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EFFECT OF SILICATE ON THE GROWTH AND ION UPTAKE IN NaCl-STRESSED PLANTS[1)]

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ABSTRACT

The purpose of this experiment was to investigate the effect of Si on the growth and ions uptake (K, Na, Ca, and Mg) in rice, bean and barley plants grown in saline conditions.

Rice and bean plants were subjected to 0 and 30 mM NaCl in the nutrient solution with and without Si, whilst for barley plants 0 and 40 mM NaCl were used. In this investigation, 2.0 mM Si was used as silicilic acid.

The results revealed that Si had the protective effect on salt injury only for rice plants. This alleviating effect of Si appeared to be associated with the interference of Si on the upward Na transport by reducing the content of Na in the shoots and retaining it in the roots. Generally, addition of Si did not affect the content of K in all plants tested. Except for rice, Si had no or less effect on Ca and Mg uptake in bean and barley plants.

RINGKASAN

Tujuan penelitian ini ialah untuk melihat pengaruh Si terhadap pertumbuhan dan serapan hara (K, Na, Ca, Mg) pada tanaman padi, buncis dan barley yang ditanam pada cekaman NaCl. Tanaman padi dan buncis ditanam pada kultur air pada konsentrasi 0 dan 30 mM NaCl dengan penambahan dan tanpa penambahan Si. Untuk barley, konsentrasi NaCl yang dipakai adalah 0 dan 40 mM. Silikat diberikan dengan konsentrasi 2.0 mM.

Hasil penelitian menunjukkan bahwa Si dapat mengurangi pengaruh buruk cekaman garam hanya pada tanaman padi. Pengaruh ini berkaitan dengan penghambatan transpor Na ke daun (pucuk), yaitu dengan mengurangi kandungan Na di daun dan menahan Na di akar. Pemberian Si tidak mempengaruhi serapan K pada semua tanaman. Kecuali pada padi, Si memberikan pengaruh yang kecil atau tidak sama sekali terhadap serapan Ca dan Mg pada tanaman buncis dan barley.

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INTRODUCTION

Silicon is a major component of soil and exists in all kinds of plants growing in the soil (Miyake and Takahashi, 1978). There is growing evidence that Si application to rice plants grown in saline medium appears to be somewhat beneficial (Matoh *et al.,* 1986). They reported that removal of Si from the culture solution brought about a more severe growth reduction in rice plants exposed to 100 mM NaCl. Matoh *et al.* (1986) also reported that Si showed an interference with the upward sodium transport in rice plants, in which the contents of Na in the shoot of plants grown in nutrient solution supplied by Si were nearly half of those in the shoot of plants which did not receive Si. However, there has been little information on the effect of Si on the growth and ions uptake in other crops exposed to saline environments.

The present work investigates the effect of Si on the growth and ions uptake in rice, bean and barley plants grown in saline conditions.

MATERIALS AND METHODS

In this investigation, rice (*Oryza sativa* L. cv. Akebono), kidney bean (*Phaseolus vulgaris* L. cv. Masterpiece) and barley (*Hordeum vulgare* L. cv. Akashinriki) were used as test plants. The seeds of plants were germinated on sand for 7 days, and the seedlings were then transplanted onto 3.5 l pots containing nutrient solutions. The composition of nutrient solution used for growing bean and barley was KNO_3 4.O mM, $NaNO_3$ 1.0 mM, NaH_2PO_4 1.0 mM, $MgSO_4$ 1.0 mM, Fe 1.0 ppm (Fe citrate), B 0.5 ppm (H_3BO_4), Mn 0.5 ppm ($MnCl_2$), Zn 0.05 ppm ($ZnSO_4$), Mo 0.01 ppm $(NH_4)_6 Mo_7 o_{28}$) and Cu 0.02 ppm ($CuSO_4$). Rice plants were cultured in the nutrient solution having NH_4+ and $NO3^-$ (4:1) as a nitrogen source, though the other elements are the same as those for bean and barley. The medium pH was adjusted to 5.5 for rice plants and 5.0 for bean and barley. Throughout the experiments, nutrient solution was aerated continuously, and renewed once a week.

