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Comparative Response of Barley Cultivars and Varieties to Deficit Irrigation in a Mediterranean Environment

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Abstract: Drought is a worldwide problem, seriously constraining global crop production (Wang *et al*., 2003). In order to compare the response of many varieties and cultivars of barley to drought tolerance, a series of morphological parameters were investigated. A field experiment was conducted in the south of Tunisia and barley varieties (Rihane, Roho and Manel) and cultivars (Ardhaoui and Pakistan) were grown on sandy soil. Treatments consisted of irrigated and rainfed using meteorological data generated at the experimental site. Our results suggest that the rainfed treatment recorded the lowest values for height. In addition, we observed a reduction in tiller number and the number of green leaves. We noted the decrease of leaf area (LA) in all investigated varieties and cultivars. Analysis of variance was employed to determine levels of significance. Results clearly show cv. Ardhoui tolerates more water stress when compared with the other varieties and cultivars.

Keywords: Barley, Green leaf number, Leaf area, Plant height, Water deficit

1. Introduction

Abiotic stress conditions cause extensive losses to agricultural production worldwide and have been subjected to intense research (Jaleel *et al*., 2007). Water deficit is one of the major abiotic stresses, which adversely affects both crop growth and yield. The Mediterranean climate is characterized by cool, wet winters and warm, dry summers. Dryland barley production under these conditions is heavily dependent on water stored in the soil during the winter supplemented by the addition to spring rainfall (Arnon, 1972). Coping with water deficit stress is a global issue to ensure survival of agricultural crops and sustainable food production. Drought leads to water deficit in the leaf tissue, which in tern affects many physiological processes such as photosynthesis (Flexas and Medrano 2002; Morales *et al*., 2006). Dissimilar water availabilities often result in significant differences in physiology, morphology, and ultimately, plant productivity (Kramer, 1983; Lambers *et al*., 1998; Flexas *et al*., 2006). Leaf enrolment is a frequent morphological strategy to reduce plant transpiration. Water stress reduces the leaf boundary layer and increases evaporation, reduces the rate of leaf elongation, and plant growth by reduction of the net assimilation rate (Lambers *et al*., 1998). These plants exhibit low vertical development and maintain an optimal leaves photosynthetic area to evade high irradiance effects. In this work, we analyzed plant growth in *Hordeum vulgare* and its relation to rainfall during the growing season. The number of green leaves was also studied. The purpose of this study was to evaluate morphological strategies to reduce plant transpiration and protect leaves from excessive radiation and wind desiccation.

2. Materials and Methods

Experiment was carried out under field conditions in 2007. In this study, Ardhaoui, a local cultivar of the south of Tunisia and a CV. 'Pakistan' were compared to the varieties of Rihane, Roho and Manel (north Tunisian varieties. The two treatments of irrigated and rainfed using meteorological data of the experimental site (**Table 1**) were applied. Leaf blade area (Houala, 1999) was then calculated as:

S= (0.7624 * L*l) + 08841

With L: the length; l: the wide; S: surface.

In addition, plant development characteristics were determined through measuring the plant height, the green leaf number and the tiller number. Statistical analysis was performed using analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT). The values are mean ± SD for six samples in each group. P values < 0.05 were considered as significant.

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Table 1. Average temperature and monthly rainfall during the decade 1995/2005.

Month	Temperature (°C)			Rainfall (mm)
	Minimum	Maximum	Average temperature	
Septemnber	21,63	32,92	27,28	13,74
October	15,82	26,95	21,39	34,82
November	10,20	21,65	15,92	10,78
December	7,36	18,38	12,87	14,77
January	5,42	17,52	11,47	20,95
February	6,13	18,46	12,30	15,44
March	8,99	22,41	15,70	20,72
April	10,74	23,46	17,10	10,97
May	14,67	26,84	20,75	1,74
June	20,11	32,49	26,30	2,15

Table 2. Combined analysis of variance showing the mean squares of the cultivar/ variety and treatment factors and the interaction Cultivar/Variety× Treatment for plant height, tiller number and green leaf number.

Parameter	Source of variation	Developmental stage		
		Tillering	Heading	Maturity
Plant height (cm)	Cultivar/Variety	197.156***	180.703***	487.593***
	Treatment	590.895***	955.539***	1677.415***
	Cultivar/Variety×Treatment	8.832	61.197***	225.661**
	Error	16.153	2.116	43.541
Tiller number	Cultivar/Variety	0.618	1.004	0.860
	Treatment	7.347**	8.961	4.909**
	Cultivar/Variety×Treatment	0.068	0.323**	0.602
	Error	0.811	0.862	0.467
Green leaf number	Cultivar/Variety	7.669	6.547	4.322
	Treatment	78.125**	58.681*	43.867**
	Cultivar/Variety×Treatment	1.421	0.319	0.706
	Error	9.502	11.920	4.323

*, **, *** significant at P< 0.05, 0.01, 0.001 respectively.

3. Results and Discussion

The effects of Cultivar/Variety and treatment were very highly significant (P<0.001) on plant height in all developmental stages (**Table.2**).

Therefore, the effect of the treatment on tiller number was highly significant (P<0.01) at the beginning and the end of the growth cycle. The green leaf number was influenced significantly by the treatment. Eventually, the interaction Cultivar/Variety×Treatment was mostly observed at heading stage. Even though a decrease of the leaf blade area under rainfed conditions was noted, the difference between studied cultivars and varieties was not significant at 0.05 level of significance regarding significant effect of the treatment on leaf blade area at heading stage (**Table 3**). Besides, the comparison of means by Duncan's test released one homogeneous group in both treatments.

