/88 net benefits and returns to labour were negative in all cases.

In 1986/87 the application of nitrogen fertiliser increased seed and straw yields of the local land-race by an average of 29% and 24% respectively, but the value of the increased yields were only slightly higher than the cost of the fertiliser and additional threshing costs. This resulted in an average increase in net benefit of only 80 R ha^{-1}, and a small decrease in returns to labour.

DISCUSSION

The results presented here clearly illustrate the marginal nature of upland Balochistan for dryland wheat production, compared to other wheat growing areas in Pakistan and other countries of West Asia and North Africa (CIMMYT, 1989, Tahir & Hayes, 1988). The low productivity of rain-fed soils in Pakistan has been attributed to both low water receipt and to low fertility status, but compared to other rain-fed areas, upland Balochistan has even lower rainfall receipts and poorer soils, with lower organic matter and nutrient status, and higher calcium carbonate content and pH than those reported for other areas (Ahmad *et al.*, 1989). The average gross returns reported here of 740 R ha^{-1} are much lower than the values of 4000 to 9000 R ha^{-1} reported by Hobbs *et al.* (1985) for the major rain-fed wheat producing area of Pakistan in the Punjab, which has annual rainfall totals of 600+ mm; yet the average returns to labour of 2 R $hour^{-1}$ are comparable with the normal wages for labour in Balochistan of 2 to 3 R $hour^{-1}$. The areas planted to wheat in upland Balochistan vary from less than 20% in "poor" rainfall years to over 70% in "good" years; a risk avoidance strategy that enables the farmers to make quite good returns on wheat production in "good" agricultural years. Farmers' estimates of the frequency of such "good" years are only three years in ten, however.

The poor response to nitrogen and phosphate fertiliser is in contrast to other low rainfall areas with soils of similar levels of calcium carbonate content and phosphate availability in the Middle East (Matar, 1977; Cooper et al., 1987), but can be attributed to the low water receipt observed in these trials. The lack of response reported here may be partially attributable to the reaction with calcium carbonate to form insoluble or poorly soluble calcium phosphate salts, but is probably largely due to the infrequent wetting of the soil around the phosphate "prills" in the soil, preventing effective root uptake of phosphate. Application of nitrogen fertiliser increased yields and net benefits in the "good" rainfall year, but the increase in net benefits were not sufficient to increase returns to labour. Weeding also had little effect on wheat yields, probably due to the nature of the weed species present; Sophora alopecuroides, Lepidium repens, Malcolmia africana, Descurania sophia and Alhagi camelorum were the five most common weed species present, and weed burdens were generally small, of the order of 10 to 20% of the crop biomass. Weeds that have been reported as serious pests in wheat in

Pakistan, such as *Chenopodium album*, *Convulvulus arvensis*, *Phalaris minor*, *Cynododon dactylon* and *Avena fatua* (Mustafa *et al*., 1984) were generally either not present or uncommon.

The water use efficiency of the local land-race of 8.7 kg ha^{-1} mm^{-1} calculated here from soil water at planting and rainfall during crop growth is reasonably comparable with other reported values (Cooper *et al*., 1987) indicating that given suitable water receipt, productivity levels using this material should be acceptable. The recommended wheat varieties for upland Balochistan generally showed little improvement over the local land-race, although they have demonstrated considerable yield advantages under irrigation (Tahir *et al*., 1983). Further development of wheat varieties for dryland conditions in upland Balochistan is clearly needed. The prospects for improving wheat productivity are, however, poor, unless crop water availability can be substantially and reliably improved. Work currently in progress on water harvesting has demonstrated that this is indeed feasible (ICARDA, 1987, 1988), suggesting that it may be possible to improve wheat productivity in upland Balochistan on a sustainable basis. The prospects for increasing productivity by encouraging a change to other more drought tolerant crops, such as barley and forage legumes, are also quite good, as discussed in the subsequent articles of this series. A combination of such changes in crop species and improved water harvesting practises could lead to substantial improvements in productivity in upland Balochistan.

