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Varietal Difference of Transplanted Rice Seedling Growth in Response to Salinity

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ABSTRACT: This study was conducted to obtain basic information of growth, chlorophyll, and Na^+ and K^+ content of rice (*Oryza sativa* L.) seedlings after transplanting in different NaCl conditions. Plants grown in pots for 8 days after germination were grown for 10 days after transplanting in 50 and 100 mM NaCl concentrations. At higher NaCl concentration, plant height, root length, dry weight and chlorophyll content were reduced with NaCl stress. Among rice cultivars, the shoot dry weight of Gancheokbyeo, Janganbyeo and Hwasungbyeo, and the root dry weight of Janganbyeo, Gancheokbyeo and Juanbyeo showed relatively low reduction compared to the other rice cultivars at 100 mM NaCl stress. The Na^+ content in seedling rapidly increased with the increase of NaCl concentration but K^+ contents decreased. There was a significant relationship between Na^+ content and shoot and root dry weight after transplanting rice seedlings to saline conditions. The shoot and root dry weight showed highly negative relationship with the Na^+/K^+ ratio in saline conditions.

***Keywords*:** rice seedling, NaCl, chlorophyll, Na^+, K^+, Na^+/K^+ ratio, seedling

Substantial portion of the world land area is salt-affected soils, amounting at approximately 33% of the irrigated soils. Soil salinity is a major limiting factor in agricultural productivity at many parts of the world, especially in arid, semi-arid, and reclaimed land areas. Salinity decreases plant growth by low soil water potential, high specific ion content, and nutrient imbalance within the plant tissues and eventually plant will die. The initial and primary effect of salinity at a moderate level is caused by its osmotic effects and/or ion toxicity and/or nutrient imbalance caused by over dominance of a specific ion.

Rice, one of the world's most important and widespread crops, is classified as moderate or weak salt tolerance The cultivated methods of rice in Korea are transplanting culture of 8, 25, or 35 days old seedlings and direct seeding cultivation in paddy field The effect of salinity on plant was various at different growth stages. Responses to salinity are more sensitive at seedling stage and transplanting time compared to germination and tiller stage in rice (Akbar, 1974). Genetic variation in salinity tolerance among rice cultivars has been reported. These variations were largely based on the classical screening method of germination rate and growth or yield response to salt (Lee *et al.*, 1992; Lee *et al.*, 1998; Shin & Lee, 1999; Won *et al.*, 1992). However, it has been suggested that the selection or breeding to increase salt tolerance may be successful if it is based on the physiological mechanism or characters conferring tolerance.

Consideration of interaction between the ion absorption and the soil salinity is very interesting subject. Ions are greatly absorbed at the high content of Na^+ and Cl^- media and accumulated continuously in the tissue (Cramer *et al.*, 1990). These ions inhibited absorption of essential elements such as K^+ and Ca^{2+}, and caused the element deficiency in tissue, and also increased Na^+/K^+, Na^+/Ca^{2+} ratio. Lynch & Lauchli (1984) reported that the Na^+/K^+ ratio increased in saline stressed barley shoots by inhibiting absorption of K^+ and transposition. Cramer *et al* (1987) reported that, since K^+ affected the osmoregulation capability and Na^+ content between cells associated with the various osmotic stresses, the K^+/Na^+ selectivity could be considered as an important index of the salt tolerance.

Therefore, this research was carried out to investigate the effect of salinity on growth, Na^+ and K^+ content after transplanting 8 days old rice seedlings, and to provide data of the growth and development of the salt tolerant cultivars.

MATERIALS AND METHODS

Plant materials and salinity treatments

This experiment was carried out at a experimental farm affiliated to Collage of Agriculture and Life Science, Chungnam National University in Korea. Eight cultivars were selected for the comparison; Ansanbyeo, Daeanbyeo, Janganbyeo, Nampyeongbyeo, Daesanbyeo, Hwasungbyeo, Gancheokbyeo, and Juanbyeo. Seeds of each cultivar were sown individually on sand soil in seedling box and grown hydroponically in the glasshouse under natural light and day/night temperature of 30/25°C. At eight days after germination, the rice seedlings were transferred to pots (20 cm diameter plastic

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pots) filled with to half strength Hoagland solution containing 0, 50, and 100 mM NaCl solution. The growth measurements were taken at 2, 4, 6, 8, and 10 days after transplanting.

Dry weight and chlorophyll determination

Shoots and roots were weighed after drying at 80 °C for 72 h. Chlorophyll content of rice seedlings was measured by the method of Yoshida *et al.* (1972). The content of chlorophyll a, chlorophyll b, and total chlorophyll was determined with spectrophotometer (UV-120-02 Shimadzu) at 663 nm, 645 nm and 652 nm, respectively.

Ion content

Na^+ and K^+ were extracted using 1 N HCl by IRRI method (Yosida *et al.*, 1972). Samples were dried 72 hours at 80 °C and pulverized. The samples then were measured with 1 g correctly and extracted for a day, and Na^+ and K^+ were measured at 589 nm and 766.5 nm, respectively, using an atomic absorption spectrophotometer (Shimazu AA-6800, Japan).

