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Growth and Ion Content of Korean Ginseng under Saline Condition

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ABSTRACT: This study was conducted to determine the effect of salinity on the growth and development of Korean ginseng (*Panax ginseng* C.A.Meyer) and to evaluate the inorganic ion content in Korean ginseng with different general complete fertilizer (GCF) and NaCl concentrations at two growth stages. The stem height of Korean ginseng treated with different GCF and NaCl concentrations decreased at the higher EC (2.0 dS m^{-1}), but there were no significant difference in the stem diameter, the leaf length, and the leaf width among different treatments. The root growth increased with the supply of GCF. Especially, the root growth was facilitated two times at 3.0 dS m^{-1} as compared to control. But the root growth more sharply decreased with NaCl treatment than GCF. The K^+ and Mg^{2+} content in leaves and roots increased with GCF at the early growth stage. At the late growth stage, the K^+ content in leaves decreased but the Ca^{2+} and Mg^{2+} content increased. The Ca^{2+} and Mg^{2+} content in roots increased but the K^+ content decreased. The Na^+ content in Korean ginseng increased sharply with NaCl treatment. The NO_3^- content in leaves and NH_4^+ content in leaves and roots increased as GCF concentration increased. The NO_3^- content in leaves, stems, and roots at the late growth stage decreased as NaCl concentration increased. The NH_4^+ content in leaves and roots decreased significantly at the early growth stage, but it decreased significantly in leaves and stems at the late growth stage. The root activity of Korean ginseng increased with GCF, but decreased as the EC increased with NaCl. The water potential of leaves with GCF showed no significant difference compare to control, but the water potential of leaves treated with NaCl decreased as EC increased.

Keywords: Korean ginseng, *Panax ginseng* C.A.Meyer, root activity, NaCl, EC, water potential

Selection and management of intended cultivation field of Korean ginseng strongly related to success of cultivation and soil characteristics of cultivation field strongly influence Korean ginseng growth regard to growing period of three to five years. Therefore, to make suitable soil for Korean ginseng growth, it was applied for ensilage or board leaf with the amount of 3~4.5 ton per 10a into the intended Korean ginseng cultivation field for one or two years and was carried out plowing and decomposing over 10 times per year. Recently, however, the electric conductance (EC), NO_3-N, and NH_4-N in intended Korean ginseng field abruptly increased due to application of organic fertilizer such as manure or inorganic fertilizer. Also, as the salt concentration of 0.29 dS m^{-1} at 3 year old, 2.0 dS m^{-1} at 4 year old, and 5.42 dS m^{-1}at 6 year old Korean ginseng cultivated field at the surface soil layer (0-2 cm), the soil electric conductance abruptly increased. The kind of salt accumulated at the soil surface layer was NO_3-N, NH_4-N, Ca, K, and Mg, and the concentration of NO_3-N was especially high.

The dry matter production of shoot and root of 6 years old Korean ginseng was 350 kg/10a and 400 kg/10a, respectively. The mineral absorption rate of 6 years old Korean ginseng also was not more than 16.3 kg of nitrogen, 4.4 kg of phosphorus, 16.5 kg of potassium, and 7.5 kg of calcium and it was one fifth of a year old crops. Thus, when the decomposed organic matter was enough, sudden application of the water soluble inorganic fertilizer at the level of natural fertility could cause growth deterioration due to the salt stress or imbalance of nutrition (Kim *et al.*, 1985).

The symptoms of salt damages to Korean ginseng were reduction of shoot emergence and growth, etiolating and early defoliation of leaves, reduction of root growth, and etc. The emergency ratio decreases as the salt concentration increases, and decomposition of rhizome increases remarkably by salt. The emergence ratio of two to three year old Korean ginseng has negative correlation with the soil EC, nitrate and ammonium concentration (Kim *et al.*, 1985; Mok *et al.*, 1998; and Song *et al.*, 1985). The salt stress occurred at root rather than shoot and at trunk rather than rootlets (Kim *et al.*, 1985).

Also, the light absorption coefficient of the Korean ginseng was the most effective at the range of 400~700 nm (kazutoshi, 1973), and the most suitable temperature for the Korean ginseng was about 20°C (Nam, 1992). In the ratio of the chlorophyll a and b, the content of the chlorophyll b increased as the light intensity decreased (Bjorkmen, 1963) but the content of chlorophyll a increased as the light inten-

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sity increased (Park, 1980).

