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Growth Response of Barley to Calcium under Saline Conditions

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Abstract: Three barley varieties (Jao–83, Jao–85 and As–54) were tested in solution culture for three salinity levels (S_1 = 0–40me l^{-1}, S_2=160-200me l^{-1}, S_3=360-400me l^{-1}) and four Ca concentrations (0, 10, 20, 40me l^{-1}). Maximum number of leaves per hill was recorded at low calcium concentration under normal salinity conditions but at higher salinity levels this parameter increased with increasing $CaCl_2$ levels. Barley variety Jao-83 produced more tillers per hill than Jao-85 and As-54. All the varieties yielded maximum shoots dry weights at less $CaCl_2$ concentration and lower salinity level. However, $CaCl_2$ concentration of 40me l^{-1} proved helpful to mitigate the ill effect of higher salinity level. Similar results were noted in case of length and dry weight of roots. The variety Jao-83 gave maximum root dry weight as well.

Key words: Barley, growth, salinity, calcium concentration Jao varieties

Introduction

The growth of plants under salinity stress is impaired largely. The importance of Ca^{+2} for plant growth and its selective uptake by plants, especially under saline conditions is well documented. Increasing calcium levels in nutrient solutions can protect plants from salt injury presumably by restricting Na^{+} influx and translocation. Kent and Lauchli (1985) found that increased Ca^{+2} levels offset the restricted growth of cotton root caused by NaCl. The K/Na selectivity may be improved by increasing Ca^{+2} concentrations under saline conditions. Low Calcium status may result in blackening and curling of the margins of the apical leaves, ultimately leading to acute chlorosis and the cessation of growth. Poor root development is also commonly associated with calcium deficiency. The Ca^{+} application increased the grain straw ratio in rice markedly whereas dry weights of root and shoot of sesbania increased with increasing Ca and decreased with increasing Na (Krasaesindhu and Sims, 1972). It was observed that uptake of ions by barley at low Ca concentration decreased with increasing NaCl level but the effect was less marked with high Ca (Hussain, 2002). Calcium additions can enhance growth of rice and wheat in saline sodic soils and ultimately the crop yields were increased significantly (Ahmad *et al.*, 2001). The wide Ca/Na also proved less favourable in maize and wheat crops while narrow ratio was conducive for growth (Hussain *et al.*, 2002). Kawasaki and Moritsugu (1978) reported that at low Ca concentration growth of barley was decreased with increasing NaCl but the effect was less marked with high Ca. In rice the level of Ca had little effect on growth depressing at high NaCl. The Na and Mg ions markedly decreased the germination and growth while soluble Ca (as Cl) was comparatively much less harmful. Exchangeable Ca had a favourable effect on the growth of root and shoot. Lime application increased dry matter yield of barley, with better growth obtained in organic and alluvial soil. Similarly calcium containing fertilizer proved better for seedling emergence, total dry matter yield and grain yield of wheat under saline-sodic condition. Ilyas (1984) concluded that application of calcium in the form of $CaSO_4$, Ca $(NO_3)_2$ or $CaCl_2$ in a natural saline-sodic field positively affected tillers, total dry matter and grain yield.
The soil salinity is one of the greatest problems of agriculture and its impact on economy of Pakistan is significant because arable acreage in the Indus plain has cut short, which results in an annual loss of Rs. 14,000 millions (Qayyum and Malik, 1985). Keeping in view the above facts, it was planned to study the interaction of Ca^{+2} and Na^{+} ions in barley growth under saline conditions.

Materials and Methods

Seeds of three barley varieties; Jao-83, Jao-85 and As-54 were sown in plastic-lined iron trays containing silica gravel. Six days old, 24 seedlings of each variety were transplanted in plastic containers covered with thermopile sheets to hold two plants in one hole. Tubs were filled with full strength Hoagland's solution (1950) prepared in distilled water. The nutrient solution was gently aerated by air compressor. After four days of transplantation, three salinity levels of calcium concentrations were created in the tubs. Detail of treatments is presented below (Table 1).

Table 1: Treatments of the experiment

Treatments	NaCl conc. (me l^{-1})	$CaCl_2$ conc. (me l^{-1})
T_1	0	0
T_2	10	10
T_3	20	20
T_4	40	40
T_5	200	0
T_6	190	10
T_7	180	20
T_8	160	40
T_9	400	0
T_{10}	390	10
T_{11}	380	20
T_{12}	360	40

Salinity was developed using reagent grade NaCl at the rate of 50 me l^{-1} per day for 4 days and 100me l^{-1} every day for next 2 days while calcium was applied as $CaCl_2$. $6H_2O$ at the rate of 10 me l^{-1} per day simultaneously. During growth period, EC of the solution was maintained according to the treatments using respective salts and distilled water, while pH of all the tubs was maintained between 6.0-6.5 by HCl or NaOH. Seedlings were harvested after 45 days of the transplantation and different growth parameters (tillering, plant height, number of leaves, shoot weight, root length and root weight) were recorded. The respective data were processed statistically through analysis of variance technique (Steel and Torrie, 1980).

