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INTERACTION BETWEEN SALINITY AND POTASSIUM ON GRAIN YIELD, CARBOHYDRATE CONTENT AND NUTRIENT UPTAKE IN PEARL MILLET

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ABSTRACT

To study the effects of different salinity levels and potassium supply on grain yield, yield components, carbohydrate content and nutrient uptake in pearl millet, a plot experiment was conducted in a greenhouse at university of Zabol, Iran. The experiment was laid out in a completely randomized factorial design with three replicates. Potassium sulfate was used as the potassium source. The rate of potassium treatment was 0, 100 and 200 kg ha^{-1}. Pearl millet was subjected to different salinity levels (0, 4, 8 and 12 ds/m) through addition of NaCl to irrigation water. Results showed by increasing salt concentration from control to 12 ds/m grain yield (45.6%), biological yield (35.3%), harvest index (15.1%) and 1000 seed weight (60.1%) decreased. In this study salt stress remarkably elevated the carbohydrate content at vegetative and reproductive stages in leaves of millet. Salinity treatment decreased potassium and magnesium uptake but application potassium increased potassium and magnesium content in leaves at two stages until 200 kg.ha^{-1}. Potassium application had significantly effect on grain yield and yield components and increased them.

Keywords: salinity, potassium, carbohydrate, ion content, pearl millet

INTRODUCTION

Soil salinity decreases crop yield through increasing osmotic stress on the plant. Under saline conditions, nutrient imbalance, reduced nutrient uptake including K^+, and ion toxicity are resulted because of high Na^+ and Cl^- concentrations (Miransari and Smith, 2007). The adverse effect of salinity on crop growth results from disturbed metabolic processes, which are most commonly manifested in stunted plant growth, poor productivity (Jin Woong and Choongsoo, 1998) and distinctly changed concentrations of key biomolecules. Plants grown under saline conditions are stressed and are characterized by increased levels of free proline and carbohydrate content in different tissues as a response to osmotic adjustment (Heuer and Nadler, 1998).

High ionic concentration competes with the uptake of other nutrients, especially K^+, leading to K^+ deficiency. Increased treatment of NaCl increases Na^+ and Cl^- and decrease in Ca^{2+}, Mg^{2+} and K^+ levels in number of plant (Khan *et al*., 2003). There is a negative relationship between Na^+ and K^+ concentration in roots and leaves. The selective uptake of K^+ as opposed to Na^+ is considered to be one of the important physiological mechanisms contributing to salt tolerance in many plant species (Ashraf and Khanum, 1997). Thus, under saline and sodic conditions, K fertilization management may need to be modified because of K^+ competition with other cations and especially Na^+ in the plant, and to the effects of salinity on K^+ reactions in soils.

Potassium play vital role and stimulates biological process in the plant cell as enzymes activity, respiration, photosynthesis, chlorophyll, creation, carbohydrate formation, water amounts balance in leaves and regulate stomata opining as well as direct effect on the disease resistance (El-Defan *et al.*, 1999). Accordingly, the objectives of this study were to: (i) study interactions between K nutrition and water salinity and their effects on grain yield, yield components, nutrient uptake and carbohydrate content of pearl millet and (ii) test the possibility of reducing damage to crops by applying higher levels of potassium.

MATERIALS AND METHODS

A plot experiment was conducted in a greenhouse at Agricultural university of Zabol, Iran during 2009 to study the effects of different salinity levels and potassium supply on pearl millet. The experiment was laid out in a completely randomized 4×3 factorial design with three replicates. Each pot (25×20 cm) was filled with non-saline sandy loam soil. Eight seeds were sown at uniform depth (1.5 cm) and after completion of emergence, thinning was done and four plants were maintained in each plot. Recommended dose of commercial fertilizer at the rate of 100 and 50 N and P kg.ha^{-1} was supplied to each plot. Air temperature in greenhouse was controlled between the ranges of 25 and 33 ˚C during day and 18 and 23˚C during night. Relative humidity ranged from 40 to 80%. Light averaged 1074 µmol m^{-2} S^{-2}, with a minimum of 244 and a maximum of 1417 µmol m^{-2} S^{-2} at noon.

