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The Mechanisms of Salinity Tolerance in the Xero-halophyte Blue Panicgrass (*Panicum antidotale* Retz)

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Abstract

Identifying the physiological traits associated with salt tolerance is important in optimal management of biosaline systems and optimum utilization of saline water resources in dry and saline areas. Therefore, some indices of photosynthetic activity, dry matter production and accumulation of sodium and potassium ions in Blue panicgrass (*Panicum antidotale* Retz) were evaluated in five levels of salinity treatment (0, 70, 140, 210 and 280 mM NaCl solution) under greenhouse conditions. The results showed that at 28 and 35 days after salt stress, plant leaf area reduced in the highest salinity treatment, 93 and 96% respectively, compared with control. Leaf stomatal conductance, CO_2 fixation and quantum efficiency of photosystem II were decreased by increasing salinity. It caused also a reduction in chlorophyll content (Chl *a*, Chl *b*) in leaves of Blue panicgrass. Content of carotenoids showed binary patterns to different salinity levels, slightly increased in 70-140 mM NaCl and decreased again in 210-280 mM, respectively. Increasing levels of salinity, increased sodium content in both roots and shoots but the shoots potassium content decreased. Decline in photosynthesis indices caused the reduction of root and shoot dry weight. This decrease resulted from lower leaf area ($r=0.91^{**}$), lower stomatal conductance ($r=0.78^{**}$), lower CO_2 fixed in photosynthesis ($r=0.63^{**}$), lower quantum efficiency of photosystem II ($r=0.54^{**}$) and lower Chl *a* ($r=0.45^{**}$), respectively. Data analysis base on using stepwise regression introduced leaf area ($\beta=0.560$), chlorophyll *a* content ($\beta=0.245$) and shoot potassium content ($\beta=0.264$) as main effective components of salinity tolerance in Blue panicgrass.

Keywords: chlorophyll fluorescence, CO_2 fixation, leaf area, Na^+ content, stomatal conductance

Introduction

Salinity in soil or water is one of the major environmental stresses, especially in arid and semi-arid regions, can severely limit production of agriculture systems (Kafi and Khan, 2008). Under this condition, the identification and cultivation of salt tolerant species are functional solution for the effective use of the soils exposed to salinity (Ahmad *et al*., 2010; Ashraf and Harris, 2005; Kafi and Khan, 2008). Evaluation of the changes in physiological and biochemical characteristics of plants tolerant to various stresses, such as Blue panicgrass (*Panicum antidotale* Retz) (Ahmad *et al*., 2010; Ashraf, 2004) provides desirable approaches for studying different aspects of hereditary stress tolerance (Niknam and Mccomb, 2000). Ashraf (2003) reported that imposition of salt stress and water-logging for 46 days caused a significant reduction in growth of *P. antidotale*.

In addition to understand the physiological mechanisms responsible for the salinity tolerance of some species, it is necessary to know whether their growth is being limited by the osmotic, or the toxic effect of the salt within the plant (Munns and Tester, 2008). Salinity stress caused a reduction in chlorophyll content, disorders in the electron transport chain and decrease in photosystem II (PSII) activity which then directly affects the leaf photosynthesis, carbon metabolism and ultimately economical yield (Sudhir and Murthy, 2004). The light-absorbing pigments such as chlorophylls provide a potential source to produce active oxygen radicals in stress condition and consequently the reducing chlorophyll content lead to a decrease in damage to the photosynthetic system (Ashraf and Harris, 2005).

Salinity stress also decreases carbonic anhydrase enzyme activity due to reduced activity of Rubisco activase (Soussi *et al*., 1998) and then decreases chlorophyll contents and photosynthetic efficiency. Netondo *et al*. (2004) stated that increasing sodium chloride concentration in solution medium to 250 mM differently decreased the efficiency of PSII and the rate of electron transfer in two sorghum cultivars. Adversely, Lu *et al*. (2002) also showed that the salinity had no effects on PSII photochemistry, light inhibition and photosynthetic pigment composition in *Suaeda salsa*. However, the effect of salinity on the photosynthetic efficiency depends on plants species and intensity of salt stress.

The purpose of the present study was to investigate the photosynthetic activity indices such as stomatal conductance, leaf CO_2 fixation, chlorophyll fluorescence parameters, photosynthetic pigments content and biomass production and accumulation of sodium and potassium in the root and shoot of Blue panicgrass as a xero-halophyte after

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imposing various levels of salinity in irrigation water and identifying main factors to its salt tolerance.