Results and Discussion

Plant height: The data indicated that increasing salinity decreased plant height of barley significantly (Table 3). This indicated that salinity suppresses the plant growth, the causes of which may be osmotic effects, imbalanced nutrition or the indirect impact through soil changes. Many research workers concluded from their experiments that plant height decreased significantly with the increase in external salinity (Ahmad *et al.*, 1987 and Randhawa, 1981). The differences in plant height due to different calcium concentrations and varieties were found statistically non-significant statistically (Table 3).
In salinity control, maximum plant height (76.04 cm) was recorded with T_2 which was at par with T_3 (74.19) and T_4 (73.47cm) followed by T_1 (68.23cm). The salinity level of 200me l^{-1} caused maximum plant height in T_8 (49.82cm) which was greater than all other calcium levels at the comparable salinity. This was followed by T_7 (49.12cm), T_6 (48.64cm) and T_5 (46.66cm). At the highest salinity level of 400me l^{-1}, maximum plant height was recorded in T_{12} which decreased gradually with decreasing levels of calcium

Table 2: Effect of various combinations of calcium and sodium on shoot growth parameters of barley

Treatments	Plant height (cm)	Number of leaves ($hill^{-1}$)	Number of tillers ($hill^{-1}$)	Shoot fresh weight (g $hill^{-1}$)	Shoot dry weight (g $hill^{-1}$)
T_1	68.23 b	31.77 a	6.77 a	17.54 a	2.08 a
T_2	76.04 a	27.80 b	6.30 a	15.63 b	2.00 b
T_3	74.19 ab	26.20 c	6.02 a	14.22 c	1.90 c
T_4	73.47 ab	23.87 d	5.66 a	13.63 d	1.87 d
T_5	46.66 c	11.37 h	2.28 c	5.43 g	1.10 h
T_6	48.64 c	13.41 g	3.53 b	5.53 fg	1.35 g
T_7	49.12 c	14.27 f	3.67 b	5.64 f	1.57 f
T_8	49.82 c	15.10 c	4.04 b	5.79 e	1.68 e
T_9	31.21 d	8.94 l	-	1.71 j	0.33 j
T_{10}	31.50 d	10.13 k	-	1.80 ij	0.38 l
T_{11}	31.96 d	10.56 j	-	1.88 hi	0.40 l
T_{12}	32.23 d	11.07 l	-	1.97 h	0.41 l

Values are means of magnitudes for three barley varieties; See Table 1 for T_1-T_{12}; Different letters indicate significant difference at 5 %.

Table 3: Shoot growth parameters of barley varieties under salinity stress and presence of calcium.

Treatments	Plant height (cm)	Number of leaves ($hill^{-1}$)	Number of tillers ($hill^{-1}$)	Shoot fresh weight (g $hill^{-1}$)	Shoot dry weight (g $hill^{-1}$)
C_1 = 0me l^{-1}	48.70 ns	17.36 a	4.53 ns	8.23 a	1.17 b
C_2 = 10me l^{-1}	52.06	17.11 b	4.91	7.66 b	1.24 b
C_3 = 20me l^{-1}	51.75	17.01 b	4.85	7.25 c	1.29 a
C_4 = 40me l^{-1}	51.84	16.68 c	4.85	7.14 d	1.30 a
S_1 = 0-40 me l^{-1}	72.98 a	27.41 a	6.19 a	15.27 a	1.95 a
S_2 = 160-200me l^{-1}	48.56 b	13.54 b	3.38 b	5.60 b	1.42 b
S_3 = 360-400me l^{-1}	31.73 c	10.18 c	-	1.84 c	0.38 c
Jao-83	51.69 ns	20.44 a	5.87 a	8.46 a	1.45 a
Jao-85	51.69	16.51 b	4.64 b	7.36 b	1.22 b
As-54	49.88	14.16 c	3.83 c	6.89 c	1.08 c

Values sharing the same letters are not significant at 5% level of significance. ns = non significant