Different rates of potassium were estimated with a population density of 160000 plant ha^{-1}. Potassium sulfate was used as the potassium source and was applied in the plot before sowing of seeds. The rate of potassium treatment was K_1=0, K_2=100 and K_3= 200 kg ha^{-1}. Pearl millet was subjected to different salinity levels (S_1 = 0, S_2 = 4, S_3 = 8 and S_4 = 12 ds/m) through irrigation water by addition of salt (NaCl) in increments after thinning. 35 days after salt treatment at vegetative stage and 50 days

after salinity treatment at reproductive stage, the plants were harvested. The extracts of mature leaves were used to determine soluble carbohydrates (Irigoyen *et al.,* 1992).

Ion contents of Na^+, K^+ and Mg^{+2} in leaves 35 days after salinity treatments at vegetative stage and 50 days after salinity treatment, at reproductive stage, were determined by using a Jemway PFP7 Flam photometer and atomic absorbsion. At the end of experiment, after ripening, millet per plot was harvested by hand to determine millet yield.

Statistical analysis

All data were analyzed with SAS Institute Inc 6.12. All data were first analyzed by ANOVA to determine significant ($P \leq 0.05$) treatment effects. Significant differences between individual means were determined using Fisher's protected least significant difference (LSD) test. Data points in the Figures represent the means ± SE of three independent experiments at least three replications per cultivar per treatment combination each.

RESULTS AND DISCUSSIONS

Grain yield and yield components

There were significant differences ($p \leq 0.01$) between salinity and potassium apply on biological yield, grain yield, harvest index and 1000 seeds weight in pearl millet (Table-1). By increasing salinity from 0 to 12 ds/m grain yield (45.6%), biological yield (35.3%), harvest index (15.1%) and 1000 seed weight (60.1%) decreased (Table-2). These results about crop yield reduction under salinity are consistent with previous findings (Taffouo *et al*., 2009). Salt stress decreased grain number. Sohrabi *et al*. (2008) also reported similar result. Salinity caused reduction in grain weight. This result was the same as results of Sohrabi *et al*. (2008) and Taffouo *et al*. (2009). Grain weight reduction was related to injury in translocation system because of high concentrations of saline ions. However, Zeng *et al*. (2000) reported few differences for grain weight in rice (*Oryza sativa* L.) genotypes in salinity conditions, so severity of salt stress effect on grain weight is related to plant genus and genotype.

On the other hand, applying potassium fertilizer significantly increased grain yield and yield components in pearl millet (Table-1). By application from 0 to 200 $kg.ha^{-1}$ potassium, grain yield (11.7%), biological yield (24.2%) and 1000 seed weight (41.1%) increased (Table-2). Application of K improved growth and yield under water stress possibly by regulating photosynthesis (Gupta *et al*., 1989). Badr and Shafei (2002) who reported that increasing K^+ application could be useful to overcome the adverse effect of salinity (NaCl) on the growth of wheat plant. It can be stated that the ability of plants to retain K^+ at high Na^+ concentration, of the external solution, may be involved in reducing the damage associated with excessive Na^+ concentration in plant tissue.

Carbohydrate content

Data listed in Table-1, showed the effect of different salinity levels on carbohydrate content in leaves of millet plants. The results of this study indicate, that application of NaCl in the growing medium significantly affected on carbohydrate content (Table-1). By increasing salinity from control ($S_0 = 0$) to S_3 (12 ds/m) carbohydrate content in leaves at vegetative (11.9%) and reproductive stages (22.3%) increased in millet plants (Figures 1 and 2). Carbohydrates such as sugars (glucose, fructose, sucrose, fructans) and starch accumulate under salt stress (Parida *et al*. 2002), playing a leading role in osmoprotection, osmotic adjustment, carbon storage, and radical scavenging. A decrease in starch content and an increase in both reducing and nonreducing sugars and polyphenol levels have been reported in leaves of *Bruguiera parviflora* (Parida *et al.* 2002). Ashraf and Tufail (1995) determined the total soluble sugar content in five sunflower accessions differing in salt tolerance; the salt tolerant lines had generally greater soluble sugars than the salt sensitive ones.

