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Varied Patterns of Sprouting and Nutrient Status of Sugarcane Sprouts in Simulated and Natural Saline/Sodic Soils Across two Growing Seasons

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Abstract

Salinity/sodicity (EC/SAR) of soil arises due to combination of cations and anions, which disturbs plant metabolism. Sugarcane (*Saccharum officinarum* L.), ranked as a medium salt-sensitive species, is grown in Spring and Autumn seasons in the subcontinent, with differential growth behaviors in both the seasons. In this study sprouting potential, growth and tissue ionic and nutrient status in natural and simulated soil conditions were determined to compare the effects of two growing seasons and natural and simulated saline/sodic soil using salinity/sodicity tolerant (CPF-246) and sensitive (S-2003-US-778) sugarcane clones. The EC (dS/m)/SAR (sodium adsorption ratio) treatments were 4/26 and 5/30 in the selected natural field and those of 5/25 and 6/30 in the simulated soil. The data were recorded after 30 days of sowing the setts for nodal bud sprouting, length and dry mass of shoot and root, tissue ionic contents for Na^+, K^+, Ca^{2+}, Mg^{2+}, N (NO_3^--N), P (PO_4^{3-}-P) and S (SO_4^{2-}-S). In both the seasons, CPF-246 had greater sprouting percentage, and sprouts length and dry weights than S-2003-US-778. There was an increase in the tissue concentration of Na^+ and Cl^- in both the clones under either soil conditions. The EC/SAR treatments reduced the amounts of K^+, Ca^{2+}, Mg^{2+}, N, P, S and K^+/Na^+ ratio both shoot and root as compared to respective controls although the reduction was greater in shoot than root. Sugarcane growing seasons had differential influence on the salinity/sodicity tolerance, since reduction in the studied parameters was greater in the autumn season. Of the two sugarcane growing media natural field conditions were more adverse than the simulated conditions. A comparison of sugarcane clones revealed that CPF-246 was more tolerant of salinity/sodicity conditions than S-2003-US-778 when grown under of the soil types and seasons. In conclusion, although natural saline/sodic fields were quite more damaging, the salinity/sodicity sensitivity in sugarcane is determined by tissue concentration of macronutrients, and the seasons have great influence on the performance of sugarcane clones.

Keywords: Sprouting, Simulation; Ionic toxicity; Essential nutrients; Sugarcane; Pakistan

Introduction

Salinity and sodicity of soils, among others, are great debacles to the utilization of these growth resources. Different plants respond in different ways to salinity/sodicity. Some plants prevent the entry of solutes reaching the main aqueous stream thus making them able to grow in saline conditions (Tester and Davenport, 2003). The excess of solutes that reach plant tissues and cells are regulated by mechanisms such as exclusion of toxic ions to lower leaves, their sequestration in the vacuole and long distance transport of ions within the plant (Hameed *et al.*, 2010; Hakim *et al.*, 2014). Salinity delays seed germination and reduces the chlorophyll contents of leaves (Jamil *et al.*, 2007). Selective nutrient uptake by crops is yet another mechanism to control the nutrient imbalance (Taiz *et al.*, 2015), but salinity antagonizes with essential nutrients and causes their deficiency and disturbs the cellular functions (Langford, 2002).

In the Indian Subcontinent sugarcane is a popular crop among the farmers, and is cultivated in Autumn and Spring seasons to fulfil the table sugar need of billions of people. Province of Punjab in Pakistan ranks first in sugarcane cultivation with respect to area and production. Sugarcane has shallow fibrous root system, which is continuous with the node. Each node has an immature bud with 1–3 rings of root primordia that help maintain moisture of buds and develops roots during sprouting. Immature buds consist of mesophyll cells, vascular bundles and elongating bud leaves that sprout when favorable conditions prevail (Rasheed, 2009). The internodes comprise of wax-coated parenchymatous cells having photo-assimilates (mainly sucrose) and vascular bundles (Anonymous, 2004; Wahid *et al.*, 2009). Recent studies also aim at developing genetically modified stress tolerant sugarcane clones (Kumar *et al.*, 2014). Nonetheless, the responses of sugarcane materials and the changes in the physiological phenomena during sprout development in

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natural saline lands are scarcely investigated.

Increased salinity/sodicity of soils are twin menaces that impede the plant growth and development enormously (Bernstein, 1975; Wang *et al.,* 2013). Available information has revealed that NaCl and $CaCl_2$ (18:1 ratio) influenced the sugarcane growth and productivity by declining the production of nrw leaves instead of declining the area and transpiration of leaves (Plaut *et al.,* 2000). While investigating the influence of salinity and waterlogging on of sugarcane materials Kahlown and Azam (2002) reported that no sugarcane clone could survive above salinity level of 12 dS/m and water table depths of less than 1–2 m. The application of salinity at advanced growth stages, revealed that although salinity stress reduced the can yield but had no influence on the juice quality of harvested plants (Wiedenfeld, 2008). Until recently it is known that the partitioning of essential nutrients to the sprouting buds is a determining factor in salinity tolerance of sugarcane (Wahid *et al.,* 2009). This is particularly important in view of the fact that transition from immature to mature buds and eventually production of sprouts are closely related (Rasheed *et al.*, 2016).

