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Chemical Composition of Barley Grown in Presence of Sodium and Calcium Salts

Nazir Hussain, Zahid Saeed, [1]M. Tahir, Abdul Bari, N. M. Hassan and Afzal Ahmad
Soil Salinity Research Institute, Pindi Bhattian, (Punjab) Pakistan, [1]UNDP/AusAID/IWASRI,
PCD Project, Site Pindi Bhattian, Pakistan

Abstract: A solution culture experiment was carried out to study the effect of calcium on the concentration of Na^+, K^+, Ca^{+2} and Cl^{-1} ions in barley under saline conditions. Barley varieties Jao-83, Jao-85 and AS-54 were germinated. Three levels of salinity; control (0-40 me l^{-1} = S_1), 200 me l^{-1} (S_2) and 400 me l^{-1} (S_3) were created by using NaCl. In addition, $CaCl_2$ was also added at the rate of 0, 10, 20 and 40 me l^{-1} to all the salinity levels replacing equivalent amounts of NaCl. Seedlings were uprooted after 45 days of salination; root and shoots were cut separately and analyzed. Increase in each level of external salinity caused an increase in sodium and chloride concentration in barley shoot and root, while the concentration of potassium and calcium decreased with progressive increase in the substrate salinity. Addition of calcium at all salinity levels decreased sodium concentration but increased chloride, potassium and calcium concentration both in root and shoot. The variety Jao-83 contained lesser concentration of sodium and chloride and more of calcium and potassium as compared to Jao-85 and AS-54.

Key words: Salinity, calcium application, barley and chemical composition

Introduction

Excessive amount of salts augments the osmotic pressure of the soil solution resulting in reduced uptake of water and nutrients by plants. Solubility product constant of calcium carbonate ($CaCO_3$) and calcium sulphate ($CaSO_4$) is easily achieved under the saline conditions which are further exaggerated under the prevailing agro-climatic conditions of arid lands like that of Pakistan. Resultantly, precipitation of calcium salts occurs and the process results in the knocking out of calcium from the solution phase, which ultimately poses deficiency of calcium in plants.

Calcium ions play a crucial, rather indispensable, role in the plant cellular processes of ion absorption and retention. Its presence in the solution around root tissues represents the normal physiological condition and is essential for the integrity of selective ion transport mechanism (Epstein *et al.*, 1962). Sodium is the predominant soluble cation in saline sodic and sodic soils while K^+ is the only alkali metal known to be universally essential for all higher plants. High Na^+ in the soil solution inhibits the K^+ uptake. In the presence of Ca^+, Na^+ interferes slightly with K^+ absorption at low Na^+ concentrations (1-2 mM), but at progressively higher concentrations of Na^+ there is little or no further inhibition of K^+ absorption. In the presence of Ca^{+2}, K^+ inhibits absorption of Na^+ at low K^+ concentrations but as the K^+ concentrations are raised, inhibition of Na^+ absorption per added increment of K^+ becomes very slight (Epstein, 1961). Jacobson *et al.* (1960) observed that the effect of Ca^{+2} in absorption of monovalent cations was related to pH and specific monovalent cations. Above pH 6.5, Ca^{+2} exerted a depressing effect on K absorption. Hassan *et al.* (2001) also recorded the benefits of the presence of calcium ion on rice in salt affected soil. Similar results were noticed by Hussain *et al.* (2001). The effect was more prominent at higher pH values. At pH 11.0, the absorption was reduced by 60% when Ca^{+2} was present. Poonia and Jhorar (1974) concluded that as the concentration of Ca^{+2} increased, sodium content deceased in plants. Ilyas (1984) observed that application of calcium caused a reduction in sodium content in leaves and grains of wheat.

This experiment was conducted to investigate the probable effects of salinity on chemical composition of barley. The usefulness of the presence of calcium ion in the growth medium to mitigate these effects was also studied so that calcium application under such circumstances may be justified.