Materials and methods

The study was conducted in greenhouse conditions in the Faculty of Agriculture, Ferdowsi University of Mashhad, Iran. Seeds of Blue panicgrass (*Panicum antidotale* Retz.) were planted in black plastic pots, 23 cm in diameter and 30 cm deep were filled with 4 kg soil (about 92% sand, 4% clay, and 4% silt) in 18th June 2011. The pots were irrigated until the four-leaf stage by about 200-250 ml of tap water (EC=0.7 dS m^{-1}) daily. During this time seedlings were eventually thinned over several times and finally kept two plants in each pot. Thus, a control and four saline treatments imposed by irrigation with saline waters contained 70, 140, 210 and 280 mM NaCl in solution, respectively. Sampling and measurements arranged 28 and 35 days after imposing different levels of salinity in irrigation water.

Plant leaf area

The non-destructive method applied for measuring plant leaf area and was estimated by the following equation:

$y=0.785x+0.164$

$R^2=0.927$

Where consisting: *y*: Leaf area per plant and *x*: the multiplying length × width of the leaf.

Photosynthesis

Gas exchange and related parameters were measured between 11 am to 1 pm using a portable ADC infra-red gas analyzer (model: LCA4), at PPFD>950 μmol m^{-2} s^{-1}; leaf chamber temperature at 33±2°C. All measurements were carried out on the intact youngest fully developed leaf, keeping the chamber constantly vertical to solar radiation, till stabilizing gas exchange in the leaf chamber. At least, 10 records were obtained for each leaf after reaching steady state.

Stomatal conductance

The leaf stomatal conductance (mmol $m^{-2}s^{-1}$) was measured with a steady state porometer (SC-1's Model), with chamber conditions set to ambient.

Chlorophyll fluorescence

Chlorophyll fluorescence parameters were measured using a leaf chamber fluorometer (Hansatech v. 1.21). Measurements were made on each plant in the four salinity treatments (n=5). Dark adapted fluorescence parameters were measured between 10:00 and 12:00 h, where ambient light intensity was 1,500-1,600 μmol$m^{-2}s^{-1}$. Plants were dark-adapted for 20 min using a dark adaptation kit designed for this purpose. The minimal fluorescence level in the dark-adapted state (F_0), and maximal fluorescence (F_m) were measured using a modulated pulse. Values of variable fluorescence ($Fv = F_m-F_0$) and maximum quantum efficiency of PSII photochemistry (F_v/F_m) were calculated from F_0 and Fm.

Chlorophyll content

Chlorophylls a and b, and total carotenoids were determined according to the method of Dere *et al.* (1998). Fresh leaves (0.1 g) were cut and extracted overnight with 95% ethanol at 0-4°C. The extracts were centrifuged at 3,000-g for 5 min. Absorbance of the supernatant was read at 666, 653 and 470 nm using a spectrophotometer for chlorophylls a and b, and total carotenoids, respectively (Hitachi-220 Japan).

Analysis growth and inorganic elements: The shoots were washed twice in distilled water while ions were removed from the free space of roots by washing for one minute in sorbitol solutions isotonic with the treatments concentration in which the plants were grown. Shoots and roots were dried at 70°C for 48 h to determine their dry weights. Dried and ground plant material (0.1 g each of shoot or root) was digested in concentrated H_2SO_4 following Wolf (1982) for determining the ionic contents of root and shoot. Cations (Na^+ and K^+) were determined with a flame photometer (Jenway, PFP-7).

Statistical analysis

The experiment was designed and analyzed as a complete randomized blocks design with salinity treatment in 5 levels and 3 replications. Statistical significance, where indicated, is at 5% level of probability as determined by analysis of variance and Fisher's LSD test. Also attributed of measured traits in salt tolerance of Blue panicgrass was evaluated from the data obtained after 28 and 35 days of stress were used by the stepwise regression method using the "statistical software PASW, version 18". In this method, ratios of the total dry weight in the saline to non-saline treatments were as dependent variable and other traits were as independent variables. Simple correlation coefficients (r) between measured traits were achieved by Pearson method.

