



SHORT COMMUNICATION

SALINITY INDUCED CHANGES IN PHOSPHORUS FRACTIONS OF SUGARCANE LAMINAE ADVERSELY AFFECT SUCROSE CONTENTS

RAMA KANT RAI†, PUSHPA SINGH, A CHANDRA AND RL YADAV

Division of Plant Physiology and Biochemistry, Indian Institute of Sugarcane Research, Lucknow, 226 002, India

Received on 19th March, 2010, Revised on 17th Aug., 2010

Growth, development and sucrose accumulation are regulated by phosphorus accumulation during growth cycle. In the present experiment, the effects of sodium salts on sugarcane growth were evaluated. The pool size of different phosphorus (P) fractions in leaf laminae of sugarcane varieties under test varied significantly as compared to control. The inorganic-P pool size was higher in CoLk 8102 as compared to Co 1148. On the contrary, organic-P fractions were lower in CoLk 8102 than Co 1148. The inorganic- P fractions were higher in CoLk 8102 as compared with Co1148 while organic P fractions were lower in CoLk 8102 as compared with Co 1148 in all treatments under evaluation. Higher concentration of sodium salts induced significant reduction in total tissue phosphorus concentration during growth cycle as compared to control in both varieties and showed strong negative correlation with leaf area, cane dry weight and sucrose contents.

Key Words: Phosphorus fractions, sodium salts, sucrose, sugarcane

Sugarcane crop is moderately sensitive to salinity with a threshold for yield reduction at 1.7 dS m⁻¹ (Hunsigi 1993). Saline soil or irrigation water have reduced sugarcane stalk yield (Ginoza and Moore 1985) by reducing both stalk population and stalk weight. Most studies have shown that salinity reduces Pol, an estimate of sucrose content, and apparent purity (ratio of Pol to Brix where Brix is an estimate of total soluble solids). As ratooning is commonly practiced in sugarcane cultivation, where in every ratoon loses the nutritional benefits of plant crop and has to produce new root system in soils, the threshold values continues to rise, making the soil progressively more salinised. The successive ratoon crop is thus only half as salt tolerant as plant crop and the difference in salt tolerance between the varieties diminish during the successive year and the deleterious effects of salinity become more apparent for each ratoon cycle (Vaieldivia 1978).

Excess of chloride salts had negative impact on phosphorus uptake and its availability in several crops (Gomez and Torres 1993). Additive NaCl causes sharp decline in phosphorus uptake and has depressed growth in sugarcane. Phosphorus adsorption was reduced when NaCl concentrations either in soil or in solution culture was increased in clover (Ravikovitch and Yoles 1971) and barley (Santa-Maria *et al.* 1997). Vacuolar inorganic phosphorus concentrations in lupin roots were decreased while salinity reduced phosphorus adsorption in cotton plants (Martinez and Lauchli 1994).

Several studies on variations in salinity tolerance in sugarcane varieties have been reported (Hunsigi 1993, Moore 1987, Tanimoto 1969) and Liu (1967) examined the differences in salt tolerance as a tool to develop salt tolerant varieties while Krisovich *et al.* (1986) claimed yields could be improved without increase of ion

*Corresponding author: E-mail: ramakantrai@rediffmail.com

concentrations in cells. However systematic work on salinity stress in relation to phosphorus uptake, distribution of its fractions and their impacts on growth and sucrose contents in sugarcane are lacking. As varieties under salt stress might be different in phosphorus utilization potential through its fractions and sugar accumulation during growth cycle, the present work was taken up to study the effects of sodium salt concentrations on soil properties, phosphorus fractions and sucrose contents during growth cycle.

