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Alleviation of Salinity Stress by Geothermal Water in Seed Germination and Seedling Growth in Wheat

By

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With 2 Figures

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Summary

ÖLÇER H., SEZGIN C. & KOCAÇALIŞKAN I. 2005. Alleviation of salinity stress by geothermal water in seed germination and seedling growth in wheat. – Phyton (Horn, Austria) 45 (2): 207 – 215, with 2 figures. – English with German summary.

The effects of geothermal waters (GW) on the seed germination and seedling growth of wheat (*Triticum aestivum* L. cv. Atay-85) at various salt (NaCl) concentrations were examined. It was found that 150 mM NaCl decreased significantly both seed germination and seedling growth of wheat. Salt stress of seed germination and seedling growth of wheat were alleviated by GWs of Sefaköy and Murat Dağı but it was not by GW Sarıkız. The highest alleviation effect was found with GW Murat Dağı and the effect was attributed to its calcium richness and lower level of toxic elements.

Zusammenfassung

ÖLÇER H., SEZGIN C. & KOCAÇALIŞKAN I. 2005. Verminderung von Salzstress durch geothermales Wasser bei Samenkeimung und Sämlingswachstum in Weizen. – Phyton (Horn, Austria) 45 (2): 207 – 215, 2 Abbildungen. – Englisch mit deutscher Zusammenfassung.

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Es wurde die Wirkung von geothermalem Wasser (GW) auf Samenkeimung und Sämlingswachstum von Weizen (*Triticum aestivum* L. cv. Atay-85) zusammen mit verschiedenen Kochsalzkonzentrationen (NaCl) untersucht. Es stellte sich heraus, dass 150 mM NaCl sowohl die Samenkeimung als auch das Sämlingswachstum von Weizen signifikant vermindert. Der Salzstress bei der Samenkeimung und beim Sämlingswachstum wurde durch GW von Sefaköy und Murat Dağı vermindert, aber nicht durch das GW von Sarıkız. Am deutlichsten war die Wirkung beim GW von Murat Dağı und dieser Effekt kann auf den reichlichen Kalziumgehalt und das geringere Ausmaß an toxischen Elementen zurückgeführt werden.

Introduction

Soil salinity is a global problem estimated to affect crop productivity in one-quarter to one-third of all agricultural land (SQUIRES 1994). Because of high salinity, the soils unsuitable for cultivation occupy 0.6 % of the total area of Turkey. The total area on which some plants are cultivated having some salinity problems occupies 2 % (KABAR 1987). Saline soils are dominated by large quantities of Na in soluble form and the sodium species in saline soils are mainly chloride (PORCELLI & al. 1995). The salinity inhibits the growth of plants due to ionic toxicity lowering the water potential in the root medium, and/or an alteration in the plant ionic status (GREENWAY & MUNNS 1980).

Several studies have been conducted to overcome salinity stress. Some of these are concerned with plant growth regulators (KABAR 1987, DATTA & al. 1998). However, most of the studies on alleviation of salinity stress have focused on the effect of calcium. Several reports have indicated that an application of calcium reduces the NaCl stress and results in a relatively increased growth of NaCl treated plants (HANSON 1984, CRAMER & al. 1985, 1986, KURTH & al. 1986a, KHAVARI-NEJAD & CHAPARZADEH 1998, REID & SMITH 2000).

The previous knowledge suggests that using calcium rich substances such as gypsum and lime in reclamation of saline-sodic soils could increase crop salt tolerance, plant growth and yield (MARSCHNER 1997). It is known that some waters originating from geothermal springs (GWs) are also rich in calcium ions (IŞIK & DILEMRE 1996). However, nothing is known about the usage potential of GWs in alleviation of salt stress. At this point we hypothesized that GWs rich in calcium may be a solution in overcoming salinity problem. Therefore the aim of this work was to investigate the alleviation effect of three different GWs (Sarıkız, Sefaköy and Murat dağı), in which calcium levels vary, on NaCl salinity stress in wheat (*Triticum aestivum* L. cv. Atay-85).

