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Original article

Study of millet (*Panicum miliaceum*) response to humic acid, silicon and mycorrhiza application under saline-sodic irrigation water stress

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Extended abstract

Introduction

Salinity and sodicity stress is one of the major problems of agriculture in arid and semi-arid regions in the production of crops. In order to sustainable management of water and soil resources, in the conditions of salinity and sodicity, in addition to management strategies, application of mycorrhizal fungi or organic matter such as humic acid causes non-contamination of the environment and also increases the stability of agro-systems by reducing the use of chemical fertilizers. Among other solutions to overcome the negative effects of salinity on the growth and yield of the plant, we can mention the role of silicon and silicon nanoparticles. This research was conducted to study to evaluate the effect humic acid, mycorrhiza and silicon (ordinary and nano) on yield and nutrient content of millet under saline-sodic irrigation water.

Materials and methods

A field experiment was conducted as split plot factorial in a randomized complete block design with three replications. The main plots consisted of saline-sodic irrigation water (S) at two levels (S1= EC: 2.1 dSm^{-1}, SAR:11.5 and S2= EC: 5.04 dSm^{-1}, SAR: 20.8) and a combination of sub factors including three treatments of silicon salts (SI) [control (Si0); silicon nanoparticles, 10 Kg Si ha^{-1} (NSi) and sodium silicate, 10 Kg Si ha^{-1} (Si)] and three levels of mycorrhiza and humic acid (MH) (control (MH0), inoculation with mycorrhizal fungi (M) and humic acid 10 Kg ha^{-1} (H)) as The factorial was placed in the main plots.

Results

The results showed that increasing salinity-sodicity of irrigation water decreased grain yield, straw yield and plant height and its effect on number of panicles per square meter and 1000 seed weight had no significant effect. The application of silica nanoparticles treatment increased the grain yield compared to non-silicon treatment, which was not observed with sodium silicate. Mycorrhizal inoculation increased grain yield, straw yield and panicle per square meter and application of humic acid also increased grain yield, number of panicles square meter. Saline-Sodic irrigation water reduced the

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concentration of nitrogen, potassium and K/Na ratio, and increased sodium concentration in millet. Application of silicon had no significant effect on nitrogen, phosphorus, potassium, sodium and K/Na ratio in the plant, but mycorrhiza and humic acid increased plant phosphorus and K/Na ratio and decreased sodium content of the plant.

Conclusion

According to the results, it can be concluded that the use of silicon nanoparticles in comparison with sodium silicate could increase the yield of millet. Also the application of humic acid or mycorrhiza can be improved the yield of millet by increasing the amount of phosphorus and K/Na ratio and decreasing sodium content in millet and thus the enhancement of resistance of the plant and the reduction of the effects of salinity-sodicity, and in this regard, the effect of humic acid was higher than mycorrhiza.

***Keywords*:** Humic, Mycorrhiza, Saline-sodic water, Silicon

Table 1. Chemical and physical properties of the soil studied (0-30 Cm)

Cu	Zn	Mn	Fe	Available K	Labile P	Organic Matter	Total N	pH	EC	Soil texture
---------- (mg kg^{-1}) ----------						---------- (%)----------			($dS\ m^{-1}$)	
1.9	0.8	4.1	3.4	135	8.4	0.2	0.024	8.23	3.18	Sandy Loam

Table 1. Continued

SAR	HCO_3^-	Cl^-	K^+	Na^+	Mg^{2+}	Ca^{2+}
	---------- ($meq.L^{-1}$) ----------					
10.9	6.9	20.6	0.43	21.2	4.2	3.4

Table 2. Chemical properties of irrigation water

Irrigation water samples	EC	pH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	HCO_3^-	SAR
	($dS\ m^{-1}$)		---------- ($meqL^{-1}$) ----------							
1	2.1	8.06	2.4	1.8	16.6	0.08	14.5	2.6	3.4	11.5
2	5.04	7.92	4.5	3.4	41.3	0.09	41.3	4.1	3.7	20.8

Table 2. Chemical properties of the soil at the end of the experiment

Irrigation water samples	EC	pH	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	HCO_3^-	SAR
	($dS\ m^{-1}$)		---------- ($meqL^{-1}$) (میلی اکی والان بر لیتر) ----------						
1	2.6	8.21	3.3	4.0	18.5	0.43	14.4	5.6	9.7
2	6.2	8.26	8.6	9.7	47.1	0.45	39.4	12.3	15.6