RESULT AND DISCUSSION

Growth

Plant height and root length greatly decreased with increasing NaCl concentration (Table 1). At 50 mM NaCl concentration, Nampyungbyeo and Daesanbyeo showed higher decrease in plant height, but Daeanbyeo and Ansanbyeo showed relatively lower reduction in plant height compared to the other cultivars at 10 days after transplanting. At 100 mM NaCl concentration, Nampyeongbyeo, Daesanbyeo, Daeanbyeo, Juanbyeo, and Janganbyeo showed higher reduction of

Table 1. Effects of plant height and root length at 2, 4, 6, 8 and 10 days after transplanting 8 day old rice seedlings in NaCl conditions

NaCl conc (mM)	CV	Plant height (cm)					Root length (cm)				
		2[†]	4	6	8	10	2	4	6	8	10
0	Gc	12 6ab[‡]	13 2ab	14 2b	19 4bc	26 8ab	4 5ns	8 0b	8 9b	10 1ns	10 5ns
	Np	13 0a	13 6ab	16 5ab	21.2bc	28.0ab	4 2ns	8 1ab	8 9b	9 5ns	11 6ns
	Ds	12 5ab	14 7a	16 6ab	21 4abc	28 4ab	4 4ns	8 6ab	9 8ab	10 5ns	12 0ns
	Da	12 1ab	13 7ab	17 2a	21 2bc	28 2ab	4 7ns	9 6a	11 2a	10 3ns	10 7ns
	As	13 9a	15 1a	17 6a	24 8a	30 5ab	4 9ns	8 7ab	10 6ab	10 9ns	11 4ns
	Ja	12 5ab	13 5ab	14 5b	18 9c	26 1b	4 5ns	7 9b	9 0b	10.3ns	11 6ns
	Ju	12 1ab	14 0ab	15 3ab	21 1bc	30 1ab	4 8ns	7 4b	9 8ab	9 1ns	10 4ns
	Hs	13 5a	15 1a	16 7ab	22 5ab	30 7a	5 2ns	8 6ab	10 0ab	11 1ns	11 0ns
50	Gc	12 7ab	13 0ab	13 7b	15 5bc	18 5ab	5 6ns	8 1ns	9 0ab	9 3c	9 5ns
	Np	12 9ab	13 3ab	14 2b	15 0c	15 9b	4 5ns	7 0ns	9 2ab	9 2c	10 0ns
	Ds	12 1ab	12 9ab	13 7b	16 4abc	17 9ab	5 2ns	7 6ns	9 1ab	9 4c	10 2ns
	Da	12 3ab	14 1a	15 2ab	18 8a	22 4a	5 5ns	8 7ns	11 3a	12 0a	11 2ns
	As	13 7a	14 4a	16 4a	18 6ab	22 3a	5 2ns	8 8ns	9 7ab	11 2ab	10 2ns
	Ja	12 4ab	13 7ab	13 9b	15 8abc	18 0ab	4 6ns	7 7ns	9 4ab	9 7bc	10 0ns
	Ju	12 0ab	12 8ab	14 1b	15 9abc	20 5ab	5 1ns	8 5ns	8 7ab	9 5c	10 5ns
	Hs	13 4a	14 0a	14 8ab	17 8abc	20 6a	5 8ns	8 2ns	11 5a	11 7a	11.6ns
100	Gc	12 0ab	12 6a	12 8a	13 4a	14 6a	5 1ns	6 9ns	7 4abc	7 0ns	8 1abc
	Np	11 5b	11 8ab	12 1ab	12 0b	12 3b	5 3ns	5 5ns	6 1bc	6 7ns	6 5c
	Ds	11 1b	11 3ab	11.7b	12.0b	12 3b	4 7ns	6 9ns	5 7c	7 4ns	7 0bc
	Da	11 2b	11 8ab	12 2ab	13 3a	14 3a	4 3ns	6 9ns	9 1ab	8 0ns	9 3ab
	As	12 8a	12 9a	13 1a	13 2a	13 1ab	5 9ns	6 7ns	9 7a	8 1ns	10 2a
	Ja	11 1b	11 6ab	12 4ab	12 7ab	14 7a	5 1ns	6 1ns	6 8abc	7 2ns	8 4abc
	Ju	11 1b	11 5ab	12 0ab	12 6b	13 3ab	5 4ns	5 9ns	6 4bc	7 5ns	8 9abc
	Hs	12 8a	13 0a	13 5a	13 6a	13 7ab	4 5ns	7 1ns	9 5a	9 7ns	7 1bc
	CV	*	**	**	**	**	*	ns	ns	ns	ns
	NaCl	*	**	**	**	**	ns	ns	*	**	*
	CV x NaCl	*	**	**	**	**	**	ns	ns	ns	*

[†] Days after transplanting
[‡] Means with the same letter between cultivars are not significantly different at the 5% level based on Duncan's multiple range test ANOVA results are shown with *, ** and ns indicating significance at p < 0 05 and 0 01, and no significance, respectively Hs Hwasungbyeo, Gc Gancheokbyeo, Ja Janganbyeo, Np Nampyeongbyeo, Ds Daesanbyeo, Da Daeanbyeo, As Ansanbyeo, Ju Juanbyeo, CV Cultivar