Material and Methods

Seeds of wheat (*Triticum aestivum* L. cv. Atay-85) were obtained from "Eskisehir Anadolu Agricultural Research Institute" and used in germination tests. After surface sterilisation with 1% sodium hypochloride twenty seeds were sown in 9 cm Petri dishes lined by two sheets of Whatman No 1 filter paper containing 15 ml of distilled water or GW (as controls) or 50, 100 and 150 mM NaCl solutions prepared either in distilled water or GW. Then, Petri dishes were left in an incubator at 24 °C in continuous dark. Germination percentages of the seeds were determined at intervals of 24 h up to 4th day and finally postgerminative growth of the seeds was determined by measuring lengths and both fresh and dry weights of the root and shoot of the seedlings.

GWs were taken from three different thermal sources in Kütahya city which is located in the west part of Turkey between the latitude of 39?-40? and the longitude of 29°–30°. GWs Murat dağı, Sarıkız and Sefaköy are located in the south-west of Kütahya that are 150, 138 and 80 km far away from the city center, respectively.

Chemical analyses of the GWs were carried out by IŞIK & DILEMRE 1996 using titration method for Ca^{++}, Mg^{++}, Cl^-, HCO_3^-, CO_3^-, gravimetric method for SO_4^-, spectrophotometric method for B^+, F^- and flame photometric method for Na^+, K^+. According to their results chemical contents of the GWs are shown on Table 1. GWs were used in seed germination without diluting as control or mixing with NaCl. Each experiment was repeated six times. After standard error calculation for each mean, a t-test was used to define significance of the NaCl effect on germination and postgerminative growth of the seeds with respect to controls (distilled water or GW).

Table 1. Chemical contents of GWs (mg L^{-1}).

	GW Sarıkız	GW Sefaköy	GW Murat dağı
Ca^{++}	100	157	453
Na^+	580	12	5.4
K^+	74	2.4	2.4
Mg^{++}	51	38	60
B^+	7	<0.1	<0.1
F^-	3.2	0.6	0.32
Cl^-	99	12	10
SO_4^-	980	337	1440
HCO_3^-	958	311	370.08
CO_3^-	<1	<1	<1
EC(dSm$^{-1)}$	2.9	1.0	1.3

Results

Seed Germination

Germination of wheat seeds was decreased significantly by 150 mM NaCl treatment (Table 2). Since the 50 and 100 mM of NaCl cocentrations were not effective significantly in decreasing seed germination and seedling growth, these values were not included in the Table. The inhibitory effect of 150 mM NaCl on germination was alleviated by GW Murat dağı and slightly by GW Sefaköy. Relative germination rate was higher in GW Murat dağı than the others. That is, relative germination rate was found to be 94% in GW Murat dağı, while it was 87%, 66% and 80% in GW Sefaköy, GW Sar‹-

ikız and distilled water, respectively (Table 2). As seen in the Fig. 1, relative germination rate was also higher in GW Murat dağı than the other GWs for 150 mM NaCl concentration. The alleviation effect of GW Murat dağı on seed germination was consistent during four days (Fig. 2).

Seedling Growth

Both root and shoot elongation of wheat seedlings was decreased significantly by 150 mM NaCl (Table 2). Growth inhibition by 150 mM NaCl in distilled water was similar in roots and shoots. But shoot elongation was inhibited more than that of roots by NaCl in GW Sarıkız. In addition, root elongation was decreased by GWs Sarıkız and Sefaköy whereas it was increased by GW Murat dağı compared with distilled water (Table 2).

Fresh and dry weights of both root and shoot of wheat seedlings were decreased significantly by 150 mM NaCl in distilled water and GWs, ex-

Table 2. Seed germination and seedling growth of wheat under salinity of 150 mM NaCl in distilled water or geothermal waters at fourth day. Means ± SE, n = 6.

