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Salt Stress Inhibits Germination and Early Seedling Growth in Cabbage (*Brassica oleracea capitata* L.)

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Abstract: Salinity induced inhibition in germination and early stages of cabbage (*Brassica oleracea capitata* L.) [two varieties (autumn cabbage and spring cabbage)] were measured in response to increasing NaCl concentration. The salinity (NaCl) concentrations in solution were 0 (control), 4.7, 9.4 and 14.1 dS m^{-1}. Different concentrations of salt stress had considerable effect on germination, germination rate ($1/t_{50}$, where t_{50} is the time to 50% of germination), root and shoot lengths, root, shoot and plant fresh weight of cabbage. Final germination in cabbage (autumn cabbage and spring cabbage) showed significant inhibition with increasing salt stress up to 14.1 dS m^{-1} NaCl. The required time for germination increased with increasing concentration of salt. The seedling growth was strongly inhibited by all salt levels, particularly at 14.1 dS m^{-1}. Furthermore Root growth was more affected then shoots growth by salt stress. Fresh weights of root, shoot and plant were also severely affected by different salinity treatments. Linear regression revealed a significant negative relationship between salinity and final germination, germination rate, root and shoot lengths and fresh weights of roots, shoots and plants.

Key words: Germination, salinity, seedling growth, relationship, *Brassica oleracea capitata* L.

INTRODUCTION

Soil salinity is one of the most important constraints that limit crop production in arid and semi arid regions (Neumann, 1995). Irrigated land is particularly at risk with approximately one third being significantly affected by salinity. Despite its relatively small area, irrigated land is estimated to produce one third of the world's food (Munns, 2002). The growth of plants is ultimately reduced by salinity stress although plant species differ in their tolerance to salinity (Munns and Termaat, 1986). One approach to reducing the deleterious effects of soil salinity on crop production is the development of salt tolerant cultivars (Epstein *et al.*, 1980). Although some crops are moderately tolerant of saline conditions, many crops are adversely affected by even low levels of salt (Greenway and Munns, 1980). The salt tolerance of crops has generally been expressed as the yield decreased expected for a given level of soluble salts in the root medium as compared with yield under nonsaline conditions (Maas and Hoffman, 1977).

There have been numerous reviews of the effects of salinity on plant physiological processes and subsequent effects on yield (Greenway and Munns, 1980; Munns, 1993; Shannon *et al.*, 1994; Neumann, 1995). In spite of this extensive literature there is still a controversy with regard to the mechanisms of salt tolerance in plants (Neumann, 1995). Salinity impairs seed germination, reduces nodule formation, retards plant development and reduces crop yield (Greenway and Munns, 1980). Salt and water stresses could reduce germination either by limiting water absorption by the seeds (Dodd and Donovan, 1999). Germination in saline seedbeds may be restricted by low soil moisture and osmotic potential or by toxic concentrations of specific ions (Roundy, 1987). Salinity stress can affect seed germination through osmotic effects (Welbaum *et al.*, 1990). Successful seedling establishment depends on the frequency and the amount of precipitation as well as on the ability of the seed species to germinate and grow while soil moisture and osmotic potentials decrease (Roundy, 1985).

The present study was undertaken to evaluate the effect of NaCl salinity tolerance in two varieties of cabbage differing in salt tolerance during seed germination and early seedling growth and also to find the relation between salinity and growth.

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MATERIALS AND METHODS

Seeds of cabbage (*Brassica oleracea capitata* L.) [two varieties (autumn cabbage cv Gaeul baechu and spring cabbage cv Bom baechu)] were obtained from Jeollabuk-do Agricultural and Extension Services, Iksan, Korea, were used in this experiment.

Experiment was established to evaluate the effect of different NaCl concentrations on germination, germination rate ($1/t_{50}$ where t_{50} is the time to 50% of germination), root and shoot lengths, fresh weights of roots, shoots and plants of the seedlings. Plastic Petri dishes (87 mm diameter, 15 mm height) with a tight-fitting lid were used for the experiment. The solution consisted of 0.0 (control), 4.7, 9.4 and 14.1 dS m^{-1}. Ten seeds for each of the four NaCl treatments as well as control were used. Seeds were hand sorted to eliminate broken and small seeds. Seed were allowed to germinate in laboratory condition on filter paper (Whatman No. 2) in Petri dishes soaked with 5 mL of the respective salt concentration. Petri dishes were sealed with parafilm to prevent evaporation of water and minimizing the changes in concentration of the solutions.

