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Yield Production of Some Barley Genotypes Related to Irrigation Management under Low Rainfall Conditions in Saudi Arabia

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Abstract: Water management is one of the most important practices affecting yield performance of most crops under limited water supplies.Field experiments included four barley genotypes (Jesto, Giza 121, Giza 123 and Local Var.) and four irrigation schedules viz., weekly irrigation, 70, 100 and 130 mm of cumulative pan evaporation (CPE) were conducted over two winter seasons at center Riyadh region, Saudi Arabia. The main objective was to compare the response of barley genotypes to deficit irrigation schedules. Results showed that gradual decrease in growth, yield component parameters were in line with decreasing irrigation schedules. Higher grain yield was obtained at medium irrigation schedules as compared to high and low irrigation schedules. Concerning varietal differences, results showed that Giza 121 outranked all other tested genotypes in most studied characters. Yield parameters viz., harvest index and water use efficiency were also affected by both factors under investigation and their interaction. Finally, obtained results clearly indicated that, sowing drought tolerant genotypes can conserved about 40% of conventional water supplies with minimum risk in grain yield.

Key words: Barley · Cumulative pan evaporation (CPE) · Water stress · Water use efficiency (WUE) · Yield potential

INTRODUCTION

Drought stress is one of the most important environmental factors affecting crop production worldwide. Severe losses in yield production are expected as a result of drought [1]. Drought resistance refers to plant ability to be grown and reproduce satisfactorily under low soil moisture content. Under such condition plants have ability to slowly modify its structure to seem better drought resistance [2]. Under Saudi Arabia condition, rain is scarce, irregularly distributed and variable from one year to another. Due to these fluctuations in water availability, crop yield also varies from one year and region to another [3]. Barley is the main cereal crop grown under arid and semi arid condition, because it shows a conservative strategy in water use when compared to other species [4, 5]. However, El-Seidy and Khattab [6], worthy clarified that barley production is limited by terminal water stress and high temperatures during grain filling. In the same concern Ashour and Selim [7], under South Sinai condition, reported that the effect of agro-ecological zone on genotype performance is one of the most important issues in crop production. Ouda *et al.* [8] also showed that, skipping the last irrigation in barley could be useful in saving irrigation water, however it could reduce final yield due to incomplete development of barley grains. Furthermore, they concluded that yield was reduced by up to 15% when last irrigation was skipped. Such reduction in barley grain yield under water stress could be attributed to the reduction in number of spikes m^{-2}, number of grains/spike and grain weight [9]. Several studies indicated that the reduction in grain yield depended upon many factors. Among these, the growth stage at which the water deficiency occurs and the severity and duration of the deficiency. Higher prolonged or excessive drought affected shortening the grain filling period. Moreover, moisture depletion during grain formation to 30-35% of available moisture content period leading to earlier maturity and 10-20% near maturity [10, 11]. The ability of a cultivar to produce high and satisfactory yield over a wide range of stress and non-stress environments is very important. Ashour and Selim [7] believed that stability over environments and yield potential are more or less independent of each other.

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The present study was proposed to clarify the most sensitive variety can be recommended and amount of irrigation water can be conserved without or with minimum risk in order to maintain grain yield.

