

EFFECT OF CALCIUM ON THE SALT TOLERANCE OF DIFFERENT WHEAT (*Triticum aestivum* L.) GENOTYPES

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In saline soil conditions the availability and uptake of Ca^{2+} is reduced that results in the loss of membrane integrity and other disorders associated with Ca^{2+} deficiency in plants. A wheat genotype efficient in uptake and utilization of calcium under saline conditions may be better able to withstand saline conditions in the field. Very little information is available on wheat response to salinity and low Ca^{2+} as screening of wheat genotypes has usually been done against salinity alone. The present study was designed to evaluate the performance of different wheat genotypes against salinity at low and adequate calcium supply. The experiment was conducted in hydroponics with four treatments including T1: non-saline with adequate Ca^{2+} , T2: non-saline with low Ca^{2+} (level of calcium was $1/4^{\text{th}}$ of the adequate level), T3: saline (125 mM NaCl) with adequate Ca^{2+} and T4: saline with low calcium. All the physical growth parameters including shoot length, root length, and shoot and root fresh weights were decreased significantly due to salinity and low calcium alone as well as in combination. Reduction was more pronounced under the combined stress of salinity and low calcium and different genotypes differed significantly in different stress treatments for shoot and root fresh weight production. In saline treatment (T3), the genotypes 25-SAWSN-39 and 25-SAWSN-31 showed better growth performance and accumulated lower Na^+ and higher Ca^{2+} where as the genotypes 25-SAWSN-35 and 25-SAWSN-47 showed less growth and had less accumulation of Ca^{2+} and high accumulation of Na^+ . In salinity + low calcium treatment the genotype 25-SAWSN-39 behaved as a tolerant genotype where as 25-SAWSN-31 behaved similar to the sensitive genotype and these differences were due to high accumulation of Ca^{2+} in 25-SAWSN-39 and vice versa. This study shows that the salt tolerance of wheat genotypes differs with the availability and accumulation of calcium. Certain genotypes can better uptake and utilize calcium than the others under low calcium supply which improves their salt tolerance under saline conditions.

Keywords: Calcium, salinity, salt tolerance, *Triticum aestivum*, wheat

INTRODUCTION

Salinity is a major agricultural problem that decreases plant growth and yield all over the world. About 7% area out of the total world land area is affected by salinity (Flowers *et al.*, 1997). The world's total irrigated area is 230 mha out of which 45 mha (about 20%) is salt affected (FAO, 2007). According to another report soil erosion and salinity has damaged about 15% of the total land area of the world (Rengasamy, 2006). Most of the world's arid and semi arid areas are subjected to salinity problem due to high temperature, limited rainfall and high evapo-transpiration (Azevedo Neto *et al.*, 2006). The salt affected lands have poor structure and drainage, and are mostly poorly managed. About 6.67 mha of the cultivated land in Pakistan is affected by salinity (Khan, 1998). This makes salinity a serious issue in Pakistani agriculture as salinity degrades the productive soil and converts it into useless land and deserts.

Salinity reduces the uptake of water and different nutrients by the plants and causes ion toxicity in the plants (Saqib *et al.*, 2004, 2005; Munns and Tester, 2008). Ashraf and Foolad (2007) have listed different effects of salinity as

osmotic effect, nutrient and hormonal imbalances, ionic effects and production of reactive oxygen species (ROS). Salinity inhibits photosynthesis by stomatal and non-stomatal factors (Seemann and Critchley, 1985). Plant growth is directly related to photosynthesis as salinity decreased photosynthesis, it decreased the growth (Heuer and Plaut, 1989). In most of the crops as the sodium concentration increased in leaves, the photosynthetic activity significantly reduced and showed a negative correlation (Yeo, 1998). In a study on wheat (James *et al.*, 2002), it has been found that at a sodium concentration of 350 mM in leaves, the photosynthetic rate was decreased by 50%. Rivelli *et al.* (2002) revealed that stomatal conductance of wheat crop was decreased with high sodium concentration of 150 mM NaCl, and increased with decrease in sodium concentration.