Table 4: Calcium and sodium interaction in root growth parameters of barley

Treatments	Root length (cm)	Root fresh weight (g $hill^{-1}$)	Root dry weight (g $hill^{-1}$)
T_1	28.62 a	5.43 a	0.33 a
T_2	28.44 a	5.12 b	0.32 b
T_3	28.01 b	4.81 c	0.32 c
T_4	27.30 c	4.00 d	0.30 d
T_5	20.22 g	1.97 h	0.18 h
T_6	20.83 g	2.06 g	0.22 g
T_7	21.23 c	2.16 f	0.24 f
T_8	21.70 d	2.24 e	0.25 e
T_9	9.07 d	0.78 j	0.09 l
T_{10}	9.37 l	0.84 l	0.10 k
T_{11}	9.56 hi	0.88 l	0.12 j
T_{12}	9.79 h	0.89 l	0.13 l

Values are means of magnitudes for three barley varieties.
Values with similar letters do not differ significantly at 5%.
See Table 1 for T_1-T_{12}

Table 5: Root growth parameters of barley varieties under salinity stress and presence of calcium.

Treatments	Root length (cm)	Root fresh weight (g $hill^{-1}$)	Root dry weight (g $hill^{-1}$)
C_1 = 0me l^{-1}	19.30 b	2.73 a	0.20 d
C_2 = 10me l^{-1}	19.55 a	2.67 b	0.21 c
C_3 = 20me l^{-1}	19.60 a	2.61 c	0.22 b
C_4 = 40me l^{-1}	19.60 a	2.38 d	0.23 a
S_1 = 0-40me l^{-1}	29.09 a	4.84 a	0.31 a
S_2 = 200me l^{-1}	21.00 b	2.11 b	0.22 b
S_3 = 400me l^{-1}	9.44 c	0.85 c	0.11 c
Jao-83	20.97 a	3.12 a	0.24 a
Jao-85	19.31 b	2.19 b	0.22 b
As-54	18.26 c	2.18 c	0.18 c

Values with similar letters do not differ significantly at 5%.

concentration (Table 2). Calcium has been reported to have a definite impact on seedling establishment in a saline environment because cell elongation and maintenance of a balanced nutrient ion uptake are two processes of great importance under such conditions, both of which require calcium (Kent and Lauchli, 1985). Similarly Kawasaki and Moritsugu (1978) and Ward *et al.* (1986) also reported that calcium reduced markedly the effect of NaCl on seedling growth under saline conditions.

Number of leaves: Data on number of leaves (Table 3) revealed that number of barley leaves decreased as the salinity in the root medium increased. Number of leaves per hill was found maximum at C_1 (the lowest calcium level) which significantly decreased at higher levels of added calcium chloride; C_2, C_3 and C_4 respectively. At minimum salinity level (C_1) maximum number of leaves per hill was recorded in T_1 (31.77 leaves per hill) closely followed by 27.80, 26.20 and 23.87 leaves per hill in T_2, T_3 and T_4 respectively. But at higher salinity level of 200me l^{-1} maximum leaves per hill was recorded in T_8 (15.10) followed by T_7 (14.27), T_6 (13.41) and T_5 (11.37). Similarly with the highest salinity level of 400me l^{-1}, maximum leaves per hill was recorded in T_{12} (11.07) which were significantly greater than all other calcium levels at the comparable salinity (Table 2). Similar results were also noted by Kawasaki and Moritsugu (1978). It may be concluded that the restricted uptake of water and nutrients by barley plants was translated into less number of leaves.

Tillering Capacity: The number of tillers per hill decreased significantly as salinity in the root medium increased (Table 3). Different levels of $CaCl_2$ application resulted in non-significant differences in number of tillers per hill. The average number of tillers per hill of Jao-83 (5.87) was significantly higher than those of Jao-85 (4.64) and As-54 (3.83). Thus, tillering capacity of barley varieties was variable under different levels of salinity. In some of the plants like rice enhanced tillering is used as salt tolerant mechanism but perhaps in barley this may not work.

Fresh weight of shoot: The data (Table 3) revealed that with progressive increase in the level of salinity, shoot fresh weight decreased significantly. Only 1.84g $hill^{-1}$ of fresh weight was recorded in the highest salinity level (S_3) as against 15.27g $hill^{-1}$ in the lowest level (S_1). On the average, shoot fresh weight was found as maximum at minimum level of calcium (C_1) and significantly decreased at C_2, C_3 and C_4. Maximum shoot fresh weight was found in Jao-83 followed by Jao-85 and As-54. This showed that Jao-83 was more salt tolerant than Jao-85 and As-54.