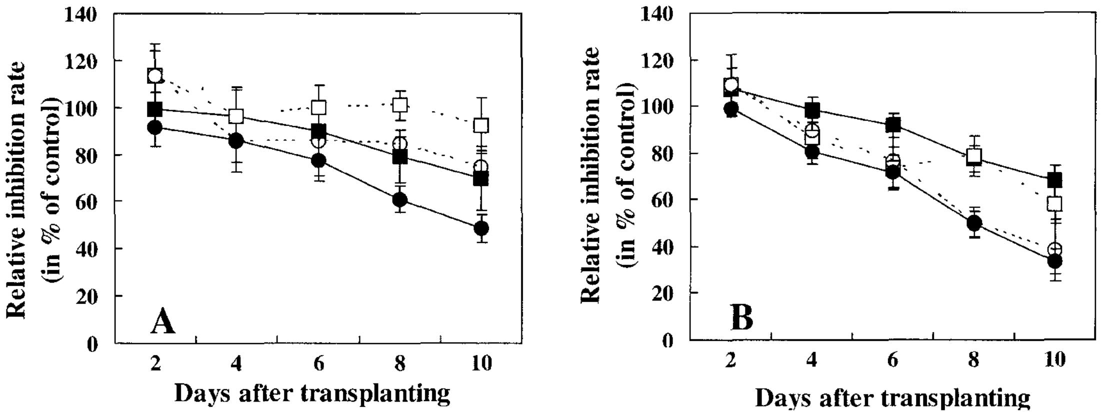

Fig. 1. Relative inhibition rate in percent of non NaCl treatment after NaCl treatment. A. plant height (solid line) and root length (dotted line), B: shoot (solid line) and root (dotted line) dry weight. ■ and □ 50 mM NaCl, ● and ○ · 100 mM NaCl Data are average value and the vars are standard errors of 8 rice cultivers

Table 2. Effects of NaCl on dry weight in shoot and root at 2, 4, 6, 8 and 10 days after transplanting 8 day old rice seedlings in NaCl conditions

NaCl conc (mM)	CV	Dry weight (mg plant^{-1})									
		Shoot					Root				
		2[z]	4	6	8	10	2	4	6	8	10
0	Gc	9.7ns[y]	12.0ns	16.6abc	28.7ns	46.6ns	4.4ab	7.8ab	7.1ns	7.2ns	10.7ab
	Np	10.1ns	12.6ns	13.0c	31.3ns	47.3ns	3.1b	7.1b	7.4ns	7.2ns	9.4ab
	Ds	9.4ns	13.3ns	19.6ab	28.7ns	50.5ns	3.9ab	9.7a	7.4ns	7.4ns	13.0a
	Da	9.1ns	13.6ns	20.1a	27.7ns	44.4ns	3.9ab	8.7ab	7.4ns	7.2ns	9.0b
	As	10.9ns	11.6ns	14.6abc	30.3ns	47.9ns	3.3ab	7.3b	7.0ns	6.8ns	9.5ab
	Ja	8.4ns	10.2ns	14.3bc	27.7ns	38.5ns	3.2ab	6.8b	6.0ns	6.8ns	8.4b
	Ju	8.8ns	12.1ns	17.5abc	31.5ns	49.3ns	3.3ab	7.8ab	6.0ns	8.6ns	9.8ab
	Hs	9.1ns	12.5ns	20.1a	30.4ns	46.8ns	4.6a	8.4ab	7.1ns	7.8ns	11.1ab
50	Gc	9.2ns	11.1ns	12.7ns	17.8cd	28.2a	4.1ab	7.1ns	5.3ab	5.7ns	5.9ab
	Np	9.0ns	8.9ns	13.2ns	17.3cd	20.0b	3.8ab	6.9ns	5.0ab	5.4ns	4.8b
	Ds	8.9ns	10.9ns	12.4ns	20.0a-d	26.0ab	3.6ab	6.8ns	4.9ab	5.3ns	5.6ab
	Da	8.9ns	11.2ns	16.9ns	24.5a	29.0a	3.7ab	6.0ns	5.7a	6.2ns	6.9b
	As	9.9ns	11.6ns	13.0ns	23.8ab	26.3ab	3.1b	6.0ns	4.1b	5.6ns	4.8b
	Ja	8.5ns	10.7ns	12.6ns	20.0ab	25.6ab	3.6ab	6.6ns	4.9ab	6.0ns	6.1ab
	Ju	9.0ns	11.3ns	14.2ns	18.4bcd	32.3a	4.1ab	5.7ns	5.2ab	6.2ns	6.5ab
	Hs	10.2ns	11.9ns	16.2ns	23.1abc	28.9a	4.4a	6.1ns	5.3ab	6.4ns	6.5ab
100	Gc	9.6ns	9.4ab	10.2ab	14.8a	16.9a	4.3a	6.3ab	5.3abc	3.9ns	4.6a
	Np	8.3ns	7.5b	10.0ab	12.0ab	12.4b	3.6ab	4.9b	5.9abc	3.7ns	3.6ab
	Ds	8.3ns	8.1b	10.0ab	12.6ab	11.8bc	3.9ab	6.1ab	5.2abc	3.9ns	3.5ab
	Da	8.1ns	9.3ab	10.7ab	13.9ab	13.8abc	3.7ab	8.0a	4.6bc	3.7ns	3.5ab
	As	8.3ns	8.5b	10.8ab	11.3b	12.0b	3.0b	7.3a	4.3c	3.3ns	2.8b
	Ja	8.3ns	8.6b	9.7b	12.6ab	15.8a	3.4ab	6.0ab	5.0abc	3.7ns	3.9ab
	Ju	8.3ns	10.2a	12.2ab	13.4ab	14.2ab	3.9ab	7.3a	6.2ab	3.9ns	4.4a
	Hs	8.7ns	10.1a	13.5a	15.1a	15.0a	4.1a	8.0a	6.6a	4.0ns	3.6ab
	CV	ns	**	**	**	**	**	ns	ns	ns	ns
	NaCl	*	**	**	**	**	ns	**	**	**	**
	CV x NaCl	ns	**	**	**	**	**	ns	ns	ns	*