The plants usually face calcium deficiency in addition to sodium toxicity under saline conditions. Salinity reduces influx of Ca^{2+} in the tissues which results in deficiency of Ca^{2+} (Davenport *et al.*, 1997; Lazof and Bernstein, 1999). The sodium present in high concentrations under saline conditions, displaces membrane-associated calcium (Ca^{2+})

(Kinraide, 1999) leading to Ca^{2+} deficiency in the plants. The Ca^{2+} deficiency induced by sodium has been reported in many plants including cereals (Adcock *et al.* 2001; Cramer 2002). High Na^+ : Ca^{2+} ratios cause the deficiency of Ca^{2+} in different species (Maas and Grieve, 1987). Different concentrations of sodium have different effects on displacement of Ca^{2+} from the membranes. The higher concentration of sodium decreases root and shoot growth and calcium concentration in plants (Maas and Grieve, 1987). It has also been observed that crop species sensitive to salinity required more calcium than the species which were tolerant to salinity (Greenway and Munns, 1980). It was observed that less displacement of Ca^{2+} occur by NaCl salinity from membranes in salt tolerant barley (Bittisnich *et al.*, 1989) and melon genotypes (Yermiyahu *et al.*, 1997) than in the respective salt sensitive genotypes. The effect of low Ca^{2+} is not as much studied as the Na^+ toxicity and the role of additional supply of calcium which usually improves salt tolerance.

Wheat is a moderately salt-tolerant crop (Maas and Hoffman, 1977). It has significant genetic differences for salinity tolerance (Saqib *et al.*, 2005) as maize has for drought tolerance (Farhad *et al.* 2011). The wheat genotypes said to be tolerant to salinity have a capacity to keep away the sodium ions from shoot and vice versa (Schachtman *et al.*, 1989). Keeping in view the importance of Ca^{2+} in plant growth under saline conditions it is hypothesized that the genetic variation among the wheat genotypes for salt tolerance may differ with the calcium levels. A wheat genotype efficient for Ca^{2+} uptake and utilization under saline conditions may be more salt tolerant and better able to withstand saline and sodic conditions in the field. Very little information is available on wheat response to salinity and low Ca^{2+} as screening of wheat genotypes has usually been done against salinity at adequate calcium alone. The present study has been designed to study the effect of calcium on salt tolerance of different wheat (*Triticum aestivum* L.) genotypes.

MATERIALS AND METHODS

Ten genotypes of wheat (*Triticum aestivum* L.) were collected from Department of Plant Breeding and Genetics and the Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad. The genotypes included 25-SAWSN-8, 25-SAWSN-12, 25-SAWSN-25, 25-SAWSN-31, 25-SAWSN-35, 25-SAWSN-39, 25-SAWSN-42, 25-SAWSN-47, SARC-7 and SARC-1. The experiment was carried out in a green-house at the Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad. The healthy seeds of the wheat genotypes were sown in trays each containing 5 cm layer of washed sand. These sown seeds were kept moistened with water and with nutrient solution before and after seedling