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Table 1. Trial locations and soil chemical and physical characteristics (0-30 cm samples analysed by the Farm Resource Management Program, ICARDA, Aleppo.)

Location	Location	Elevation (m)
Maslakh	30°20'N 66°40'E	1750
Quetta	30°13'N 66°57'E	1700
Dasht	29°58'N 66°52'E	1750
Mastung	29°48'N 66°50'E	1650
Kovak	29°28'N 66°47'E	1950
Kalat	29°06'N 66°33'E	1900
Khuzdar	27°47'N 66°23'E	1200

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
Kalat	8.4	21.6	9.0	0.5	427	-	-	-	
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

Table 2. Soil water at planting to 1 m depth (mm), rainfall (mm), average minimum and maximum air temperatures and number of frost days (minimum air temperature below 0 C) during the crop growth periods.

Trial	Soil water (mm)	Rain (mm)	Temperature Min. (C)	Temperature Max. (C)	Frost days	Olsen P (ppm)	Kjeld. N (ppm)
1985/86							
Mastung	52	143	4.1	22.1	37	3	299
Dasht	34	137	6.3	22.1	31	4	356
Dasht R[1]	80	184	6.3	22.1	31	4	386
Quetta	66	151	6.3	22.1	31	7	418
Maslakh	38	132	-	-	-	4	320
1986/87							
Khuzdar R	116	162	6.3	29.1	5	6	366
Kovak R	53	194	3.3	23.7	97	8	581
Dasht	111	221	4.4	21.9	96	6	459
1987/88							
Khuzdar PI[2]	133	32	11.2	27.8	1	3	257
Kalat PI	87	51	-	-	-	9	502
Kovak R	41	107	7.3	25.1	15	8	447
Dasht R	45	147	11.2	22.8	4	10	276
Dasht	26	102	11.2	22.8	4	8	133

[1] "Run-on" site, i.e. one which receives occasional stream-flow irrigations.
[2] Pre-planting irrigation applied.

Table 3. Straw and grain yields (kg ha^{-1}), 1985/86.

	Straw					
	Mastung	Dasht	DashtR	Quetta	Maslakh	Mean
Local land-race	165	490	514	224	213	321
Zarghoon cv.	231	554	683	310	247	405
	***			***		***
-N fertiliser	179	500	565	274	250	354
+N fertiliser	217	544	633	261	210	373
-P fertiliser	175	504	559	255	232	345
+P fertiliser	221	540	639	280	228	382
	*					
-K fertiliser	216	570	670	263	253	394
+K fertiliser	180	475	528	272	207	332
						*
- weeding	203	546	655	283	216	381
+ weeding	193	498	543	251	244	346
$S.E._{Main\ effects}$	13	50	74	13	21	18
$S.E._{Interactions}$	19	71	105	19	30	26

	Grain					
	Mastung	Dasht	DashtR	Quetta	Maslakh	Mean
Local land-race	30	210	371	34	31	135
Zarghoon cv.	22	266	309	20	53	134
-N fertiliser	27	213	380	24	53	140
+N fertiliser	26	262	300	28	30	129
-P fertiliser	27	203	265	27	50	114
+P fertiliser	26	272	415	25	33	154
						*
-K fertiliser	29	229	360	25	47	139
+K fertiliser	24	246	314	27	36	129
- weeding	30	231	314	32	39	129
+ weeding	23	245	366	20	45	140
$S.E._{Main\ effects}$	6	26	51	5	7	12
$S.E._{Interactions}$	9	36	72	7	10	17

*, ***, Treatment means significantly different at $P < 0.05$ or 0.005, respectively.

Table 4. Straw and grain yields (kg ha^{-1}), 1986/87.