[z] Days after transplanting
[y] Means with the same letter between cultivars are not significantly different at the 5% level based on Duncan's multiple range test ANOVA results are shown with*, ** and ns indicating significance at $p<0.05$ and 0.01, and no significance, respectively Hs Hwasungbyeo, Gc Gancheokbyeo, Ja· Janganbyeo, Np Nampyeongbyeo, Ds Daesanbyeo, Da· Daeanbyeo, As· Ansanbyeo, Ju Juanbyeo, CV Cultivar

plant height, but Gancheokbyeo and Ansanbyeo showed relatively low reduction. Plant height showed sharp reduction from 6 days and 4 days after transplanting in 50 mM and 100 mM NaCl concentrations, respectively (Fig. 1-A). Lee *et al.* (1998) reported that the plant height of rice varieties did not differ at 7 days after NaCl stress, but at 20 days after at 0 8% NaCl treatment, the plant height was reduced to 30 ~ 50% of control in tolerant varieties and 24 ~ 27% of control in susceptible varieties

The root length of rice seedlings showed no significant change at 50 mM NaCl concentration. But at 100 mM NaCl concentration, the root length started to decrease at 4 days after transplanting and decreased sharply at 6 days. Similar results were reported by Shalhevet *et al* (1995) who reported that the salinity generally reduced the shoot length of plants more than the root length in 12 plant species. There was a significant difference of the plant height among rice cultivars from 2 days after transplanting in saline conditions, meanwhile, the root length showed a significant difference only from 6 days after transplanting.

Table 2 showed the dry weight of 8 days old seedlings after transplanting in 50 and 100 mM NaCl conditions. Munns & Termeat (1986) and Cho (1997) reported whole plant response to salinity that the root growth of barley was almost always more sensitive than shoot growth to increasing salinity so that the root/shoot ratio generally increased. The shoot dry weight decreased with increasing NaCl concentration and salt shock period. At 100 mM NaCl concentration, the dry weight reduction was 1.1%, 19.6%, 28.3%, 50.6% and 66.5% at 2, 4, 6, 8 and 10 days after transplanting, respectively, compared to the control (Fig. 1-B). The dry weight among rice cultivars at 100 mM NaCl condition,

Table 3. Effect of NaCl on chlorophyll content at 2, 4, 6, 8 and 10 days after transplanting 8 day old rice seedlings in NaCl conditions.