Stalks of sugar cane varieties CoLk 8102 and Co 1148 (*Saccharum* spp. hybrids) (after 10 months of growth), were cut to obtain single bud setts of the same girth (approximately 2.3 cm). These bud setts were raised in plastic trays filled with sand and earthen pots with soil and they were regularly irrigated so that seedlings were raised after 35 d of planting. The pots were laid in six replications in completely randomized block design (CRD) and plants were irrigated with saline water under seven treatments (T1-T7) prepared by dissolving sodium chloride, sodium sulphate and their combinations in deionised water as given in Table 1. Phosphorus fractions were separated after 300 d of the growth in young leaf of both cultivars by method of Hall and Hodges (1966). Sucrose% was determined in cane juice by method of Meade and Chen (1977). Data are mean of three replicates and factorial analysis of the data was tested by analysis of variance (ANOVA). Regression analysis and correlation coefficients were calculated using MS Excel statistical tools to assess the interrelationships

Table 1. Concentrations of salt and osmotic potential of irrigation water used for inducing salinity (ion) stresses.

| Treatments | | Salt Concentration (mg eqL ⁻¹) |
|---|----|---|
| Control | T1 | Deionised water |
| NaCl I | T2 | 34.2 |
| NaCl II | T3 | 205.1 |
| Na ₂ SO ₄ I | T4 | 53.5 |
| Na ₂ SO ₄ II | T5 | 353.5 |
| NaCl I + Na ₂ SO ₄ I | T6 | 17.4 +24.8 |
| NaCl II+ Na ₂ SO ₄ II | T7 | 105.3+176.3 |

between treatments means across the variety amongst different parameters. Treatments were considered to be significant when $p < 0.05$.

Inorganic-P fractions were found to be higher in CoLk 8102 as compared to Co1148 while organic P fractions were higher in Co 1148 with all treatments. The inorganic-P fraction was maximum in CoLk 8102 and was 13% higher than Co 1148. Contrary to inorganic-P, organic-P fraction was higher in Co 1148 with all treatments than CoLk 8102. While the organic-P concentrations increased at all salt levels in both varieties, the residual-P decreased with treatments as compared to control (Table 2). Also residual P contents were higher in CoLk 8102 than in Co 1148. Acid soluble phosphorus, lipid phosphorus, nucleotide and nucleoprotein P were adversely affected by all treatments in both varieties (Table 2). The maximum organic-P was in form of nucleoprotein-P in Co 1148. Acid soluble-P was higher in Co1148 ranging from 10-60% with different treatments. Maximum increase of 60% was recorded with T3 followed by 38 and 33% in T5 and T7. Similar trend was obtained in lipid and nucleotide-P wherein the percent increase in Co 1148 as compared to CoLk 8102 was in range 10-33% and 11-50% respectively.

Significant reduction in sucrose contents occurred with T7, there was significant reduction by 89 and 80% in CoLk 8102 and Co1148. Over all, in Co 1148, the sucrose contents were higher than Co Lk 8102 by 14, 37 and 48% with T7, T5 and T3, respectively.

Decreased saturation% causes clogging of soil pores by cation and anions leading to decrease in water holding capacity of soil and finally creates water deficit and nutritional imbalance in plants. Our results have indicated that treatments except, T2 and T4, where the concentrations were low raised soil pH and calcium carbonate levels. The increase in pH and CaCO₃ percent was higher in CoLk 8102 than Co1148 implicating the growth attributes. The slower growth processes under salinity in both varieties at both stages are explained to be due to the fact that increased pH directly interferes with transmembrane pH gradient, electropotential gradients and proton anion co-transport at

Table 2. Phosphorus fractions (%) in sugarcane leaf laminae.