Materials and Methods

This experiment was conducted in nutrient culture solution. Seed of three barley varieties: Jao-83 (V_1), Jao-85 (V_2) and AS-54 (V_3) were sown in plastic lined iron trays containing silica gravel. Distilled water was used for irrigation of seeds/seedlings. Six days old, 24 seedlings of each variety were transplanted in plastic tubs covered with thermopol sheet to hold the two plants in a hole. Tubes were filled with full strength Hoagland's solution (Hoagland and Arnon, 1950) prepared in distilled water. Air compressor was used to aerate gently the nutrient solution in order to meet the air requirements of the growing seedlings. After four days of transplantation on the establishment of seedling in the plastic tubs, three salinity levels (S1 =0-40, S2 = 200 and S3 =400 me l^{-1}) and four calcium levels (C1 = 10, C2 = 20, C3 = 30 & C4 = 40 mel^{-1}) were raised by addition of calcium chloride or sodium chloride per treatments (Table 1).

Table 1: Detail of treatments

Treatment No.	NaCl conc. (mel^{-1})	$NaCl_2$ conc. (mel^{-1})
T_1	0	0
T_2	0	10
T_3	0	20
T_4	0	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 analar grade NaCl while calcium was applied as $CaCl_2$. $6H_2O$. During the growth period, EC (Electrical conductivity) 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 using HCl or NaOH. Seedlings were harvested after 45 days of the transplanting uprooted, washed, dried and analyzed for Na, Ca, K and Cl. All the data were expressed on the basis of dry matter. The respective data were processed statistically (Steel and Torrie, 1980).

Results and Discussion

Sodium concentration: Data indicated that mean sodium concentration of shoot significantly increased with increasing levels of salinity (Table 2). The numerical value at the highest level of salinity was too high as compared with the initial one. Barley variety AS-54 contained significantly higher sodium concentration in shoot (56.25 $me100g^{-1}$) than the other two; Jao-85 (47.52 $me100g^{-1}$) and Joa-83 (45.29 $me100g^{-1}$). Hence, there was a better control for Na uptake in barley variety Jao-83. Increasing concentration of $CaCl_2$ in the external solution decreased sodium concentration of the shoot in a linear manner. The observed trend was mainly due to the fact that at higher salinity levels, the absolute concentration of sodium in the external solution was lower in the treatments where calcium was also added. Nevertheless, even at the lowest salinity levels where external sodium concentration was constant, addition of calcium in growth medium significantly reduced sodium concentration in shoots. In general, sodium concentration in the shoot was highly dependent on the absolute level of sodium in the external solution.

The maximum sodium concentration (82.89 me $100g^{-1}$) in shoot was recorded at maximum salinity (400 mel^{-1}) and it was significantly higher than all other treatment (Table 3). Supplementation of Ca^{+2}(10, 20 and 40 mel^{-1}) depressed the Na concentration at both the salinity levels of 200 and 400 $me1^{-1}$ and the created differences were significant. The minimum sodium concentration (10.01 me $100g^{-1}$) was recorded in T_4 where calcium chloride alone was added @40 mel^{-1}.

Exactly similar trend was observed for root concentration of Na (Table 4 & 5) in respect of salinity levels, presence of calcium in the external medium as well as difference among the varieties. The maximum sodium concentration (97.46 me $100g^{-1}$) in root was observed at T_9 (400 mel^{-1} NaCl alone) while minimum was recorded for T_4 (40 mel^{-1} $CaCl_2$). On the average (Table 4) maximum sodium concentration (96.39 me $100g^{-1}$) in root was recorded at S_3 that was significantly higher than the concentration at S_2(60.84 me $100g^{-1}$) and S_1 (15.09 me $100g^{-1}$). Mean sodium concentration at different levels of calcium application decreased significantly with increasing levels of calcium chloride. Behavior of different varieties was the same as for Na concentration in shoot. Kent and Lauchli (1985) also reported the beneficial effect of high calcium concentrations on root growth in a saline environment that might be due to maintenance of K/Na selectivity and adequate calcium status in the roots.

