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Response of Barley to Different Levels of Water Under Sprinklers in Arid Environment

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Abstract: The rainfed Omani barley 'Duraqui' was studied for its response, with respect to yield and yield contributing characters, to three moisture levels under sprinklers during winter, 1995-96 at Agriculture Research Center (ARC) and Livestock Research Center (LRC), located at Rumais in South Batinah region of Sultanate of Oman. Water levels had a significant effect only for total water applied, while the location effect was significant for plant height, spike weight, grain yield and WUE (grain yield). The interaction effect between water level and location was evident for both grain and biological yields. The expressions of all the characters, except total tillers were of higher magnitude in the crop at LRC, as compared to ARC, because of better quality of soil and irrigation water. Although grain and biological yields at LRC increased with increasing levels of water, water use efficiency (WUE) for grain yield was higher for low water level. At ARC. yield differences were non significant and yields were of low magnitude. WUE was significantly higher for low water level. The nature and magnitude of pooled character correlations of high and low water levels were different. There were 28 significant correlations out of 45 character combinations under high water level, while under low water level there were only 16 significant correlations.

Key words: Correlation, response, stability, water use efficiency

Barley (*Hordeum vulgare* L.) is an important source of both food and feed in the Sultanate of Oman. About 1,294 ha area is under this crop (Anonymous, 1994), and ranks after alfalfa (11,735 ha). Six-rowed barley is usually cultivated for fodder with alfalfa, all along the Batinah coast. In the interior, Sharqiya and Western Hajar, it is grown for grains, utilized mostly as component of poultry feed. In Musandam, a few land races are grown exclusively as rainfed crop in a very limited area for human consumption (Anonymous, 1989). The most prominent land race is Duraqui, which is grown traditionally for its earliness and drought tolerance.

The line source approach is most convenient to create soil moisture gradient. This has been used successfully to screen large number of genotypes in different crops (INTSORMILL, 1984), including sorghum (Garrity *et al*., 1983; Hofmann *et al*., 1984 and Ibrahim, 1995), wheat (Hang and Miller, 1993), barley (Fernandez *et al*., 1993) and pearl millet (Ibrahim *et al*., 1986; 1990; 1995) to facilitate measurements of various crop features over a wide range of moisture levels. The present investigation was undertaken at two locations, that differ in soil and water characteristics, to study the response of local barley variety 'Duraqui' to three water levels with respect to grain and biological yields along with associated characters.

Materials and Methods

The performance of variety 'Duraqui' was studied under three moisture levels created by sprinkler during winter, 1995-96 at Agriculture Research Center (ARC) and Livestock Research Center (LRC), located at Rumais in South Batinah region of Sultanate of Oman. The characteristics of the experimental soils of ARC and LRC, and meteorological data for the cropping season are presented in Tables 1 and 2, respectively. LRC has fairly good quality of irrigation water (2 dS m^{-1}), while ARC has saline irrigation water (5 dS m^{-1}). The trials were laidout in modified Randomized Complete Block Design with three water levels and three replications. Crop was sown on Nov. 11, 1995 at ARC and on Nov. 14, 1995 at LRC. The crop was planted at a seed rate of 125 kg ha^{-1} in 3 m long rows spaced 25 cm apart, and fertilized with 150 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1} in the form of urea, triple super phosphate and potassium sulphate, respectively. The entire quantities of potassium and phosphatic fertilizers along with one-fourth nitrogen fertilizer were applied before sowing, while the remaining nitrogen was applied in three equal doses, a week after sowing, at heading stage and milky grain stage. The crop was irrigated 2 to 3 times a week both at ARC and LRC. Water levels were assigned as high (six rows planted 1 m from the sprinkler line), medium (six rows planted 5.5 m away from the sprinkler line and those were positioned in middle area), and low (six rows planted 10 m away from the sprinkler line). Catch cans were placed in the middle of each plot of six rows and the water was measured from the catch can after each irrigation.

Table 1. Values of some physical and chemical characteristics of the experimental soils at ARC and LRC

Characteristics	ARC	LRC
Physical		
Coarse sand (%)	6.90	21.70
Fine sand (%)	76.80	63.00
Silt (%)	4.90	3.90
Clay (%)	11.40	11.40
Texture	Sand	Sand
Chemical		
EC (1:5)	10.00	2.00
pH (1:5)	7.90	7.70
Soluble Cations (meq/100 g)		
Na	144.30	15.90
K	1.50	0.17
Soluble Anions (meq/100 g)		
Cl	115.00	19.50
Av. P	18.84	15.76
N (%)	0.05	0.04

The observations on crop growth and yield were recorded at appropriate stages of crop growth and total irrigation (cm) irrigation at each water level was computed as sum total of water applied at different times till rainfall occurred (Jan. 27, 1996), when irrigation was stopped (Table 3). Yields and total water applied in respective plots, were used to calculate WUE, both in terms of grain and biological yields (Singh and Kanemasu, 1980). The data were subjected to statistical analyses as for RCBD (Gomez and Gomez, 1984).

