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Comparative Study of Nutritional Imbalance in Pearl Millet Genotypes as Induced by NaCl Salinity

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ABSTRACT

Comparative behaviour of some tolerant and sensitive pearl millet genotypes to accumulate nutritional elements in different parts under increased levels of NaCl salinity was studied. Two levels of salinity i.e. 10 and 15 dS m^{-1} in addition to control (2.5 dS m^{-1}) were developed daily @ of 2 dS m^{-1}. Three genotypes of pearl millet i.e. Togo (tolerant), DB-5 (medium tolerant) and Ghana white (sensitive) were used to study their comparative responses to salinity at three growth stages. Tolerant genotype showed least stress induced nutritional imbalance as compare to medium tolerant and sensitive genotype. The pattern of nutrient elements was found to be different in different parts and also at different growth stages under stress conditions.

Key Words: Growth stages; Nutrient status; Pearl millet; Salinity

INTRODUCTION

In the plants grown in salt affected soils, the variable ionic strength of growth media results in disturbed nutrient ratio in the cell due to predominated accumulation of certain ions. This nutrient imbalance is one of the factors for yield reduction in saline soils (Fageria, 1983). Increased salinity in the root medium interferes with the uptake and translocation of Ca^{2+} and K^{+} (Jeschke, 1984; Sharma, 1986), possibly due to high level of Na^{+} in tissue (Sharma, 1986). Such an induced nutrient deficiency leads to lowering of nutrient ratio. Higher concentration of Na^{+} and Cl^{-} reduces the uptake and utilization of NO^{-3} (Munns & Termaat, 1986), Ca^{2+}, N and P (Wahid *et al.*, 1997), which may be one of the reasons for growth reduction. This is due to the enhanced uptake of Na^{+} and Cl^{-} as compared to rest of the nutrients in the growth media, which causes nutrient imbalance and deficiencies (Lauchli & Epstein, 1990). High uptake of Na^{+} hinders Ca^{2+} up take and so causes disturbance of Ca^{2+} Nutrition (Rengel, 1992). In the present study, an attempt was made to assess changes to accumulate nutrient elements in various parts of the selected salt sensitive and tolerant pearl millet genotypes in relation to Na^{+} and Cl^{-} contents at different root zone salinity levels.

MATERIALS AND METHODS

Plant material. Three pearl millet (*Pennisetum americanum* L.) genotypes selected for this study were screened under increased level of NaCl salinity at various growth stages and declared as highly tolerant (Togo), moderately responsive (DB-5) and highly sensitive (Ghana white), based on EC_{50} values. For the elucidation of the role of Ca^{2+}, Mg^{2+}, N and P as nutrients, these genotypes were grown under no salinity (control 2.5), 10 and 15 dS m^{-1} level of NaCl salinity. The role of above mentioned nutrients was studied at seedling, tillering and grain filling stages in younger and older leaves, younger and older sheath, younger and older 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 Ca^{2+} and Mg^{2+}, 0.2 g of dried ground material was heated in HNO_3 (3:1 ratio) at 250^0C 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 Ca^{2+} and Mg^{2+} using an atomic absorption spectrophotometer (Pye Unicom Ltd. York street, Cambridge UK) (Yoshida *et al.*, 1976). Total N contents of plant tissue were determined with the micro- kjeldahl method as described by Bremner (1965). Total P was extracted and estimated followed the method of Youshida *et al*. (1976). Absorbance of the coloured complex was measured at 420 nm using spectrophotometer. The two way analysis of variance was used to find out significant differences among genotypes, growth stages, treatments, plant parts and their interaction, using M STAT-C computer software.

RESULTS

Calcium (Ca^{2+}). The content of this element in various parts of pearl millet genotypes as affected by increased root zone salinity, revealed significant ($p<0.01$) differences (Table I). All the interactions were also found to be significant ($p<0.01$). It was noted that Ca^{2+} content was reduced with an increase in root zone salinity in various parts of the genotypes at all three stages of growth, but decrease was more apparent in the sensitive than the tolerant and moderately tolerant genotypes. All the genotypes tended to accumulate greater amount of Ca^{2+} under either conditions, especially in the younger leaf and root, but the worst performer under salinity was sensitive genotype.