NaCl conc (%)	CV	Chlorophyll content (mg g^{-1}f wt)														
		2[J]			4			6			8			10		
		a	B	A+b	a	b	a+b	a	B	a+b	a	b	a+b	a	b	a+b
0	Gc	3 3ab[♪]	1 0ab	4 3ab	3 7ab	0 9ab	4 6ab	3 9b	1 1ab	5 0b	6 2ab	1 7ns	8 0ab	6 2ab	1 7a	7 9b
	Np	3 9a	1 2a	5 0a	6 3a	1 6a	7 9a	4 5ab	1 2ab	5 7ab	7 6a	2 0	9 6a	7 5a	2 2a	9 7a
	Ds	3 8a	1 6a	5 5a	4 4ab	1 1a	5 5ab	5 4a	1 4a	6 8a	7 4a	2 0	9 5a	8 2a	2 3a	10 6a
	Da	3 3ab	1 0ab	4 3ab	3 2b	0 8ab	4 0b	5 1a	1 4a	6 4a	7 0a	2 0	9 0a	6 4ab	1 8a	8 1ab
	As	4 5a	1 3a	5 8a	4 5ab	1 1a	5 6ab	5 5a	1 5a	7 0a	5 3b	1 6	6 9b	6 1b	1 8a	7 9b
	Ja	2 8ab	1 6a	4 4ab	4 2ab	1 0a	5.2ab	4.8ab	1 3a	6 1ab	5 8ab	1 7	7 6ab	5 8b	1 5ab	7 3b
	Ju	2 8ab	0 8ab	3 6ab	5 1a	1 3a	6 3a	4 8ab	1 4a	6 2ab	5 5b	1.7	7.2b	7 5a	2 1a	9 6a
	Hs	4 1a	1 3a	5 4a	4 5ab	1 1a	5 6ab	5 9a	1 7a	7 6a	5 9ab	1 8	7 7ab	6 9ab	1 9a	8 8ab
0 3	Gc	3 0ab	1 0ab	4 0ab	2 8b	0 6ab	3 4ab	4 4a	1 1a	5 5a	6 0a	1 7a	7 7a	4 5ab	1 3a	5 8ab
	Np	2 8b	0 8ab	3 6b	3 5ab	0 8ab	4 3ab	4 2a	1 0ab	5 3ab	5 3ab	1 4ab	6 7ab	3 8b	1 1ab	4 9ab
	Ds	2 9ab	0 8ab	3 7ab	2 8b	0 7ab	3 5ab	2 7b	0 7b	3 4b	4 8b	1 3ab	6 1ab	4 2b	1 2a	5 4ab
	Da	3 4a	1 0ab	4 5b	4 4a	1 1a	5 5a	5 1a	1 4a	6 6a	5 3ab	1 6a	6 9a	5 6a	1 6a	7 2a
	As	3 6a	1 0ab	4 6b	5 0a	1 3a	6 4a	5 0a	1 1a	6 1a	5 4a	1 5a	6 9a	5 2a	1 4a	6 6a
	Ja	3 1ab	0 9ab	4 0b	3 2ab	0 7ab	4 0ab	4 0ab	1 0ab	5 0ab	5 2ab	1 5a	6 6a	5 2a	1 5a	6 7a
	Ju	3 3ab	1 0ab	4 3b	3 6a	0 8ab	4 4ab	4 3a	1 2a	5 6a	5 4a	1 5a	6 8a	5 8a	1 7a	7 4a
	Hs	5 3a	1 5a	6 8a	5 1a	1 2a	6 4a	5 1a	1 5a	6 6a	5 2ab	1 5a	6 7ab	5 1ab	1 5a	6 6a
0 6	Gc	3 0a	0 9a	4 0a	2 7a	0 7a	3 4a	3 1a	0 8a	3 8a	3 1a	0 7a	3 8a	2 9a	0 9a	3 9a
	Np	2 7ab	0 8a	3 5ab	1 8b	0 5ab	2 3b	1 6b	0 4ab	2 0b	1 3bc	0 4ab	1 7b	0 4c	0 1c	0 5c
	Ds	1 9b	0 6ab	2 5ab	2 1ab	0 5ab	2 6b	1 5b	0 4ab	1 9b	1 0bc	0 2b	1 2bc	0 9b	0 3b	1 2bc
	Da	2 6ab	0 7ab	3 3ab	2 5a	0 6ab	3 1ab	2 0ab	0 5ab	2 5ab	2 2a	0 6a	2.8a	2 1a	0 6ab	2 7a
	As	3.5a	1 2a	4 7a	2 2ab	0 6ab	2 8ab	1 7b	0 4ab	2 1b	1 2b	0 3b	1 5b	1 3b	0 3b	1 6b
	Ja	2.9ab	0 9a	3 8a	2 7a	0 6ab	3 3a	2 3ab	0 5ab	2 8ab	1 8a	0 5a	2 3ab	1 6ab	0 4ab	2 0b
	Ju	3 4a	1 2a	4 6a	1.8b	0 5ab	2 3b	1 7b	0 5ab	2 2b	1 8a	0 4ab	2 3ab	1 7ab	0 2b	1 9b
	Hs	3 8a	1 2a	5 0a	3 2a	0 9a	4 0a	3 3a	0 8a	4 1a	2 4a	0 6a	3 1a	2 2a	0 5ab	2 7a

[J] Days after transplanting
[♪] Means with the same letter between cultivars are not significantly different at the 5% level based on Duncan's multiple range test ns not significance, CV Cultivar, Hs Hwasungbyeo, Gc Gancheokbyeo, Ja Janganbyeo, Ju Juanbyeo, Ds Daesanbyeo, Da Daeanbyeo, As Ansanbyeo, Np Nampyeongbyeo, a chlorophyll a, b chlorophyll b

Ansanbyeo, Nampyeongbyeo, Daesanbyeo, and Juanbyeo showed relatively higher reduction, but Gancheokbyeo, Janganbyeo and Hwasungbyeo showed relatively lower reduction. The root dry weight of eight rice seedlings showed no difference between treatments and control at 2 days after transplanting, but there was sharp decrease of about 14.9% at 4 days, 21.7% at 6 days, 48.9% at 8 days, and 62.4% at 10 days. Among rice cultivars, Daesanbyeo (73%), Ansanbyeo (71%), Hwasungbyeo (68%), Nampyeongbyeo (62%), Daeanbyeo (61 %) showed relatively high reduction of the root dry weight at 100 mM NaCl stress, but Janganbyeo (54 %), Gancheokbyeo (57%) and Juanbyeo (55%) showed relatively low reduction.

Chlorophyll content

The chlorophyll content of rice seedlings grown with 50 and 100 mM NaCl was shown in table 3. The chlorophyll content decreased with increasing NaCl concentration and also with prolonged NaCl stress periods. The chlorophyll

