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# Ion Distribution Response of Pearl Millet (*Pennisetum americanum* L.) to NaCl Salinity

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## ABSTRACT

Pattern of distribution of $Na^+$, $Cl^–$ and $K^+$ ions was examined in three pearl millet lines at three growth stages in response to increased levels (control, 10, 15 dS $m^{-1}$) of NaCl salinity. Analysis for $Na^+$, $Cl^–$ and $K^+$ were performed for younger and older leaves, sheath, stem and roots. A clear-cut compartmentation of $Na^+$ and $Cl^–$ ions was exhibited by tolerant line (Togo) followed by DB-5 showing very low content of these toxic ions in the younger parts while highest content in the older parts. Tolerant lines used this strategy to cope with salinity while sensitive line (Ghana white) failed to exclude the ions in inactive parts.

**Key Word:** Ion distribution; Growth stages; Pearl millet; Salinity

## INTRODUCTION

Variations in salinity tolerance amongst those plant species showing glycophytic adaptation is related to the efficiency with which they exclude excess of $Na^+$ or $Cl^–$ from their leaves. Exclusion of salt followed by transport and compartmentation is one of the most important strategies of plants to achieve salt tolerance and which could be the primary target for manipulation in engineering of salt tolerance (Winicov, 1998). Exclusion of toxic ions is considered the ideal salt resistance mechanism in all plants facing the problem of root zone salinity. Halophytes possess special features to get rid of toxic ions, as these plants take large amount of these ions for their turgor maintenance (Greenway & Munns, 1980). On the other hand, glycophytes lack such characteristics and use other strategies to cope with the hyper salinity. Ion exclusions possess a variety of mechanisms that limit the amount of $Na^+$ and $Cl^–$ that reaches the shoot. Such plants usually maintain relatively high shoot $K^+/Na^+$ ratio (Greenway & Munns, 1980; Gorham *et al*., 1985; Aslam *et al.*, 1993).

Potassium is a vital macronutrient for plants, while $Na^+$ is required by $C_4$, especially under condition of low $K^+$ supply (Kuiper *et al*., 1988). All plant, however, are highly selective for uptake of $K^+$ over $Na^+$ under saline or non-saline condition (Cheeseman, 1988). The selective uptake of $K^+$ over $Na^+$ can be shown by computing the $K^+$:$Na^+$ ratio within the tissues as related to that of the external medium. As a general rule actual $K^+$:$Na^+$ ratio in the tissue decreases but the selectivity ratio increases with salinity (Salim & Pitman, 1983). This criterion has been used as an index for salt tolerance in various crops by different workers (Chauhan *et al*., 1980; Gorham *et al*., 1985). Salim (1991) identified a barley variety, which accumulated high content of $Na^+$ and $Cl^-$ in shoots and exhibited increased salt tolerance and by contrast emmer wheat enhanced salinity tolerance was due to low $Na^+$ uptake (Nevo *et al*., 1992). It seems probable that tolerance may change with ontogenic development of plants (Shannon, 1985).

The work presented here shows compartmentation of $Na^+$, $Cl^–$ and $K^+$ ions under increased salinity conditions in differentially salt tolerant pearl millet lines at three growth stages using a novel approach.

## MATERIALS AND METHODS

**Plant material.** Three pearl millet (*Pennisetum americanum* L.) lines selected for this study were screened under increased level of NaCl salinity at various growth stages and declared highly tolerant (Togo), moderately responsive (DB-5) and highly sensitive (Ghana white), based on $EC_{50}$ values (Javed *et al*., 2000). For the elucidation of the role of $Na^+$, $Cl^–$ and $K^+$: $Na^+$ ratio as ions, these lines were grown under no salinity 2.5 (control), 10 and 15 dS $m^{-1}$ level of NaCl salinity. The role of above mentioned ions was studied at seedling, tillering and grain filling stages in young and old leaves, young and old sheath, young and old stem and roots. The salt application treatment and rest of the growth details were similar to as described else where by Javed *et al.* (2001). To prepare sample for the estimation of $Na^+$, $K^+$ and $Cl^-$, 0.2 g of dried ground material was heated in $HNO_3$ (3:1 ratio) at 250ºC until tissue was completely digested. The digest was diluted to 50 mL with distilled water. The above samples were further diluted as required and analyzed for $Na^+$ and $K^+$ using a flame photometer (Sherwood Model-410) (Yoshida *et al*., 1976). Chloride in the above extract was determined with a chloride analyzer (Corning Chloride Analyzer mode 925. Essex, UK). The two way analysis of variance was used to find out significant differences among lines, growth stages, treatments, plant parts and their interaction, using M STAT-C computer software.