Table I. Statistics for some nutrients in different parts of pearl millet genotypes at various growth stages under salinity

(A)		Analysis of variance (F- values)			
Parameters	**df**	**Ca^{2+}**	**Mg^{2+}**	**N**	**P**
Harvests (H)	2	46.86**	16.44**	30.63**	20.83**
Genotypes (C)	2	292.39**	366.17**	181.45**	29.04**
Salinity (S)	2	1670.95 **	1369.20**	12.73**	236.56**
Parts (D)	6	2046.88**	15561.48**	451.22**	75.35**
H X C	4	39.24**	8.87**	3.25*	172ns
H X S	4	11.41**	3.26*	16.26**	1.09ns
C X S	4	171.99**	116.80**	3.37*	1.40ns
H X C X S	8	10.95**	6.07**	415.67**	6.39**
H X D	12	19.53**	18.48**	11.41**	4.30**
C X D	12	313.08**	125.64 **	69.95**	0.89ns
H X C X D	24	20.78**	10.07**	11.47**	1.69ns
S X D	12	65.63**	198.66**	1.11ns	0.83ns
H X S X D	24	8.73**	8.56**	2.47*	0.59ns
C X S X D	24	20.79**	43.48**	3.49*	1.38ns
H X C X S X D	48	5.26**	9.20**	3.02*	0.44ns
	Comparison of means				
(B)					
Genotypes					
Togo		46.36a	58.96a	1.29a	2.93a
DB-5		44.84b	53.23c	1.08c	2.78b
Ghana white		41.25c	53.98b	1.16b	2.61e
Salt levels(dS m^{-1})					
Control	(2.5)	50.48a	61.05a	1.34a	3.26a
	10	44.02b	56.06b	1.18b	2.73b
	15	37.94c	49.05c	1.00e	2.33c
Stages					
Seedling		43.50b	55.86a	1.23a	2.66a
Tillering		45.36a	55.67b	1.15b	2.82b
Grain filling		43.58b	54.63c	1.14c	2.26c
Parts					
Young leaf		62.27a	42.72d	1.69a	3.40a
Old leaf		43.78d	33.97f	1.31b	2.91c
Young Sheath		47.19c	36.80e	1.11c	2.85d
Old Sheath		38.72e	33.39g	0.99e	2.51e
Young stem		35.18f	64.32b	1.04d	2.43f
Old stem		30.80g	55.94c	0.99e	2.26g
Root		51.10b	120.57a	1.10c	3.06b

Significant at *,p 0.05;**, p 0.01; NS, non-significant. Means with same letter differ non-significantly (P>0.05)

DB-5 retained Ca^{2+} more in younger parts, i.e. younger leaf, sheath and root than the older parts. More notably, Togo was able to accumulate greater amount of this element in various parts especially in the younger leaf and root at all growth stages.

Magnesium (Mg^{2+}). The genotypes differed significantly ($p<0.01$) for the level of Mg^{2+} in various parts at different stages of growth (Table I). The individual and overall interactions of the mentioned factors were also significant ($p<0.01$). There was a trend of decrease in Mg^{2+} content in different parts under salinity, but Togo indicated a minimum decrease. DB-5 and Ghana white showed a similar pattern of accumulation under either conditions at various stages of growth. As regards the parts the root, among all parts, indicated the greatest accumulation of Mg^{2+} in all the genotypes, but the level of accumulation varied greatly under different salinity levels. In the root of Togo, there was the greatest level of Mg^{2+} even at 15 dS m^{-1} level of salinity. In the other genotypes, similar pattern of Mg^{2+} accumulation was evident under control, but not under saline conditions.