	Straw					
	Khuzdar	Kovak uncut	Kovak cut	Dasht uncut	Dasht cut	Mean
Local land-race	770	1008	1212	1680	1587	1251
Zarghoon cv.	628	699	639	968	950	777
		***	***	**	**	***
-N fertiliser	564	877	806	1186	1106	908
+N fertiliser	833	829	1045	1462	1430	1120
	**		*			***
-P fertiliser	675	915	907	1342	1220	1012
+P fertiliser	723	791	944	1306	1316	1016
-K fertiliser	651	881	922	1355	1282	1018
+K fertiliser	746	825	929	1293	1255	1010
- weeding	734	789	929	1232	1187	974
+ weeding	664	918	923	1416	1350	1054
S.E.$_{\text{main effects}}$	64	56	64	128	147	45
S.E.$_{\text{interactions}}$	90	79	91	181	207	63

	Grain					
	Khuzdar	Kovak uncut	Kovak cut	Dasht uncut	Dasht cut	Mean
Local land-race	566	357	377	568	618	497
Zarghoon cv.	345	247	216	500	440	350
	***	*	***		*	***
-N fertiliser	379	286	267	506	505	389
+N fertiliser	532	318	326	522	524	458
	*					***
-P fertiliser	444	290	271	546	534	417
+P fertiliser	467	314	322	522	524	430
-K fertiliser	428	342	308	583	533	439
+K fertiliser	483	262	285	485	525	408
- weeding	486	292	288	535	536	427
+ weeding	425	312	305	534	522	419
S.E.$_{\text{main effects}}$	48	29	32	64	45	19
S.E.$_{\text{interactions}}$	67	41	45	90	64	27

*, **, *** Treatment means significantly different at $P < 0.05$, 0.01 or 0.005 respectively.

Table 5. Straw and grain yields (kg ha^{-1}), 1987/88.

	Straw					
	Khuzdar	Kalat	Kovak	Dasht	Dasht R	Mean
Local land-race	385	489	105	265	106	270
Zamindar cv.	306	363	99	165	235	234
		*		*	*	*
-N fertiliser	309	430	109	201	170	244
+N fertiliser	383	421	96	229	171	260
-P fertiliser	372	418	106	200	179	255
+P fertiliser	320	434	99	230	162	249
-K fertiliser	382	449	104	229	156	264
+K fertiliser	309	403	101	201	185	240
- weeding	297	463	81	239	165	249
+ weeding	395	389	123	191	176	255
$S.E._{Main\ effects}$	51	38	19	18	18	13
$S.E._{Interactions}$	72	54	27	26	26	18

	Grain					
	Khuzdar	Kalat	Kovak	Dasht	Dasht R	Mean
Local land-race	89	13	76	11	26	43
Zamindar cv.	170	10	54	10	63	52
	*				*	*
-N fertiliser	132	12	66	9	47	53
+N fertiliser	128	10	65	12	42	51
-P fertiliser	142	10	68	10	42	54
+P fertiliser	118	12	62	11	47	50
-K fertiliser	128	11	69	10	42	52
+K fertiliser	132	11	61	11	46	52
- weeding	120	11	73	10	41	51
+ weeding	140	11	58	11	48	54
$S.E._{Main\ effects}$	18	2	8	2	4	7
$S.E._{Interactions}$	26	3	11	2	6	10

* Treatment means significantly different at $P < 0.05$.

Table 6. Season mean straw and grain yields (kg ha^{-1}), production costs (R ha^{-1}), gross and net benefits (GB & NB, R ha^{-1}), labour requirements (hours ha^{-1}) and returns to labour (RL, R $hour^{-1}$) for the local land-race of wheat.

Season	Straw	Grain	Cost	GB	NB	Labour	RL
85/86	335	146	412	460	48	44	1.1
86/87	1115	435	562	1604	1042	83	12.4
87/88[1]	134	16	344	166	-178	27	-6.6
Mean	528	199	440	743	304	51	2.3
86/87:							
-N fertiliser	1115	435	562	1604	1042	83	12.4
+N fertiliser	1388	559	889	2012	1123	99	11.1

[1] Excluding the two trials that received pre-planting irrigation.

