Effects of Salinity on the Growth and Root Tip Structure of Rice Cultivars

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Abstract

Effects of NaCl on relative growth, ion uptake and root tip structure were examined in four rice *(Oryza sativa* L.) cultivars with different salt sensitivity. Experiments were conducted to find the differences among the cultivars in salinity responses during seedling and more developed stages. NaCl was applied with nutrient solution at concentrations of 0, 25 and 50 mM for 7 days after germination or from 7th day after germination. Growth inhibition by salinity was more prominent in seedling stage than in developed stage. Root was more sensitive than shoot. Based on the growth, the order of sensitivity was IR24>Nipponbare>Nona Bokra>Pokkali. Sensitive cultivars IR 24 and Nipponbare accumulated high amount of Na and absorbed low amount of K and maintained higher Na/K ratios in roots and shoots under both stages than tolerant cultivars Nona Bokra and Pokkali. Relative growth of rice cultivars was negatively and significantly correlated with Na content and Na/K ratios in roots and shoots under both stages. SEM observation revealed that the root cap tissues proliferated and more layered and extended to the basal part of root tip regions. Effects on root cap structures were more prominent in early seedling stage than in developed stage.

Media summary

Exclusion of Na from roots and shoots plays a critical role in expression of salinity resistance in rice cultivars.

Key words

Ion accumulation, root tip, salt resistance, sodium chloride.

Introduction

Rice (*Oryza sativa* L.) is one of the most important cereals in the tropics and subtropics and is sensitive to salinity. Cultivation of indica rice is being affected severely by salinity, particularly in coastal areas and irrigated land. Furthermore the development of salinity in temperate zones is one of the main obstacles to increase the productivity of japonica rice. There have been numerous reviews of the effects of salinity on plant physiological processes and subsequent effects on yield (Maas and Hoffman et al.1977; Greenway and Munns et al., 1980; Munns et al., 1993). However, there is still a controversy with regards to the mechanism of salt tolerance in plants (Neumann et al., 1995). The plant organ first exposed to salt stress is the root and it plays an important role in uptake of water and micronutrients. Excess Na accumulation reduces the plant growth (Akita and Cabuslay 1990) and induces ultrastructural change (Rahman et al., 2001; Mitsuya et al., 2003; Miyake et al., 2006). Salinity impairs seed germination, reduces nodule formation, retards plant development and reduces crop yield (Greenway and Munns et al., 1980). Rice plants are very sensitive to salinity stress at the young seedling stages and less so at reproductive stages (Flowers and Yeo et al., 1981; Lutts et al., 1995). Therefore, improvement in salinity tolerance of rice is likely to be most successful by investigating sensitivity at the most susceptible growth stages. This study was carried out to elucidate the effect of salt stress on growth at different stages, the uptake of Na, K and the root tip structure of rice cultivars exhibiting difference in salinity tolerance. Comparison of these responses could be useful in identifying the relative ability of each cultivar to cope with salinity.

Methods

Four rice (*Oryza saliva* L.) cultivars differing in salt tolerance and being categorized into two ecogeographic types (salt sensitive-indica type IR 24 and japonica type Nipponbare; salt tolerant-indica types Nona Bokra and Pokkali) were used. Salinity treatment for 0, 25 and 50 mM NaCl (with the presence of Kimura's nutrient solutions B-pH 5.5) in hydroponic cultured was made for 7 days after germination or from 7th day after germination. The growth was followed by measuring the dry weight, together with the analysis of Na and K contents and the observation of root tip structure.

Results

The salt-sensitive cultivars showed reduced the growth (Table 1), higher Na and lower K content with increasing salinity while the salt-tolerant cultivars did not exhibit the similar trend. The growth reduction was more prominent in roots than in shoots. Growth reduction was tended to be higher in the seedling stage than in the developed stage. There was a significant negative correlation between relative growth and Na/K ratio in roots and shoots regardless of cultivars and stages (Fig. 1). The correlation of Na/K ratio was higher with root growth than with shoot growth. The root cap length was increased at 25 mM and 50 mM NaCl in all cultivars (Fig. 2). However, the root cap length of salt-sensitive cultivars was decreased at 50 mM NaCl due to fall off at high NaCl.