			Geothermal waters		
		D. water	Sarıkız	Sefaköy	Murat dağı
Germination percentage	Control	91±1.1	88±2.5	95±1.1	88±2.5
	NaCl	73±1.3*	58±2.8*	83±3.1*	83±1.5
	[%]	80	66	87	94
Root elongation (cm seedling^{-1})	Control	6.85±0.10	5.10±0.16	3.82±0.18	8.24±0.20
	NaCl	3.21±0.12*	1.88±0.11*	1.97±0.12*	5.41±0.16*
	[%]	47	37	52	66
Shoot elongation (cm seedling^{-1})	Control	4.72±0.05	4.63±0.09	4.25±0.10	5.85±0.18
	NaCl	2.16±0.08*	1.26±0.07*	2.20±0.09*	3.36±0.12*
	[%]	46	27	52	57
Root fresh weight (mg seedling^{-1})	Control	42.18±1.45	33.83±3.96	29.68±2.85	51.81±3.54
	NaCl	18.79±0.86*	15.43±1.95*	13.96±2.02*	28.33±0.12*
	[%]	45	46	47	57
Shoot fresh weight (mg seedling^{-1})	Control	45.67±1.21	46.86±2.43	43.27±1.44	58.48±2.45
	NaCl	20.17±1.17*	10.33±1.41*	19.90±0.92*	30.81±3.75*
	[%]	44	22	46	53
Root dry weight (mg seedling^{-1})	Control	3.21±0.11	3.00±0.38	2.29±0.22	3.95±0.214
	NaCl	1.88±0.14*	1.41±0.04*	1.38±0.15*	2.45±0.237*
	[%]	59	47	60	62
Shoot dry weight (mg seedling^{-1})	Control	4.28±0.11	4.46±0.26	3.85±0.29	5.33±0.43
	NaCl	2.82±0.12*	2.12±0.36*	2.82±0.10*	3.98±0.51
	[%]	66	48	73	75

* NaCl treatments are significantly different from control (distilled water or GW) at 0.01 level according to t-test.

[%] Relative germination or relative growth with respect to control.

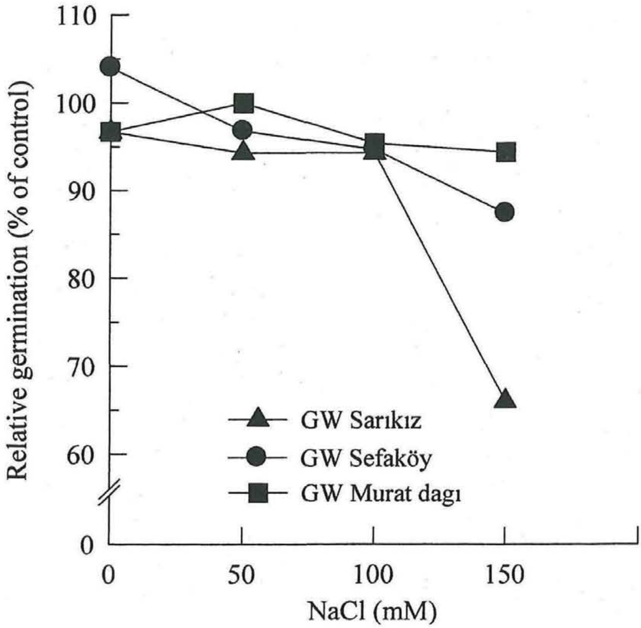

Fig. 1. Effect of GWs on the relative germination of wheat seeds at various NaCl concentrations.

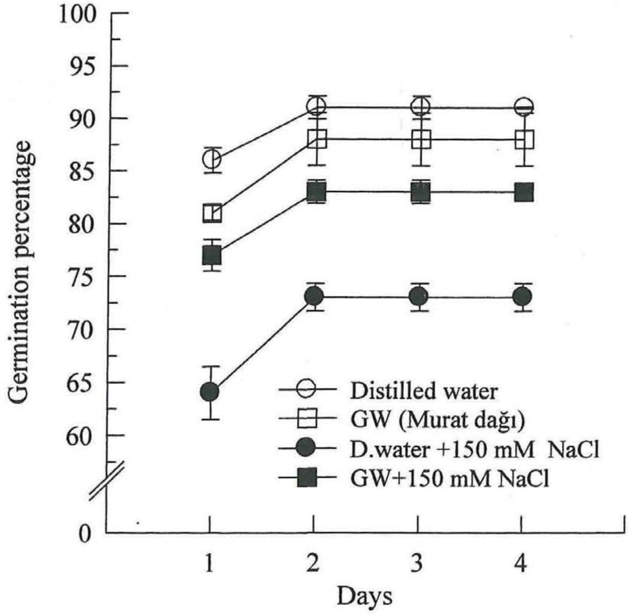

Fig. 2. The time course of germination percentage of wheat seeds as effected by NaCl, GW and NaCl + GW. Vertical bars are ± SE.