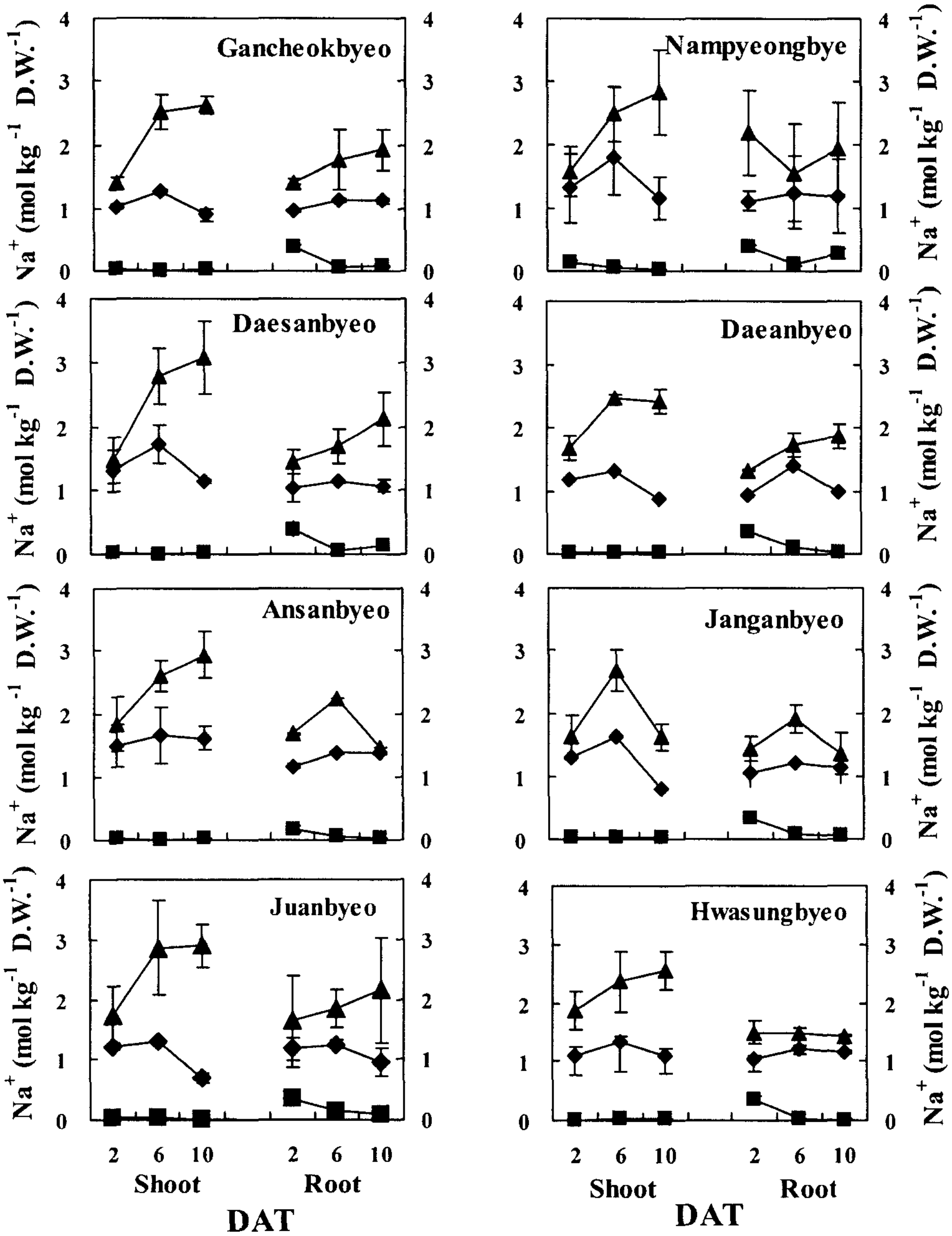

Fig. 2. Effects of NaCl on Na^+ concentration at 2, 6 and 10 days after transplanting in 0 (■), 50 (◆), and 100 mM (▲) NaCl concentrations on 8 days old rice seedlings.

content showed a little reduction at 50 mM NaCl concentration compared to that at 100 mM NaCl treatment. The chlorophyll content tended to decrease sharply from 2 days after salinity treatment.

Nampyeongbyeo, Daesanbyeo, Ansanbyeo and Juanbyeo showed high, but Gancheokbyeo, Daeanbyeo, Janganbyeo, and Hwasungbyeo showed low reduction of chlorophyll content at 10 days after 100 mM NaCl treatment. In case of rice, Lee *et al.* (1992) reported that there was negative correlation between the chlorophyll content and salt concentration in seedlings at 0.6% NaCl stress and there was a significant difference between salt stressed rice cultivars. Lutts *et al.* (1996) also reported that chlorophyll content had a highly significant relationship between sensitive and tolerant rice cultivars with NaCl stress.

Sodium and Potassium content

The plants grown in high saline soil absorb ions such as Na^+ and Cl^- excessively, and inhibit absorption or transition of the essential elements such as K^+ or Ca^{2+}. Consequently, this interfers with the metabolism or induced the nutritional imbalance and, eventually, leaded to withering to death by the nutritional starvation (Cho *et al.*, 2002). Thus, ions at high concentrations in the external solution (Na^+ or Cl^-) are taken up at high rates, which may lead to excessive accumulation in tissues. These ions may inhibit the uptake of the other ions into the root and their transport to the shoot. There is the potential for many nutrient interactions in salt-stressed plants which may have important consequences for growth (Cramer *et al.*, 1990).