At salinity control, maximum shoot fresh weight was recorded in T_1 (17.54g hill^{-1}) where no salt (either NaCl or $CaCl_2$) was added. At higher salinity, however the differences in shoot fresh weight become apparent. At salinity level of 200me l^{-1} maximum shoot fresh weight was recorded in T_8 which was significantly greater than all other calcium levels at the comparable salinity. Similarly, at the highest salinity level of 400me l^{-1} maximum shoot fresh weight was recorded in T_{12} which was at par with T_{11} and T_{10} followed by T_9 where no calcium was added (Table 2). Beneficial effect of calcium under saline conditions has also been reported by Hussain *et al.* (2001). It may be argued that calcium at the moderate level is useful to offset the harmful effects of salinity.

Shoot dry weight: The data (Table 3) reveal that shoot dry weight decreased with the increase in salt concentration in the external solution around the roots. These results are in agreement with Muhammad and Ata (1983). However, shoot dry weight increased with increase in the level of $CaCl_2$ concentration in the solution. The three barley varieties gave the significant differences in the magnitudes of this parameter. It was observed that (Table 2) at salinity control, maximum shoot dry weight was produced by T_1, which was significantly decreased in T_2, T_3 and T_4. But at higher salinity level of 200me l^{-1}, maximum shoot dry weight was recorded in T_8. This value was greater than all other calcium levels at the comparable salinity. Similarly, at the highest salinity level of 400me l^{-1} maximum shoot dry weight was recorded in T_{12} which was statistically at par with T_{11} and T_{10} but significantly greater than T_9 where no calcium was added. The results are in line with those of Alam (1984), Ali (1984) and Ilyas (1984). Barley variety Jao-83 proved the most salt tolerant followed by Jao-85 and As-54 in the descending order. It may be inferred that salinity decreased the dry matter yield of barley crop through a significant decrement in number of leaves and plant height whereas calcium addition could mitigate these effects up to some extent.

Root length: It was observed that (Table 5) root length decreased with increase in salinity. On the average, length of root increased with increase in each level of $CaCl_2$ application. At salinity control (Table 4), maximum root length was recorded in T_1 which was at par with T_2 and decreased significantly in T_3 and T_4. At higher salinity (200me l^{-1}), however, the differences in root length due to calcium chloride application become more apparent and maximum root length was recorded in T_8 which was significantly higher than all other calcium levels at the comparable salinity. At the highest salinity level (400me l^{-1}) maximum root length was recorded in T_{12} which was at par with T_{11} and significantly greater than all other calcium level at the corresponding salinity. The data clearly showed that calcium chloride applications had a beneficial effect on length of root at the higher salinity levels. Kent and Lauchli (1985) also reported improvement in root growth at higher salinity levels by the addition of calcium. The osmotic effects of salts and the resulting nutrients imbalance would have appeared as depressed root elongation.

Fresh weight of root: The data presented in (Table 4) revealed that root fresh weight decreased with the increase in salinity, after 45 days of salination. The decreased root growth as discussed in the earlier section may have caused a significant cut in fresh weight of root. The barley variety Jao-83 had significantly more root fresh weight followed by Jao-85 and AS-54. At control salinity level (Table 4) maximum root fresh weight per hill was recorded in T_1 which significantly decreased in T_2, T_3 and T_4 respectively. But at higher salinity of 200me l^{-1}, maximum root fresh weight was recorded in T_8 which was significantly greater than all other calcium level at the comparable salinity. Similarly, at the highest salinity level of 400me l^{-1}, maximum root fresh weight was recorded in T_{12} which was at par with T_{11} and T_{10}, followed by T_9 where no calcium chloride was added. It means that Ca is helpful to offset the ill effects of salinity. Kawasaki and Moritsugu (1978) also observed favourable effect of Ca on the growth of root.

Dry weight of root: The data (Table 5) showed that root dry weight decreased significantly with the Increase in external salinity. Randhawa (1981) also reported that dry matter yield decreased with increasing salinity level. On the overage, maximum root dry weight was recorded at C_4, which was significantly decreased with the decrease in calcium chloride concentration in C_3, C_2 and C_1 respectively. Maximum root dry weight was recorded in Jao-83 followed by Jao-85 and As-54. The data (Table 4) showed that at higher salinity level of 200me l^{-1}, maximum root dry weight was recorded in T_8 which significantly decreased with the decrease in calcium chloride concentration at T_7, T_6 and T_5 respectively. Similarly, at the highest salinity level of 400me l^{-1}, maximum root dry weight was recorded in T_{12} followed by T_{11}, T_{10} and T_9. Ward *et al.* (1986) reported improvement in root growth and increase in dry matter yield with the addition of calcium under saline condition. The dry weight of roots followed the same pattern as observed in case of fresh weight. Therefore, the similar reasons hold good here.

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