Results and Discussion

The mean data on the performance of Duraqui under three water levels at two locations with respect to various characters

Table 2. Rainfall (mm), temperature (°C) and relative humidity (RH) during cropping period during 1995-96

Month and year	Rainfall (mm)	Temperature (°C)		Relative humidity (RH)
		Mean maximum	Mean minimum	
November 1995	0.0	29.6	18.5	64.0
December 1995	101.2	25.6	18.8	56.5
January 1996	16.7^{+}	24.2	16.6	64.0
February 1996	19.7^{+}	25.6	17.8	69.0

+ - Ineffective.

along with parameters of pooled analysis are presented in Table 4. Water levels had a significant effect only with respect to total water applied, while the locational effects were significant for plant height, spike weight, grain yield and WUE (grain yield). The interaction effect between water level and location, however, was interestingly evident for both grain and biological yields. The expressions of all the characters except total tillers, were of higher magnitude in the crop of LRC as compared to ARC because of good quality of soil and irrigation water. The differences between the water levels, with respect to total water applied, were highly significant at both locations while the magnitude of water applied was almost similar at each water level at ARC and LRC (34.3 and 33.6 cm in high, 29.5 and 28.4 in medium and 20.3 and 19.1 cm in low water level). Among remaining characters, effect of water levels were significant for spike length and WUE (grain yield) at ARC, and for plant height, number of tillers m^{-2}, grain and biological yields at LRC. The water levels, however, were not significantly different for the characters, viz., plant stand, days to flowering, total tillers and WUE (biological yield) at both the locations. WUE computed for both grain and biological yields were of higher magnitude at LRC (44.57 to 54.94 and 160.99 to 211.70 kg ha^{-1} cm^{-1} water) as compared to those at ARC (19.70 to 20.70 and 110.30 to 150.30 kg ha^{-1} cm^{-1}). At LRC, though grain and biological yields increased with increasing levels of water (1043.0 to 1803.0 kg ha^{-1} of grain yield and 3663.0 to 7550.0 kg ha^{-1} of biological yield), WUE (grain yield) was higher for low water level. At ARC, however, were yields of low magnitude (417.0 to 680.0 kg ha^{-1} of grain yield and 2993.0 to 4437.0 kg ha^{-1} of biological yield and differences were non-significant. Water levels by differed significantly for WUE (grain yield) which was significantly higher at low water level (20.70 kg ha^{-1} cm^{-1}) than those at other levels. Thus WUE declined with increase in the moisture levels (Singh and Kumar, 1981; Singh and Sharma, 1983). The increased grain yield at high water levels, as compared to that at low water level, was 63% with 5% loss of WUE at ARC, while it was 73% with 8% loss of WUE at LRC. However, increased biological yield was only 26% with 25% loss of WUE at ARC, but at LRC there was 106% increase in biological yield with 10% gain in WUE. This clearly indicates that Duraqui responds favorably, with marginal loss of efficiency, to increased water level with respect to grain yield irrespective of conditions of growth (Table 5). This has also been observed in the investigations conducted in Mexican highlands endowed with 93% dry land

Table 3. Water obtained through sprinklers and rainfall in different water levels at LRC and ARC during cropping season 1995-96

Location	Water level	Water received through				Total water applied (cm)
		Irrigation			Rainfall (cm)	
		Hours of irrigation	Average irrigation depth (cm)	Water applied (cm)		
LRC	High	34	0.6897	23.45	10.12	33.57
	Medium	34	0.5370	18.26	10.12	28.38
	Low	34	0.2626	8.96	10.12	19.05
ARC	High	35	0.6897	24.14	10.12	34.26
	Medium	35	0.5528	19.35	10.12	24.97
	Low	35	0.2894	10.13	10.12	20.25

agriculture with 350 to 600 mm annual rainfall, where barley had higher WUE in terms of both grain (61.30 kg ha^{-1} mm^{-1}) and biological (167.70 kg ha^{-1} cm^{-1}) yields (Hofmann *et al.*, 1984), while highest WUE for grain and dry matter was also recorded in barley as compared to other crops (Rao and Agarwal, 1985; Siddique *et al.*, 1990).