Cherel (2004) reported potassium plays an important role in balancing membrane potential and turgor, activating enzymes, regulating osmotic pressure, stoma movement and tropisms. Results in this study showed, application potassium from 0 to 200 $kg.ha^{-1}$, had significantly affect on carbohydrate accumulation in millet plants under salinity stress at vegetative and reproductive stages (Figures 1 and 2).

Sodium, potassium and magnesium

Based on the analysis of variance, the overall effect of salinity was highly significant ($P<0.01$) on the concentrations of Na^+, K^+ and Mg^{+2} in the leaves of millet plants at vegetative and reproductive stage (Table-1). Salt treatments increased significantly Na^+ concentration of plants, whereas potassium concentration of plants at two vegetative (38.7%) and reproductive (38.2%) stages and magnesium (34.7% at vegetative and 36.2% reproductive), decreased (Figures 3 - 6).

Salinity stress disturbs the uptake and accumulation of essential nutrients (Shannon and Grieve, 1999). Generally, Ca^{2+} and K^+ are decreased in plants under saline conditions. These decreases could be due to the antagonism of Na^+ and K^+ at uptake sites in the roots, the effect of Na^+ on K^+ transport into the xylem or the inhibition of uptake processes (Al-Harbi, 1995).

Potassium application significantly ($P<0.01$) affected on the leaf potassium, magnesium and sodium concentration in millet plants (Table-1). Figures 3-6 showed that potassium and magnesium content in leaves plants under salinity treatments, significantly increased and sodium content decreased with increasing potassium levels from 0 to $200kg.ha^{-1}$.

The decrease in Na^+ content can be attributed to K^+ competition with Na^+ for binding sites on the plasma membrane which suppressed the influx of Na^+ from the external solution (Al-Uqaili, 2003). Potassium is essential for many physiological processes, such as photosynthesis,

translocation of photosynthates into sink organs, maintenance of turgescence, activation of enzymes and reducing excess uptake of ions such as Na and Fe in saline soils (Mengel and Kirkby, 2001).

CONCLUSIONS

From this study one can draw the following conclusions: (i) potassium fertilization did eliminate the deleterious effects of salinity on pearl millet yield and yield components. It effects on increasing K^+, Mg^{+2} carbohydrate content in the plant and reducing the Na^+ in the plant tissue; (ii) increasing salinity did reduce K^+ concentration in the plant dry matter.

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Table-1. Results of variance analysis (ANOVA) of salinity (S), potassium (P) and their interaction for grain yield, yield components, carbohydrate and ion content.

Dependent variable	Independent variable		
	Salinity (S)	**Potassium (P)**	**S*P**
Grain yield	0.24^{**}	0.019^{**}	0.0006^{ns}
Biological yield	2.49^{**}	2.12^{**}	0.02^{ns}
Harvest index	25.06^{**}	56.77^{**}	0.42^{ns}
1000 seeds weight	4.09^{**}	2.63^{**}	0.1^{**}
Carbohydrate at vegetative stage	6.88^{**}	4.58^{**}	0.08^{**}
Carbohydrate at reproductive stage	13.32^{**}	3.66^{**}	1.01^{**}
Sodium at vegetative stage	1.59^{**}	0.42^{**}	0.103^{**}
Sodium reproductive stage	1.89^{**}	0.47^{**}	0.09^{**}
Potassium at vegetative stage	0.97^{**}	3.12^{**}	0.03^{*}
Potassium reproductive stage	1.45^{**}	4.84^{**}	0.24^{**}
Magnesium at vegetative stage	0.72^{**}	0.047^{*}	0.001^{ns}
Magnesium at reproductive stage	0.83^{**}	0.04^{*}	0.0006^{ns}

Number represent *F*-values at 5% level
^{ns} Non-Significant, * and ** significant at $P<0.05$ and $P<0.01$

Table-2. Grain yield, yield components, carbohydrate and ion content in pearl millet as affected by salinity and potassium rate.