The Na^+ content in eight rice seedlings under NaCl stress is shown in Fig 2. Na^+ content of shoot tended to increase with increasing NaCl concentration in media and prolonging the period of time in plant. At 50 mM NaCl concentration, Na^+ content of shoot tended to increase up to 6 days but decreased after that time. Cultivars which increased Na^+ content were Daesanbyeo, Ansanbyeo, Nampyeongbyeo, and Hwasungbyeo, but in Ansanbyeo, Nampyeongbyeo, Janganbyeo, and Hwasungbyeo, Na^+ content decreased on 6 days after 100 mM NaCl treatment. Miki *et al.* (2001) reported that Na^+ content in the leaves of salt tolerant rice plants under salt stress was about 4 times more than control, but Na^+ content in sensitive cultivars was 10 to 12 times more than cultivars without NaCl stress. Therefore, this research could conclude that the higher the NaCl content in rice leaves was the lower the salt tolerance of rice grown under saline conditions. Also, Na^+ content of root increased in Gancheokbyeo, Daesanbyeo, Juanbyeo, and Daeanbyeo, but decreased in Ansanbyeo, Nampyeongbyeo, Janganbyeo, and Hwasungbyeo at the same NaCl concentration. There was a significant relationship between Na^+ content and shoot and root dry weight after transplanting in saline conditions (Fig 3)

K^+ content in rice seedlings decreased with increasing NaCl concentration in media (Fig. 4). K^+ content in shoot of eight rice cultivars decreased up to 2 days with NaCl treatment and the reduction rate of the K^+ content tended to increase slightly by increasing NaCl concentration and prolonged stress periods. Relatively high K^+ content was shown in Gancheokbyeo, Ansanbyeo, Juanbyeo, and Hwasungbyeo, but low K^+ content in Daesanbyeo and Nampyeongbyeo at 10 days after 50 mM NaCl condition There was no difference in K^+ content of shoot among rice cultivars with

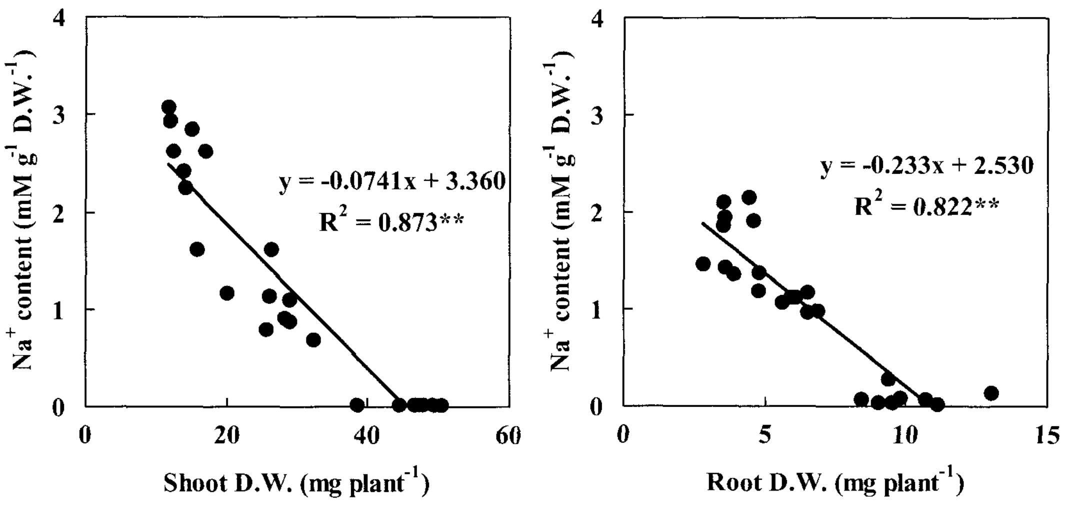

Fig. 3. Relationship between shoot and root dry weight, and Na^+ content at 10 days after transplanting in 50 and 100 mM NaCl concentrations on 8 days old rice seedlings ** significant at 0 01 %.