emergence. At two leaf stage, seedlings of all the genotypes under study were transplanted in foam plugged holes in polystyrene sheets floating over nutrient solution in 100 liter tubs (1m x 1m x 0.25m). The experiment was conducted in hydroponics with four treatments including T1: non-saline with adequate Ca^{2+} , T2: non-saline with low Ca^{2+} (level of calcium was 1/4th of the adequate level), T3: saline (125 mM NaCl) with adequate Ca^{2+} and T4: saline with low calcium. In the low Ca^{2+} treatment tubs the level of calcium was kept at 1/4th of the normal level. After two days of transplantation salinity (125 mM NaCl) was developed in three increments (one per day) in the salinity treatment tubs of different calcium levels whereas no salt was added in control. The solution pH was adjusted at 5.5 ± 1 with dilute NaOH or HCl and the solution was changed weekly during the period of study. Plants were harvested after 4 week growth in the treatment solutions and the data regarding root and shoot lengths and, root and shoot fresh weights were recorded. The ionic concentration for Na^+ and Ca^{2+} in the shoots was determined following wet digestion method (Ryan *et al.*, 2001). The shoot/ leaf samples were oven dried at 65°C for 72 hours and the ashing of these dried samples was done in muffle furnace at 550 °C for 6 hrs. The ashed samples were dissolved in 2.5ml, 5M HNO_3 and volume was made 50 ml with distilled water and this material was used for ionic analysis (Saqib *et al.*, 2005). Na^+ in plant samples was determined by Sherwood 410 Flame Photometer with the help of self prepared standard solutions using reagent grade salt of NaCl. Calcium in the plant samples was determined by Atomic Absorption Spectrophotometer with the help of self prepared standard solutions using reagent grade salt of CaCl_2 . Data were analyzed statistically and genotypic tolerance to salinity at low and adequate Ca^{2+} levels was determined based on relative shoot fresh weight.

RESULTS

Shoot and root growth: The shoot fresh weight (SFW) was decreased significantly by the stress treatments in the following trend i.e. low calcium < saline < low calcium + saline (Table 1). In low calcium treatment (Ca^{2+} concentration 1/4th of the control treatment) percent decrease in SFW as compared to control was 28%, in saline treatment (125 mM NaCl) it was 45 % and in combined treatment (125 mM NaCl + low calcium) it was 69%. The genotypes also differed significantly in different stress treatments. The comparison of genotypes in different treatments showed that in low calcium treatment the maximum SFW was produced by 25-SAWSN-39 and it did not differ significantly with 25-SAWSN-12, 25-SAWSN-42 and SARC-1. The minimum SFW was observed in 25-SAWSN-35 which was statistically at par with the genotype 25-SAWSN-25, 25-SAWSN-31. In saline treatment (125 mM NaCl with adequate calcium), 25-SAWSN-39, 25-SAWSN-12, 25-SAWSN-31, 25-SAWSN-

Table 1. Effect of salinity (125 mM NaCl), low calcium (1/4th of control) and their interaction on shoot fresh weight (g plant⁻¹) of different wheat genotypes

	Control	Low Calcium	Salinity	Low Calcium + Salinity
25-SAWSN-8	10.43	7.5 (72)	5.55 (53)	2.75 (26)
25-SAWSN-31	10.7	7.85 (73)	6.53 (61)	4.05 (38)
25-SAWSN-25	10	7 (70)	5.43 (54)	2.95 (30)
25-SAWSN-12	10.34	7.25 (70)	6.48 (63)	2.92 (28)
25-SAWSN-35	10.19	6.22 (61)	4.68 (46)	2.18 (21)
25-SAWSN-39	10.64	8.78 (83)	6.78 (64)	4.28 (40)
25-SAWSN-42	10.53	8.53 (81)	6.5 (62)	4.03 (38)
25-SAWSN-47	10	6.44 (64)	4.44 (44)	1.94 (19)
SARC-7	10.5	7.32 (70)	5.32 (51)	2.99 (29)
SARC-1	10.22	7.98 (78)	5.73 (56)	3.52 (34)
Mean	10.36	7.48	5.74	3.16

Values are mean of four replications. LSD value at $P \leq 0.05$ is 0.63.

42 and SARC-1 were statistically similar and performed better than 25-SAWSN-35 and 25-SAWSN-47. The minimum SFW in the salinity treatment was found in 25-SAWSN-47. In the combined treatment (125 mM NaCl + low calcium) the maximum SFW was observed in 25-SAWSN-39 and it was statistically similar to 25-SAWSN-12, 25-SAWSN-42 and SARC-1 whereas the minimum SFW was found in 25-SAWSN-47 and it did not differ significantly with 25-SAWSN-31.

