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SALT TOLERANCE OF TURF GRASS *Puccinellia distans*: I. GROWTH RESPONSE AND ION ACCUMULATION[1)]

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ABSTRACT

The aim of this study was to see the salt tolerance of turfgrass *Puccinellia distans* in term of ion accumulation and ionic interactions under salt stress condition. Plants were grown hidroponically in culture solution with addition of NaCl (0, 25, 50, 100 and 200 mM).

High concentrations of NaCl brought about growth reduction; the decrease of shoot dry matters was in the range of 30-84% and 30- 70% for root dry matters. Althought the yield of plants decreased so much in the presence of 200 mM NaCl, but plants were able to remain alive without showing any visible symptoms of injury. Much more Na was accumulated in the roots than in the shoots. Exposing plants to salinity results in the decrease of K, Ca and Mg contents.

RINGKASAN

Tujuan dari penelitian ini ialah untuk melihat daya adaptasi tanaman rumput *Puccinellia distans* terhadap cekaman garam ditinjau dari aspek akumulasi ion dan interaksi antar ion. Tanaman ditumbuhkan pada kultur air dengan pemberian NaCl (0, 25, 50, 100 dan 200 mM).

Konsentrasi NaCl yang tinggi menyebabkan penurunan pertumbuhan. Penurunan pada daun (pucuk) berkisar antara 30-84%, sedangkan untuk akar 30-70%. Walaupun terjadi penurunan produksi bahan kering yang tinggi, tanaman mampu bertahan hidup pada 200 mM NaCl tanpa terlihat gejala keracunan NaCl. Unsur Na lebih banyak diakumulasi pada akar dibanding pada daun. Perlakuan stres garam menyebabkan turunnya kadar K, Ca dan Mg pada tanaman.

INTRODUCTION

It has been proposed that for turfgrasses, the most important purpose is not yield of forage, but their survival, density, color and other qualities are important consideration (Lund *et al.*, 1981). *Puccinellia distans*, a halophytic monocotyledon, is known as turfgrass for covering the sides of roads and garden in the areas having high concentration of NaCl. However, there has been little information on salinity tolerance of this halophytic monocotyledon.

Lunt *et al.* (1981) reported that *Puccinellia distans* survived relatively well when the plants were grown in sand cultures with addition of 330 meq of NaCl, as shown by the reduction of growth only 25% as compared to control plants. In their work, NaCl treatments were started when the plants were 4-months old. However, the mechanism of tolerance of this halophytic monocotyledon in the terms of ion accumulation and ionic interactions has not been elucidated.

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The present work investigates the growth response and ion accumulation of plants exposed to high concentrations of NaCl in the culture solution.

MATERIALS AND METHODS

In this investigation, two experiments were conducted using culture solution. These were different in the age at which the plants were exposed to high concentrations of NaCl. For Experiments I, the seeds were germinated on vermiculite for about 5 weeks. The seedlings were then transplanted into 3.5 1 pots containing nutrient solution. One week after transplanting, the plants were initially supplied with 25 mM NaCl, and then the full concentration of NaCl was added 2 weeks later when the plants were 2-months old. In Experiment I, the plants were harvested after 4 week exposure to NaCl. In Experiment II, the older plants (3-month-old) were exposed to high concentrations of NaCl, and were harvested after 4 weeks exposure to NaCl. In both experiments, the treatments of NaCl were started after the plants were well established and growing uniformly. Experiments I was conducted mostly in winter season, and Experiment II in summer.

In both experiments, the same basic nutrient was used. The nutrient solution consisted of KNO_3 4.0 mM, $NaNO_3$ 1.0 mM, NaH_2PO_4 1.0 mM, $MgSO_4$ 1.0 mM, $CaCl_2$ 1.0 mM, Fe 1.0 ppm, B 0.5 ppm. Mn 0.5 ppm. Mn 0.5 ppm, Zn 0.05 ppm, Cu 0.02 ppm, Mo 0.01 ppm. Every other days, Fe citrate was added, and the medium pH was adjusted to 5.0. Throughout experiments, the nutrient solution was aerated continuously, and renewed once a week. The concentrations of NaCl used in Experiments I were 0, 25, 50, 100, 150, and 200 mM, whilst in Experiments II the concentration of 25 mM was omitted.

After a certain period, the plants were harvested, and separated into shoot and root. Each part of plant was blotted dry, weighed, and dried in an oven at 100^{o}C. The dried tissues were ashed at 450^{o}C, and the ashes were dissolved with dilute hydrochloric acid. In this experiments, Na, K, Ca and Mg content in plants were analyzed by atomic absorption spectrophotometry.