Therefore, this research carried out to investigate effects of the salt stress on the growth, inorganic ion content, and root activity of Korean ginseng by controlling the soil EC with GCF and NaCl.

MATERIALS AND METHODS

Plant and growth condition

The experiment was carried out in fields shaded with blue-white polyethylene. Two-year old Korean ginseng roots (Korean ginseng seedling, 0.8~0.9 g) were sterilized by Diethofencarb 500 times solution and transplanted with the planting density of 8 x 8 cm at April 3, 2000.

Salinity was applied with different EC levels controlled as 0.0, 1.0, 2.0 and 3.0 dSm^{-1} using NaCl and general complex fertilizer (GCF; N 13%, P_2O_5 18%, MnO 0.1% and CuO 0.15%) solution. The salinity treated three times at May 9, 16, and 23, and the saline solution was flushed by overhead flooding method.

Ion and chlorophyll content

Inorganic ion concentration of Korean ginseng harvested at June 5 and August 7 was measured from leaves, stems and roots. Samples, dried at 80°C for 7 days, were weighed then grounded into a fine powder. One gram of ground sample was extracted to determine minerals for 24 hr. The contents of Na^+, K^+, Ca^{2+}, and Mg^{2+} were measured at 589.6 nm, 769.9 nm, 396.8 nm and 279.6 nm, respectively, using an atomic absorption spectrophotometer (Shimazu AA-6800, Japan). Chlorophyll content was measured by IRRI method (Yoshida *et al.,* 1972) at June 5 and August 7.

Nitrate and ammonium contents

Nitrate content was determined by the method of Cataldo *et al.* (1975) with slight modification. For the nitrate analysis, the harvested fresh samples were grounded with a mortar and pestle in 2 volumes of deionized water and centrifuged at 12000 g for 15 minutes. The supernatant was used for analysis. Extracted solution of 0.2 ml was mixed with 0.8ml of 5% salicylic acid in sulfuric acid. After 20 minutes, this mixture was alkalinized with 19.0 ml of 2 N NaOH. Absorbance was read at 410 nm (Spectronic genesys 2PC, USA). For ammonium analysis, 0.2 ml of extracted solution was mixed with 1 ml of reagent I (1 L of deionized water containing 50 g phenol and 0.25 g sodium nitroprusside) and 1 ml of reagent II (1 L of deionized water containing 25.0 g sodium hydroxide and 21.0 g sodium hypochlorite). The solution was incubated in a water bath at 60°C for 5 minutes. After diluting solution with 23 ml water, the absorbance of the sample was read at 625 nm.

Root Activity

The root activity was determined by modified TTC (triphenyl-tetrazolium chloride) method (Lee *et al.,* 1996). The root activity of samples, harvested at June 5 and August 7, were measured with fresh sample of 5 g with TTC solution (1% TTC : 0.1 M sodium phosphate: distilled water=1 : 4 : 5) for 2 hours on water bath of exhausted air at 30°C. Then, the formazan was extracted with a homogenizer using 3-5 mL of ethyl acetate while the reaction of samples was stopped by 2N H_2SO_4 and it was determined with a spectrophotometer (Spectronic genesys 2PC, USA) at 470 nm. The standard curve of root activity was obtained using $Na_2S_2O_4$ and ethyl acetate.

RESULTS AND DISCUSSION

Growth

Table 1 showed the shoot growth of Korean ginseng harvested at June 5 and August 7. The stem length of the Korean ginseng harvested at June 5 decreased as GCF and NaCl con-

Table 1. Effects of electrical conductivity on the growth characteristics of 2 years old Korean ginseng on June 5 and August 7.

Materals	EC (dSm^{-1})	Stem length (cm)		Leaf area (cm^2)		Root length (cm)		Root diameter (mm)		Root D.W. (g $plant^{-1}$)		Chlorophyll (mg g^{-1} F.W.)	
		Jun.5	Aug.7	Jun.5	Aug.7	Jun.5	Aug.7	Jun.5	Aug.7	Jun.5	Aug.7	Jun.5	Aug.7
	Con.	7.9a	8.68a	11.5a	11.5a	14.5b	16.3ab	4.8ab	5.3b	0.09b	0.21b	2.22ab	1.61b
GCF	1.0	7.8a	8.45a	11.6a	12.1a	15.4ab	16.9ab	5.4a	6.4ab	0.13a	0.32b	2.28ab	2.08ab
	2.0	7.6a	8.44a	11.1a	12.0a	16.1ab	18.1ab	5.6a	6.4ab	0.15a	0.37b	2.54a	2.51a
	3.0	7.2a	8.39a	11.2a	11.9a	19.3a	21.1a	5.9a	7.3a	0.16a	0.66a	2.41a	2.41a
NaCl	1.0	7.2a	8.42a	10.6a	10.2ab	14.6b	12.1b	4.4ab	5.3b	0.08b	0.20b	2.12ab	1.32b
	2.0	6.7ab	8.13a	10.4a	10.1ab	13.6c	11.8b	4.2ab	5.2b	0.06b	0.18c	2.09ab	1.13c
	3.0	6.2ab	7.49ab	8.8b	9.5b	10.6d	10.3c	4.2ab	5.1b	0.06b	0.15c	1.54b	1.03c