MATERIALS AND METHODS

The present study was carried out at the Agricultural Research Station, College of Food and Agriculture Sciences, Derab, near Riyadh, King Saud University, Saudi Arabia (24°42N latitude and 46°44E longitudes, altitude 600 m), during winter season of 2008/2009 and 2009/2010. The main objective of this study was to evaluate the response of four barley genotypes viz., Jesto, Giza 121, Giza 123 and Local Variety to water irrigation schedules viz., weekly, 70, 100 and 130 mm of cumulative pan evaporation (CPE), compared to traditional water irrigation (weekly irrigation). Before commencement the experiment, sample from 0-30 cm of soil layer of the experimental soil site was taken for chemical and physical analyses according to the methods described by Cottenie *et al.*[12] and But [13]. Results cleared that, soil texture was sandy clay loam soil (50% sand, 26% silt and 24% clay), pH in 1:2.5 soil water (8.15), EC (2.1 dS m^{-1}) in extracted soil paste (2:1) and $CaCO_3$ (29.9%). Soil macronutrients N, P and K were 120.6, 270.0 and 124.0 mg kg^{-1} soil, respectively. While soil micronutrients in mg kg^{-1} soil were 2.4, 15.1, 13.1 and 0.3 for Fe, Zn, Mn and Cu, respectively. Water used in irrigation was also analyzed; results registered that, values of cation in irrigation water content in meq L^{-1} were 6.0, 3.2, 13.0 and 0.7 for Ca, Mg, Na, K and for anions Co_3^-, HCO_3^-, Cl^-, SO_4^{--} were 0.6, 5.8, 8.61 and 8.5, respectively. Irrigation water EC (2.3 dSm^{-1}), pH (7.2) and (6.06) sodium adsorption ratio (SAR). Seed bed was prepared before sowing as recommended according to the conventional production practices followed at the central region of Saudi Arabia. Phosphorus and potassium fertilizers were applied broadcasting during soil preparation, phosphorus as the form of super phosphate (16% P_2O_5) at the rate of 70 kg P_2O_5 ha^{-1}, whereas potassium as the form of potassium sulphate (48% K_2O) at the rate of 100 kg K_2O. Recommended dose of N (100 kg N ha^{-1}) was applied in three split equal doses in the form of ammonium nitrate (33.3% N) at sowing, during tillering and at anthesis. Experimental soil sites were divided into plots, each plot contained 8 lines 20 cm apart, 3m in length. Plot area was 4.80 m^2. Split-plot design with four replications was laid out. Irrigation was randomly assigned in main plots. Whereas genotypes were occupied the sub-plots. All recommended cultural practices were followed. Number of irrigation for each treatment and amount of water supplied over the growing season in both seasons were calculated and presented in Table 1. Seeds were sown, by hand drill at the rate of 120 kg ha^{-1} on November, 10 and 3, in the first and second seasons, respectively. Water irrigation treatments were followed after one month from sowing, according to the experimental treatments using flood irrigation system, through line pipe provided with meter gages for measuring amount of water applied as a sum of daily-recorded evaporation from USWB class A open pan, compared to the control treatment (weekly irrigation).

During the end of growth stage and pre-harvest time, some growth parameters such as numbers of days to 50% of flowering and maturity as well as rate of grain filling were recorded. Whereas, at harvest two central rows from each sub plot were harvested for determination of grain yield (ton ha^{-1}), biological yield (ton ha^{-1}) and harvest index. Water use efficiency was also calculated based on dry biomass production (WUE_b), kg per hectare for each amount of water supplied during the growing season according to formula described by Bos [14].

Data obtained for each season were subjected to statistical analysis according to the methods described by Gomez and Gomez [15]. Means were compared using Fishers Protected Least Significant Differences method (LSD) at 0.05 level of probability.

Table 1: Number of irrigation and amount of water used for each treatment over the two growing seasons

Irrigation treatment (Irrigation schedules)	Mean of total water applied (m^3/ha.)	Number of irrigations	
		First season	Second season
Weekly irrigation	7000	14	14
70 mm of CPE	4000	8	8
100 mm of CPE	2000	4	4
130 mm of CPE	1500	3	3

RESULTS

Effect of Irrigation Treatments, Varietal Differences and Their Interactions on Growth Traits: Effect of irrigation schedules on growth parameters of the tested barley genotypes in both seasons are presented in Table 2. Significant differences among irrigation schedules in most of growth parameters were noticed in both seasons. In general, plant height was gradually decreased as water supplies decreased, in the first season the highest plant height (78.00 and 67.82 cm) were recorded at weekly irrigation (7000 $m^3 ha^{-1}$) and at 70 mm CPE (4000 $m^3 ha^{-1}$), respectively as compared to low irrigation schedules 100 and 130 mm of CPE, which recorded the lowest plant height (66.74 and 59.23 cm.), respectively. This finding was almost true through both seasons. Furthermore, number of days to 50% of flowering and maturity stages, in the same table, demonstrated irreversible decrease in either 50% of flowering or maturity stage as water supplies decreased, in both seasons. The same trend was also observed in rate of grain filling.

Concerning the effect of varietal differences, it could be noticed from the data manifested in Table 3 that C.V. Jesto recorded the highest number of days to 50 % of flowering as compared to the other check genotypes; Giza 121, Giza 123 and local variety the same trend was also observed in number of days to maturity stages, in both seasons. The different among genotypes could be attributed to genetic constituencies. In the respect of interaction effect on growth parameters under the present investigation, data presented in Table 8 revealed that only number of days to 50% of maturity in the first season and rate of grain filling in both seasons were significantly responsible to the interaction effect although, significant effect on such traits may be attributed to the early effect of each factor. Regarding to the other characters, no particular trend was noticed.