The root fresh weight (RFW) was also decreased significantly by different stress treatments and the observed trend was as: low calcium < saline < saline + low calcium (Table 2). In low calcium treatment the average percent decrease in RFW as compared to control was 25%, in saline treatment it was 45% whereas in interactive treatment (low calcium + 125 mM NaCl) it was 71%. The comparison of genotypes in each treatment showed that in low calcium treatment the maximum RFW was produced by 25-SAWSN-

39 and it did not differ significantly with 25-SAWSN-12, 25-SAWSN-25, 25-SAWSN-42 and SARC-1. The minimum RFW in this treatment was found in 25-SAWSN-35 followed by 25-SAWSN-47. In saline treatment (125 mM NaCl) the minimum RFW was produced by 25-SAWSN-35 and it was statistically at par with 25-SAWSN-47 and SARC-7. The genotype 25-SAWSN-39 produced the maximum RFW in saline treatment and differed significantly only from the genotypes producing the minimum RFW. In the interactive treatment (125 mM NaCl + low calcium) 25-SAWSN-39, 25-SAWSN-12, 25-SAWSN-42 and SARC-1 were statistically similar and produced better RFW than the rest of the genotypes.

The differences among treatments regarding shoot length (SL) were significant however, there were no significant differences among the genotypes under different treatments and there was no interaction between the treatments and genotypes for this growth parameter (Table 3). On overall

Table 2. Effect of salinity (125 mM NaCl), low calcium (1/4th of control) and their interaction on root fresh weight (g plant⁻¹) of different wheat genotypes

	Control	Low Calcium	Salinity	Low Calcium + Salinity
25-SAWSN-8	5.17	3.43	2.65	1.07
25-SAWSN-31	5.25	3.65	3.05	1.67
25-SAWSN-25	4.94	3.69	2.72	1.14
25-SAWSN-12	5.16	3.30	2.90	1.05
25-SAWSN-35	5.32	3.10	2.20	1.03
25-SAWSN-39	5.13	3.97	3.03	1.72
25-SAWSN-42	4.92	3.89	2.83	1.58
25-SAWSN-47	4.90	3.31	2.04	1.04
SARC-7	4.99	3.41	2.31	1.05
SARC-1	4.86	3.71	2.67	1.43
Mean	5.30	3.55	2.64	1.28

Values are mean of four replications. LSD value at $P \leq 0.05$ is 0.21.

mean basis SL was the maximum in control. In all other treatments it decreased in the given trend i.e. low calcium < saline < low calcium + saline. In low calcium treatment percent decrease in SL as compared to control was 17 %, in saline treatment (125 mM NaCl) it was 43% whereas in interactive treatment (125 mM NaCl + low calcium) it was 59%. Similar to shoot length there were significant differences among the treatments for root length (RL) production but the effect of genotype as well as interaction between genotypes and treatments was non-significant (Table 4). On overall mean basis the maximum RL was observed in control. In all the other treatments it was significantly decreased with the highest reduction in low calcium + saline treatment followed by salinity and low calcium treatments, respectively. In low calcium treatment percent decrease in RL as compared to control was 18%, in saline treatment it was 58% whereas in interactive treatment (125 mM NaCl + low calcium) it was 83%.

Leaf ionic composition: Significant differences were observed among treatments as well as genotypes regarding leaf sodium concentration (Table 5). Similarly, the interaction between genotypes and treatments was also significant. Salinity significantly increased the leaf Na^+ concentration. On overall mean basis, in saline treatment (125 mM NaCl) Na^+ concentration was significantly higher than the leaf Na^+ concentration in the non-saline treatment. The low calcium treatment under non-saline conditions did not affect the leaf Na^+ concentration significantly. The comparison of genotypes in saline treatment showed that the maximum leaf Na^+ concentration was found in 25-SAWSN-

35 and SAWSN-47 and they did not differ significantly. In saline treatment, 25-SAWSN-39 and 25-SAWSN-12 accumulated statistically similar and significantly lower leaf Na^+ concentration than the other genotypes. In the interactive treatment (125 mM NaCl + low calcium) the maximum leaf Na^+ concentration was found in 25-SAWSN-47 followed by 25-SAWSN-35 whereas the minimum leaf Na^+ concentration was found in 25-SAWSN-12 followed by 25-SAWSN-39 and 25-SAWSN-42.