RESULT

Growth response

Figure 1 shows the growth response of *P. distans* grown in Experiment I (Fig. IA) and II (Fig. IB) in the presence of various concentrations of NaCl. High concentrations of NaCl reduced remarkably shoots dry weight and slightly the roots growth. The magnitude of growth reduction was principally similar in both plants grown in Experiment I and II. In both experiments, comparison of shoot dry matters of NaCl-treated plants to that of control plants shows about 50% growth reduction in the presence of 100 mM NaCl and about 84% at 200 mM. The plants exposed to NaCl in Experiment II (Fig. 1B) had nearly twice of shoot growth compared to those plants grown in Experiment I (Fig. 1A), thought only about 30% more for root growth. Both experiments showed that although the yield of plants decreased so much in the presence of 200 mM, but plants were able to remain alive at this concentration without showing any visible symptoms of salt injury.

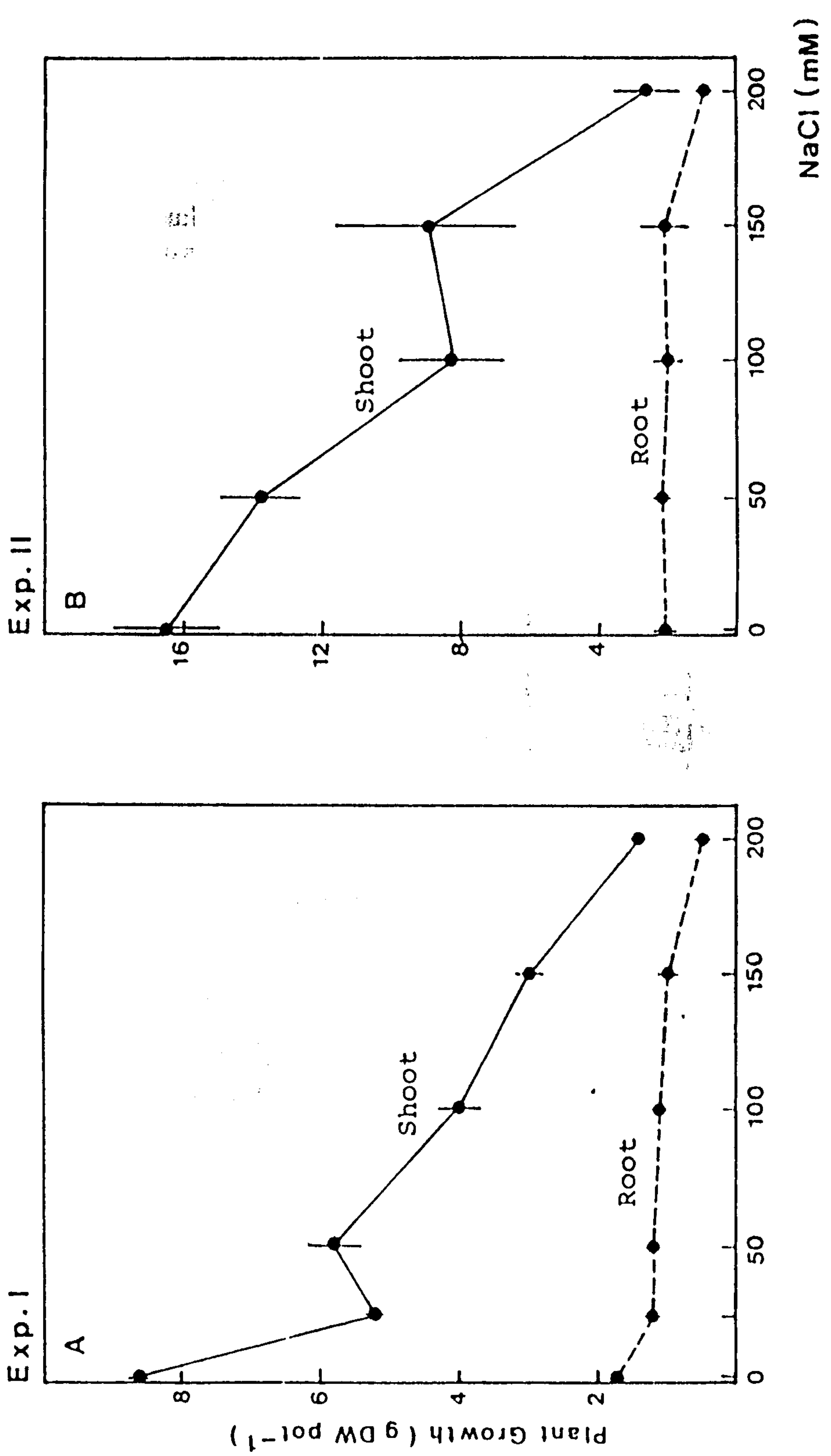

Fig. 1. Growth response of *Puccinellia distans* in different concentrations of NaCl. Bars denote SD.