Table 4. Analysis of variance for millet yield and yield components under the influence of experimental treatments

S.O.V	df	Grain yield	Straw yield	1000 seed weight	Number of spikes per m^{-2}	Plant height
Block	2	125053	833020	0.014	1044	7.6
S	1	1028928**	7916611**	0.026^{ns}	2817^{ns}	690**
Error a	2	19062	31151	0.05	293	0.3
SI	2	258864**	1235644*	0.03^{ns}	725*	0.03^{ns}
HM	2	352997**	981883**	0.005^{ns}	1050**	0.84^{ns}
S×SI	2	2477^{ns}	44011^{ns}	0.005^{ns}	30^{ns}	2.2^{ns}
S×MH	2	26161^{ns}	112026^{ns}	0.019^{ns}	281^{ns}	4.1^{ns}
SI×HM	4	57801^{ns}	436939^{ns}	0.01^{ns}	115^{ns}	8.8^{ns}
S×SI×HM	4	50403^{ns}	54292^{ns}	0.002^{ns}	34^{ns}	5.5^{ns}
Error b	32	41202	166252	0.0183	182	5.1

**Significant at the 0.01 probability level, * Significant at the 0.05 probability level and ns Not significant.

S: Salinity-sodicity, Si: Silicon, NSi: Nano Silicon, M: Mycorrhiza, H: Humic Acid

Table 5. Comparison of the main effects of experimental treatments on grain and straw yield and yield components of millet

Treatment	Grain yield	Straw yield	Number of spikes per m^{-2}	Plant height
	----------kg.ha^{-1} ----------			cm
Salinity-Sodicity1	2994^{a}	5409^{a}	238^{a}	64^{a}
Salinity-Sodicity2	2718^{b}	4643^{b}	223^{a}	57^{b}
Si_0	2840^{b}	5142^{a}	229^{ab}	60.5^{a}
NSi	2983^{a}	5210^{a}	238^{a}	60.5^{a}
Si	2744^{b}	4726^{b}	225^{b}	60.4^{a}
MH_0	2712^{b}	4779^{b}	222^{b}	60.7^{a}
Mycorrhiza	2862^{a}	5244^{a}	232^{a}	60.6^{a}
Humic	2992^{a}	5055^{ab}	237^{a}	60.2^{a}

Numbers followed by the same letter are not significantly different using Duncan test (P<0.05).

Si: Silicon, NSi: Nano Silicon, M: Mycorrhiza, H: Humic Acid. S1: (SAR = 11.5, EC= 2.1 ds/m), S2: (SAR = 20.8, EC = 5.04 ds/m)

Table 6. Analysis of variance for millet nutrients concentration under the influence of experimental treatments

S.O.V	df	N	P	K	Na	K/Na
Block	2	0.07	0.00044	0.174	0.083	0.0076
S	1	0.17*	0.0026^{ns}	0.758*	1.72**	3.81**
Error a	2	0.0054	0.00019	0.038	0.0037	0.0061
SI	2	0.00007^{ns}	0.0003^{ns}	0.028^{ns}	0.017^{ns}	0.0068^{ns}
HM	2	0.0066^{ns}	0.0029**	0.041^{ns}	0.114*	0.127**
S×SI	2	0.0023^{ns}	0.00003^{ns}	0.028^{ns}	0.0318^{ns}	0.042**
S×MH	2	0.0008^{ns}	0.00005^{ns}	0.037^{ns}	0.029^{ns}	0.0133^{ns}
SI×HM	4	0.0016^{ns}	0.00006^{ns}	0.02^{ns}	0.132*	0.048**
S×SI×HM	4	0.0024^{ns}	0.00002^{ns}	0.046^{ns}	0.029^{ns}	0.048**
Error	32	0.02	0.00014	0.027	0.012	0.0065

** Significant at the 0.01 probability level, * Significant at the 0.05 probability level and ^{ns} Not significant

S: Salinity-sodicity, Si: Silicon, NSi: Nano Silicon, M: Mycorrhiza, H: Humic Acid

Table 7. Comparison of the main effects of experimental treatments on nutrients concentration of millet

Treatment	N (%)	P (%)	K (%)	Na (%)	K/Na
Salinity-Sodicity1	1.25 a	0.135 a	2.2 a	1.27 b	1.75 a
Salinity-Sodicity2	1.14 b	0.121 a	1.97 b	1.62 a	1.22 b
MH_0	1.19 a	0.114 b	2.03 a	1.51 a	1.39 b
Mycorrhiza	1.18 a	0.137 a	2.09 a	1.42 b	1.51 a
Humic	1.22 a	0.133 a	2.13 a	1.40 b	1.55 a