Means followed by different letters within all treatments are significantly ($p<0.05$) different according to DMRT. GCF; general complete fertilizer.

centration increased. Especially, the decrease slop was sharp in over 2.0 dS m^{-1} of GCF and 1.0 dS m^{-1} of NaCl concentration. However, the decrease of the stem length at August 7 was smaller than that of at June 5. The leaf length of the Korean ginseng, no general tendency was observed in its change with GCF, but with NaCl, the leaf length showed decreasing tendency, at higher concentration over 3.0 dS m^{-1}. The leaf length at August 7 increased with GCF in late growth stage. But there was no difference in leaf width at June 5 and August 7.

The leaf area of Korean ginseng at June 5 with GCF showed no change among different concentrations. At August 7, however, the leaf area was increased with GCF compared to that of non-treatment and showed the largest value at the EC 1.0 dS m^{-1}. The leaf area showed decreasing tendency with increasing NaCl concentration. Reduction of the leaf area with NaCl at August 7 was much greater than that of at June 5. From these results, the GCF did not greatly influence shoot growth of Korean ginseng. These results were opposite to the result that if EC of soils was high, the stem length and the stem diameter of Korean ginseng decreased greatly from the base parts of leaf due to low leaf expansion and stem elongation (Nam, 1992). However, the stem length, the leaf length, and the leaf area of Korean ginseng were sharply reduced with increased NaCl concentration. This result showed similar results reported by Mok *et al.* (1999) in which the salt damage of Korean ginseng varied depending on the kind of salt and the concentration of each salt, and especially, the Na^+ or Cl^- caused a remarkable growth reduction. This research considered that the reason of the growth reduction of Korean ginseng by salt stress appeared at the late growth stage was caused by the salt which continuously affected soil property. Therefore, the salt must be excluded as early as possible in Korean ginseng fields.

The length, weight, and diameter of root of Korean ginseng increased at higher GCF concentration. But, the fresh weight, dry weight, root length, and root diameter decreased at higher EC by NaCl addition, but the reduction in root was less than the reduction in shoot. Also, the reduction of growth at late growth stage (August 7) was greater than that of early growth stage (June 5). This result considered as that the amount of NaCl permeated continuously from the soil surface to the rhizosphere of Korean ginseng field was greater at the late growth stage.

Also, the critical NaCl concentration that influenced the roots growth was more than 1.0 dS m^{-1}, in general, the growth reduction of root was less than that of shoot at the same NaCl concentration. This result was similar to results reported by Munns & Termeat (1986) and Shalhevet *et al.* (1995). However, this was opposite result that salt stress more highly affected the growth of root than that of shoot (Kim *et al.*, 1985).

The chlorophyll content of Korean ginseng with GCF and NaCl was shown in Table 1. The chlorophyll content was measured at June 5 and August 7. With GCF at higher EC, the chlorophyll content increased, but the chlorophyll content decreased with NaCl, and the chlorophyll content decreased greatly as the EC increased. This was similar to the result reported by Nam (1992), which stated that the chlorophyll content did increase if the concentration of nutrients increased, and the accumulation of the chlorophyll content was accelerated according to the absorption of nutrients increased.

Table 2. Inorganic ion content in leaf and root of 2 years old Korean ginseng with different EC levels.

