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Effect of Soil Water Deficit on Growth and Water Use Efficiency for Three Tunisian Pastorals Species (*Lotus creticus, Plantago albicans* and *Rhanterium suaveolens*)

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Abstract: Three pastorals species (*Lotus creticus*, *Plantago albicans* and *Rhanterium suaveolens*) were subjected to two watering regimes (50 % and 100 % of field capacity (FC)). The aim of the current work is to study the effect of water deficit on growth parameters (leaf area, leaf elongation and biomass production) and water use efficiency of the studied species during two growth stages: seedling or establishment stage and full vegetative stage. We noted that water stress induced a reduction of all studied parameters mainly in the second stage. The highest decreases in leaf area (50.00%) and in leaf elongation were shown in *Plantago albicans*. However, we noted an increase of water use efficiency on all studied species; *Rhanterium suaveolens* used more efficiently water (52.37%) in stress conditions than *Lotus creticus* (11.77%) and *Plantago albicans* (3.62%).

Keywords: Arid land, Pastoral plants, Water stress, Water use efficiency

1. Introduction

Several environmental factors adversely affect plant growth, development and final yield performance of crop. Drought, salinity, and extremes of temperature are among major environmental constraints known to limit plant productivity in many regions of the world. Recent studies have shown that growth rates of several plants are directly proportional to the water availability in the soil (Kameli and Loser, 1995). It is estimated that less than 10.00% of the world's arable lands may be free of major environmental stresses (Dudal, 1976). Pastorals plants are known in arid land to support dryness. When exposed to water stress they develop some mechanism of tolerance and/or resistance.

2. Materials and Methods

2.1. Plants material

The studied species are *Lotus creticus*, *Plantago albicans* and *Rhanterium suaveolens* which were collected from several places of Tunisian arid lands. Seeds were sown into pots. Experiments were carried out under glasshouse-controlled conditions (T: 26 ˚C and ordinary light).

2.2. Water regimes

Water supply was varied in two levels, according to 100% (control) and 50% of water field capacity (WFC). Water content at maximum water holding capacity was determined as the amount of water retained by representative samples of the substrate. Water regimes were implemented 8 weeks after sowing. Adjustment of the intended water contents was accomplished on a weight basis every second day. Plants were sampled after one month of stress (establishment stage) and then after two months of stress (full vegetative stage).

2.3. Growth parameters

The growth parameters measured are leaf area ($cm^2.plant^{-1}$), leaf elongation (mm^2), dry weight shoot (DWS), dry weight root (DWR) (g) and the allocation of resources (DWR / DWS). The leaf area (LA) was calculated using mesurim pro 6 software.

2.4. Water use efficiency (WUE)

Water use efficiency was calculated by integrating over the vegetation period dividing accumulated dry matter (shoot and root) by cumulative water use (WUE).

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2.5. Statistical analysis

All analyses were done on a completely randomized design. All data obtained were subjected to one-way analysis of variance (ANOVA) and the mean differences were compared by Duncan test. Each data point was the mean of six replicates (n = 6). Comparison with *P* values < 0. 05 were considered significantly different.

3. Results and Discussion

3.1. Morphological parameters

The effect of water stress on growth parameters for all species was illustrated in **Table 1**. For the leaf area, the comparison between the three species showed that on establishment stage, stressed plants of *L. creticus* and *R. suaveolens* formed a homogeneous group. In this stage, it was *R. suaveolens* which was more affected by water stress (57.00%). While, at the full vegetative stage, it was rather *P. albicans* which was more sensitive to water stress (53.00%). The differences between all species was statistically significant (p<0.05). The highest leaf elongation has been recorded on *P. albicans.* On establishment stage, the drought stressed plant, decreased their leaf elongation from 100 to 68 mm (32.00 %). On the full vegetative stage, the leaf elongation decreased by about 50.00%. However, on *R. suaveolens*, drought stress decreased the leaf elongation (p<0. 01) by 30.00%.

Water stress caused a significant reduction of leaf area and leaf elongation. Similar results were obtained by Hall (1993) in *Medicago sativa* subjected to water deficit. Harrouni *et al.* (1995) concluded that drought stress reduced vegetative growth and particularly leaf expansion. According to Thakur and Rai (1982), drought stress induced a slowing in plant growth. It results in reduction of elongation of all internodes. Harrouni *et al.* (1995) suggested that the effect of drought was expressed by a progressive slowing of the primary growth since the water deficit reduced the turgescence and consequently the expansion capacity of leaves.