Potassium concentration: On average basis of salinity (Table 2), maximum potassium concentration (30.85 me $100g^{-1}$) in shoot was recorded at S_1, which significantly decreased at S_2 and S_3 consecutively. Comparatively less content of potassium in shoot at increasing levels of salinity may be due to more concentration of sodium in the solution and competition between potassium and sodium. Muhammad and Ata (1983) reported that K concentration decreased with the increasing level of salinity. Variety Jao-83 contained significantly higher potassium concentration (21.72 me $100g^{-1}$) in shoot as compared to Jao-85 (19.46 me $100g^{-1}$). Joshi *et al*. (1985) reported significantly higher concentration of potassium in the shoot of tolerant variety as compared to the sensitive one. Basing upon these data it may be argued that Jao-83 is better tolerant to salinity compared with Jao-85 and As-54. The maximum shoot potassium concentration (22.35 me $100g^{-1}$) was recorded at C_4 where calcium was applied @ 40 mel^{-1} $CaCl_2$ and the minimum (18.00 me $100g^{-1}$) at C_1. So, presence of Ca^{+2} is helpful in K^+ uptake. Gorham *et al*. (1986) also reported that addition of $CaCl_2$ in NaCl had a beneficial effect on growth and leaf K concentration. Table 4 shows that the maximum potassium concentration (14.44 me $100g^{-1}$) was observed at T_4 while the minimum (4.84 me $100g^{-1}$) was recorded at T_9, which was the highest salinity without Ca^{+2}.

Table 2: Mean values of Na, K, Cl and Ca ions concentration (me $100g^{-1}$) in shoots

	Sodium (Na)	Potassium (K)	Chloride (Cl)	Calcium (Ca)
Means for different $CaCl_2$ concentration levels				
C_1 = 0 me l^{-1}	51.19a	18.00d	80.75d	18.55d
C_2 = 10 me l^{-1}	50.54b	18.75c	83.98c	23.31c
C_3 = 20 me l^{-1}	49.42c	20.11b	86.55b	43.50b
C_4 = 40 me l^{-1}	47.57d	22.35a	91.74a	61.22a
Means for different salinity levels				
S_1 = 0-40 mel^{-1}	11.13c	30.85a	35.10c	36.01a
S_2 = 200 me l^{-1}	56.88b	18.49b	71.10b	22.86b
S_3 = 400 me l^{-1}	81.03a	10.07c	151.51a	11.07c
Means for different barley varieties				
Jao-83	45.29c	21.72a	80.80c	39.36a
Jao-85	47.52b	19.46b	84.74b	36.65b
AS-54	56.25a	18.23c	91.73a	34.93c

Table 3: Effect of calcium on concentration of Na, K, Cl and Ca ions (me $100g^{-1}$) in barley shoots under saline conditions

Treatments	Sodium (Na)	Potassium (K)	Chloride (Cl)	Calcium(Ca)
T_1	12.12j	28.17d	30.24l	37.67e
T_2	11.58j	29.50c	32.79k	46.20c
T_3	10.81k	32.29b	35.49j	92.67b
T_4	10.01l	33.49a	41.90j	127.50a
T_5	58.54e	16.97h	65.94h	11.68j
T_6	57.74f	17.14g	70.01g	15.05h
T_7	56.76g	17.84f	72.27f	24.47f
T_8	54.48h	22.01e	76.18e	40.27d
T_9	82.89a	8.88l	146.08d	6.30l
T_{10}	82.30b	9.60k	149.13c	8.69k
T_{11}	80.69c	10.25j	151.90f	13.37j
T_{12}	78.22d	11.55j	157.13a	15.93g

Table 4: Effect of calcium on concentration of Na, K, Cl and Ca ions (me $100g^{-1}$) in barley roots under saline conditions

Treatments	Sodium (Na)	Potassium (K)	Chloride (Cl)	Calcium (Ca)
T_1	15.87l	12.54d	20.24l	31.85d
T_2	15.57j	13.11c	21.91h	42.75c
T_3	14.94k	14.16b	24.35g	89.43b
T_4	14.00l	14.44a	30.98l	124.86a
T_5	61.61e	7.56h	75.91h	15.55h
T_6	61.19f	7.64g	77.97g	18.02g
T_7	60.62g	8.07f	79.53f	38.42f
T_8	59.93h	8.94e	82.22e	53.15e
T_9	97.46a	4.84l	110.60d	7.53l
T_{10}	96.81b	5.12k	112.17c	10.34k
T_{11}	96.11c	5.42j	113.97b	21.93j
T_{12}	95.17d	5.73l	119.20a	30.02d

On average basis of salinity (Table 5), maximum root potassium concentration was recorded at S_1, which showed a significant decrease at S_2 and S_3. On the average, the minimum mean potassium concentration (8.31 me $100g^{-1}$) was recorded at C_1. It increased to 8.61, 9.20 and 9.70 (me $100g^{-1}$) at C2, C3 and C4 respectively. The increase in potassium concentration of root with increasing concentration of calcium in the external solution may be due to the better maintenance of membrane functions (Kent and Lauchli, 1985) by calcium in high calcium salt solution. This superior maintenance of membrane functions could result in reduction in a K^+ efflux. Barley variety Jao-83 contained the highest mean root K^+ concentration, which was significantly more than Jao-85 and AS-54. It was minimum (4.84 me $100g^{-1}$) at T_9 and maximum (14.44 me $100g^{-1}$) at T_4 (Table 4).