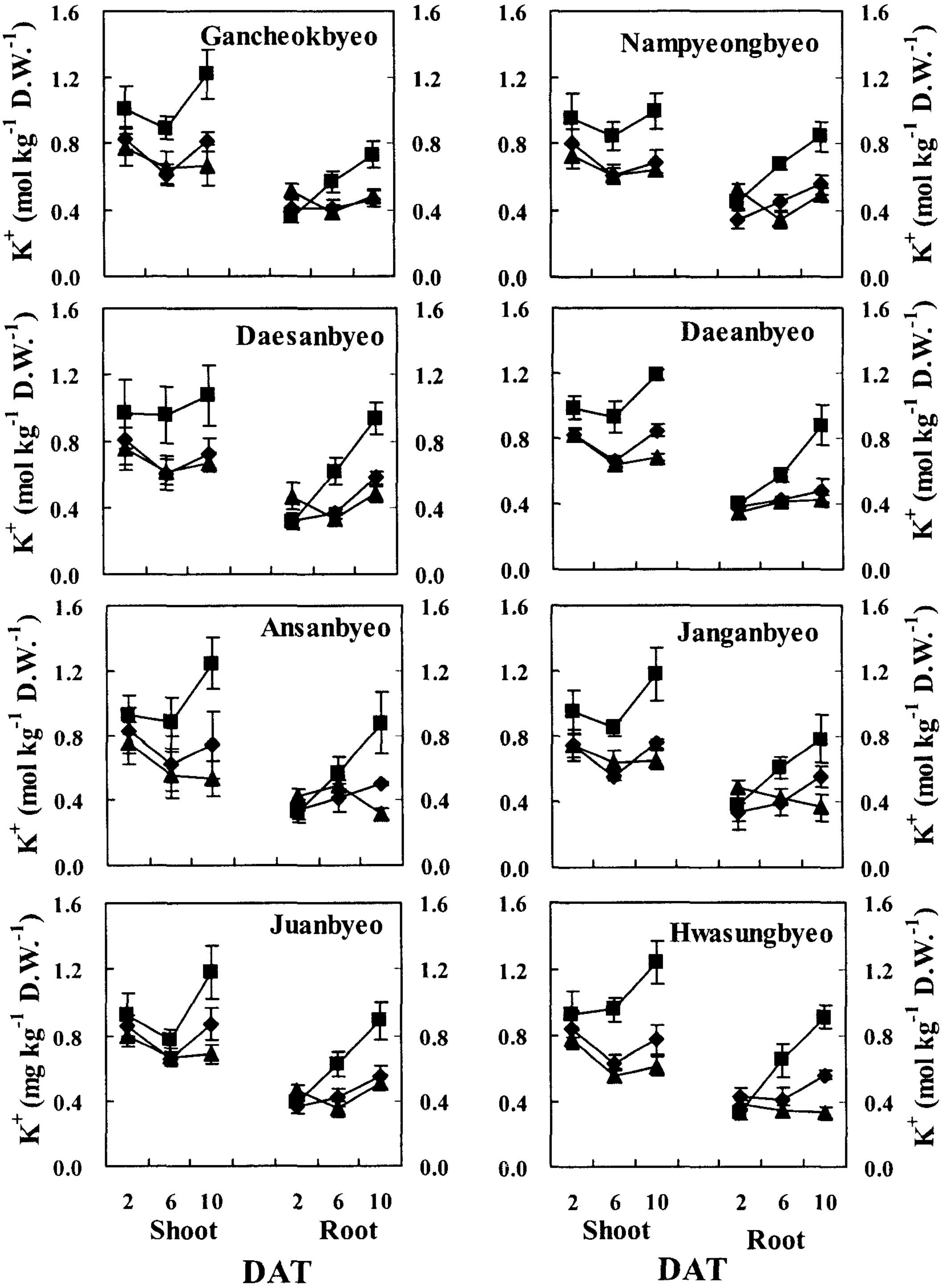

Fig. 4. Changes of K^+ content at 2, 6 and 10 days after transplanting in 0 (■), 50 (◆), and 100 mM (▲) NaCl concentrations on 8 days old rice seedlings

100mM NaCl concentration. K^+ content in root of rice seedlings showed increasing tendency with growth. At 100 mM NaCl condition, however, we could classify with two groups among rice cultivars. One was decreasing cultivars such as Janganbyeo and Hwasungbyeo, and the other, decreasing K^+ content quite a while but increasing followed by, cultivars such as Gancheokbyeo, Daesanbyeo, Juanbyeo, and Nampyeongbyeo.

On the other hand, the high concentration of K^+ in plant is indispensable for metabolic processes and growth of plants.

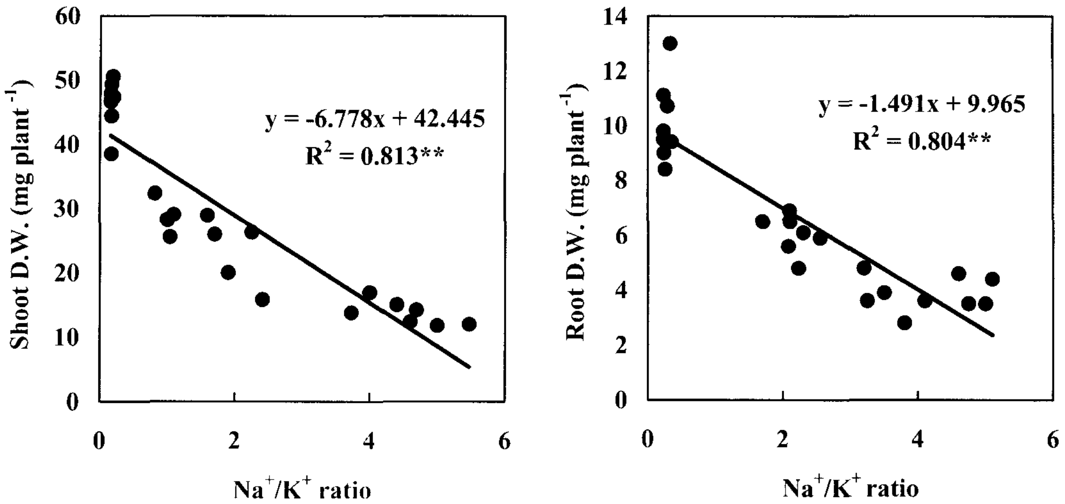

Fig. 5. Relationship between shoot and root dry weight, and Na^+/K^+ ratio up to 10 days after transplanting in 50 and 100 mM NaCl concentrations on 8 days old rice seedlings ** significant at 0.01 %

Therefore, Na^+/K^+ ratio is an important factor in the salt tolerance of plants and, in general, Na^+/K^+ ratio of barley seedlings tended to increase in NaCl-treated conditions rather than control conditions, or in roots rather than in shoots (Cho & Kim, 1998). Dionisio-Sese and Tobita (2000) stated that, in rice leaves, the salt sensitive cultivars showed an increasing Na^+/K^+ ratio with increasing salinity, but the salt tolerant cultivars did not exhibit this pronounced increase in the ratio during 1-week exposure to salinity stress. Results obtained from this research, the shoot and root dry weight showed a highly negative relationship with the Na^+/K^+ ratio up to 10 days after transplanting in saline conditions on 8 days old seedlings of eight rice cultivars (Fig 5)

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