Under rainfed conditions, CV. ‘Pakistan’ barley exhibited a similar behaviour as CV. ‘Ardhaoui’ cultivar when considering plant height parameter at heading at maturity stages basing on Duncan's test (**Table 4**).

The same test did not yield significant differences between studied Cultivars/Varieties for the tiller number and the number of green leaves (Table 4). Higher shoot extension was registered at maturity in

Table 3. Effect of the variety on leaf blade area. Values presented are means ± SE for the set of 5 cultivars under irrigated and rainfed field conditions.

Parameter	Cultivar/Variety	Treatment	
		Irrigated	Rainfed
Leaf blade area (cm^2)	Ardhaoui	8.02±0.60a	7.83±0.79a
	Pakistanais	9.00±1.15a	6.15±1.01a
	Rihane	8.06±0.94a	7.40±0.98a
	Roho	9.62±0.73a	6.86±0.40a
	Manel	9.23±1.04a	7.33±0.69a

In a column, means followed by common letter (s) are not significantly different at the 5% level by Duncan's multiple range test (DMRT).

Table 4. Effect of the variety on plant height, tiller number and green leaf number. Values presented are means ± SE for the set of 5 cultivars/varieties under irrigated and rainfed field conditions.

Parameter	Treatment	Cultivar/Variety	Developmental stage		
			Tillering	Heading	Maturity
Plant height (cm)	Irrigated conditions	Ardhaoui	21.01±0.78a	34.53±0.62a	47.53±0.51a
		Pakistanais	20.93±0.55a	25.32±0.30b	32.75±0.98b
		Rihane	19.32±0.88b	24.95±0.82b	27.85±0.51b
		Roho	18.16±0.94c	24.17±0.98b	41.96±0.88c
		Manel	16.18±0.83d	23.85±0.92c	42.08±0.74d
	Rainfed conditions	Ardhaoui	15.43±0.85a	23.30±0.96a	35.44±0.26a
		Pakistanais	14.36±0.48b	22.57±0.95a	31.02±0.91a
		Rihane	13.6±0.36bb	18.60±0.96b	22.94±0.72b
		Roho	12.81±0.98c	18.59±0.98b	33.33±0.40c
		Manel	11.68±0.48c	17.17±0.99b	35.57±0.98d
Tiller number	Irrigated conditions	Ardhaoui	2.23±1.04a	2.4±0.82a	1.86±0.33a
		Pakistanais	2±0.88a	2.36±0.97a	1.2±0.33ab
		Rihane	1.8±0.75a	1.93±0.97a	1.16±0.33ab
		Roho	1.73±0.80a	1.53±0.90a	0.93±0.33ab
		Manel	1.4±0.58a	1.3±0.67a	0.42±0.41a
	Rainfed conditions	Ardhaoui	1.26±0.40a	1.2±0.83a	0.42±0.34a
		Pakistanais	1.2±0.66a	1.13±0.71a	0.42±0.41a
		Rihane	1.16±0.57a	1.13±0.52a	0.42±0.70a
		Roho	0.86±0.66a	1.03±0.80a	0.4±0.33a
		Manel	0.83±0.38a	0.8±0.67a	0.36±0.33a
Green leaf number	Irrigated conditions	Ardhaoui	10.43±0.97a	10.43±0.99a	8.33±0.84a
		Pakistanais	9.2±0.72a	10.03±0.86a	7.86±0.94a
		Rihane	8.6±0.85a	9.3±0.88a	6.8±0.30a
		Roho	8.26±0.55a	8.73±0.99a	6.6±0.35a
		Manel	7.06±0.57a	8.2±0.35a	6.13±0.50a
	Rainfed conditions	Ardhaoui	6.8±0.38a	8.03±0.77a	5.73±0.85a
		Pakistanais	6.36±0.87a	7.5±0.86a	5.6±0.43a
		Rihane	6.3±0.84a	7.16±0.95a	5.26±0.71a
		Roho	6.26±0.91a	7.13±0.75a	5±0.70a
		Manel	5.33±0.94a	6.03±0.48a	4.76±0.48a

In a column, means followed by common letter (s) are not significantly different at the 5% level by Duncan's multiple range test (DMRT).

Ardhaoui (35.44 cm) and Pakistan cultivar (31.02 cm) that ranked in the same group. Average tiller number in Ardhaoui was 1.26 whereas in Manel accounted for only 0.83 under rainfed conditions.

Under water deficit constraint, all varieties and cultivars exhibited continuous leaves senescence during

the mid and late growing season. Mean values of barley shoot length, green shoot leaves number are shown in Table 4. Modifications in aboveground structures, including tissue morphology may benefit plant–water use by diminishing transpirative water loss (Hinckley *et al*., 1978; Kramer, 1983). Modifications in leaf area (as indicated by limited aboveground growth) in barley are characteristic of drought avoidance, and may allow this plant to withstand and survive limited water conditions (Morgan, 1984; Jones and Corlett, 1992). Structural avoidance of excessive irradiance can be crucial for plant survival in high-light environments (Pearcy *et al*., 2005). Barley morphological adaptations to water deficit appear to be an extension of shoots only in the most favorable water availability periods and gradual leaves senescence throughout the growing season.

4. Conclusions

Results of this investigation indicated that even if there were no significant difference between studied varieties and cultivars at tillering stage was documented, the degree of tolerance to drought was emphasized at maturity mainly in plant height. Morphological adaptations confer a greater degree of drought tolerance and aid in the recovery from drought induced damage.

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