Treatments	Grain yield	Biological yield	Harvest index	1000 seeds weight	Carbohydrate		Potassium		Sodium		Magnesium	
					vegetative	reproductive	vegetative	reproductive	vegetative	reproductive	vegetative	reproductive
	($gr.plant^{-1}$)		(%)	(gr)	(µmol Glucose g FW)		(mg/g DW)		(mg/g DW)		(mg/g DW)	
Salinity (ds/m)												
0	0.81a	3.37a	24.5a	2.58a	6.07d	8.7d	2.04a	2.38a	0.09d	0.03d	1.67a	1.71a
4	0.74b	3.13b.	23.8ab	1.94b	6.43c	9.15c	1.77b	1.85b	0.23c	0.23c	1.57a	1.64a
8	0.58c	2.69c	22.1bc	1.4c	7.22b	10.7b	1.69b	1.73b	0.73b	0.75b	1.21b	1.22b
12	0.44d	2.18d	20.84c	1.03c	8.03a	11.2a	1.25c	1.42c	0.99a	1.02a	1.09c	1.09c
Potassium (kg/ha)												
0	0.61c	2.58b	23.35a	1.19b	6.28c	9.37c	1.12c	1.18c	0.69a	0.71a	1.32b	1.36b
100	0.65b	2.62b	24.69a	1.99a	7.03b	10.02b	1.82b	1.91b	0.53b	0.52b	1.39ab	1.43ab
200	0.68a	3.32a	20.44b	2.02a	7.51a	10.47a	2.12a	2.44a	0.31c	0.31c	1.44a	1.46a

† Means followed by the same letter are not significantly different within rows and column according to Duncan's test ($P \leq 0.05$)

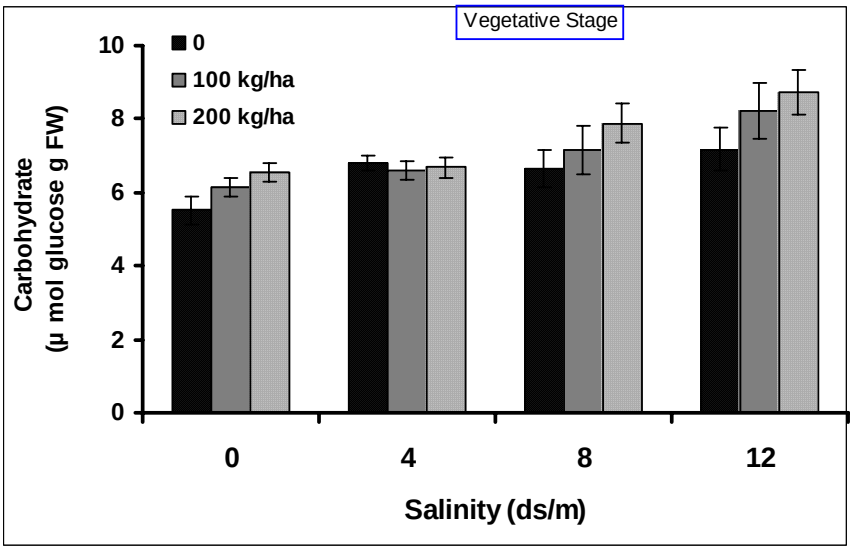

Figure-1. Effects of salinity and potassium on carbohydrate content in leaves at vegetative stage