For dry weight shoot, growth of pastorals plant was affected by water stress. On establishment stage, there was no large difference between the three species. But on the second stage of development, the

Table 1. Effect of drought stress during experiment period on growth parameters; leaf area (LA), leaf elongation (LE), dry weight roots (DWR) and dry weight shoot (DWS).

		Establishment stage			Full vegetative stage		
		Control	Stress	Reduction (%)	Control	Stress	Reduction (%)
LA (cm^2)	F calculated and signification	55.29**	19.53**		256,59**	67,40**	
	L. creticus	$0.46±0.08^b$	$0.25±0.08^b$	44.78	$0.84± 0.37^c$	$0.45± 0.12^c$	46.01
	P. albicans	$5.20± 1.50^a$	$2.77±1.43^a$	46.56	$10.41±1.29^a$	$4.67±1.11^a$	52.34
	R.suaveolens	$1.20±0.21^b$	$0.52±0.09^b$	56.73	$3.42± 0.43^b$	$2.19± 0.21^b$	33.86
LE (mm)	F calculated and signification	237.30^{**}	191.35^{**}		$743,646^{**}$	$89,18^{*}$	
	L. creticus	$9.71±1.30^c$	$6.14±1.95^c$	36.76	$11.10± 6.90^c$	$6.57 ± 1.71^b$	40.81
	P. albicans	$100.40±14.2^a$	$68.40±10.9^a$	32	$174.4±14.9^a$	$90.71±21.8^a$	47.87
	R.suaveolens	$22.86±2.79^b$	$15.80±0.37^b$	29.97	$30.20± 0.75^b$	$20 ± 0.00^b$	28.39
DWS (g)	F calculated and signification	9.41^{*}	2.18^{ns}		1.94^{ns}	5.19^{*}	
	L. creticus	$0.71± 0.17^a$	$0.18± 0.11^a$	74.14	$1.23 ±0.24^a$	$0.63± 0.29^b$	48.70
	P. albicans	$0.90± 0.48^a$	$0.25± 0.12^a$	71.92	$2.68 ± 0.42^a$	$1.24± 0.69^{ab}$	53.62
	R.suaveolens	$0.21±0.11^b$	$0.13 ± 0.08^a$	36.01	$1.91 ± 2.30^a$	$1.66± 0.72^a$	12.99
DWR (g)	F calculated and signification	5.30^{**}	8.01^{**}		18.59^{**}	5.87^{**}	
	L. creticus	$0.20±0.05^b$	$0.08 ±0.03^b$	57.15	$0.88 ± 0.72^b$	$0.62 ±0.41^{ab}$	29.35
	P. albicans	$0.46± 0.42^a$	$0.18± 0.12^a$	60.5	$1.93 ± 0.52^a$	$1.25 ± 0.91^a$	35.27
	R.suaveolens	$0.03±0.007^b$	$0.02± 0.01^b$	32.41	$0.24 ±0.16^c$	$0.18 ± 0.16^b$	23.69

Means ± S.D. based on 6 replicates (n = 6). Significant differences are indicated with *, ** for α < 0.05, 0.01, n.s = non significant. Same letters indicate homogeneous groups.

Table 2. Effect of drought stress during experiment period on the ratio: dry weight root (DWR) / dry weight shoot (DWS) on *Lotus creticus, Plantago albicans* and *Rhanterium suaveolens*.

	Establishment stage			Full vegetative stage			
	Control	**Stressed**	**Increase (%)**	**Control**	**Stressed**	**Increase (%)**	**Decrease (%)**
L.creticus	0.20±0.03[ab]	0.51± 0.13[a]	84.17	0.69±0.4[a]	0.88±0.27[a]	27.35	
P.albicans	0.42±0.25[a]	0.66 ±0.22[a]	55.89	0.74±0.28[a]	1.08±0.88 [a]	45.43	
R.suaveolens	0.21±0.11[b]	0.22±0.10[b]	6.66	0.17±0.08[b]	0.12±0.10[b]		27.32
F calculated and signification	2.87*	13.02**		6.77**	6.21**		

behaviour of each species became different and *R. suaveolens* presented the lowest reduction of dry weight (12. 99 %).