Parts	Materials	EC (dS m^{-1})	K^+ (% D.M.$^{-1}$)		Ca^{2+} (% D.M.$^{-1}$)		Mg^{2+} (% D.M.$^{-1}$)		Na^+ (% D.M.$^{-1}$)	
			Jun.5	Aug.7	Jun.5	Aug.7	Jun.5	Aug.7	Jun.5	Aug.7
Leaf		Con	39.5b	49.9a	57.9b	10.7b	13.9c	16.1b	0.10f	0.11c
	GCF	1.0	45.1a	47.9ab	83.5a	10.6b	26.9a	19.1a	0.07f	0.17c
		2.0	52.0a	50.0a	60.1b	13.2a	18.8b	18.3a	0.28d	0.10c
		3.0	44.6b	54.7a	51.6b	14.4a	16.6b	20.7a	0.23d	0.07c
	NaCl	1.0	34.2bc	30.2c	65.7b	8.9c	15.5b	15.8b	1.45bc	2.01b
		2.0	44.7b	28.7c	55.5b	7.7c	11.6c	15.1bc	1.79b	2.45b
		3.0	39.1b	26.3c	45.6c	7.1c	9.6d	13.9c	2.74a	3.09a
Root		Con.	36.8ab	71.9b	18.1ab	21.2a	11.6b	10.3a	0.33c	0.13c
	GCF	1.0	37.9a	88.2a	15.4b	19.0ab	12.0b	9.9a	0.14c	0.17c
		2.0	42.4a	71.3b	20.7a	21.9a	17.0a	10.0a	0.21c	0.12c
		3.0	38.7a	67.8b	17.4ab	23.3a	13.1b	10.9a	0.14c	0.10c
	NaCl	1.0	36.1ab	66.0b	15.5b	20.3ab	8.6bc	9.6a	2.11b	2.31b
		2.0	34.2ab	58.3bc	17.5ab	18.1ab	8.9bc	9.3a	2.45ab	3.04a
		3.0	28.4b	55.2c	13.6b	16.4b	7.6c	9.7a	3.98a	3.65a

Means followed by different letters in a column are significantly ($p<0.05$) different according to DMRT. GCF; general complete fertilizer.

Ion content

The inorganic ion content of Korean ginseng under various GCF and NaCl concentration was shown in Table 2. There was no change of K^+ content in leaves and stems with GCF at June 5. But, K^+ content of roots increased at higher GCF concentration. At late growth stage of August 7, K^+ content in leaves and stems decreased at higher GCF concentration. In roots, there was no significant difference in K^+ content. Generally, the salt stress of plants is attributed to a decrease in water potential of growing medium, ion toxicity and nutrient deficiency because of abnormal accumulation or uptake of inorganic ions (Greenway & Munns, 1980; Haung & Redmann, 1995). The K^+ content with NaCl in leaves & stems of Korean ginseng showed no general tendency at June 5, but in roots it showed a little increase. At August 7, however, the K^+ content in leaves and stems could not measure because ginseng plants were withered by the salinity, but in roots, the K^+ content decreased with NaCl treatment. In case of the Ca^{2+}content, there was no significant difference with all GCF or NaCl levels compared to the control. The Mg^{2+} content in leaves and roots slightly increased with GCF at June 5. At August 7, the Mg^{2+} content in leaves increased at higher GCF concentration. But, there was no significant difference of Mg^{2+} content in roots and stems. At June 5, the Na^+content in leaves and stems increased at higher GCF concentration, but the Na^+ content decreased in roots. The Na^+ content increased rapidly at higher NaCl concentration compare to the control. Specially, the highest increase of Na^+ content was observed in roots among the parts of Korean ginseng plant. At August 7, the Na^+ content with GCF increased sharply at the EC of 1.0 dS m^{-1}, and then decreased at high EC greater than 2.0 dS m^{-1}. The Na^+ content in all leaves and stems could not measure because of the dying with the higher salinity, but the Na^+ content in roots increased at higher NaCl concentration.

The NO_3^- content was measured for two years old Korean ginseng at June 10 and August 10. The NO_3^- content with GCF measured at June 5 showed no difference compared to the control. The highest in NO_3^- content was in leaves among plant parts in ginseng plant treated with GCF (Fig. 1). This result was similar to the previous report of Nam