Shoot calcium concentration was decreased significantly with the application of low calcium and salinity. Significant differences were observed among the treatments as well as the genotypes and there was a significant genotype x treatment interaction (Table 6). On overall mean basis, in the interactive treatment the minimum calcium concentration was found as compared to the other treatments. The comparison of genotypes in each treatment showed that in low calcium treatment the maximum Ca^{2+} concentration was found in 25-SAWSN-12 which was statistically at par with 25-SAWSN-8, 25-SAWSN-39, 25-SAWSN-42 and SARC-1. The minimum Ca^{2+} concentration was found in 25-SAWSN-47 and it differed significantly from the genotypes mentioned in the previous sentence. In saline treatment, 25-SAWSN-47 accumulated the minimum Ca^{2+} in its leaves and did not differ significantly from all the other genotypes except 25-SAWSN-12, 25-SAWSN-39, 25-SAWSN-42 and SARC-1 which accumulated higher leaf Ca^{2+} concentration. A similar genotypic trend was observed in the interactive treatment where low calcium was combined with 125 mM NaCl salinity.

Table 3. Effect of salinity (125 mM NaCl), low calcium (1/4th of control) and their interaction on shoot length (cm) of different wheat genotypes

	Control	Low Calcium	Salinity	Low Calcium + Salinity
25-SAWSN-8	47.2	39.4	26.5	19.6
25-SAWSN-31	47.9	41.4	29.6	21.8
25-SAWSN-25	46.8	38.9	26.9	18.9
25-SAWSN-12	46.3	39.6	26.6	19.0
25-SAWSN-35	44.8	36.5	24.8	17.1
25-SAWSN-39	47.0	40.0	27.6	21.0
25-SAWSN-42	46.5	38.7	25.8	18.7
25-SAWSN-47	45.5	35.9	24.6	16.6
SARC-7	46.4	37.1	25.9	17.5
SARC-1	46.6	37.6	27.2	20.0
Mean	46.5	38.5	26.5	19.0

Values are mean of four replications. LSD value at $P \leq 0.05$ is 2.05.

Table 4. Effect of salinity (125 mM NaCl), low calcium (1/4th of control) and their interaction on root length (cm) of different wheat genotypes

	Control	Low Calcium	Salinity	Low Calcium + Salinity
25-SAWSN-8	31.1	25.7	14.4	7.31
25-SAWSN-31	32.3	26.9	16.8	9.32
25-SAWSN-25	29.3	24.9	14.8	7.56
25-SAWSN-12	30.4	25.6	15.2	7.21
25-SAWSN-35	31.3	23.9	13.3	5.54
25-SAWSN-39	32.5	26.8	16.6	9.69
25-SAWSN-42	30.0	25.5	15.1	7.78
25-SAWSN-47	28.8	23.0	13.1	5.34
SARC-7	30.7	25.1	14.4	6.78
SARC-1	28.9	24.3	15.6	6.44
Mean	30.5	25.2	14.9	7.30

Values are mean of four replications. LSD value at $P \leq 0.05$ is 2.1.

Table 5. Effect of salinity (125 mM NaCl), low calcium (1/4th of control) and their interaction on leaf sodium concentration (mmol g⁻¹ dry wt.) of different wheat genotypes

	Control	Low Calcium	Salinity	Low Calcium + Salinity
25-SAWSN-8	0.18	0.26	1.15	1.57
25-SAWSN-31	0.17	0.23	0.82	1.39
25-SAWSN-25	0.18	0.26	1.13	1.65
25-SAWSN-12	0.18	0.26	1.01	1.69
25-SAWSN-35	0.18	0.28	1.29	1.80
25-SAWSN-39	0.16	0.23	0.86	1.44
25-SAWSN-42	0.17	0.24	1.03	1.52
25-SAWSN-47	0.17	0.28	1.25	1.83
SARC-7	0.18	0.26	1.15	1.56
SARC-1	0.18	0.26	1.07	1.48
Mean	0.18	0.26	1.08	1.59

Values are mean of four replications. LSD value at $P \leq 0.05$ is 0.053.