Results

Plant leaf area (cm^2)

Analysis of variance showed significant differences at 99% probability levels for plant leaf area at 28 and 35 days after imposing various levels of salinity in irrigation water. It was reduced by 90% in 280 mM sodium chloride when compared to the non-saline treatment, although the strongest reduction observed in 70 mM (Tab. 1)

Stomatal conductance (mmol $m^{-2}s^{-1}$)

There were significant differences ($p<0.01$) for stomatal conductance of leaves at various levels of salinity. The variation between the highest salinity levels in 280

mM compared with non saline were 97% at 28 days after stress and 100% after 35 days (Tab. 1).

Leaf CO_2 fixation rate (µmol $m^{-2}s^{-1}$)

Analysis of variance showed significant differences at the 1% probability levels for CO_2 fixed by leaf at 28 and 35 days after imposing various levels of salinity in irrigation water. It was reduced by 96 and 100% in 280 mM sodium chloride when compared to the non-saline treatment after 28 and 35 days (Tab. 1)

Chlorophyll fluorescence parameters

There were significant differences at the 1% probability levels for The minimal fluorescence state (F_0) at various levels *of salinity* and the lower values belonged to strong salinity (Tab. 1 and 2). However, the difference between the different levels of salinity stress was not significant for F_0 after 35 days (Tab. 1).

Analysis of variance showed significant differences for maximal fluorescence (F_m) in different levels of salinity, 28 days after imposing stress but was not significant at 35 days. Differences among various salinity treatments for maximum quantum efficiency of PSII photochemistry (Fv⁄Fm) were significant at 99% probability levels 28 days after stress and 95% at 35 days. Means value of F_v/F_m was reduced by increasing intensity of salinity stress (Tab. 1).

Photosynthetic pigments (µg g^{-1} fw)

For chlorophyll *a* content there were significant differences among various levels of salinity stress at 28 (p<0.01) and 35 days after stress (p<0.05). Chlorophyll *a* content decreased with increasing salinity levels and leaves had about 62% and 77% lower Chlorophyll *a* in 280 mM sodium chloride compared to non saline treatment, respectively (Tab. 2). Similarly, chlorophyll *b* content significantly decreased by 65 and 85% in the presence of 280 mM salinity compared to control. For carotenoids content, 28%

Tab. 1. Mean comparison for leaf area, stomatal conductance, CO_2 exchange rate and different parameters of chlorophyll fluorescence of Blue panicgrass (*Panicum antidotale* Retz) in various salinity levels of irrigation water at 28 and 35 days after stress (DAS)

DAS	Salinity (mM)	Leaf area (cm^2)	Stomatal conductance (mmol $m^{-2}s^{-1}$)	CO_2 fixed (µmol. $m^{-2}s^{-1}$)	F_o	F_m	F_v/F_m
28	0	419	9.33	7.54	625	2365	0.746
	70	83.5	7.37	2.82	606	1460	0.573
	140	51.1	6.03	2.33	671	1500	0.520
	210	36.3	0.567	0.44	239	338	0.330
	280	27.7	0.233	0.26	292	300	0.066
$LSD_{5\%}$		36.4	2.44	2.66	169	723	0.317
35	0	520	13.26	6.54	545	2249	0.762
	70	141	8.10	1.82	958	2403	0.603
	140	49.8	6.16	1.56	837	1949	0.561
	210	48.2	5.70	0.77	522	1237	0.374
	280	21.2	0.00	0.00	531	759	0.228
$LSD_{5\%}$		109	3.38	2.45	466.55	999	0.301

Tab. 2. Mean comparison photosynthetic pigments, biological yield and root to total weight ratio of Blue panicgrass (*Panicum antidotale* Retz) in various salinity levels of irrigation water at 28 and 35 days after stress (DAS)

DAS	Salinity (mM)	Photosynthetic pigments (µg g^{-1} fw)			Biological yield (mg $plant^{-1}$)			Root/Total weight (%)
		Chl *a*	Chl *b*	Cartenoids	Root	Shoot	Total	
28	0	10.0	9.32	1.26	2964	4656	7621	39.1
	70	11.6	6.41	1.00	1689	1842	3531	47.6
	140	7.98	5.93	0.987	770	1034	1805	42.7
	210	3.97	4.88	0.974	590	643	1233	46.9
	280	3.72	3.23	0.318	493	498	991	50.9
$LSD_{5\%}$		2.65	2.28	0.647	754	1132	1834	14.5
35	0	9.06	4.106	0.866	7478	12701	20179	36.22
	70	5.48	3.08	1.42	1594	3275	4869	34.14
	140	4.72	2.31	1.64	878	2304	3182	27.88
	210	4.63	2.27	1.35	843	1686	2528	34.14
	280	2.21	0.628	0.622	443	531	974	45.52
$LSD_{5\%}$		1.38	0.993	0.457	2729	3070	5243	14.36

different between highest level of salinity and non saline treatments at 28 days after the stress and 74% at 35 days after stress were recorded.