Seed germination was evaluated after every 12 h. After 36 h seeds had started to germinate (seeds were considered to be germinated with the emergence of the radical). The germinating seeds were counted at daily intervals. The lengths of roots and shoots of the germinated seeds, which were more than 2 mm in length, were measured and recorded after 20 days of sowing. In all treatments a continuous increase in the number of germinating seeds as well as in the lengths of roots and shoots was observed during the subsequent days of germination.

The experiment was established by using a randomized complete block design with three replications. Analysis of variance was performed using MS-Excel and differences between the means were compared through Least Significant Difference (LSD) test ($p<0.05$) (Li, 1964). Linear regression equations were developed by using Minitab version 14.0 statistical software package.

RESULTS

Germination percentage of cabbage (spring cabbage and autumn cabbage) was strongly inhibited by all salinity treatments. The inhibition being strongest particularly at the higher level of salt treatment compared to control. Highest percentage of germination was observed in autumn cabbage while lowest germination was investigated in spring cabbage (Fig. 1A). The final germination rate of seeds of these plant species under various conditions of salinity was expressed as a $1/t_{50}$ of the germination of seeds of the same population as in

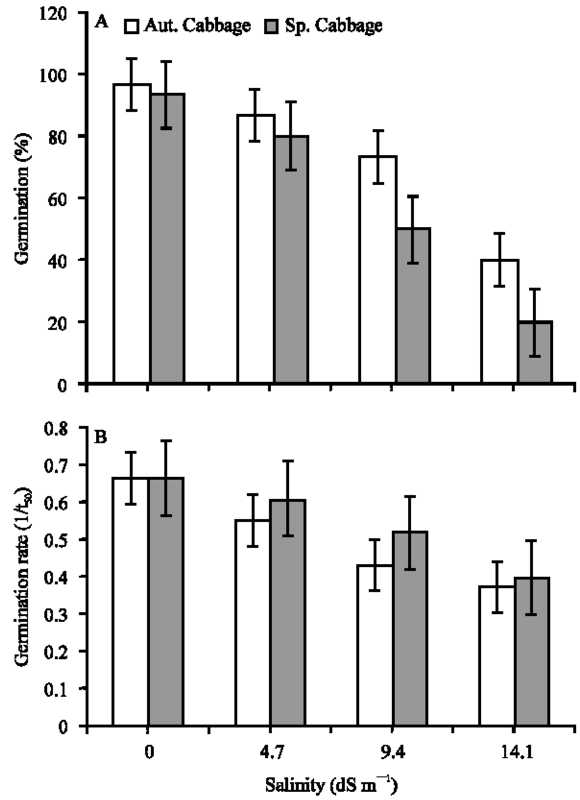

Fig. 1: Effect of different treatments of NaCl stress on germination (A) and germination rate (B) of cabbage (autumn cabbage and spring cabbage)

control. Seed germination delayed as the salinity level increased. The germination response of both varieties under investigation showed marked differences in the timing of initiation and completion of germination. The germination started within 36 h and was complete on the 6th day. Figure 1B showed that autumn cabbage comparatively took more time to complete germination.

Experiment was prolonged to investigate the effect of salinity (NaCl) on seedling vigor of germinating seeds of cabbage (autumn cabbage and spring cabbage). It was investigated that an increased salinity level caused delayed emergence of root and shoot as compared to controls. The increase in length of root and shoot was continuously observed in frequent hours of germination in both cabbage varieties in the control as well as salt treatments. The average length (Fig. 2) of root and shoot of the seedlings of the both cabbage varieties raised in increasing levels of salt solutions shows that both cabbage varieties showed a strong inhibition, but the magnitude of decrease in length was more prominent in root as compared to shoot in all NaCl salt treatments in both. Highest reduction of root and shoot length was in spring cabbage as compared to autumn cabbage (Fig. 2).