## RESULTS AND DISCUSSION

**Sodium ($Na^+$).** Significant ($p<0.01$) differences in $Na^+$ content were indicated by different parts of all pearl millet lines under increased salinity at different growth stages (Table I). The individual and overall interaction for different factors was also significant ($p<0.01$). Although there was a general increase of this element with increased salinity levels, older leaf and sheath revealed the best storage sites as compare to the younger leaf and sheath, at all growth stages. Likewise, older stem indicated greater amount of $Na^+$ than the younger one. This trend was more pronounced in Togo than other lines. All the lines indicated least storage of $Na^+$ the roots than in other parts; but most promising response was given by roots of Togo (tolerant line). The sensitive line (Ghana White), exhibited a differential distribution of $Na^+$ in the different parts. In this line younger parts also indicated substantially greater amounts of this ion.

**Potassium ($K^+$).** Application of salinity at different growth stages indicated significant ($p<0.01$) (Table I) differences for the accumulation of $K^+$ in different parts of tolerant and sensitive lines of pearl millet. Most of the interaction of these factors was also significant ($p<0.01$). It is evident from the data that content of this ion was generally reduced in all parts with increased salinity irrespective of the stage of growth, yet there appeared high ability of tolerant (Togo) and moderately behaving (DB-5) lines to accumulate this ion in young leaf, young sheath, younger stem and root. Ghana White did not show this promising response for the ion at all the growth stages, but this trend was more apparent at seedling stage. At the grain filling stage, more accumulation of $K^+$ in older leaves was evident than the younger parts and roots.

**$K^+$: $Na^+$ ratio.** This ratio in different parts of pearl millet lines showed significant ($p<0.01$) differences with applied salinity at all stages of growth (Table I). The individual and overall interaction for different factors was also significant ($p<0.01$). Generally, a reduction was evident in $K^+$: $Na^+$ ratio with increased root zone salinity in various parts of the tolerant and sensitive lines. The tolerant line Togo, especially in younger parts and root, followed by DB-5, displayed least reduction in this ratio. However, this pattern was not observed in the sensitive line where slight differences in younger and older parts were noted for this parameter.

**Chloride ($Cl^-$).** Significant ($p<0.01$) differences in $Cl^-$ content in various parts of selected lines of pearl millet under increased root zone salinity at three stages of growth were noted (Table I). The individual and overall interactions were also significant ($p<0.01$). There was a general increase in $Cl^-$ content in various parts at all the growth stages due to salinity, but tolerant and sensitive lines displayed differential pattern of its distribution. Togo (tolerant line) accumulated less chloride in younger parts and roots than the older ones, followed by moderately behaving line (DB-5) indicated a similar trend of accumulation but to a lesser extent. In Ghana White, there was more accumulation of this ion in the younger parts and root than Togo or DB-5.

**Table I. Statistics for some elements in different parts of pearl millet lines at various growth stages under salinity**