Dry matter production and allocation (mg plant^{-1})

There were significant differences (p<0.01) in various levels of salinity for both root and shoot dry mater accumulation. The root and shoot dry matter was reduced averaging more than 80% in 280 mM compared to non saline treatment (Tab. 2). Ratio of root to total dry weight was not significant among treatments but generally it was increased with exceeding salinity (Tab. 2).

Na^+ and K^+ content (mg g^{-1}dry weight)

Na^+ content in root was increased significantly by increasing salinity, averaging 11 mg g^{-1} more in 280 mM compared to non saline treatment. Similarly the shoot Na^+ content was significantly increased by 70.6 and 42.7 mg g^{-1} at 28 and 35 days after stress in 280 mM salinity compared to control (Tab. 3). In addition, there were significant differences (p<0.01) among various levels of salinity stress for K^+ content of both root and shoot. The K^+ content of root in 280 mM was 6.4 mg g^{-1} more than non saline treatment at 28 days after stress and adversely 43.5 mg lower at 35 days after. The shoot K^+ content was significantly decreased by 21.4 and 24.6 mg at 28 and 35 days after stress in 280 mM compared to control, respectively (Tab. 3).

Na^+/K^+ ratio

As shown in Tab. 3, there were significant differences in Na^+/K^+ ratio of root and shoot among various levels of salinity stress. Na^+/K^+ ratio of root was 2.8 times more in 280 mM sodium chloride compared to non saline treatment at 28 days after salinity stress, but there was not a significant difference at 35 days after salinization. After 28 and 35 days, shoot Na^+/K^+ ratio in 280 mM sodium

Tab. 3. Mean comparison of Na+ and K+ content and Na^+/K^+ ratio in the root and shoot of Blue panicgrass (*Panicum antidotale* Retz) in various salinity levels of irrigation water at 28 and 35 days after stress (DAS)

DAS	Salinity (mM)	Na^+ content (mg g^{-1}dw)		K^+ content (mg g^{-1}dw)		Na^+/K^+	
		Root	Shoot	Root	Shoot	Root	Shoot
28	0	8.20	7.38	12.9	39.9	0.655	0.634
	70	11.4	11.3	22.9	21.8	1.26	2.27
	140	12.3	28.6	5.39	18.8	2.29	4.98
	210	16.7	67.7	8.50	19.2	2.09	3.63
	280	20.8	78.0	6.50	18.5	3.46	4.63
	$LSD_{5\%}$	8.27	51.4	3.42	10.3	1.79	4.46
35	0	3.67	6.80	4.46	37.2	0.867	0.191
	70	7.01	13.4	7.29	17.3	0.961	0.845
	140	12.8	23.1	54.4	12.8	0.239	1.79
	210	14.5	24.0	58.0	12.3	0.260	1.96
	280	15.2	49.5	48.2	12.6	0.330	4.02
	$LSD_{5\%}$	4.45	8.14	19.4	8.78	0.251	0.687

Tab. 4. Statistical summary of the stepwise regression results for the salinity tolerance index of Blue panicgrass

Model	Variable	Adjusted R square	df	F	P-value
Step1	Plant Leaf Area (PLA)	0.829	1	136	0.000
Step2	Chlorophyll *a* (CHA)	0.903	1	125	0.000
Step3	K Content in Shoot (KCS)	0.921	1	101	0.000

Tab. 5. The estimated coefficients of salinity stress tolerance model of Blue panicgrass in the stepwise regression method

	Model	Beta coefficient (β)	Adjusted Beta coefficient (β)	t	P-value
Step1	Intercept	0.115	-	3.34	0.002
	Plant leaf area (PLA)	0.002	0.911	11.6	0.000
Step2	Intercept	-0.066	-	-1.37	0.181
	Plant leaf area (PLA)	0.001	0.732	10.2	0.000
	Chlorophyll *a* (CHA)	0.036	0.324	4.51	0.000
Step3	Intercept	-0.151	-	-2.70	0.012
	Plant leaf area (PLA)	0.001	0.560	5.85	0.000
	Chlorophyll *a* (CHA)	0.027	0.245	3.34	0.003
	K content in shoot (KCS)	0.009	0.264	2.48	0.020

chloride were 3.99 and 3.88 times more than non saline treatment (Tab. 3).