Rice and bean plants were subjected to 0 and 30 mM NaCl in the nutrient solution with and without Si, whilst for barley plants, 0 and 40 mM NaCl were used. In this investigation, Si (2.0 mM) was supplied as silicilic acid, prepared from a Na_2SiO_3 solution by passing through a cation exchange resin. Salinity and Si treatments were initiated when the seedlings were transplanted (7 days-old). This experiment was conducted in 5 replications.

Being grown for about 3 weeks, the plants were then harvested, and separated into shoots and roots. The parts were washed with deionized water, blotted dry, weighed, and dried in an oven at 100^oC. The dried tissues were then grounded, and an alliquot of ground tissues were ashed at 450^oC, then the ashes were dissolved with diluted hydrochloric acid. The contents of Na, K, Ca and Mg in the tissues were measured by an atomic absorption spectrophotometer.

RESULTS

Plant Growth

Figure 1 shows the growth of rice, kidney bean and barley plants grown under saline conditions in the presence and absence of Si. The upper part of the figure shows the growth of plant shoots, and the bottom part for the roots.

Rice plants showed a large decrease in growth when exposed to 30 mM NaCl. As compared to rice plants, NaCl had a lesser effect on the growth of bean, and just slightly reduced the growth or barley roots. Addition of Si remarkably stimulated the growth of rice and barley plants grown in NaCl-free solution. In rice plants, removal of Si from the culture solution caused a more severe growth reduction of plants subjected to 30 mM NaCl. However, Si had no effect on growth of bean plants cultured in both control and saline medium, and also for barley plants exposed to 40 mM NaCl. Thus, the results indicate that the alleviating effect of Si on the inhibition of growth due to NaCl was only found in rice plants.

Ion Absorption

The effects of salinity and Si on the uptake of Na and K in rice, bean and barley plants were presented in Fig. 2. When rice plants were exposed to saline conditions, addition of Si resulted in the decrease of Na contents in the shoots to less than half of those in the shoots of plants which did not receive Si. On the other hand, in the root of plants supplied with Si, Na increased nearly 2-fold as compared to that in plants grown with NaCl alone. In bean and barley, however, Si had no effect on Na uptake.

High concentrations of NaCl decreased K content in rice and barley plants, though did not change so much the content of K in bean plants. Generally, application of Si did not affect the content of K in all plants tested.

Except for rice plants, Si had no or less effect on Ca and Mg uptake in plants (Fig. 3). It was indicated that in the shoot of rice plants grown in both control and saline medium, the contents of Ca and Mg were reduced by Si. At 30 mM NaCl, rice plants which did not receive Si revealed a higher Ca content than did those of plants supplied with Si. This higher Ca content was due to a lower growth yield of plants which were not supplied with Si than that of plants supplemented with Si (Fig. 1). There was no significant change in Mg content in the shoot of rice plants grown under salinity, though Mg content in the roots increased nearly 2-fold. Both salinity and Si addition did not affect the uptake of Ca and Mg in bean plants. In the shoot of barley plants, 40 mM NaCl decreased both Ca and Mg contents. Generally, there was no clear effect of Si on the uptake of Ca and Mg in Barley plants.