**(A) Analysis of variance (F- values)**

| Parameters | df | $Na^+$ | $K^+$ | $K^+$ : $Na^+$ | $Cl^-$ |
|---|---|---|---|---|---|
| Harvests ( H ) | 2 | 44.41** | 84.73** | 24.32** | 81.42** |
| Lines ( C ) | 2 | 3900.18** | 135.31** | 285.70** | 24.73** |
| Salinity ( S ) | 2 | 32984.07 ** | 720.34** | 3924.69** | 47074.72** |
| Parts ( D ) | 6 | 3202.02** | 1155.97** | 401.57** | 2194.59** |
| H X C | 4 | 284.60** | 65.32** | 19.10** | 7.82** |
| H X S | 4 | 124.43** | 1.99 ns | 34.69** | 27.02** |
| C X S | 4 | 642.40** | 25.53** | 38.34** | 23.22** |
| H X C X S | 8 | 87.38** | 1.95 ns | 4.21** | 5.23** |
| H X D | 12 | 62.97** | 34.38** | 9.19** | 7.96** |
| C X D | 12 | 112.45** | 183.10 ** | 65.29** | 129.49** |
| H X C X D | 24 | 78.03** | 37.55** | 4.23** | 4.74** |
| S X D | 12 | 763.78** | 19.12** | 82.77** | 528.10** |
| H X S X D | 24 | 30.32** | 7.45** | 6.12** | 7.47** |
| C X S X D | 24 | 92.71** | 10.04** | 11.55** | 41.28** |
| H X C X S X D | 48 | 80.57** | 6.80** | 3.17** | 5.73** |
| **(B) Comparison of means** | | | | | |
| **Lines** | | | | | |
| Togo | | 76.57b | 208.73b | 86.22c | 4.32a |
| DB-5 | | 73.90c | 216.33 a | 87.42 b | 4.10 b |
| Ghana white | | 99.95a | 199.32c | 88.71a | 2.89 c |
| Salt levels(ds $m^{-1}$) | | | | | |
| Control | | 36.60c | 227.22a | 25.5c7 | 7.05a |
| 10 | | 98.03b | 209.23b | 108.06b | 2.50 b |
| 15 | | 115.87a | 187.93c | 128.54a | 1.77 c |
| **Stages** | | | | | |
| Seedling | | 82.33c | 203.49b | 85.22b | 4.00a |
| Tillering | | 85.23a | 205.02b | 87.39a | 3.56c |
| Grain filling | | 82.94b | 215.86a | 79.74c | 3.75b |
| **Parts** | | | | | |
| Young leaf | | 81.57d | 257.64a | 74.50f | 5.26a |
| Old leaf | | 110.82a | 199.04d | 100.19b | 2.90b |
| Young Sheath | | 82.22c | 237.32c | 84.84c | 3.97c |
| Old Sheath | | 106.84b | 169.67f | 112.00a | 2.14d |
| Young stem | | 65.86f | 189.34c | 86.25d | 3.65e |
| Old stem | | 80.81e | 160.73g | 96.93c | 2.56f |
| Root | | 56.38g | 243.14b | 57.43g | 5.90g |

Significant at *P=0.05;** P=0.01; ns= non-significant; Means with same letter differ non-significantly (P>0.05)

Sensitivity of crops to increased level of salinity has been regarded as a chronic factor in displaying poor growth and economic yield. This has mainly been attributed to the salinity induced deficiency of essential nutrients and enhanced toxicity of the elements present in excess in the salinity affected soil (Zeng & Shannon, 2000). Some reports indicate that various parts of a plant show varied pattern of distribution of ions when it is grown under high levels of salinity (Sharma, 1986; Wolf *et al.,* 1992). In this study substantial differences were evident as regards the accumulation of ions in various parts of all the three lines studied at three growth stages.

In general, Togo (tolerant line) indicated enhanced capability to accumulate $Na^+$ in older than in younger parts, while $K^+$ was greater in the younger parts and roots as compared to DB-5 and Ghana White. Salinity resulted in a considerably reduced $K^+$: $Na^+$ ratio in all the lines under salinity, but there were considerable differences among the lines. Togo followed by DB-5 displayed a greater $K^+$: $Na^+$ ratio in the root followed by young leaf and young sheath at all the growth stages. The trend of $Cl^-$ accumulation was similar to $Na^+$, but Togo indicated comparatively less content of this ion in the young leaves than older ones. It appears from the data that both $Na^+$ and $Cl^-$ are equally detrimental to the growth of pearl millet, but it is the effective partitioning strategy of any line through which it can cope with adverse effects of these elements. This strategy appears to be effectively adapted by the tolerant line in the regulation and partitioning of $Na^+$ and $Cl^-$ in various parts. A greater $K^+$ content and $K^+$: $Na^+$ ratio in the root determined the enhanced ability of Togo to maintain physiological activity at a reasonably good pace (Wilson *et al.*, 2000). A decrease in the content of $K^+$ in older parts revealed that, as a physiologically beneficial nutrient, $K^+$ was preferentially transported to the young leaves where it played a significant role in better growth of young parts (Munns & Termaat, 1986; Bernstein *et al.,* 1993). The physiological role of $K^+$ has been envisaged in terms of regulation of osmotic activity, protein synthesis and as co-factor in the activity of some enzymes (Khan *et al.,* 2000). It is believed that by virtue of having a prolific root system, Togo managed to partition excess of $Na^+$ and $Cl^-$ in physiologically less active parts, showing their lowest accumulation in the root.

## CONCLUSIONS

The present investigations on ions distribution have revealed considerable variability in the three pearl millet lines. Togo has been recognized as a salinity tolerant line followed by DB-5, while Ghana white proved it to be the sensitive one. In present case salt tolerant line (Togo) was earmarked for growth in saline areas particularly under irrigated conditions.

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