Table 6. Effect of salinity (125 mM NaCl), low calcium (1/4th of control) and their interaction on leaf calcium concentration (mmol g⁻¹ dry wt.) of different wheat genotypes

	Control	Low Calcium	Salinity	Low Calcium + Salinity
25-SAWSN-8	0.48	0.30	0.25	0.14
25-SAWSN-31	0.47	0.34	0.33	0.20
25-SAWSN-25	0.49	0.29	0.26	0.12
25-SAWSN-12	0.50	0.27	0.24	0.12
25-SAWSN-35	0.48	0.26	0.22	0.10
25-SAWSN-39	0.47	0.33	0.32	0.18
25-SAWSN-42	0.47	0.34	0.30	0.20
25-SAWSN-47	0.49	0.25	0.21	0.11
SARC-7	0.50	0.27	0.24	0.12
SARC-1	0.51	0.31	0.28	0.17
Mean	0.48	0.29	0.26	0.14

Values are mean of four replications. LSD value at $P \leq 0.05$ is 0.047.

DISCUSSION

Salt stress is an important environmental factor that decreases plant growth and yield (Parida and Das, 2005; Turan *et al.*, 2009). High salt concentration disturbs several physiological processes of plants which result in impaired plant growth and development (Taffouo *et al.*, 2004). All the physical growth parameters like shoot length, root length and, shoot and root fresh weights were decreased significantly due to salinity and low calcium alone as well as under their combined stress (Tables 1-4). Calcium is required for cell wall and membrane integrity and a decrease in calcium availability reduces plant growth. A decrease in Ca^{2+} concentration of saline solution may further reduce plant growth over salinity alone. It might be due to removal of Ca^{2+} ions from the cell plasma lemma and internal pool (Cramer *et al.*, 1987; Lauchli, 1990). All the growth parameters were decreased more by a combined stress of low calcium and salinity followed by salinity alone and low calcium alone, respectively. There was a significant negative correlation between shoot fresh weight and leaf Na^+ concentration (Fig. 1) and a significant positive correlation between shoot fresh weight and leaf Ca^{2+} concentration (Fig. 2).

The concentration of Na^+ was increased with the application of salinity and this increase was the maximum in the combined treatment of low calcium and salinity. On the other hand the concentration of Ca^{2+} was decreased with salinity and low calcium. High sodium concentration in saline solution competes with Ca^{2+} and K^+ for uptake at root level and reduces the uptake of these ions where by the uptake and accumulation of Na^+ is increased. External calcium supply alters the selectivity of non selective cation channels facilitating the uptake of potassium, which is one of the main competitors of sodium entrance into the roots (Maathuis and Sanders, 2001). However, if there is a deficiency of calcium, then the reverse seems true i.e. non selective cation channels are used for Na^+ hyper accumulation in the cell. At higher concentrations, sodium also displaces calcium associated with membranes (Cramer *et al.*, 1985). Calcium deficiency caused by sodium has been observed in many plant species, including cereals (Ehret *et al.*, 1990; Cramer, 2002). This situation becomes worse with low solution calcium concentration under saline conditions. Genc *et al.* (2007) and Saqib *et al.* (2005, 2006, 2008) reported that there is a great variability among wheat genotypes for sodium exclusion and tolerance to elevated levels of sodium in the plant cells. The wheat genotypes used in the present study also performed differently in different treatments. In the saline + low calcium stress the genotype 25-SAWSN-39 performed better as compared to the other genotypes where as the performance of 25-SAWSN-35 and 25-SAWSN-47 was the poorest of all the genotypes. External calcium supply facilitates the uptake of