| | Inorganic Phosphorus | Acid soluble Phosphorus | Lipid Phosphorus | Nucleotide Phosphorus | Nucleoprotein Phosphorus | Final Residue Phosphorus | CD (p=0.05) |
|------------------|----------------------|-------------------------|------------------|-----------------------|--------------------------|--------------------------|-------------|
| CoLk 8102 | | | | | | | |
| T1 | 59±0.23 | 5± 0.11 | 8±0.23 | 5± 0.11 | 17± 0.09 | 6± 0.05 | 0.04 |
| T2 | 47± 0.11 | 9± 0.31 | 10± 0.11 | 8 ± 0.11 | 21± 1.11 | 5±0.02 | 2.51 |
| T3 | 64±0.12 | 2± 0.23 | 7± 0.22 | 4 ±0.23 | 19± 1.21 | 4 ±0.05 | 1.22 |
| T4 | 51 ±0.11 | 7± 0.11 | 9± 0.11 | 7 ±0.20 | 17± 1.01 | 9 ±0.01 | 0.21 |
| T5 | 62 ±0.21 | 5 ± 0.22 | 8± 0.01 | 6 ± 0.21 | 15± 1.01 | 4 ±0.03 | 0.02 |
| T6 | 37±0.11 | 10± 0.11 | 12± 1.04 | 9 ± 0.11 | 28± 1.02 | 4 ±0.04 | 2.11 |
| T7 | 67±0.23 | 4 ± 0.34 | 6± 0.34 | 2 ± 0.01 | 18±0.09 | 3 ±0.01 | 0.90 |
| Co 1148 | | | | | | | |
| T1 | 48±0.31 | 6±0.20 | 10 ±0.12 | 7 ±0.27 | 19±0.13 | 10±0.14 | 0.02 |
| T2 | 43± 0.03 | 10±0.30 | 13 ±0.14 | 9 ±0.31 | 23 ±0.11 | 2± 0.09 | 0.03 |
| T3 | 54± 0.15 | 5 ±0.43 | 11 ±0.13 | 6 ±0.02 | 21 ±0.92 | 3± 0.02 | 0.32 |
| T4 | 41± 0.41 | 9 ±0.33 | 10±0.14 | 9 ±0.34 | 19 ±0.72 | 12±0.03 | 0.08 |
| T5 | 52± 01.23 | 8 ±0.01 | 11 ±0.11 | 8 ±0.51 | 17 ±0.46 | 4 ± 0.03 | 0.12 |
| T6 | 32±0.43 | 12±0.12 | 10 ±0.31 | 11 ±0.12 | 33 ±0.39 | 2±0.04 | 0.01 |
| T7 | 58 ±0.53 | 6 ±0.23 | 9 ±0.43 | 4±4.17 | 21 ±0.28 | 2 ±0.01 | 0.02 |

F-interaction analysis for phosphorus fractions in leaf laminae: Treatment (Tr) S (Significant); Variety (V), S; Tr x V, S., Inorganic phosphorus: (Tr) S; (V), S; Tr x V, S; Acid soluble Phosphorus: (Tr) S; (V), S; Tr x V, S, Lipid Phosphorus: (Tr) S; (V), S; Tr x V, S, Nucleotide Phosphorus (Tr) S; (V), S; Tr x V, S, Nucleoprotein Phosphorus (Tr) S; (V), S; Tr x V, S, Final Residue Phosphorus (Tr) S; (V), S; Tr x V, S, ± SD (Standard deviation of mean of three replicates) T1: Control, T2: NaCl I, T3: NaCl II, T4: Na₂SO₄ I, T5: Na₂SO₄ II, T6: NaCl I + Na₂SO₄ I, T7: NaCl II + Na₂SO₄ II

plasmamembrane and thus inhibit root growth and its elongation.

Increasing calcium carbonate percent levels at higher pH with higher salt treatments further support the poor growth attributes, lower sucrose contents and its higher impact in CoLk 8102 than Co 1148. The disproportionate presence of sodium in both the cellular and extra cellular compartments, negatively impacts on acquisition and homeostasis of phosphates. The negative effects of salts occur in form of ionic interaction between Ca²⁺ and cellular compartments such as cell wall pectin's and membrane phospholipids which are highly sensitive to excess cations such as Na⁺. Although the sites typically have much affinity for Ca²⁺ than Na⁺, the larger molar Na⁺ : Ca²⁺ ratio leads to dissociation of Ca²⁺ from its binding sites affecting the integrity of cell walls and cell membranes (Apse *et al.* 2007). Calcium ions play a role in protecting the roots and a molar ratio of calcium to total cations of 0.15 is needed for maximal growth. Higher salt concentrations at higher pH lead to increase

in this ratio, hampering the water permeability and aeration more significantly in CoLk 8102 than in Co 1148, causing the consequent effects on the growth attributes and sucrose contents (Fig. 1).