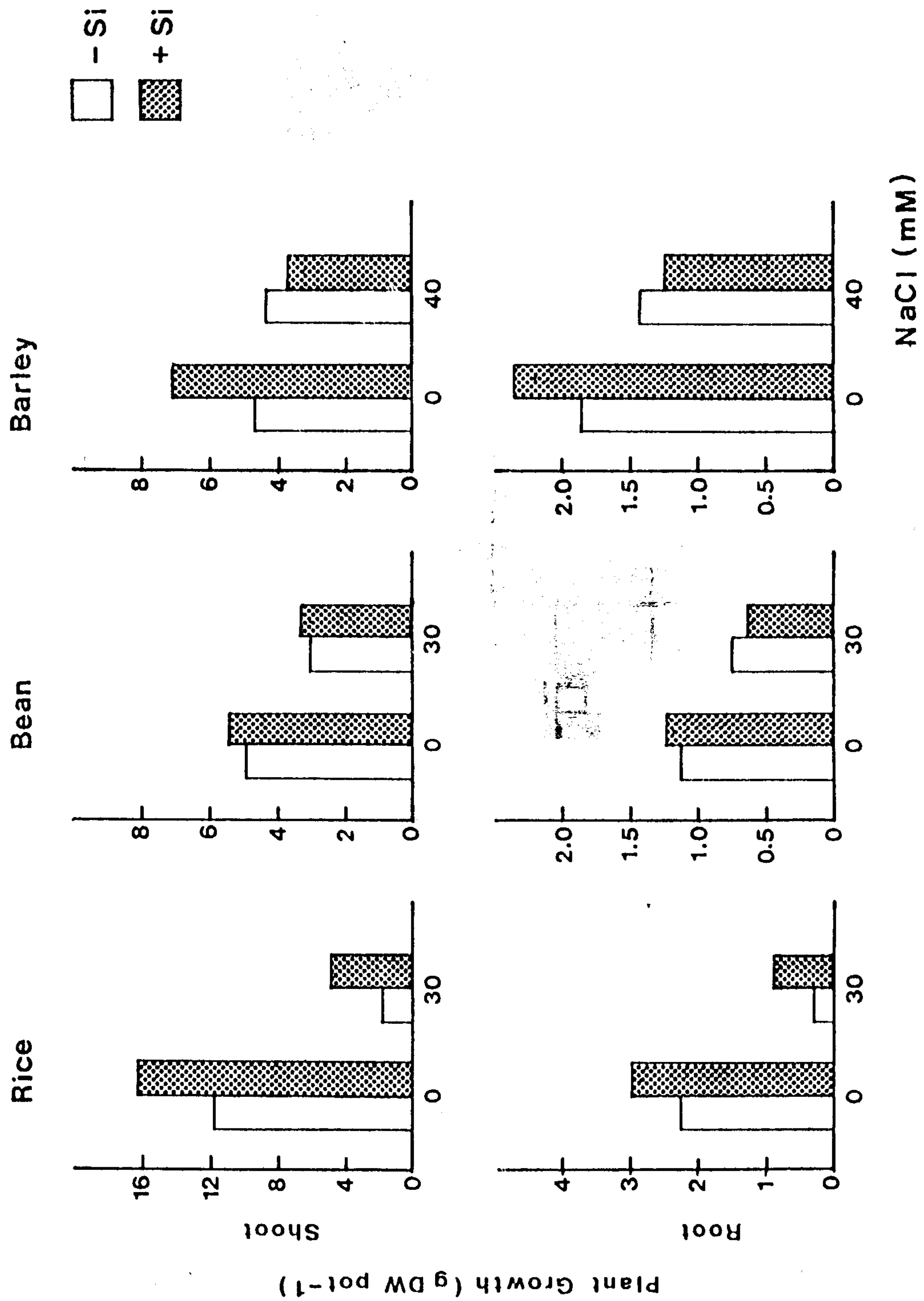

Fig 1. The growth of plants grown in saline conditions in the presence and absence of Si