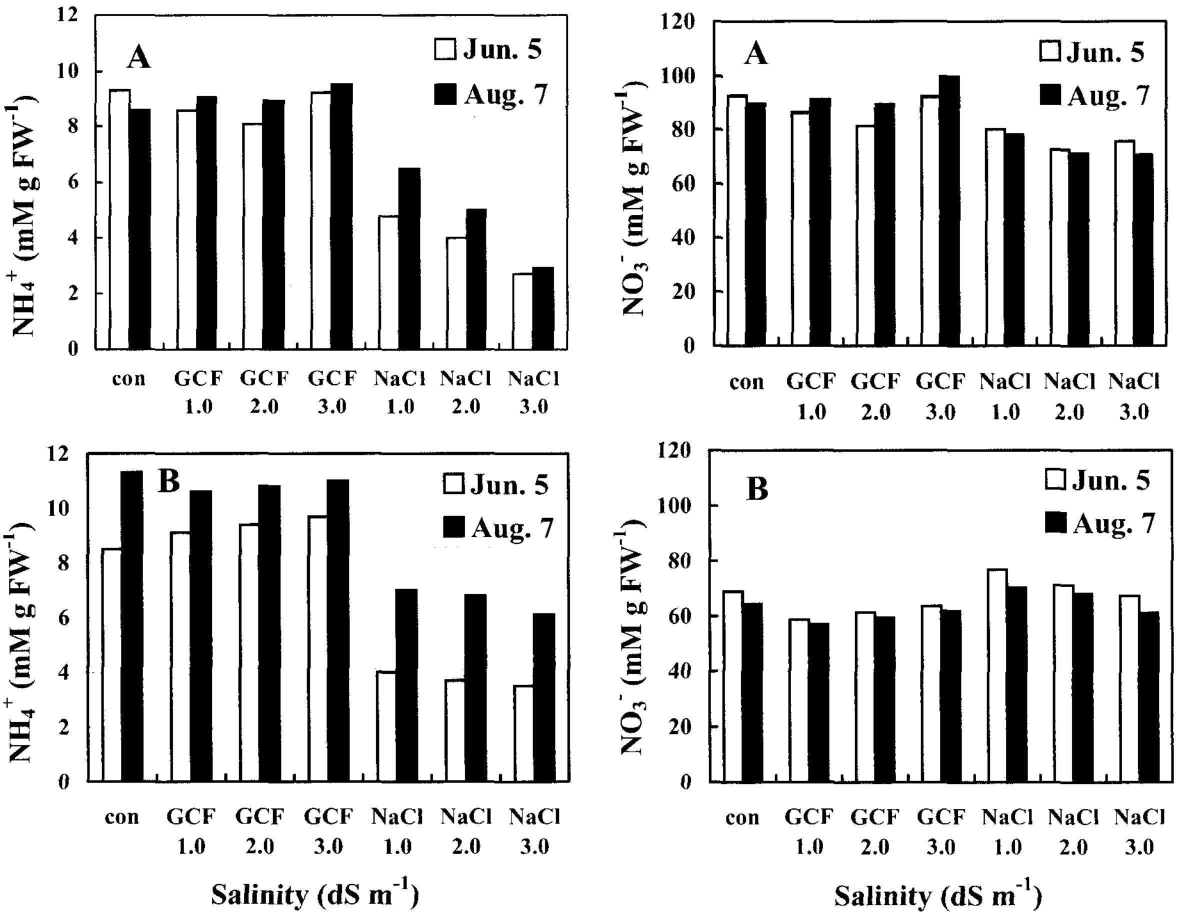

Fig. 1. NH_4^+ and NO_3^- content in 2 years old Korean ginseng with different EC levels on 5 June and 7 August. A; leaf, B; root, GCF; general complete fertilizer.

(1992) that the nitrogen content increased at higher EC level of solution in Korean ginseng. But, in leaves, the NO_3^- content decreased with NaCl, and the reduction was higher at higher NaCl concentration. The NO_3^- content of stems with NaCl did not show difference, but it increased in roots with NaCl. Also, the NO_3^- content with GCF was not different with that of the control in leaves, stems, and roots. But the NO_3^- content in leaves and stems decreased greatly with NaCl, and the slope of the decrement increased at higher NaCl concentration.

In the meantime, the NH_4^+ content was higher in leaves and roots, and was relatively less in stem. The NH_4^+ content of the Korean ginseng with GCF was not difference with that of control, but the NH_4^+ content with NaCl decreased greatly and it decreased rapidly at the higher NaCl concentration. Also, the NH_4^+ content of root with NaCl was higher at August 7 than at June 5, but NH_4^+ content in stems was low at August 7 (Fig. 1). Lee *et al.* (1988) reported that the nitrogen content in roots of Korean ginseng was less than 1% at harvest because the nitrogen decreased rapidly until June 10, and it was not changed from June 10 to July 10, and then it slightly increased up to about 1.5% by August. In shoot, the nitrogen content decreased as the growth progressed, and the degree of decrement was small between June 10 and July 10, and then the degree of decrement was high after July 10. Lee *et al.* (1983) reported that the nitrogen content in stems or leaves decreased after September but it increased continuously in roots. This suggested that accumulated nitrogen in leaves which decreased rapidly in roots at May, was transferred to roots in Korean ginseng at late growth stage.