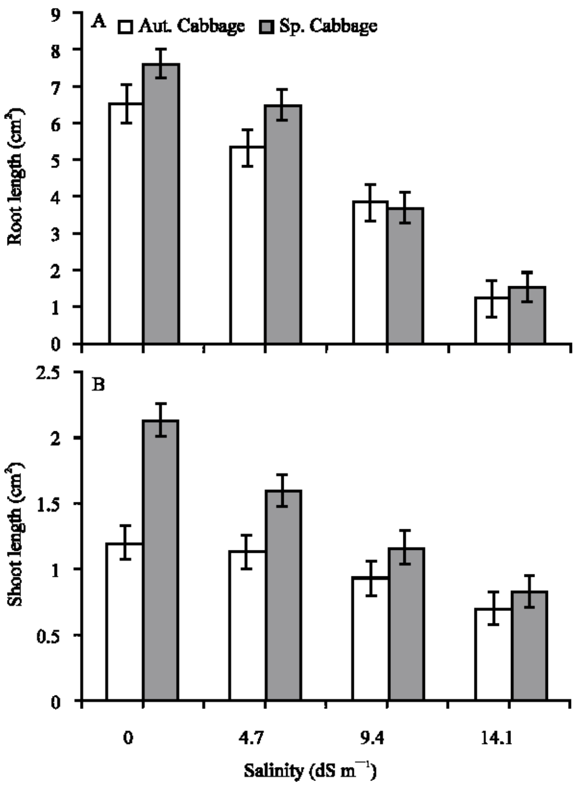

Fig. 2: Effect of different treatments of NaCl stress on root length (A) and shoot length (B) of cabbage (autumn cabbage and spring cabbage)

Increase in salt concentration caused a significant reduction in fresh weights. Result presented in Fig. 3 revealed highly significant differences in cabbage (spring cabbage and autumn cabbage) for root, shoot and plant fresh weight. Figure 3 also shows that fresh weight of root, shoot and plant of cabbage (autumn cabbage and spring cabbage) was strongly affected by all salinity treatments. Root, shoot and plant fresh weight was significantly inhibited in both varieties at all salinity levels (4.7-14.1 dS m^{-1} NaCl), whereas fresh shoot weight was reduced more as compared to fresh root weight. Reduction in fresh shoot weight was more in spring cabbage then autumn cabbage (Fig. 3B). Fresh root weight of autumn cabbage was strongly inhibited by all salt treatments as compared to spring cabbage (Fig. 3B). Maximum reduction in plant weight was investigated in autumn cabbage (Fig. 3C).

Linear regression equations were developed to find the relationship between salinity and final germination, germination rate, root and shoot lengths and fresh weights of roots, shoots and plants (Table 1). Linear regression revealed a significant negative relationship between salinity and final germination, germination rate, root and shoot lengths and fresh weights of roots, shoots and plants. Linear regression also revealed a strong (R^2 = 0.98 p<0.001) negative significant relationship between salinity and germination rate. There was also a weak (R^2 = 0.61 p = 0.02) negative significant relationship between Salinity and shoot length (Table 1).

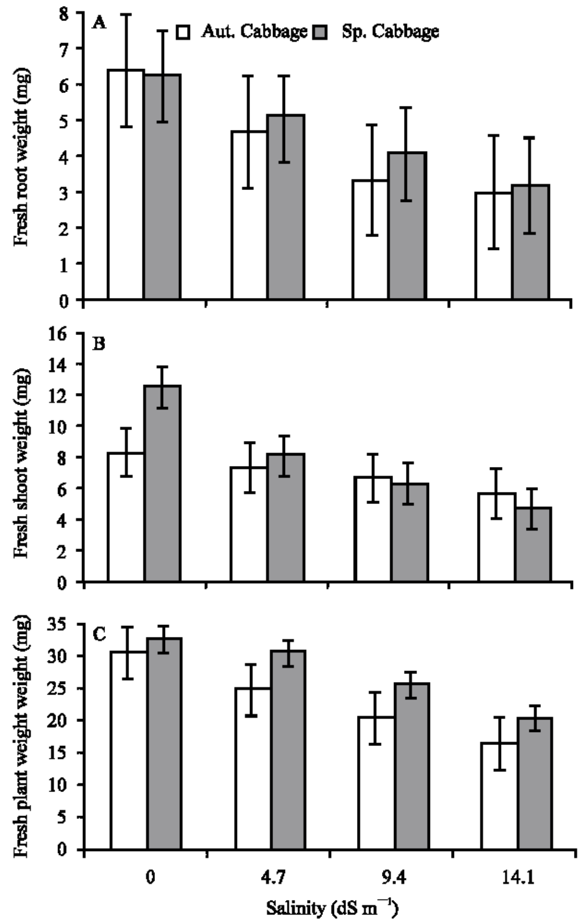

Fig. 3: Effect of different treatments of NaCl stress on fresh weights of roots (A), shoots (B) and plants (C) of cabbage (autumn cabbage and spring cabbage)

Table 1: Relationship between salinity and germination percentage, germination rate, root length, shoot length and fresh weight of plants, shoots and roots.