In order to comprehend interrelationships between yield and yield associated characters under two extreme conditions, viz., high and low moisture levels, irrespective of the environments, simple correlation values were computed pooling the data of two locations for high and low water levels (Table 4). The nature and magnitude of correlations for high and low water levels were different with each other. There were 28 significant correlations out of 45 character combinations under high water level, while under low water level there were only 16 significant correlations. Total tillers had absolutely no association with any of the characters under either low or high water level as days to heading had no association with other characters under low water level. Under high water level, days to heading had significant positive association only with spike length (0.819*). Plant height was positively and significantly associated with spike length (0.875**), spike weight (0.903**), grain (0.818*) and biological (0.913**) yields under high water level, while it was significantly associated with only spike length (0.826*) and grain yield 0.865*) under low water level. While spike length was positively and significantly associated with spike weight (0.940**), grain yield (0.896**) and biological yield (0.904**) under high water levels, while under low water level, only with spike weight (0.970**) and grain yield (0.989**). Spike weight was positively and significantly associated with both grain (0.985***) and biological (0.891**) yields under high water level, but only with grain yield (0.946**) under low water level. Similarly, grain yield was positively and significantly associated with biological yield (0.827*) only under high water level. Thus, the above associations involving agronomic and yield characters clearly depict that there would be no definite relationship between biological yield and any other character under low water level as source-sink relationship would be irregular owing to improper grain filling.

The total water applied had positive and significant association with plant height (0.885**), spike length (0.915**), spike weight (0.867**), grain (0.785*) and biological (9.989***) yields under high water level in contrast to negative relationship with these characters under low water level. WUE (for both grain and biological yields) were positively and significantly associated with plant height (0.807* and 0.918**), spike length (0.889** and 0.904*), spike weight (0.981*** and 0.897**), grain (0.999** and 0.834*) and biological (0.810* and 1.000***) yields under high water level as it is favorable for crop growth. However, under low water level, associations seemed to be varying. WUE (grain) was positively correlated with plant height (0.861*), spike length (0.964***), spike weight (0.945***) and grain yield (0.999***) while WUE (biological yield) was associated positively only with plant height (0.881**) and biological yield (0.970***). Both WUE's, however, had positive relationship with each other (0.817*). Such studies on interrelationships among growth and yield attributes in barley under high and low water levels have not been attempted earlier. However, similar observations were made with respect to associations between WUEs

Table 4. Mean data of total water applied, WUE (grain yield), WUE (biological yield) and eight characters of rainfed Omani barley "Duraqui" under three water levels in two locations during winter, 1995-96

Location	Water level	Water applied (cm)	Plant stand (0-10)	Days to heading	Plant height (cm)	Total tillers per m	Spike length (cm)	Spike weight (g)
LRC	High	33.57	9.33	58.00	77.23	128.9	15.00	1.45
	Medium	28.38	9.33	58.67	58.33	97.4	14.73	1.35
	Low	19.05	9.00	57.67	55.22	92.2	14.33	1.19
	F-Test	**	NS	NS	**	**	NS	NS
	SEm ±	0.46	0.19	0.50	1.99	3.33	0.44	0.07
ARC	High	34.26	7.67	55.00	41.44	128.3	13.60	0.51
	Medium	29.47	7.33	57.33	37.55	138.6	11.87	0.44
	Low	20.25	8.17	57.33	38.33	113.0	10.03	0.39
	F-Test	**	NS	NS	NS	NS	NS	NS
	SEm ±	0.35	0.451	1.07	1.78	21.87	0.43	0.08
Pooled analysis over the locations								
Water levels		**	–	NS	NS	NS	NS	NS
Locations		NS	–	NS	*	NS	NS	**
W x L		NS	–	NS	NS	NS	NS	NS
SEm ±		1.30	–	0.80	1.89	15.6	0.44	NS

* - Significant at 0.05 level of significance; ** - Significant at 0.01 level of significant

Table 5. Yield and WUE of rainfed Omani barley "Duraqui" under three water levels at two locations during winter, 1995-96

Location	Water level	Grain yield (kg ha^{-1})	Biol yield (dry matter) (kg ha^{-1})	WUE (grain yield kg ha^{-1} cm^{-1} water)	WUE (biol yield kg ha^{-1} cm^{-1} water)
LRC	High	1803.0	7550.0	50.70	211.70
	Medium	1267.0	4550.0	44.57	160.99
	Low	1043.0	3663.0	54.94	192.37
	F-Test	**	**	NS	NS
	SEm ±	3.16	15.63	2.43	12.45
ARC	High	680.0	3773.0	19.70	110.30
	Medium	580.0	4437.0	19.70	150.30
	Low	417.0	2993.0	20.70	147.70
	F-Test	**	NS	*	NS
	SEm ±	6.33	16.1	0.70	1.59
Pooled analysis over the locations					
Water levels		NS	^NS	^NS	^NS
Locations		*	NS	**	NS
W x L		**	**	NS	NS
SEm ±		5.13	15.92	1.78	8.87

* - Significant at 0.05 level of significance; ** - Significant at 0.01 level of significance.

and yield characters under stress conditions in pearl millet (Ibrahim *et al.*, 1986; 1990; 1995).

In the light of above results, it is concluded that early barley genotypes like 'Duraqui', which matures in less than 90 days, have higher WUE for grain under moisture stress conditions and would be expected to dominate in the arid and semi-arid and receiving 200-400 mm rainfall during the cropping season (ICARDA, 1995).

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