Sodium content in plants

Figures 2A and B show the content of Na in plants grown in Experiment I and II, respectively. The result in Experiment I revealed that much more Na was accumulated in the root than in the shoot of plants (Fig 2A), though this was not found for the plants grown in Experiment II (Fig. 2B). It is shown that plants grown in Experiment II accumulated Na in the same extent both in the shoot and root at the concentrations of NaCl up to 150 mM, though Na in shoot excessively increased as the concentration of NaCl was increased to 200 mM. Moreover, the plants cultured in summer season (Experiment II, Fig. 2B) accumulated nearly twice of Na amount in the shoots than did those of plants grown in winter (Experiment I, Fig 2A), when they were exposed to high concentrations of NaCl. The roots of both plants, however, accumulated Na in the nearly same extent.

Potassium content in plants

Exposing plants to salinity results in the decrease of K content in both plants (Fig. 2C and D), the decrease of which was more pronounced in the plants grown in Experiment II (Fig. 2D). The accumulation of K in plants grown in Experiments II was lower than that in plants cultured in Experiment I. This lowering in K content in plants grown later was probably due to the greater accumulation of Na, as shown in Fig. 2B. Both plants showed that the content of K in the shoots was higher than in the roots.

Calcium and magnessium contents in plants

Figure 3A and B show the effect of high concentrations of NaCl on Ca content in both plants grown in Experiment I and II, respectively. High concentrations of NaCl decreased Ca content in both plants, and the magnitude of the decreased was similar in both plants. Both plants grown in two experiments showed that more Ca was accumulated in the roots than in shoots.

High concentrations of NaCl decreased the Mg content in plants cultured in both experiments (Fig. 3C and D). A larger decrease of Mg content was observed in the plants cultured in Experiment II (Fig. 3D) as compared to plants grown earlier in Experiment I (Fig. 3C).