In addition to the reduction of dry weight shoot, dry weight root was also affected by water stress. Duncan test classified the studied species on different groups. On establishment stage, water stressed plant of *L. creticus* and *R. suaveolens* formed a homogeneous group but with different percentage of reduction. Yet, on full vegetative stage, *R. suaveolens* was distinguished by less developed roots. *P. albicans* was the specie which presented the highest reduction of DWR on establishment stage by 60.50% and by 35.27% on full vegetative stage. All the studied species increased their ratio DWR/DWS in water stress conditions on establishment stage. *L. creticus* and *P. albicans* presented the highest level of increase, although, on full vegetative stage, only *R. suaveolens* decreased its ratio by 27.35% (**Table 2**).

Shoot and root dry weight decreased significantly in case of water shortage. Similar results were shown by Bloch et al., (2006) in sugar beet plant**.** In *Medicago sativa*, dry matter production is the most sensitive parameter to water rationing, a reduction of water supply from flowering phase leads to a decline of dry matter of 50.00% (Vidal and Pagnonec, 1985).

On three pastoral species the resources allocation between aerial and taproots parts was dependent on species and water regime. The ratio DWR/DWS was higher on drought condition than on well watered conditions for *Lotus creticus* and *Plantago albicans*. This is due to the reduction of DWS and of DWR (Jaballah, 2007; Knight *et al*., 2006; Malik *et al*., 2002). However, for *R. suaveolens* there was no significant difference between stressed and well watered plants. This indicates that there was an equal distribution of resources between aerial and roots parts.

3.2. Water use efficiency

On well watered conditions, WUE amounted to 11.04; 14.91 and 15.14 g kg^{-1} for *L. creticus*, *P. albicans* and *R. suaveolens* respectively (**Table 3**). Difference between groups for this treatment was non-significant. Drought stress increased significantly WUE by 11.77 % for *L. creticus*; 3.62 % for *P. albicans* and by 52.37 % for *R. suaveolens.*

Generally, dry matter production and water use of crop stands are closely related and the relationship between cumulative water use and yield, characterized by the water-use efficiency (WUE), is to a large extent independent of the level of water supply and water use (Ehlers and Goss, 2003). However, in the

Table 3. Effect of drought stress during experiment period on the water use efficiency (WUE) on *Lotus creticus, Plantago albicans* and *Rhanterium suaveolens.*

	WUE (g. kg^{-1})		
	control	**stress**	**Increase (%)**
F calculated and signification	1,634 [ns]	3.601 *	
L. creticus	11.04 ± 2.92 [a]	12.34 ± 3.50 [b]	11.77
P. albicans	14.91 ± 4.85 [a]	15.45 ± 9.90 [ab]	3.62
R. suaveolens	15.14 ± 5.99[a]	23.07 ± 8.20 [a]	52.37

Means ± S.D. based on 6 replicates (n = 6). Significant differences are indicated with *, for $\alpha < 0.05$, n.s = non significant. Same letters indicate homogeneous groups.

present study the relationship between water use and yield was modified by water supply. WUE increased for all studied species. Similar results were found for sugar beet by Bloch *et al.* (2006) which reported that WUE amounted to 7.4 g and 6 g total dry matter per litre H_2O for drought and control, respectively. The higher efficiency of water use under stress is due to the fact that drought-stressed plants wilt far more than unstressed plants and wilting invariably occurs in times when the saturation deficit of the atmosphere is large. Therefore, the plant assimilates only in times when the saturation deficit is small and hence loses less water for every carbon molecule fixed (Clover *et al.*, 2001).

Araus *et al.* (2002) and Bacelar *et al.* (2007) suggested that the increase in water use efficiency under drought stress was as a strategy to improve crop performance underwater-limited conditions and differences in WUE may therefore need to be combined with other crop traits to be of practical value for crop improvement in dry environments.

4. Conclusion

Different behavior of the three species was recorded under water stress conditions. All studied parameters were affected and especially on full vegetative stage. It's recommended to study the survival mechanism of plants under long periods of dryness such as physiological mechanism which give more precision about the adaptation of plants to stress and ameliorate mechanism of adaptation to stress in sensitive plants.

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