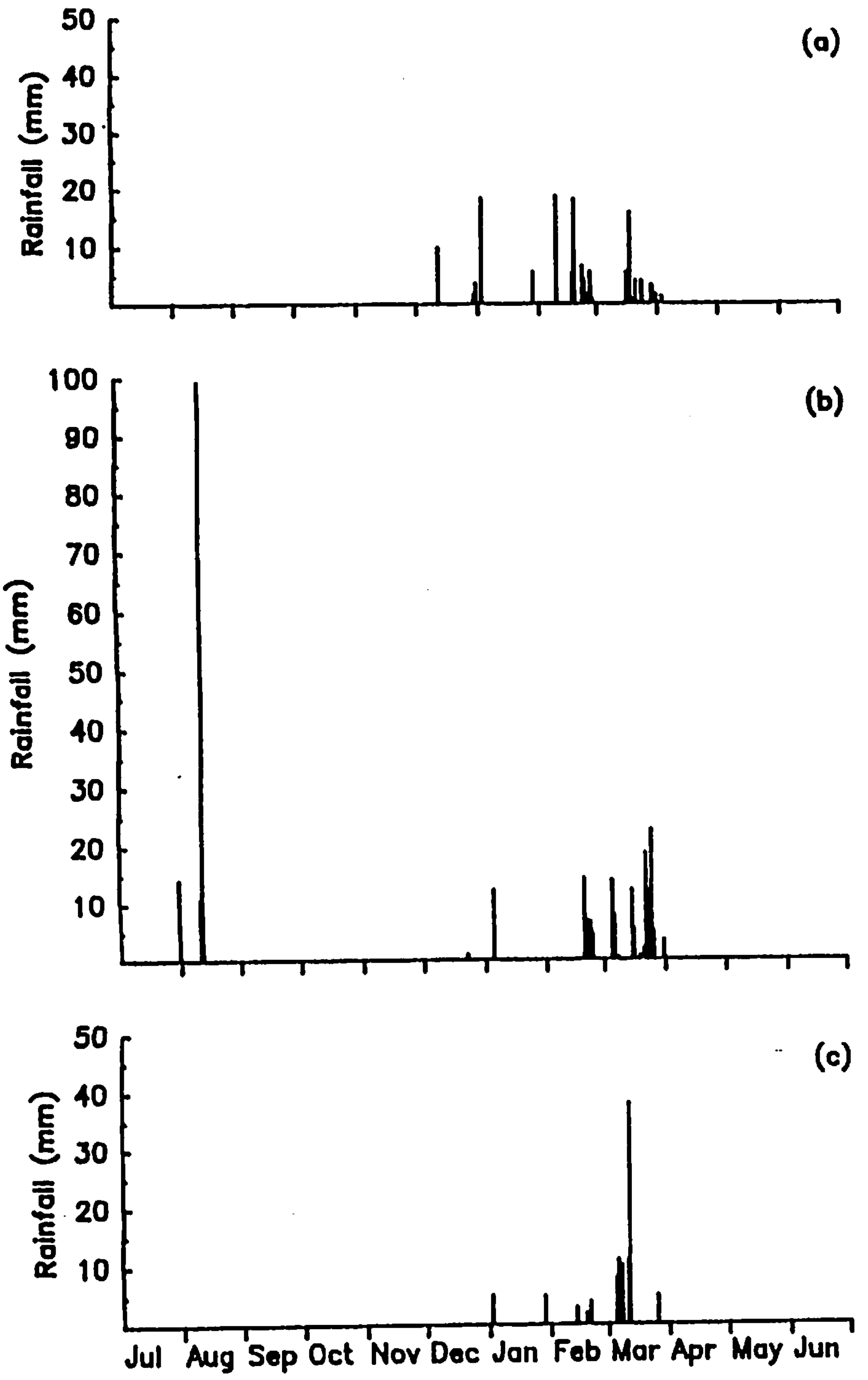

Figure 1. Seasonal course of rainfall at Dasht site. (a) 1985/86; (b) 1986/87; (c) 1987/88.