Parameters	Linear regression equation (Salinity [dS m^{-1}]=)	Regression coefficient (R^2)	Probability
Germination	19.7923-0.18877x‡	0.87	0.001
Germination rate (1/t_{50})	32.2153-48.8383x	0.98	0.000
Root length (cm)	17.5899-2.32927x	0.95	0.000
Shoot length (cm)	18.5802-9.50946x	0.61	0.022
Fresh plant weight (mg)	29.1016-0.87507x	0.83	0.002
Fresh shoot weight (mg)	22.0826-2.01780x	0.73	0.007
Fresh root weight (mg)	25.5682-4.13046x	0.94	0.000

‡ x denotes the parameters in linear equations

DISCUSSION

Seed germination is important growth stage often subject to high mortality rates. Salinity inhibits the germination and germination rate of cabbage (autumn cabbage and spring cabbage) as the salt treatment increased (Fig. 1). It is assumed that in addition to toxic effects of certain ions, higher concentration of salt reduces the water potential in the medium, which hinders water absorption by germinating seeds and thus reduces germination (Maas and Nieman, 1978). Salt-induced inhibition of seed germination could be attributed to osmotic stress or to specific ion toxicity (Huang and Redmann, 1995). These results are similar in line with Francois *et al.* (1984). They found that soil salinity up to 50 mM did not significantly inhibit germination of *Sorghum bicolor* seeds, but salt levels greater than 100 mM delayed germination. Some of the results obtained in this study are similar to those of some other workers who showed that in general, increased salinity results in decrease in germinability and delayed rate of germination (El-Sharkawi and Springuel, 1979). In 1985 Ayers and westcot investigated that salinity delay germination of several species but does not appreciably reduce the final germination percentage.

The root and shoot length are the most important parameters for salt stress because roots are in direct contact with soil and absorb water from soil and shoot supply it to the rest of the plant. For this reason, root and shoot length provides an important clue to the response of plants to salt stress (Jamil and Rha, 2004). Figure 2 showed that lengths of roots and shoots of cabbage (autumn cabbage and spring cabbage) raised in increasing levels of salt solutions showed a strong inhibition. It was also observed that the degree of reduction increased with the increasing concentration of salt. Inhibition of plant growth by salinity may be due to the inhibitory effect of ions. High salinity may inhibit root and shoot elongation due to slowing down the water uptake by seeds (Werner and Finkelstein, 1995) may be another reason for this decrease. Reduction of plant growth under saline conditions is a common phenomenon in plants (Ashraf and Harris, 2004), but such reduction occurs differently in different plant organs. For example in present study, decrease in length of root was more prominent as compared to shoot in all NaCl salt treatments. (Fig. 2). Similar kind of results was earlier reported by Jamil *et al.* (2005). They observed that Salt stress inhibited the growth of shoot more than root in *Brassica* species. Demir and Arif (2003) also obtained similar results. They observed that the root growth of safflower was more adversely affected compared to shoot growth by soil salinity. Our results were also similar with the findings of Hussain and Rehman (1995, 1997). They found that the roots of seedlings were more sensitive than the shoots.

Fresh weights of roots, shoots and plants were significantly inhibited in cabbage (autumn cabbage and spring cabbage) at all salinity levels (Fig. 3). Some researchers could argue that because dry weights were not much affected compared to the fresh weights, growth reduction would be attributable to osmotic effects. Jeannette *et al.* (2002) reported that faster rate of germination allowed the emerging seedlings to accumulate more biomass relative to the control but conversely, total fresh weight of root and shoot of cultivated accessions was significantly reduced with increased salt stress. These results are also similar in line with Shannon and Grieve (2000) indicated that salinity reduced fresh weight of all nine vegetables with increasing salt concentration.

Linear regression revealed a significant negative relationship between salinity and final germination, germination rate, lengths of roots and shoots and fresh weights of roots, shoots and plants (Table 1). A negative relation of salinity on germination has been reported in several studies (Boorman, 1968; Khan and Ungar, 1984; Greenway and Munns, 1980). Salinity reduced total plant biomass by negatively affecting root, stem and leaf mass (Greenway and Munns, 1980; Ashraf and Harris, 2004).

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