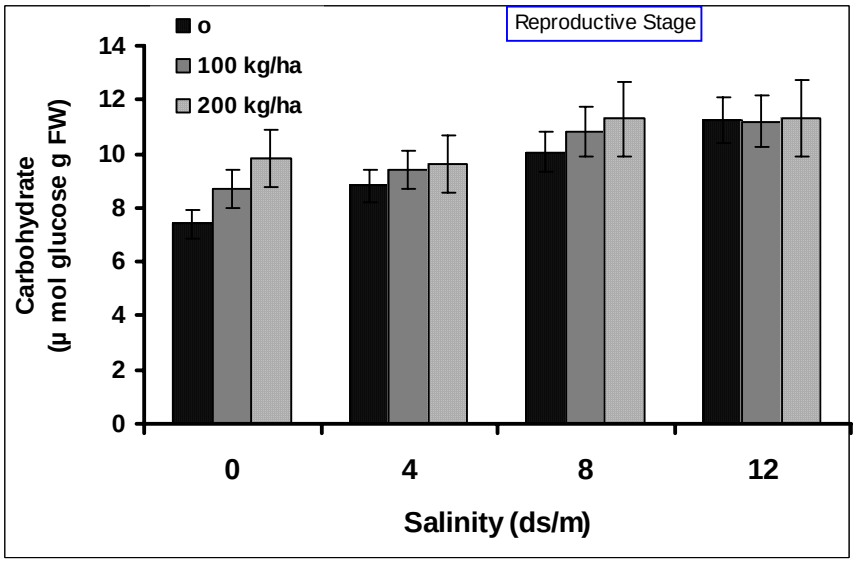

Figure-2. Effects of salinity and potassium on carbohydrate content in leaves at vegetative stage.

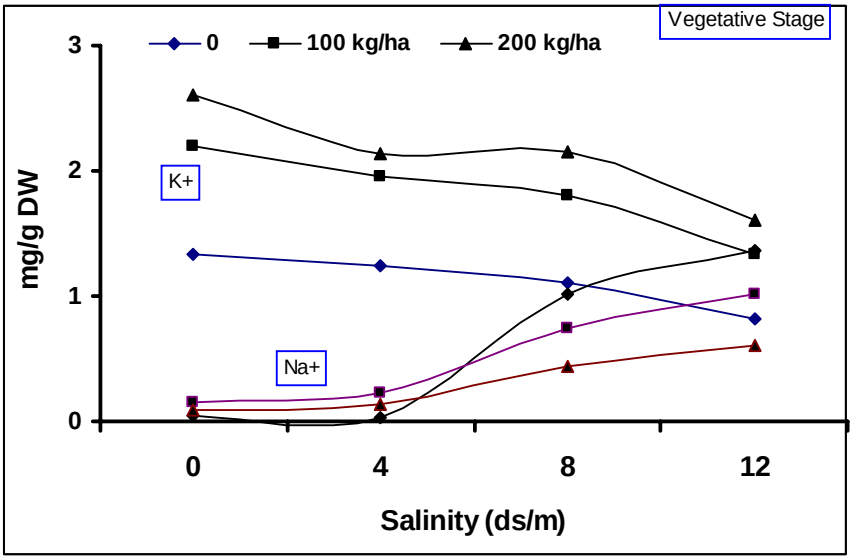

Figure-3. Effects of salinity and potassium on K^+ and Na^+ content in leaves at vegetative stage.

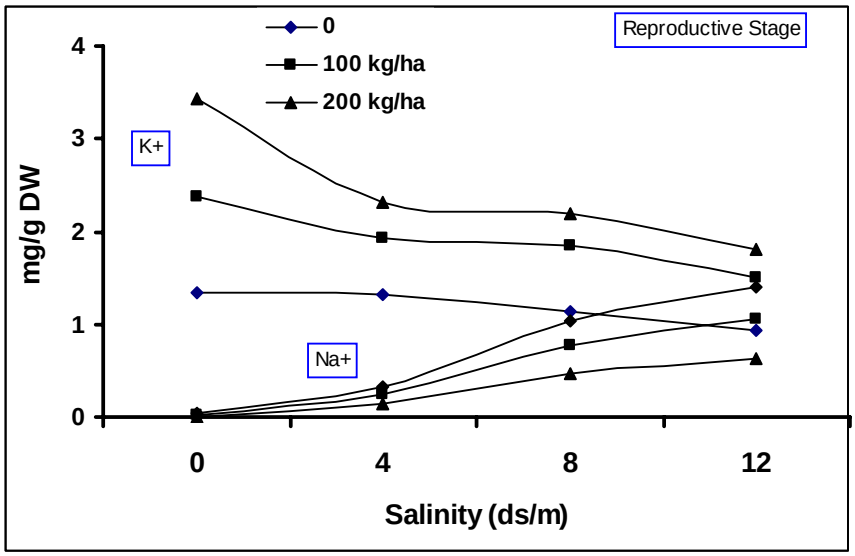

Figure-4. Effects of salinity and potassium on K^+ and Na^+ content in leaves at reproductive stage.