The optimum phosphorus requirement for growth is 0.3-0.5% of plant dry matter during vegetative phase (Marschner 1995). With increase in soil pH, the available phosphorus gets precipitated in form of tricalcium phosphate due to de-sorption and adsorption of phosphorus hindering its mobility and implicating root/shoot growth (Hinsinger 2001). Our results showed that treatments led to significant reduction in phosphorus contents in the morphological components of both varieties at early growth stage significantly and the contents were lower than optimal requirement. As the soil properties of CoLk 8102 were affected more, their phosphorus content were significantly lesser than Co 1148 at both early and maturity phase (Table 2) in all morphological components and was reflected in sucrose contents. Inorganic-P contents remained unutilized for

SODIUM SALT INDUCED CHANGES IN P- FRACTIONS OF SUGARCANE

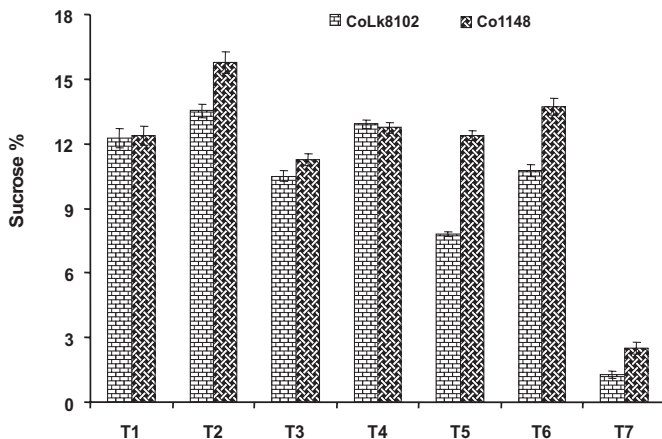


Fig. 1. Effects of salinity levels on sucrose contents in two sugarcane cultivars at different saline levels. T1: Control, T2: NaCl I, T3: NaCl II, T4: Na₂SO₄ I, T5: Na₂SO₄ II, T6: NaCl I + Na₂SO₄ I, T7: NaCl II + Na₂SO₄ II. Vertical bars represent \pm SD (Standard deviation of mean of three replicates).

growth process in CoLk 8102, whereas their lesser contents in Co 1148 suggested its better utilization. Our results are supported by reports on depressions in phosphorus uptake and translocations in cotton and tomato (Martinez and Lauchli 1991, 1994, Awad *et al.* 1990), where the utilization efficiency of phosphorus in leaves gets depressed with increasing salt concentrations.

The inorganic-P contents in CoLk 8102 was higher than Co 1148 and thus reduction in leaf area, tiller number, plant height and sucrose contents were significantly higher in CoLk 8102. Decrease in sucrose contents at higher salt levels in CoLk 8102 is explained by reports on decrease in phosphorylation and carbon partitioning in light-dark cycle at low inorganic-P contents (Robinson and Giersch 1987). Contrary to this, organic fractions namely acid soluble, lipid, nucleic acid and nucleoprotein phosphorus were significantly higher in Co 1148, compared to CoLk 8102. In CoLk 8102, utilization in lipid -P, nucleotide-P, nucleoprotein-P was lesser than Co 1148 with different treatments indicated poor utilization of phosphorus in CoLk 8102. The lower pool size of inorganic-P in Co 1148 thus maintained high metabolic activities under salt stress as compared to CoLk 8102. Increased partitioning into lipid P, nucleoprotein P and low residual P further was able to provide it with tolerance potential against salinity stress.

Varying concentrations of sodium chloride and sodium sulphate decreased the inorganic and organic P fractions in sugarcane during its growth. The salts increased residual-P fractions while decreased organic phosphorus fractions. Reduction in acid soluble, lipid, nucleotide and nucleoprotein phosphorus contents in sugarcane further suggested the possibility of reduction in conversion of inorganic-P fractions to organic-P fractions during growth cycle and overall reduction in total tissue phosphorus contents, adversely affected the sucrose contents.