cept in GW Murat dağı which was not significantly affected (Table 2). The effect of NaCl on fresh weight of root growth was similar to the affected shoot growth, except in GW Sarıkız it was 22% of shoot but 46% of root (Table 2). However, root and shoot dry weights were affected by NaCl rather different. Relative growth as dry weight was higher in shoot than in root but it was not different in GW Sarıkız (Table 2).

Discussion

In this study, germination of wheat seeds was inhibited by 150 mM NaCl. Negative effects of NaCl salinity on germination have been known for a long time. However, there are different findings and opinions on the mechanisms involved in the literature. Some researchers suggested osmotic effects (Brown & Khan 1976, Kabar 1987) and specific ion effects (Redmann 1974, Bozcuk 1981, Chrominski & al. 1986) while some others claimed that the endogenous hormonal balance of seeds was disturbed (Boucaud & Ungar 1976, Khan 1978).

Several studies have been carried out so far overcoming salinity stress by application of calcium ions. But we have not encountered any study about the effects of GW on salinity stress. In the present study, we have shown that salinity stress of wheat was clearly alleviated by GW Murat dağı, which is rich in calcium. In addition, not only seed germination but also seedling growth of wheat as root and shoot elongation and fresh and dry weight were alleviated by GW Murat dağı in 150 mM NaCl. The other GWs were not rich in calcium and in addition GW Sarıkız has higher potentially toxic levels of Na^+, B^+ and F^-. Probably, due to both lower calcium and higher toxic ions of GW Sarıkız, it inhibited seed germination and seedling growth of wheat. GW Sefaköy was found to alleviate the effects of salt stress to some extent as well.

GWs generally contain toxic quantities of sodium, chloride, boron and flour ions and these toxic elements can restrict germination and seedling growth (Lee & al. 1996, Nebiler & al. 1999). GW Murat dağı does not contain these toxic elements in high levels and additionally it has elevated levels of calcium. Therefore, its alleviation effect on the salt stress may be attributed to its calcium richness and lower level of toxic elements. On the other hand, some elements such as titanium and nickel, which were not determined in the GWs studied, may be exist and take place in alleviation of the salt stress. Thus, titanium has been indicated to increase plant growth and calcium uptake by plants depending on the species (Duman & Ernst 1988). Nickel supplement up to 0.1 mg L^{-1} reduced urea toxicity and enhanced plant growth (Tan & al. 2000), and nickel has also been identified as an essential element for plant growth (Witte & al. 2002). In addition some rare earth elements such as lanthanum and cerium increase plant growth when used as a foliar sprays (Marschner 1997).

Several studies about alleviation of salt stress by calcium have been done. Calcium stabilizes cell membranes by connecting various proteins and lipids at the membrane surface. Additionally, calcium ions can be exchanged by mono-valance cations such as Na^+, K^+ and H^+ during stress responses (CRAMER & al. 1985, HIRSCHI 2004). In the presence of toxic levels of Na^+, supplementation of the medium with high levels of Ca^{++} alleviates growth inhibition (YERMIYAHU & al. 1997, KINRAIDE 1998). Furthermore, supplementation of a saline medium with calcium has been shown to improve root elongation (KENT & LÄUCHLI 1985, KURTH & al. 1986b) and shoot growth (CRAMER & al. 1989). It has also been reported that growth of wheat seedlings was strongly inhibited by 150 mM NaCl, but improved as the calcium concentration in the medium was increased up to 2.34 mM (REID & SMITH 2000). The role of calcium ions as a second messenger in many biological systems indicates that plants are able to adjust to high salt environments by activating a signal transduction system involving calcium (BRESSAN & al. 1998). In the light of the information mentioned above, we can say that as GW Murat dağı is rich in calcium and poor in toxic elements it may alleviate salt stress of wheat. Also some rare elements may be exist in the GW Murat dağı, which were not determined, may play a role in alleviation of salt stress of wheat.

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