Table 5: Mean values of Na, K, Cl and Ca ions concentration (me 100g DM^{-1}) in roots.

Treatments	Sodium (Na)	Potassium (K)	Chloride (Cl)	Calcium (Ca)
Means for different $CaCl_2$ concentration levels				
C_1 = 0 me 1^{-1}	58.32a	8.31d	68.92d	18.31d
C_2 = 10 me 1^{-1}	57.89b	8.61c	70.68c	23.37c
C_3 = 20 me 1^{-1}	57.23c	9.21b	72.61b	49.92b
C_4 = 40 me 1^{-1}	56.36d	9.70a	77.47a	69.35a
Means for different salinity levels				
S_1 = 0-40 $me1^{-1}$	15.09c	13.56a	24.37c	71.98a
S_2 = 200 me 1^{-1}	60.84b	8.04b	78.91b	31.29b
S_3 = 400 me 1^{-1}	96.39a	5.27c	113.98a	17.45c
Means for different barley varieties				
Jao-83	53.05c	44.12a	67.36c	44.12a
Jao-85	56.22b	41.70b	73.42b	41.70b
AS-54	63.06a	34.90c	76.48a	34.90c

Chloride concentration: The concentration of this cation in barley shoot (Table 2 & 3) and root (Table 4 & 5) was observed as minimum in control while it increased in the subsequent treatments. Maximum chloride concentration was recorded in T_{12}. On the average basis of salinity (Table 2), maximum chloride concentration of shoot was recorded at the highest level (S3). It significantly decreased with decrease in external salt concentration at S_2 and S_1. Within the same salinity levels, mean chloride concentration of shoot increased with increasing levels of Ca in the external solution. Ahmad *et al*. (1987) also recorded similar results. Variety AS-54 had significantly higher chloride concentration (91.73 me $100g^{-1}$) followed by Jao-85 (84.74 me $100g^{-1}$) whereas Jao-83 had minimum content of Cl (80.80 me $100g^{-1}$). Maximum mean Cl root concentration was recoded at S_3 (113.98 me $100g^{-1}$), which significantly decreased with a decrease in salinity (S_2 and S_1). Increased chloride concentration of plant material at higher salinity levels may be due to increase in the absolute level of chloride in the root medium as using NaCl and $CaCl_2$ created the salinity. Mean chloride concentration of root within the same salinity levels increased with each increase in the level of $CaCl_2$ in the external solution. Variety AS-54 had significantly higher chloride concentration (76.48 me $100g^{-1}$) followed by Jao-85 (67.36 me $100g^{-1}$) and Jao-83 (67.36 me $100g^{-1}$).

Calcium concentration: In case of shoot (Table 2), the maximum calcium concentration (127 me $100g^{-1}$) was recorded at T_4 where $CaCl_2$ alone was added @ 40 mel^{-1}. Minimum numerical value of 6.30 me $100g^{-1}$ was obtained in T_9 (400 mel^{-1} NaCl alone). The Na cation intensified the deficiency of Ca. Calcium accumulation in shoots and roots of the stressed plants was less than unstressed plants (Dwivedi *et al*., 1981). Variety Jao-83 contained significantly higher concentration of calcium (39.36 me $100g^{-1}$) followed by Jao-85 (36.65 me $100g^{-1}$) and AS-54 (43.93 me $100g^{-1}$). On the average basis, calcium concentration of both root and shoot decreased with increase in concentration of salts in external solution (Table 2 & 5). Within the same levels of salinity, the mean calcium concentration in shoots and root increased significantly with increase in the level of calcium in the external solution. In case of roots (Table 4), the maximum Ca concentration (124.84 me $100g^{-1}$) was in T_4 whereas minimum was obtained in T_9. Barley variety Jao-83 contained significantly higher calcium concentration in roots followed by Jao-85 and AS-54 (Table 5).

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