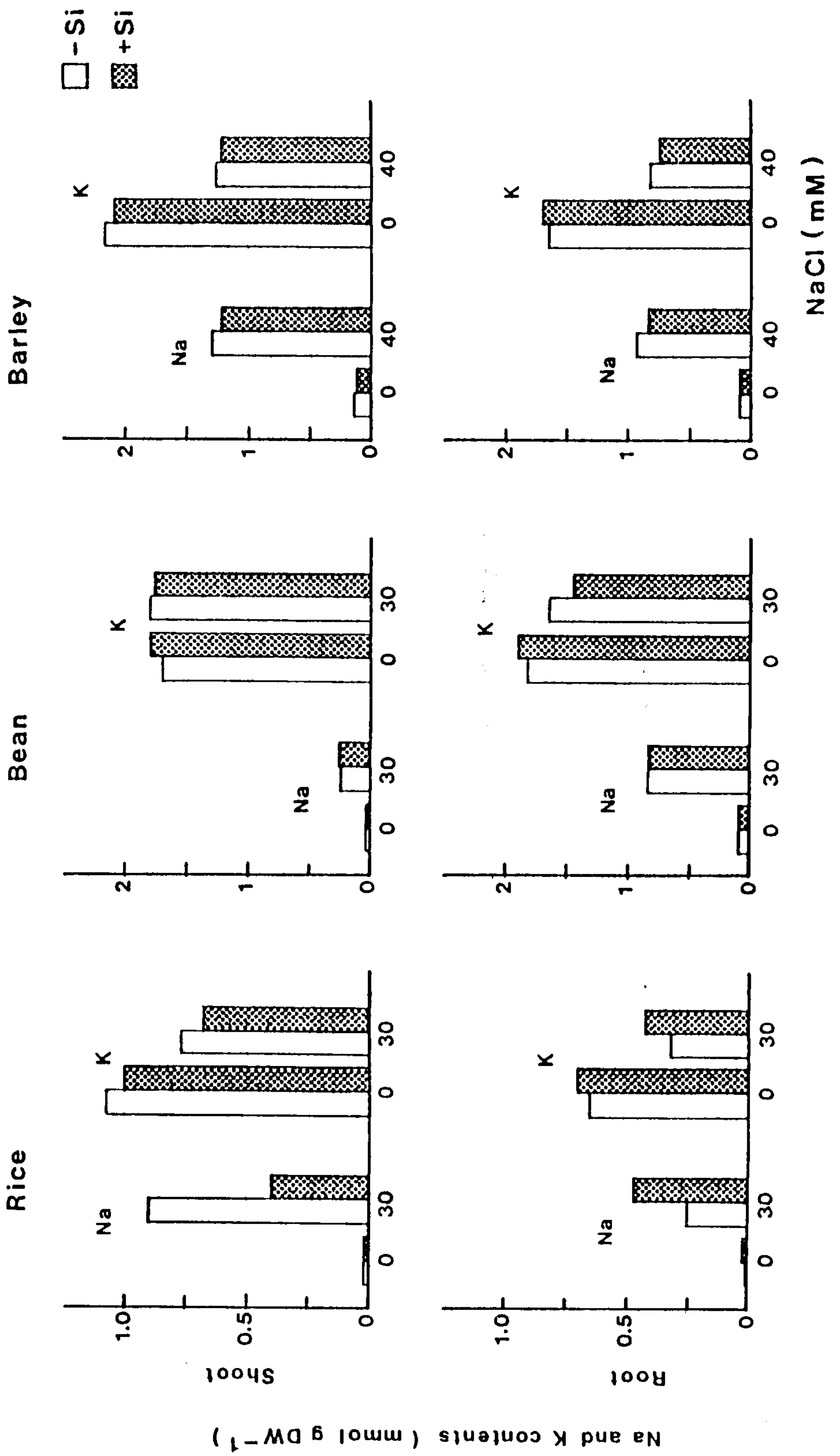

Fig 2. Effects of salinity and Si on the absorption of Na and K in rice, bean and barley plants