ACKNOWLEDGMENT

We thank the technical staff and Research fellows at the Division of Plant Physiology and Biochemistry, IISR, Lucknow for assistance during experimentation.

REFERENCES

- Apse, M.P. and Blumwald, E. (2007). Na⁺ transport in plants. *FEBS Lett.* **581**: 2247-2254.
- Awad, A.S., Edwards, D.G. and Campbell, L.C. (1990). Phosphorus enhancement of salt tolerance of tomato. *Crop Sci.* **30**: 123-128.
- Ginoza, H. and Moore, P.H. (1985). Screening sugarcane varieties for tolerance to salinity. *Report of the Hawaiian Sugar Technologists.* **43**: FE5-FE6.
- Gomez, P.J.F. and Torres, A.J.S. (1993). Effect of salinity in the development of production of two varieties of sugarcane (*Saccharum* spp). *Serre Tecnica- Centro, de Investigacion de la cana Azucar de Columbia.* **12**: 35-36.
- Hunsigi, G. (1993). Production of sugarcane-Theory and practice. Advance Series in Agricultural Sciences, Springer Verlag, Berlin, Heidelberg. **21**: 37-40.
- Hall, J.R. and Hodges, T.K. (1966). Phosphorus metabolism of germinating oat seeds. *Plant Physiol.* **41**: 1459-1464.
- Hinsinger, P. (2001). Bioavailability of soil Inorganic P in the rhizosphere as affected by root induced chemical changes: A review. *Plant and Soil.* **237**: 173-195.
- Jackson, M.L. (1973). Soil chemical analysis, Prentice Hall of India, Ltd, New Delhi, pp. 498.

- Kresovich, S., McGee, R.E., Drawe, H.J. and Rivera, J.L. (1986). Variability of agronomic characters in populations of tissue culture derived and vegetatively propagated sugarcane. *Proc of 19th Congress ISSCT*, pp. 528-532.
- Liu, L.J. (1967). Salinity effect on sugarcane germination, growth and root development. *J of Agric Univ Puerto Rico*. **3**: 201-209.
- Martinez, V. and Lauchli, A. (1994). Salt induced inhibition of phosphate uptake in plants of cotton (*Gossypium hirsutum* L.). *New Phytol.* **125**: 609-614.
- Moore, P.H. (1987). Breeding for stress resistance. In: Heinz DJ (ed), Sugarcane improvement through breeding. Elsevier Amsterdam, pp. 503-542.
- Meade, G.P. and Chen, J.C.P. (1977). Cane Sugar Handbook, Wiley, New York
- Marschner, H. (1995). Mineral nutrition of higher plants. 2nd Edition London UK, Academic Press, pp 489.
- Martinez, V. and Lauchli, A. (1994). Salt induced inhibition of phosphate uptake in plants of cotton (*Gossypium hirsutum* L.). *New Phytol.* **125**: 609-614.
- Robinson, S.P. and Giersch, C. (1987). Inorganic phosphate concentration in the stroma of isolated chloroplasts and its influence on photosynthesis. *Aust. J. Plant Physiol.* **14**: 451-462.
- Ravikovitch, S. and Yoles, D. (1971). The influence of phosphorus and nitrogen on millet and clover growing in soils affected by salinity. 1. Plant composition. *Plant and Soil.* **35**: 568-588.
- Santa-Maria, G., Rubio, F., Dubcovski, J. and Rodriguez-Navaro, A. (1997). The HAK1 gene of barley is member of large gene family and imports a high affinity potassium transporter. *The Plant Cell.* **9**: 2281-2289.
- Tanimoto, T.T. (1969). Differential physiological response of sugarcane varieties to osmotic pressure of saline media. *Crop Sci.* **9**: 683-688.
- Vaildivia, V.S. (1978). Effect of excess sodium on sugarcane yield. *16th Proc. ISSCT*, Brazil, pp. 861-866.