Table 2: Effect of irrigation treatments, on some growth parameters of barley genotypes grown under arid environment of Saudi Arabia, in 2008/2009 and 2009/2010 seasons

	First season				Second season			
	No. of days to			Rate of	No. of days to			Rate of
Irrigation treatments	50% Flowering	50%Maturity	Plant height, (cm)	grain filling (g/day)	50% Flowering	50% Maturity	Plant height, (cm)	grain filling (g/day)
Weekly irrigation	65.63	100.80	78.00	35.12	69.31	104.69	82.56	35.38
70 mm of CPE	65.13	100.60	67.82	35.44	67.88	102.88	80.68	35.38
100 mm of CPE	64.75	94.88	66.74	30.50	68.31	102.50	72.79	34.19
130 mm of CPE	64.38	94.75	59.23	30.00	65.19	102.25	68.44	37.06
LSD at0.05 level	1.13	0.84	4.75	1.25	2.16	1.79	3.25	2.56

Table 3: Mean of growth parameters for some barley genotypes as affected by varietal differences, under arid environment of Saudi Arabia in 2008/2009 and 2009/2010 seasons

	First season				Second season			
	No. of days to			Rate of	No. of days to			Rate of
Genotypes	50% Flowering	50%Maturity	Plant height, (cm)	grain filling (g/day)	50% Flowering	50% Maturity	Plant height, (cm)	grain filling (g/day)
Jesto	70.81	103.06	57.44	32.25	76.00	113.94	60.45	37.94
Giza 121	62.13	96.00	71.33	33.88	64.50	98.19	72.93	33.69
Giza 123	65.19	100.06	75.44	34.88	65.44	104.94	92.34	39.50
Local Var.	61.75	91.81	67.35	30.06	64.75	95.25	79.34	30.88
LSD 0.05	0.78	1.25	3.24	1.26	1.20	1.97	5.44	2.44

Table 4: Effect of water irrigation treatments, on yield component characters of barley genotypes grown under arid environment of Saudi Arabia, in 2008/2009 and 2009/2010 seasons

	First season					Second season				
Irrigation treatments	Plant height, (cm)	No. of spikes/m^2	Spike length (cm)	No. of grains/spike	1000 grains weight(g)	Plant height (cm)	No. of spikes/m^2	Spike length (cm)	No.of grains/spike	1000grains weight, (g)
Weekly irrigation	90.00	635.00	7.13	39.69	42.49	94.98	604.38	6.53	38.94	42.20
70 mm of CPE	79.94	638.80	7.89	40.25	40.71	92.78	566.25	6.71	43.81	40.08
100 mm of CPE	78.25	687.50	7.94	40.25	38.64	84.79	672.50	6.92	43.06	38.44
130 mm of CPE	71.44	575.00	7.14	34.94	39.42	80.45	530.00	6.38	37.50	39.23
LSD at0.05 level	5.30	130.60	0.78	4.89	1.40	3.90	74.73	0.39	4.30	1.60

Table 5: Mean of yield component characters for some barley genotypes as affected by varietal differences, under arid environment of Saudi Arabia in 2008/2009 and 2009/2010 seasons

	First season					Second season				
Genotypes	Plant height, (cm)	No. of spikes/m^2	Spike length (cm)	No. of grains/spike	1000 grains weight(g)	Plant height (cm)	No. of spikes/m^2	Spike length (cm)	No.of grains/spike	1000grains weight, (g)
Jesto	69.38	547.50	6.70	64.25	39.90	72.37	485.63	5.99	49.88	39.78
Giza 121	83.13	666.13	9.34	41.81	41.34	84.95	600.00	8.54	41.94	40.96
Giza 123	87.44	608.75	8.86	44.31	45.24	104.40	581.25	8.08	46.88	44.76
Local Var.	79.44	606.88	7.61	22.75	44.78	91.34	506.25	6.52	24.63	44.45
LSD at 0.05 level	3.14	85.89	0.46	3.30	1.23	3.82	74.27	0.28	2.41	0.95

Table 6: Effect of water irrigation treatments, on yield and some yield parameters of barley genotypes grown under arid environment of Saudi Arabia, in 2008/2009 and 2009/2010 seasons

	First season				Second season			
Irrigation treatments	Grain yield, ton/ha	Biological yield, ton/ha	Harvest index, HI (%)	WUE_{bKg/m^3}	Grain yield, ton/ha	Biological yield, ton/ha	Harvest index, HI(%)	$WUE_{b\ Kg/m^3}$
Weekly irrigation	6.56	24.52	26.75	3.50	8.940	24.98	35.79	3.57
70 mm of CPE	7.00	21.66	27.40	5.42	9.250	23.89	35.66	5.97
100 mm of CPE	5.90	21.97	31.86	10.99	8.520	22.88	40.43	11.44
130 mm of CPE	5.99	19.83	30.21	13.22	8.440	21.74	38.82	14.49
LSD 0.05	0.92	1.84	--	--	1.025	2.17	--	--