	Seeding stage				Developed stage			
	Root		Shoot		Root		Shoot	
	25 mM	50 mM	25 mM	50 mM	25 mM	50 mM	25 mM	50 mM
IR 24	68±1.2 *	48±1.3 **	70±0.8 *	54±1.8 *	78±1.5 *	71±1.7 *	75±1.7 *	69±1 *
Nipponbare	72±1.5 *	55±1.7 *	78±2.5 *	67±1.6 **	81±0.7 **	74±0.6**	85±1.5 *	70±1.8 **
Nona Bokra	78±0.6 *	64±2.2 *	80±3 *	77± 1.7 *	85±1.8 *	80±1.5 *	95±1.9 *	88±1.9 *
Pokkali	82±1.5 *	65±2.4 *	98±3.4	95±1.7 *	98±1.8	88±1.2 *	100±3.5	99±2

Table 1. Effects of NaCl on relative growth in roots and shoots of four rice cultivars in the seedling and developed stages. (A)Relative growth for seedling stage = dry weight of treated plant (7d)/dry weight of control plant (7d) ×100. (B)Relative growth for developed stage = [dry weight of treated plant (14d)-dry weight of control plant (7d)] / [dry weight of control plant (14d)-dry weight of control plant (7d)] ×100. Each value is mean ± standard error from five independent experiments. ** and * represent significant difference from the control (100) at $P<0.01$ and $P<0.05$, respectively. Data were statistically analyzed by Tukey's HSD test.

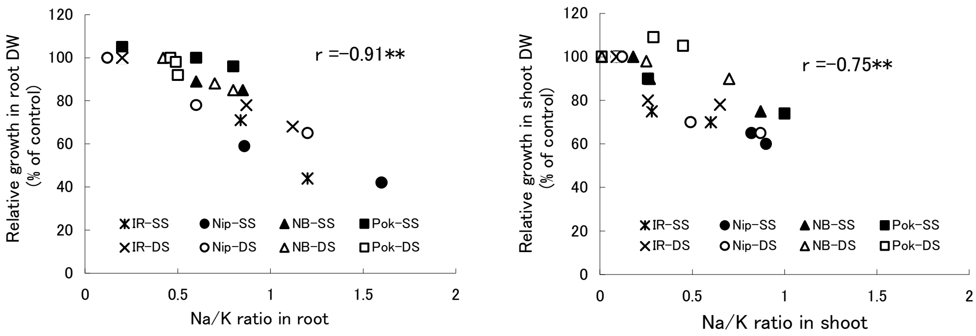

Figure 1. Effect of NaCl on correlation between Na/K ratio and relative dry weight in roots and shoots of four rice cultivars [IR 24 (IR 24), Nipponbare (Nip), Nona Bokra (NB) and Pokkali (Pok)] in the seedling stage (SS) and developed stage (DS). Data were obtained from three independent experiments. R values followed by **, represent significance of correlation at P<0.01.

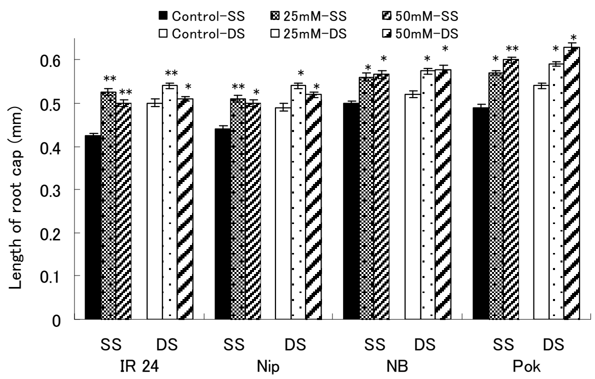

Figure 2. Effect of NaCl on the length of seminal root cap in four rice cultivars [IR 24 (IR 24), Nipponbare (Nip), Nona Bokra (NB) and Pokkali (Pok)] in the seedling stage (SS) and developed stage (DS). Data were obtained from three independent experiments. Vertical bars on each graphs represent SE. **and* represent significant difference from the control at P<0.01 and P<0.05, respectively. Data were statistically analyzed by Tukey's HSD test.

Conclusion

NaCl stress inhibits the growth of roots more than shoots. Early seedling stage was more susceptible to salinity than more developed stage. Salinity resistance at different stages shown as same behave as interdependent characteristics that the variability of salt resistance were statistically correlated with all cultivars. Root cap proliferation might be related to NaCl tolerance in rice seedling. Essentially the present results suggest that Na exclusion from roots and shoots and maintenance of K seem to play a critical role in expression of salinity resistance in rice seedling.

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