Numbers followed by the same letter are not significantly different using Duncan test (P<0.05).
S: Salinity-sodicity, Si: Silicon, NSi: Nano Silicon, M: Mycorrhiza, H: Humic Acid, S1: (SAR = 11.5, EC= 2.1 ds/m), S2: (SAR = 20.8, EC = 5.04 ds/m)

Table 8. Analysis of variance for Na concentration and K/Na in millet under HM treatments in SI levels

S.O.V	df	Na	K/Na
Si_0	2	0.070572 **	0.1753**
NSi	2	0.046817 *	0.0482**
Si	2	0.005617 ns	0.0054ns

Numbers followed by the same letter are not significantly different using Duncan test (P<0.05).
Si: Silicon, NSi: Nano Silicon

Table 9. Analysis of variance for K/Na in millet under SI treatments in Salinity-Sodicity levels

S.O.V	df	K/Na
Salinity-$Sodicity_1$	2	0.0402**
Salinity-$Sodicity_2$	2	0.0086ns

Numbers followed by the same letter are not significantly different using Duncan test (P<0.05).

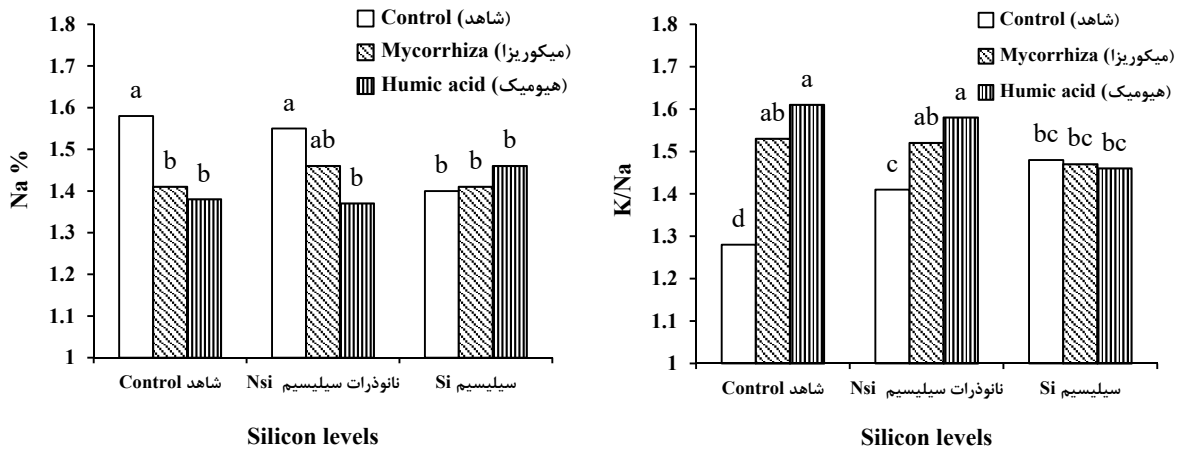

Fig. 1. Interaction effects of mycorrhiza, humic acid with silicon on sodium and K/Na ratio of millet

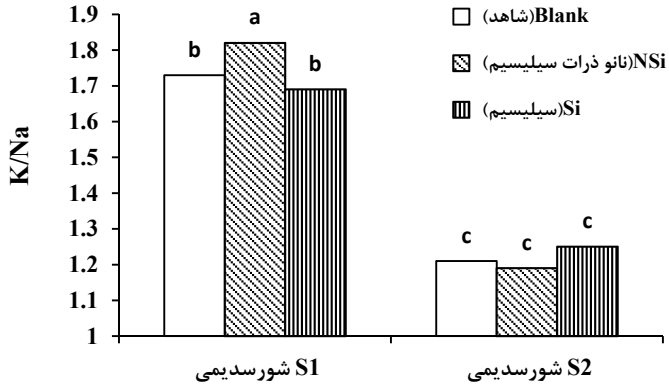

Fig. 2. Interaction effects of salinity-sodicity of irrigation water with silicon on K/Na ratio of millet. The salinity-sodicity levels of irrigation water were S1 (SAR = 11.5, EC= 2.1 ds/m) and S2 (SAR = 20.8, EC = 5.04 ds/m)