Table 7: Mean of yield and some yield parameters for some barley genotypes as affected by varietal differences, under arid environment of Saudi Arabia in 2008/2009 and 2009/2010 seasons

	First season				Second season			
Genotypes	Grain yield, ton/ha	Biological yield, ton/ha	Harvest index, HI (%)	WUE_{bKg/m^3}	Grain yield, ton/ha	Biological yield, ton/ha	Harvest index, HI(%)	$WUE_{b\ Kg/m^3}$
Jesto	6.22	20.72	30.02	5.72	8.92	21.79	40.94	6.01
Giza 121	7.23	22.96	31.49	6.33	9.87	23.57	41.87	6.50
Giza 123	6.32	23.79	26.57	6.56	9.40	25.52	36.83	7.04
Local Var.	5.69	20.51	27.74	5.66	6.95	22.59	30.77	6.23
LSD 0.05	0.74	1.64	--	--	0.90	1.47	--	--

Yield Component Characters: Data presented in Tables 4 and 5 represent positive effect on most of yield component characters viz., plant height, number of spike m^{-2}, spike length in cm, number of grains/spike and 1000 grains weight (g) for the four tested barley genotypes due to water irrigation supplies. Obtained results, revealed that gradual decrease in all yield component characters were pronounced as irrigation water decreased. The decrement in yield and yield component characters were 20.62; 9.45; 7.63; 11.97 and 7.23% and 15.30; 12.31; 2.30; 3.70 and 7.04% for plant height; number of spikes m^{-2}; spike length in cm; number of grains/spike and 1000 grains weight (g) as irrigation water was decreased from conventional irrigation (weekly irrigation) to irrigation at 130 mm of CPE, in the first and second seasons, respectively (Table 4). Data in the same table showed that the differences between weekly irrigation and irrigation at 70 mm in some studied characters were not significant. Nearly the same values in both seasons for most of yield component characters were obtained.

Regarding genotypic variation, among the four barley genotypes. Data presented in Table 5 worthy indicated that C.V. Giza 121 outranked all the other genotypes in number of spikes /m^2 and spike length in both seasons, whereas Giza C.V. 123 recorded the highest values of plant height and 1000 grains weight in both seasons. Data in the same table also showed that Jesto genotype surpassed the other genotypes in number of grains per spike in both seasons.

Concerning the effect of interaction between irrigation treatments and varieties, data presented in Table 8 indicated that significant differences for some of yield component characters such as rate of grain filling, number of grains per spike and 1000 grains weight in both seasons. Whereas number of days to 50 % maturity was significant only in the first season.

Table 8: The effect of interaction between four barley cultivars grown under different levels of water irrigation treatments

	Barely genotypes							
	2008/2009 season				2009/2010 season			
Irrigation treatments	Jesto	Giza 121	Giza 123	Local variety	Jesto	Giza 121	Giza 123	Localvariety
	No. of days to 50 % Maturity				Rate of grain filling (g/day)			
Weekly irrigation	103.00	98.00	101.75	99.50	36.00	35.00	36.50	34.00
70 mm of CPE	100.75	94.00	99.00	85.75	37.00	31.50	38.00	30.25
100 mm of CPE	103.75	94.00	98.00	83.25	42.00	32.75	43.75	29.75
130 mm of CPE	104.75	98.00	101.50	98.75	36.75	35.50	39.75	29.50
LSD at0.05 level		2.50				4.89		
	Rate of grain filling				No. of grains/spike			
Weekly irrigation	32.50	36.25	36.25	36.75	55.75	48.25	44.50	26.75
70 mm of CPE	30.50	32.75	34.50	34.25	50.50	48.25	49.50	24.00
100 mm of CPE	33.25	30.75	33.00	33.00	44.25	38.50	43.75	23.50
130 mm of CPE	32.75	35.75	35.75	36.25	49.00	32.75	49.75	24.25
LSD 0.05		2.53				4.83		
	No. of grains/spike				1000 Grain weight, g			
Weekly irrigation	51.00	47.00	39.25	23.75	29.35	42.73	43.80	44.43
70 mm of CPE	44.00	44.00	45.50	23.50	29.28	40.20	42.25	42.05
100 mm of CPE	40.75	36.25	41.75	21.00	29.30	39.58	45.53	42.50
130 mm of CPE	49.25	40.00	50.75	22.75	31.20	41.33	47.45	48.83
LSD 0.05		6.61				1.91		
	1000 grains weight, g				--	--	--	--
Weekly irrigation	29.63	--	45.48	44.98	--	--	--	--
70 mm of CPE	28.60	--	42.50	43.05	--	--	--	--
100 mm of CPE	39.33	--	46.03	42.25	--	--	--	--
130 mm of CPE	32.05	--	46.95	48.85	--	--	--	--
LSD 0.05		2.47			--	--	--	--