From this research, increase of the NH_4^+ and NO_3^- content at higher EC level by GCF were similar with the result by Lee *et al.* (1983). On the other hand, the NH_4^+ content with NaCl showed opposite result reported by Kim *et al.* (1999) that the NH_4^+ content of the barley increased with NaCl treatment. It was assumed that the NH_4^+ content in barley increased by increase of the Na^+ in plant when treated with NaCl, but the NH_4^+ accumulation in the Korean ginseng was not remarkable.

Root activity and Water potential

The method measuring the succinate dehydrogenase activity which was directly connected with the respiratory activity was highly correlated with reductive reaction of TTC which reflects the respiratory capability. Fig. 2 showed the root activity of the Korean ginseng at June 5 and August 7 with different GCF and NaCl concentration. The root activity increased with high GCF concentration compare to the control at the two measuring times. The root activity,

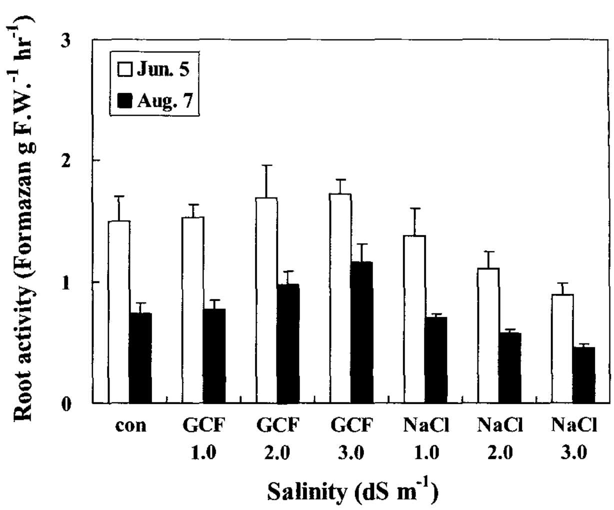

Fig. 2. Root activity of 2 years old ginseng as affected by controlled salinity with GCF and NaCl solution on 5 June (□) and 7 August (■). Means are shown ±SE (n=5). GCF; general complete fertilizer.

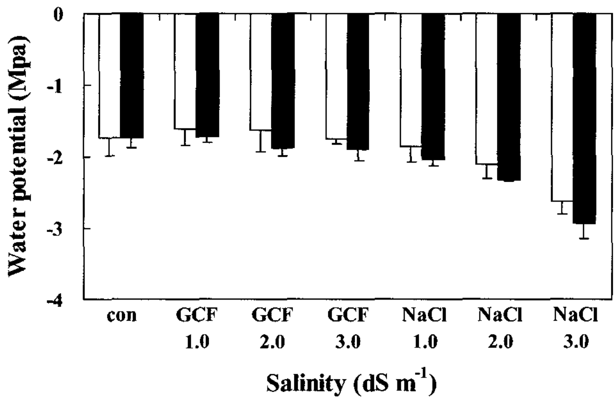

Fig. 3. Water potential of leaf of 2 years old ginseng as affected by controlled salinity with GCF and NaCl solution on at 5 June (□) and 7 August (■). Means are shown ±SE (n=9). GCF; general complete fertilizer.

however, reduced with NaCl treatment.

The water potential in leaves of two years old Korean ginseng with different GCF and NaCl concentrations is shown in Fig. 3. The water potential in leaves of Korean ginseng with GCF was higher or similar compared to control, but the water potential of leaves with NaCl decreased rapidly and it decreased linearly at higher NaCl concentration. The water potential at August 7 was lower than that at June 5, and the difference of the two values became conspicuous as NaCl concentration increased. The water potential was affected by the water content or viability of leaves, the inorganic ion content, and the level of various osmotica *in vivo*. The reduction of the water potential in Korean ginseng with salinity considered to be depended on water content, rapid accumulation of osmotica *in vivo*. Specially, the reduction of water potential may be caused by excessive accumulation of Na^+ and Cl^- absorbed to plant.

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