Stepwise multiple regression

Results of stepwise regression showed that the plant leaf area (PLA), Chlorophyll *a* (CHA) and K content in shoot (KCS) can put in model during three steps (Tab. 4). Also based on beta values in Tab. 5, the regression equation can be written as follow:

STI=-0.151+0.001PLA+0.027CHA+0.009KCS

Where consisting: STI: Salinity tolerance index; PLA: Plant leaf area; CHA: Chlorophyll *a* and *KCS*: K content in shoot. Base on beta value, one unit variation in the plant leaf area will change 0.560 units in standard division of salinity tolerance index as the dependent variable, while one unit variation in the chlorophyll *a* (CHA) and K content in shoot (KCS) will change 0.245 and 0.264 units in this index, respectively.

Discussion

Although the halophyte species are naturally adapted to the salinity, but salt tolerance of them are strongly influenced by the origin of ecotype and plant development stage (Megdiche *et al*., 2007). Study on photosynthetic activity indicators of Blue panicgrass in this study showed that increasing the salinity reduced plant leaf area and there was a relatively rapid decline slope, especially in the treatment of 70 mM (Tab. 1). However, different between 0 and 70 mM NaCl treatments used in this experiment was 4.52 dS m^{-1} but the accumulation of salts in the soil over time, increased levels of stress to the plants and thus was not unexpected relatively high reduction in the leaf area. Muuns *et al*. (2003) stated that over time and with increasing the salinity, was reduced the cell growth and division and final size of plant leaves. Munns *et al*. (2006) also reported reduction of leaf growth by accumulation of salts around the roots that mainly due to the osmotic effect of salinity.

Leaf stomatal conductance, CO_2 fixed by leaf and maximum quantum efficiency of PSII photochemistry (F_v/F_m) were declined with increasing salinity, that are as major factors in reducing photosynthetic production and decreased allocation to the development of various organs (Munns and James, 2003). Ashraf (2004) also noted that net CO_2 assimilation and stomatal conductance of Blue panicgrass were positively associated and the former variable also had a strong positive relationship with transpiration. The positive correlation coefficients between leaf area and CO_2 fixation rate (r=0.81**), leaf stomatal conductance (r=0.76**) and efficiency of PSII photochemistry (r=0.58**) also emphasizes this issue (Tab. 6). Increase in salinity decreased chlorophyll concentration (Tab. 4) that indicate that other factors also reduce the efficiency of photosynthetic activity and ultimately reduce development of the plant's leaf area (Munns *et al*., 2006). Leaf chlorophyll content showed strong reduction in the *Cakile maritima* as halophyte that was more evident in the salt sensitive ecotypes (Megdiche *et al*., 2007). Positive correlation between chlorophyll *a* and *b* with other traits was shown the potential role of these pigments to protect capacity for photosynthesis and plant biomass accumula-

Tab. 6. Simple correlation coefficients between different measured traits of Blue panicgrass under different levels of salinity stress