Grain Yield and Yield Parameters: Yield is a complex character affected by many factors. It is clear from data presented in Tables 6 that, application of water supplies at 70 mm of cumulative pan evaporation (CPE), recorded the highest grain yield (7.00 and 9.25 ton ha^{-1}) in the first and second season, respectively and consequently recorded the highest values of either harvest index (HI) or water use efficiency (WUE). Furthermore, gradual decrease was observed in grain yield and most of yield parameters accompanying decreasing water supplies treatments. While, the differences between irrigation at 70 mm (CPE) and weekly irrigation were insignificant. Such effect indicated that much irrigation water can be conserved, without any risk in grain yield (Table 6). Genotypic variation among genotypes was observed in grain yield and yield parameters. Data manifested in Table 7, shows that varieties divided into two groups, the first one was Giza 121 and 123 recorded the highest grain yield in both seasons (7.23 and 6.32 ton ha^{-1}) and (9.87 and 9.40 ton ha^{-1}) in the first and second season, respectively and surpassed the other two varieties (Jesto and Local variety).The superiority of both varieties may be due to their genetic constituencies. Furthermore, the present results could be assigned that, adopting most proper varieties is very important to achieve high grain yield. As for the interaction, it can be noticed that they had no clear significant effect.

DISCUSSION

The main objective of the present study is to clarify the beneficial roles of integration water management by selecting the most effective interaction between schedule irrigation and some barley varieties recorded high values of growth, grain yield and as well as yield component characters and can conserve much of irrigation water. In both seasons, results demonstrated that the irreversible decrease of most growth parameters viz., plant height, number of days to flowering, maturity and rate of grain filling could be ascribed to less extensive of soil water and soluble nutrients in root zone, which could not satisfy the needs of the plant. This thereby pushed plants to yield formation period trying to end their life circle. Such effect could be assigned to positive influence of drought stress on growth. Furthermore, this finding was more pronounced in the rate of grain filling, in both seasons, in which clear that shorting grain filling period was found as soil water stress increased (Table 2). Various results are in line with the findings of Turner [2], Rahman and Islam [10] and Chepian *et al.* [11]. Alderfasi [16] reported under the same condition that application of irrigation water either at 50 mm (CPE) or weekly irrigation (normal irrigation system) are nearly equal in most of growth parameters and exceeded significantly water supplies at 100, 150 and 200 mm of cumulative pan evaporation.

Regarding the increase in yield and yield component characters i.e., number of spikes m^{-2}, spike length (cm), number of grains/spike and 1000 grains weight (g) may be attributed to the effect on growth which is closely linked with yield component characters [9]. The effect of irrigation water at 70 mm of CPE as compared to other treatments, on grain yield, yield parameters viz.; harvest index (HI) and water use efficiency (WUE) was significant. Positive results of the reduced irrigation water may call attention to replacement of the weekly irrigation in the related barley production water conserved. The present results are in agreement with those obtained by Mishra and Shivakumar [4], Ouda *et al.* [8] and Alderfasi [16] mentioned the same conclusion when they reported that through management irrigation schedules for several crops can conserve much of water supplies and achieve high grain yield. The noteworthy observation was that the excelled of one cultivar than others may be due to genetic constituencies especially that have well sources to drought tolerance and also to the interaction effects between climatic differences and genetic consistent. These results confirmed those reported by El-Seidy and Khattab [6], Ashour and Selim [7] and Alderfasi [16].

CONCLUSION

It can be concluded that sowing highly drought tolerance genotype under low irrigation water supplies by the rate not more than 4000 m^3/ha, which recorded at 70 mm of cumulative pan evaporation (CPE), is acceptable to achieve grain yield insignificantly lower than grain yield at higher amount of water application (weekly irrigation). It is also recommended that further researches must be carried out to evaluate irrigation water management and barley genotypes relationship under limited irrigation at different locations.

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