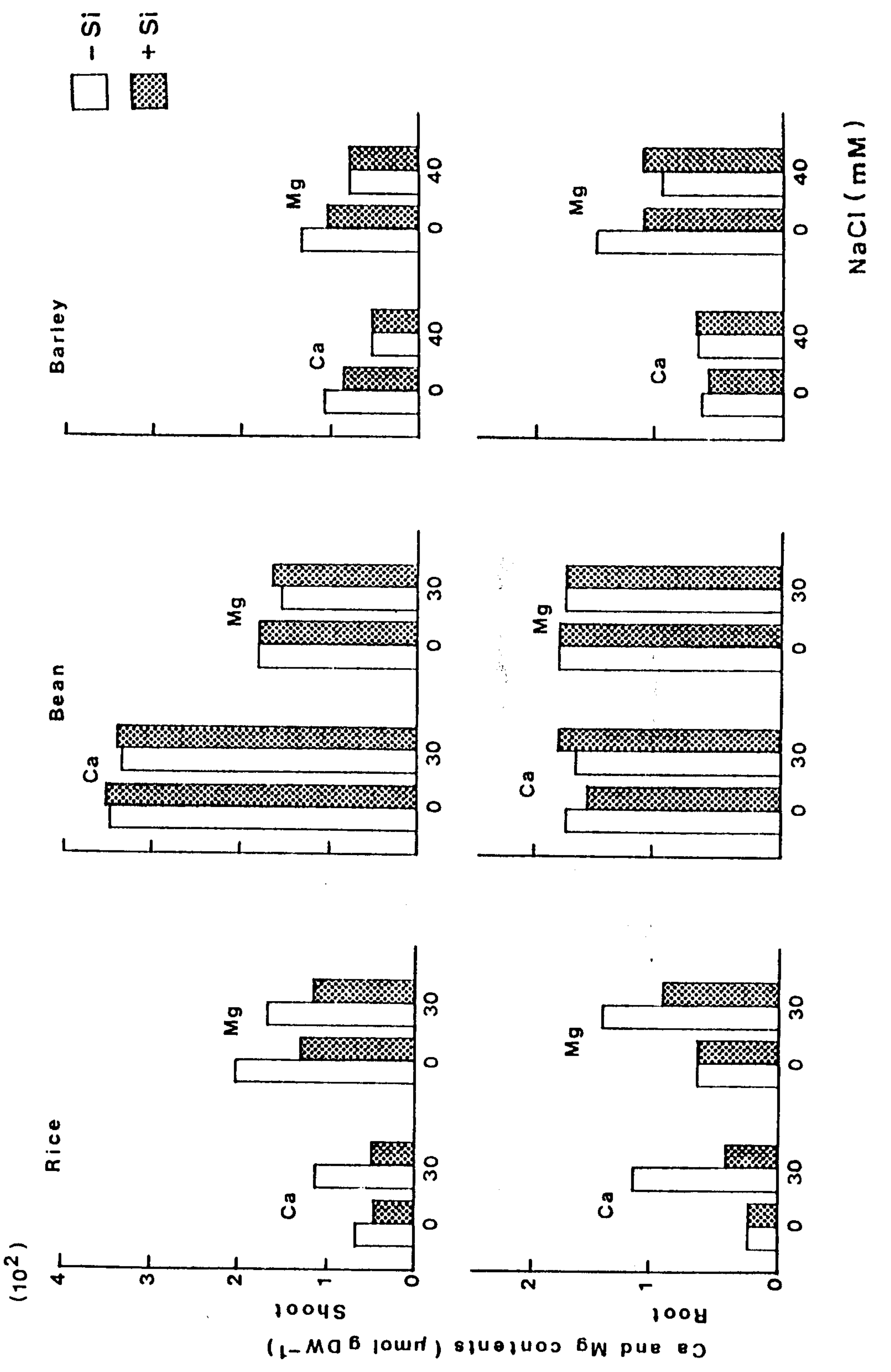

Fig 3. Effects of salinity and Si on the absorption of Ca and Mg in rice, bean and barley plants

DISCUSSION

The results showed that among the plants tested, rice was the most sensitive plant to NaCl stress, as compared with bean and barley. These results put forward the consideration that improvement of breeding strategy in rice plants is a prerequisite, since the cultivation of rice plants in salt-affected marginal lands, especially in Indonesia, is one of the most important programmes.

Application of Si appears to be beneficial for growth of rice and barley cultured in control medium, but not for bean plant. Okuda and Takahashi (1965) and Ayres (1966) suggested that Si is an important mineral element for the growth or rice, barley and sugarcane. The present investigation showed that alleviating effect of Si on growth damage due to high concentrations of NaCl was found only in rice. The same evidence in rice plants was also reported by Matoh *et al.* (1986). Werner and Roth (1983) pointed out that Si application to rice plants has been considered to be somewhat benefical, though the mechanism underlying this effect has not been fully elucidated. Among the most important crop species, rice is the plant which most often be used to study the physiological effects of growth in the absence of added Si (Werner and Roth, 1983). A number of workers showed that removal of Si from the culture solution caused a silicon deficiency in tomato (Miyake and Takahashi, 1978) and cucumber plants (Miyake and Takahashi, 1983). However, there has been no information, as far as known, on the alleviating effect of Si on salt damage in other crops, except rice. Thus, Si is unlike Ca which showed an importance for major crops, especially for glycophytes, ~~in the~~ maintenance of salt tolerance (Sopandie, 1990).

The results obtained in rice plants revealed that Si interfered with the upward sodium transport by reducing the contents of Na in the shoots and retaining it in the roots, though this feature was not observed in other plants. This evidence has also been reported by Matoh *et al.* (1986). In rice plants, however, the mechanism underlying the interference of Si with Na transport from root to shoot is not yet been known. Yoshida (1965) and Matoh *et al.* (1986) suggested that the alleviating effect of Si on salt injury in rice plants resulted from the depression of excessive transpiration. The present study suggests that decreasing the upward Na transport by Si may lessen the toxicity of excess Na in the shoots, thereby leading to the alleviation of growth.

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