Total nitrogen (N). Applied salinity indicated a significant ($p<0.05$) difference in the levels of N in various parts, which differed greatly in the genotypes at different growth stages (Table I). The interactions of these factors were found to be significant ($p<0.05$), except the interaction of salinity levels x parts ($p>0.05$). At seedling stage, the N content was lower in different parts of Togo as compared to DB-5 and Ghana white, where it was further decreased under salinity. This

Table II. Correlation co-efficient (r) of Na^+ and Cl^- with some endogenous elements of pearl millet genotypes under control and 15 dS m^{-1}

Genotypes	Growth stages	Elements	Correlation co-efficient			
			Na^+		Cl^-	
			Control	15 dS m^{-1}	Control	15 dS m^{-1}
Togo	Seedling	Ca	-0.500ns	-0.526ns	-0.239ns	-0.796*
		Mg	-0.526ns	-0.689ns	-0.026ns	-0.777*
		P	+0.305ns	-0.296ns	-0.478ns	-0.783*
	Tillering	Ca	-0.621ns	-0.463ns	-0.353ns	-0.799*
		Mg	-0.556ns	-0.830*	-0.087ns	-0.748ns
		P	-0.760*	-0.178ns	-0.410ns	-0.644ns
	Grain filling	Mg	-0.512ns	-0.832*	-0.167ns	-0.827*
		N	-0.110ns	+0.794*	-0.123ns	-0.431ns
DB-5	Seedling	Mg	-0.604ns	-0.167ns	-0.192ns	-0.797*
	Tillering	Mg	-0.096ns	-0.797*	-0.126ns	-0.724ns
	Grain filling	Mg	-0.027ns	-0.621ns	-0.164ns	-0.823*
Ghana white	Seedling	Mg	-0.418ns	-0.863*	-0.091ns	-0.782*
	Tillering	Ca	-0.808*	-0.067ns	-0.257ns	-0.209ns
		Mg	-0.507ns	-0.618ns	+0.079ns	-0.779*
		N	-0.274ns	+0.806*	-0.270ns	+0.386ns
	Grain filling	Ca	-0.685ns	+0.771*	-0.500n	+0.552ns
		Mg	-0.244ns	-0.854*	-0.214ns	-0.737ns
		N	-0.508ns	+0.870*	+0.142ns	+0.172ns

Significant at *, $p<0.05$; **, $p<0.01$; ns, non-significant ($p>0.05$). The `r' values have been presented for only those means, which are significantly correlated at any level of EC.

decrease in N was more pronounced in case of Ghana white followed by DB-5 as assessed on the basis of respective control values at tillering and grain filling stages. Togo indicated an enhanced accumulation of N in different parts while DB-5 and Ghana white respectively indicated slightly and severely decreased accumulation of this element, particularly in the younger parts at respective growth stages.

Total phosphorus (P). Different genotypes of pearl millet indicated significant ($p<0.05$) changes in the level of P in various parts at different growth stages with increasing application of salinity (Table I). However, most of the interactions of these factor were not evident ($p>0.05$), except the interactions genotype x salinity and genotype x parts ($p<0.05$). The level of P did not change in various parts of the tolerant genotype (Togo) at different growth stages under study. This was particularly evident in case of younger parts and root. Moderately tolerant genotype, DB-5, deviated slightly, while Ghana white deviated appreciably from the trend of P accumulation, as indicated by Togo at all the growth stages. The accumulation of P was greater at seedling and tillering stages but comparatively low at grain filling stage.

DISCUSSION

Sensitivity of crop 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 soil (Wyn Jones, 1984; Zeng & Shannon, 2000) rendering a lowered availability of water to plant root (Joly, 1989). Some reports indicated that various parts of a plant indicate varied pattern of distribution of ions when it was grown at high levels of salinity (Sharma, 1986; Cramer *et al.,* 1987; Wolf *et al.,* 1992). In this study substantial differences were evident as regards the accumulation of nutrients in seven different parts of all the three genotypes studied at three growth stages.

An important adverse effects of salinity is induced nutrient deficiency. Root and younger leaf of Togo had the highest content of Ca^{2+} at three growth stages followed by DB-5. Ghana white displayed a similar pattern but the accumulation was far less in root and younger leaf tissue. Among the reported effects of salinity, hampered Ca^{2+} nutrition of the plant was one of the important attributes (Cramer *et al*., 1987; Rengel, 1992; Suhayda *et al.,* 1992). Salinity either competitively inhibited Ca^{2+} uptake or displaced it from the membrane surface (Cramer & Lauchli, 1986). In this study enhanced uptake of essential nutrients by Togo in younger parts and root revealed the adaptive potential of this genotype to combat salinity (Schachtman & Munns, 1992; Wolf *et al.,* 1992). Ghana white, on the contrary, could not exercise an effective control in the acquisition and transport of Ca^{2+} to the younger parts. This appeared to form the basis of reduced salinity tolerance of this genotype at respective growth stages.