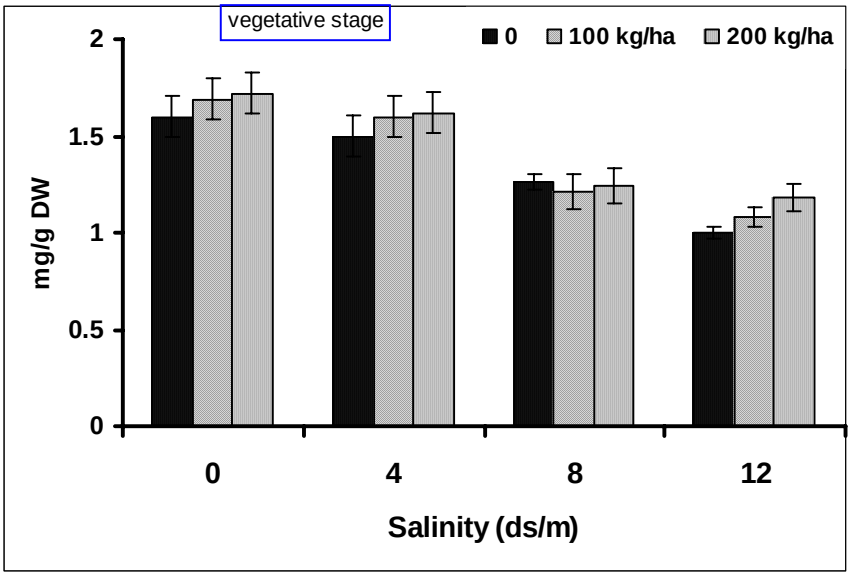

Figure-5. Effects of salinity and potassium on magnesium content in leaves at vegetative stage.

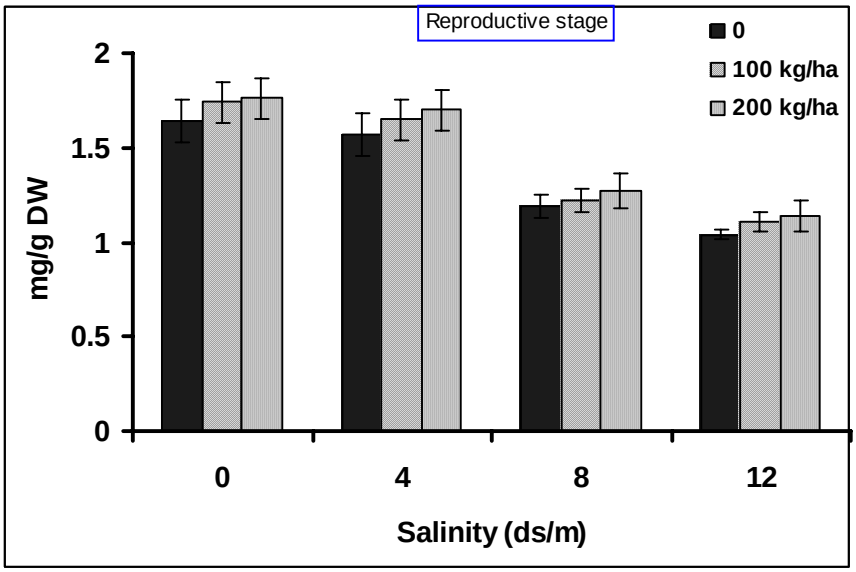

Figure-6. Effects of salinity and potassium on magnesium content in leaves at reproductive stage.