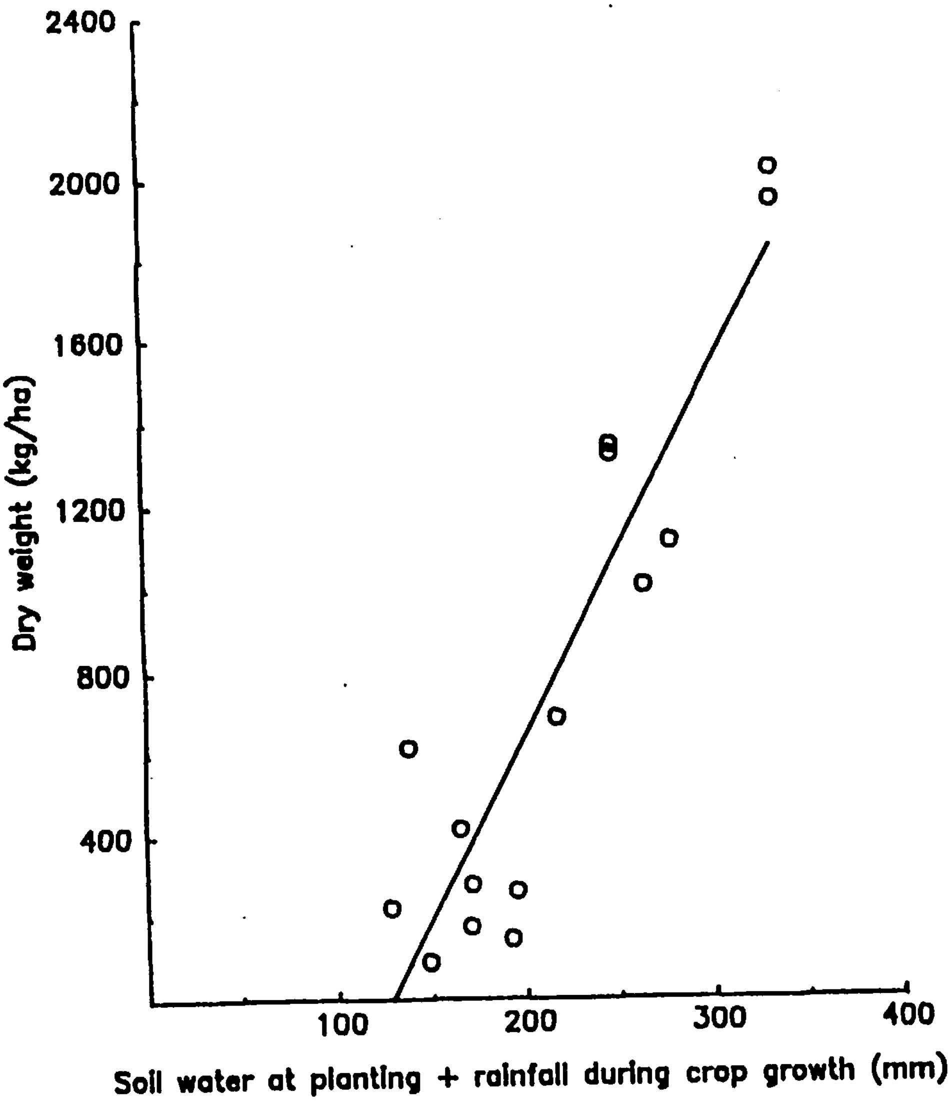

Figure 2. Relation between total above-ground dry weight at maturity and (soil water at planting + rainfall during crop growth).
$y = 8.69(x - 126)$.