The accumulation of Mg^{2+} in various parts of pearl millet genotypes indicated almost similar trend in various parts. However, the content of Mg^{2+} under salinity was quite variable in the three genotypes investigated. All the genotypes at all the growth stages indicated greater accumulation of Mg^{2+} in the root as compared to rest of the parts. The changes in the level of Mg^{2+} in various parts of

genotypes differing in sensitivity to salinity led to the conclusion that increased Mg^{2+} content played an effective role in the better growth of root and consequently the salinity tolerance of this genotype (Suhayda *et al*., 1992). The greatly enhanced uptake of Mg^{2+} by roots suggested that in the parts deprived of Ca^{2+}, the accumulation of Mg^{2+} fulfilled Ca^{2+} deficiency and enabled the plant to grow better. This possibility seemed to be strongly apparent in the tolerant genotype studied here.

It is well established that N and P play an important role in the dry matter production of plant (Pessarakli, 1999; Martinez & Lauchli, 1991). Their deficiency lead the plants considerably to display reduced growth and economic yield as these were involved many metabolic reactions (Gouia *et al.,* 1994). Salinity reduced in the acquisition and assimilation of N and P among the other essential elements (Lauchli, 1986; Cramer *et al.,* 1991). In this study, the differences among genotypes were clearly discernible for these elements. The tolerant genotype (Togo) indicated a lesser decrease in the level of N and P in younger leaves, while Ghana white indicated no appreciable differences in the content of N and P in its different parts. These findings revealed that increased level of both N and P in various parts, particularly the younger ones and root, enable the tolerant genotype to utilize both these elements efficiently in dry matter production under salinity (Cusido *et al.,* 1987). This suggested that the supplementation of these elements in appropriate concentration may be helpful in enhancing salinity tolerance of the promising genotypes (Awad *et al.,* 1990). There was an antagonistic relationship between salinity inducing components and essential nutrients (Pessarakli *et al.,* 1991) and it varied with the tolerance level of any variety (Wilson *et al.,* 2000). In this study tolerant genotype indicated a greater accumulation of Ca^{2+}, Mg^{2+}, N and P even at the highest level of salinity. These data allude to the fact that a massive root system enabled the tolerant genotype (Togo) to harness beneficial elements in greater amounts even at 15 dS m^{-1}. This strategy enabled this genotype to sustain physiological activity at root level, resulting in greater growth of shoot. This trend appeared to be missing slightly in DB-5 and greatly in Ghana white.

The credibility of increased accumulation of physiologically more important elements in root or younger growing tissues was assessed by the establishment of certain relationships between content of Na^+, Cl^- and Ca^{2+}, Mg^{2+}, N and P at control or 15 dS m^{-1} (Table II). The Na^+ was not correlated with Ca^{2+}, Mg^{2+} and N while Cl^- was not related with any of the elements at any stage in Togo under control condition. Contrarily, Ca^{2+} and N did not show any correlation with Na^+ at any stage at 15 dS m^{-1}. While the correlations of Ca^{2+} and N were well established at all the growth stages in Togo. DB-5 (moderately tolerant) seldom indicated any relationship with Na^+ and Cl^- under control condition, but at 15 dS m^{-1}, negative relationships were evident between Na^+ and Mg^{2+} at different stages of growth. Ghana white revealed almost similar relationship of Na^+ and Cl^- with other elements as reported for Togo and DB-5 under control conditions. However, at 15 dS m^{-1}, Ca^{2+} was not correlated with Na^+ and Cl^- while Mg^{2+} indicated a negative correlation (Table II). Although we found the association of various elements with the salt tolerance abilities of the genotypes was clear but whether the changes in the levels of these elements were the cause of tolerance can not be ascertained Furthermore toxicity due to Cl^- was greater in Togo as compared to DB-5 and Ghana white. Both the latter genotypes appeared to suffer enhanced toxicity effect of Na^+. Therefore to look for tolerant strategies as manifested by Togo, in other high yielding germplasm of pearl millet can greatly contribute to the solution of problem in view.

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