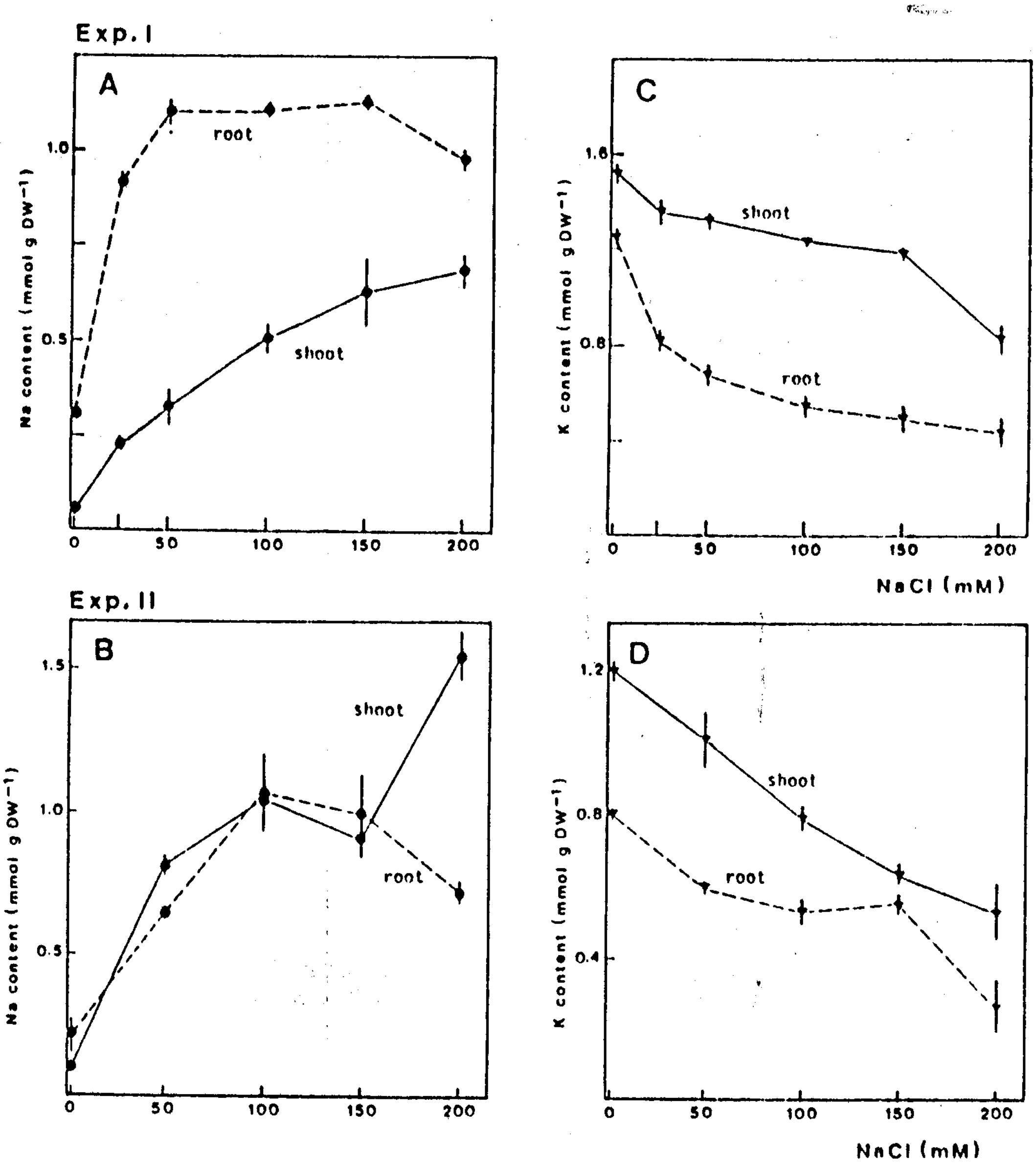

Fig. 2. The contents of Na and K in *Puccinellia distans* grown in different concentrations of NaCl. Bars denote SD.