potassium and a deficiency of calcium leads to Na^+ hyper accumulation in the cells. This process has occurred more in the case of 25-SAWSN-35 and 25-SAWSN-47 which accumulated more Na^+ as compared to the other genotypes. As a result of excessive Na^+ uptake their growth was very low as compared to 25-SAWSN-39 which proved to be relatively more tolerant to both salinity and low calcium supply in the surrounding medium. The better growth performance of 25-SAWSN-39 might be due to its better adaptation to both salinity and low calcium. The performance of genotype 25-SAWSN-31 has been very interesting as it performed better than the salt-sensitive genotypes under saline condition but did not differ significantly from the salt-sensitive genotypes under salinity + low calcium. This shows that it cannot uptake calcium efficiently under low calcium conditions which is evident from its calcium concentration in low calcium and low calcium + salinity treatments.

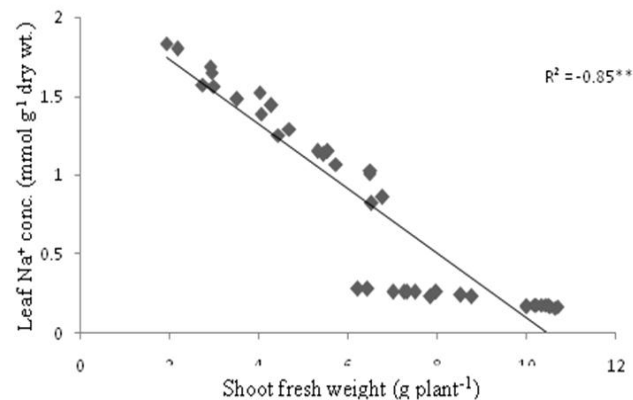


Figure 1. Relationship of shoot fresh weight (g plant^{-1}) with leaf Na^+ concentration (mmol g^{-1} dry wt.)

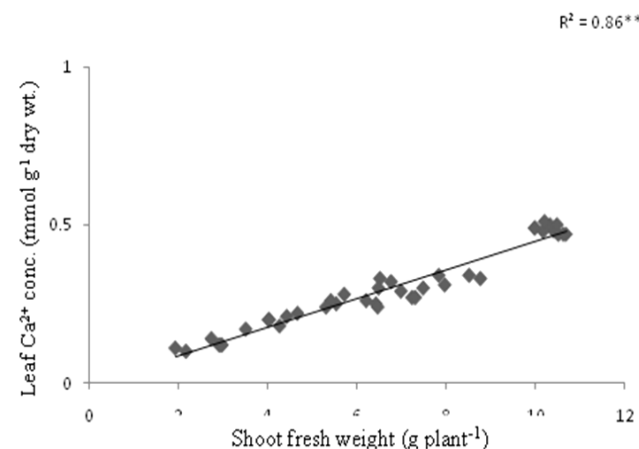


Figure 2. Relationship of shoot fresh weight (g plant^{-1}) with leaf Ca^{2+} concentration (mmol g^{-1} dry wt.)

In addition to absolute shoot fresh weight the relative shoot fresh has also been considered an informative and reliable parameter for the comparison of genotypic performance under stress conditions (Qureshi *et al.*, 1990). On the basis of the relative shoot fresh weight of a genotype under stress conditions as compared to non-stress conditions the wheat genotypes 25-SAWSN-39 may be considered as resistant to salinity and salinity + low calcium and 25-SAWSN-35 and 25-SAWSN-47 may be considered as sensitive genotypes to both the conditions (Table 1). The behavior of the genotype 25-SAWSN-31 has also been unique as it performed good under saline conditions in the presence of high calcium but does not perform well under saline conditions in the presence of low calcium. This may be due to its poor calcium uptake and calcium use efficiency which is required for better salt tolerance under low calcium and saline conditions.

Conclusion: This study shows that the salt tolerance of wheat genotypes differs with the availability and accumulation of calcium. Certain genotypes can better uptake and utilize calcium than the others under low calcium supply which improves their salt tolerance under saline conditions. The genotype 25-SAWSN-39 performed better than all the other genotypes in salinity + low calcium conditions and may be recommended for use on salt-affected soils.

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