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1																		
2	0.76**	1																	
3	0.14ns	0.43*	1																
4	0.57**	0.75**	0.75**	1															
5	0.58**	0.74**	0.47**	0.86**	1														
6	0.81**	0.66**	0.23ns	0.65**	0.64**	1													
7	0.55**	0.68**	0.23ns	0.54**	0.67**	0.66**	1												
8	0.43**	0.37*	-0.02ns	0.32ns	0.41*	0.66**	0.75**	1											
9	0.07ns	0.35ns	0.57**	0.63**	0.65**	0.18ns	0.18ns	0.05 ns	1										
10	0.91**	0.78**	0.17ns	0.52**	0.54**	0.65**	0.43*	0.14ns	0.07ns	1									
11	0.88**	0.76**	0.02ns	0.42*	0.52**	0.58**	0.47**	0.20ns	0.00ns	0.95**	1								
12	0.91**	0.78**	0.12ns	0.49**	0.54**	0.63**	0.45**	0.17ns	0.05ns	0.99**	0.98**	1							
13	-0.24ns	-0.40ns	-0.71**	-0.61**	-0.40*	-0.23ns	-0.06ns	0.16ns	-0.59**	-0.32ns	-0.12ns	-0.25ns	1						
14	-0.68**	-0.78**	-0.49**	-0.76**	-0.74**	-0.63**	-0.62**	-0.31 ns	-0.36ns	-0.68**	-0.63**	-0.67**	0.42*	1					
15	-0.51**	-0.75**	-0.48**	-0.72**	-0.76**	-0.55**	-0.65**	-0.27ns	-0.58**	-0.48**	-0.44*	-0.47**	0.43*	0.82**	1				
16	-0.35ns	-0.21ns	0.08ns	-0.16ns	-0.26ns	-0.36ns	-0.48**	-0.56**	0.24ns	-0.27ns	-0.32ns	-0.29ns	-0.29ns	-0.22ns	-0.03ns	1			
17	0.82**	0.56**	0.06ns	0.45*	0.45*	0.81**	0.66**	0.68**	-0.08ns	0.63**	0.61**	0.63**	-0.08ns	-0.55**	-0.35ns	-0.51**	1		
18	-0.23**	-0.37**	-0.45*	-0.45*	-0.40*	-0.21ns	-0.13ns	0.15ns	-0.50**	-0.24ns	-0.17ns	-0.21ns	0.53**	0.58**	0.69**	-0.58**	-0.07ns	1	
19	-0.57**	-0.64**	-0.38*	-0.58**	-0.57**	-0.42*	-0.43**	-0.17ns	-0.44*	-0.55**	-0.49**	-0.53**	0.42*	0.71**	0.69**	-0.02ns	-0.49**	0.62**	1

ns, * and **: Non significant, significant at 5% and 1% levels of probability, respectively; Numbers 1 to 19, respectively, represent: 1: Plant leaf area ; 2: Stomatal conductance; 3: Fo; 4: Fm; 5: Fv / Fm; 6: CO2 fixation by leaves; 7: Chlorophyll a concentration; 8 Chlorophyll b concentration; 9: Carotenoids concentration; 10: Shoot dry matter; 11: Root dry matter; 12: Total dry matter; 13: Root /Total weight ratio; 14: Root sodium concentration; 15: Shoot sodium concentration; 16: Root potassium concentration; 17: Shoot potassium concentration; 18: Root sodium to potassium ratio; 19: Shoot sodium to potassium ratio

tion (Tab. 6). When halophytes such as *Paspalum vaginatum* Swartz (Lee *et al*., 2005), *P. antidotale* (Ashraf, 2003) and field crop, including wheat (Bajji *et al*., 2001), were exposed to salinity stress, net photosynthesis, stomatal conductance and chlorophyll content were reduced.

The total content of carotenoids followed a binary pattern in response to different intensities of salinity and relatively increased in 70 and 140 mM but adversely was associated with decreased in 210 and 280 mM salt treatments (Tab. 2). Also there were significant positive correlation between total carotenoids and different parameters of chlorophyll fluorescence (Tab. 6).

Concurrent with the decline in leaf photosynthetic characteristics, root and shoot dry weight was also reduced (Tab. 1). This decrease resulted from lower leaf surfaces (r=0.91**), lower stomatal conductance (r=0.78**), lower CO_2 fixed (r=0.63**), r=0.91**quantum efficiency of PSII (r=0.54**) and lower leaf chlorophyll *a* (r=0.45**), respectively (Tab. 6).

With increasing salinity, sodium concentration in the root and shoot increased consequently sodium to potassium ratio decreased (Tab. 6). However, toxicity of sodium ion after increasing Na^+/K^+ ratio in the root and shoot are a possible reason for the decline in photosynthesis rate and dry matter yield (Munns and Tester, 2008).

Negative correlation between total dry matter yield and sodium concentrations of root (r=-0.67**) and shoot (r=-0.47**) and positive correlation between total dry matter yield and K^+ concentrations of shoot (r=0.63**) is emphasized (Tab. 6). These results are consistent with findings of other researchs on *Cakile maritime* (Megdiche *et al*., 2007) and *Hordeum vulgare* genotypes (Taghipour and Salehi, 2008).

Conclusions

Although, in the study of Ashraf (2003) growth of *P. antidotale* adapted to saline habitats was associated with higher net CO_2 assimilation and stomatal conductance, but under the present experiment conditions stepwise regression showed that leaf area, chlorophyll a content and shoot K^+ content are the main components of salt tolerance in Blue panicgrass.

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