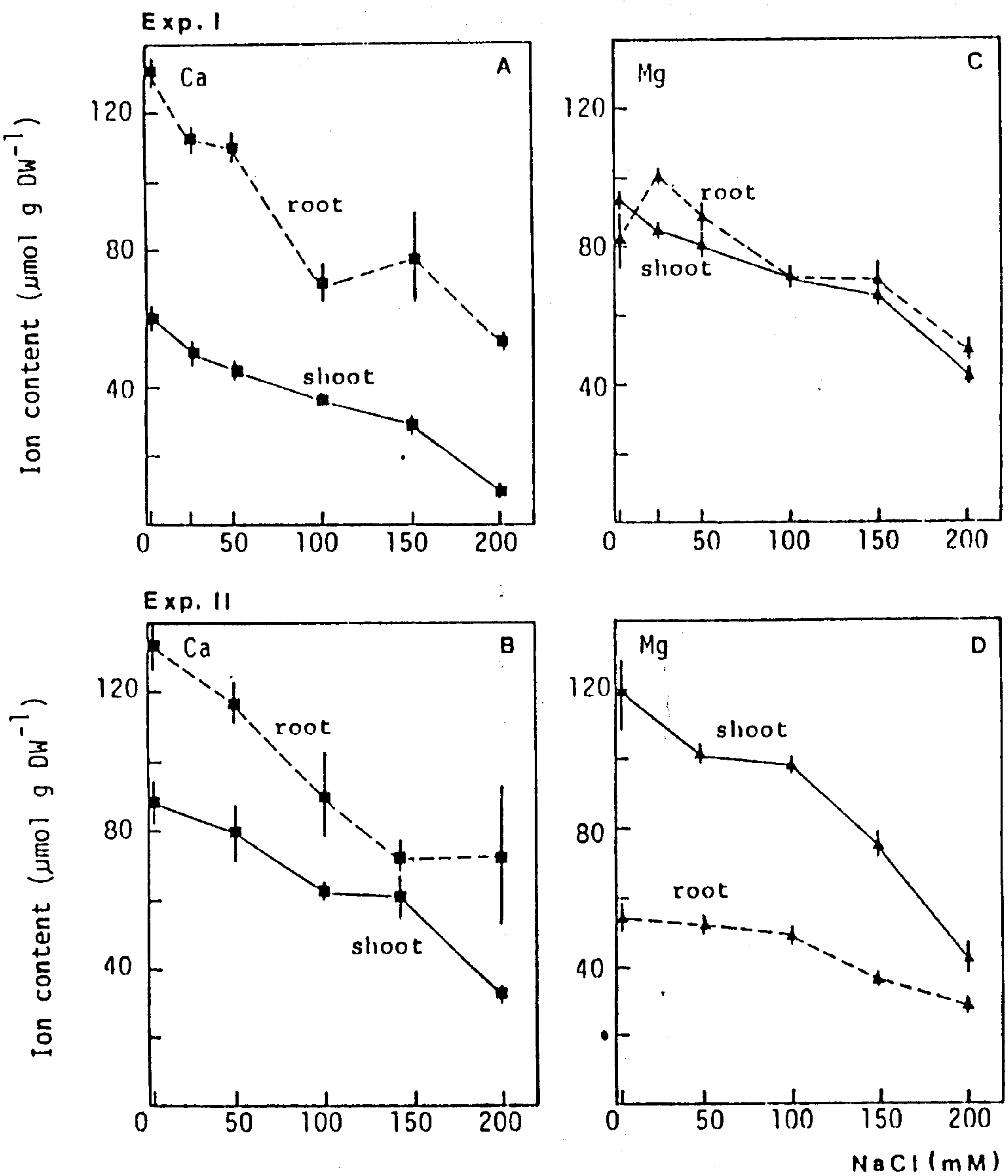

Fig. 3. The contents of Ca and Mg in *Puccinellia distans* grown in different concentrations of NaCl. Bars denote SD.

DISCUSSION

There is evidence that exposing plants to high concentrations of NaCl brought about growth reduction of both plants grown in Experiment I and II. It has been shown that the magnitude of the growth reduction was principally similar (Figs. 1A and B) in plants grown in both experiments. Although the yields decreased under salinity, they were able to survive in 200 mM NaCl without showing any serious injury. Thus, it might be suggested that the survival of these plants is a more important consideration to be used as a turf, rather than the yield of plants.

Greenway and munns (1980) have classified the species of halophytic monocotyledons in the group of plants which are able to survive in 250 mM NaCl, although the yields appear to be reduced. Lunt *et al.* (1981), however, showed that 4-month-old *Puccinellia* plants grown in sand culture could tolerate 330 meq NaCl, with a reduction of growth of only 25% as compared to control plants. In fact, the present results using solution culture showed no significant difference in the tolerance between the 2-month-old plants and those of older ones, in which their yields were considerably reduced by 200 mM NaCl. Thus, it appears that salt tolerance of plants differs very much depending on the condition in which the plants are treated with salinities. Culturing plants in sand culture (Lunt *et al.*, 1981) might bring about a better tolerance of the plants to salt stress compared to those grown in culture solution. Probably, when the plants are grown in solution culture, the roots will be in direct contact with the external medium of NaCl throughout of experiment, leading to more serious injury of plants.

The obtained results revealed that the shoots of younger plants grown in winter season accumulated less Na as compared to the roots (Fig. 2A), though this evidence was not observed in summer (Fig. 2B). It was evidenced that in the more mature plants, Na was found to be taken excessively up by shoots. It is hard to judge, however, if the plants do regulate Na in different way depending on the age, since the temperature difference might highly contribute to the difference of the results. In summer season, the high temperature may bring about the excessive transpiration form the shoots, which can induce a passive transport of Na accumulation in the shoots. Therefore, it appears that this discrepancy in the Na accumulation is closely related to the influence of temperature.

Concerning the salt tolerance and Na regulation in plants, Gorham *et al.* (1985) has proposed that the salt tolerance in salt-tolerance grasses is mainly associated with exclusion of sodium from the shoot. Greenway and Munns (1980), however, pointed out that the major regulation of the ion concentration in the leaves of halophytic monocotyledons is likely to occur during transport to the stele, as evidenced for Na in *Puccinellia peisonis.* Greenway and Munns (1980), moreover, pointed out that classification of these species as "ion-excluders" is misleading, as indicated that the shoots of *Puccinellia peisonis* contain about 200 mM Na and 300 mM Cl in the presence of 100-250 mM NaCl in external medium. They assumed that efficient ion compartmentation in the leaf cells is therefore likely, but there is no definitive information. Thus, it seems to be that the mechanism of Na regulation in these species is still unclear.

High concentrations of NaCl reduced K content in both shoots and roots, and a similar result was also found in barley, spinach, leaf beet, bean and peanut (Sopandie, 1990; Sopandie *et al.*, 1995).

It is likely that in general K content often decreases as salinity is increased, as it was also found in halophytic dicotyledon *Suaeda maritima* (Flowers *et al.*, 1977). The result in Ca and Mg absorption was principally similar with that generally found in glycophyte plants (Sopandie, 1990; Sopandie *et al.*, 1995; Greenway and Munns, 1980; Kawasaki *et al.*, 1978a and 1978b). Judging from the ionic interactions among Na, K, Ca and Mg, therefore, it can be suggested that the pattern of ion accumulation in *Puccinellia distans* was nearly similar with that generally found in glycophyte plants.

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