Sugarcane is a salt medium-sensitive crop with salinity tolerance threshold of 1.7 dS m^{-1} and is regarded as medium sensitive crop species (Bernstein *et al.,* 1966) and salinity tolerance limit of around 3.5 dS m^{-1} (Wahid *et al.,* 1997). It is a cross-pollinated crop species and different genotypes are expected to behave individualistically for tolerance to abiotic stresses. Large and polyploid genome (10 Gb) of sugarcane (Mendes-Souza *et al.,* 2011) complicates the elucidation of salinity/sodicity tolerance phenomena. The *in situ* testing of sugarcane materials for salinity/sodicity tolerance remains a highly pragmatic option for understanding the growth responses of sugarcane.

Considering the graveness of the matter, the reclamation of saline/sodic lands and their profitable exploitation has been the subject of interest (Qadir *et al.,* 2001; Arshadullah *et al.,* 2012). Sugarcane is amongst the crops planted in two seasons and show differential growth behaviors. It is hypothesized that salinity tolerance of sugarcane is determined by composition of soil medium and prevailing conditions during sowing seasons. Therefore, the determination of growth responses of sugarcane in both the seasons using natural and simulated soil systems was considered of great interest for understanding the mechanism of salinity/sodicity tolerance in different growing seasons. The present study was aimed at to determine changes in sprouts growth and tissue ionic and nutrient relations and elucidating possible mechanism of salinity/sodicity tolerance comparing two selected differentially salinity/sodicity tolerant sugarcane clones in the natural and simulated saline/sodic fields in Autumn and Spring seasons for two years.

Materials and Methods

The experiments were performed in simulated conditions in Old Botanical Garden, University of Agriculture, Faisalabad, while field trials were carried out at Saline Soil Research Institute (SSRI), Pindi Bhattian, Pakistan in Autumn and Spring seasons of 2013–2014 and 2014–2015. The stalks of both the sugarcane clones were obtained from Sugarcane Research Institute, Ayub Agricultural Research Institute, Faisalabad, Pakistan. For Autumn and Spring season experiment under natural fields or simulated conditions, the sugarcane setts were planting in third week of September and last week of February, respectively, while harvesting was done after 72 days after sprouting. The selected natural saline/sodic field soil had EC/SAR of 4/26 and 5/30, while control used was reclaimed field (EC= 2.75 dS m^{-1} and SAR= 14.5). In the natural saline/sodic field, the composite soil samples were collected from the upper 0–30 cm soil depth mixed thoroughly and analyzed for physico-chemical properties (Moodie *et al.,* 1959; Table 1). Since Pindi Bhattian is located just 50 km away from Faisalabad there were insignificant difference in the climate both the locations. For Autumn season, weather was dry with no rainfall, and average day/night temperature was 25ºC±3/17ºC±3. The RH ranged from 62 to 72%. Spring season was dry with no precipitation, and average day/night temperature was 27ºC±4/17ºC±2. The RH ranged from 48 to 54%. On the termination of experiments in Autumn season the average temperature was 22ºC±2/14ºC±2 and RH was 68 to 75%, while in Spring season the average temperature 31ºC±3/20ºC±3, whereas RH was 42 to 48%.

For natural field studies, 100 single noded buds of each of a salinity tolerant (CPF-246) and a sensitive (S-2003-US-778) sugarcane clones were sown in triplicate in the plots of both the natural and simulated salinity/sodicity levels. Normal irrigation practices were followed. The characteristics of pumped ground water to irrigate the fields were: pH 8.1, EC 1.7 dS m^{-1}, RSE 15.2 meq L^{-1} and bicarbonates 17.5 meq L^{-1}. The experiments were laid out in randomized complete block design with three replications.

For soil simulated trials, 40 kg of garden soil (EC= 2.5 dS m^{-1} and SAR= 13.5) was filled in plastic tanks (1.35 m × 0.75 m × 0.45 m) and were planted with 25 buds in each. The experimental design was randomized complete block design with five blocks. The factors were sugarcane clones and salt treatments. Commercial grade NaCl, Na_2SO_4, $CaCl_2$ and $MgSO_4$ salts were thoroughly mixed in the proportion of 3:4:2:1 to develop artificial EC/SAR of 5/25, 6/30 on 50% field capacity moisture contents in addition to original soil status comparison. Quadratic equation was used to calculate different amounts of Na^+, Ca^{2+} and Mg^{2+} salts for the development of desired levels of EC and SAR (Richards, 1954; Mahmood *et al.,* 2009). After three days, 25 single noded buds of both the sugarcane clones were sown in the plots in each treatment and each treatment was replicated thrice. The characteristics of pumped ground water to irrigate the fields were: pH 7.5, EC 0.8 dS m^{-1}, RSE 10.2 meq L^{-1} and bicarbonates 7.5 meq L^{-1}.

For both sets of experiment, the nodal bud sprouting

was observed for 72 days, and then harvested. The number of nodal roots was counted and their shoot and root length was measured. The dry weight of shoot and roots was determined after drying both the parts in an oven at 70ºC for seven days.

For the determination of ionic concentrations in the sprouts shoot and root, 0.25 g of dried ground samples was properly digested using a mixture of nitric acid and perchloric acid (3:1 ratio) initially at 100ºC and then gradually raised the temperature to 250ºC. The samples were digested till the time the sample became clear. The samples were filtered and made the volume up to 50 mL using distilled water. The amounts of Na^+ and K^+ were measured on flame photometer (Sherwood 410, UK), while those of Ca^{2+} and Mg^{2+} were measured on Atomic Absorption Spectrophotometer (AA100, Perkin Elmer, USA), as described by Yoshida *et al.* (1976). Total amount of P (PO_4^{3-}-P) in the samples was determined by Molybdate-Vanadate reagent method and N (NO_3^--N) was analyzed by chromotropic acid methods (Kowalenko and Lowe, 1973). For the determination of S (SO_4^{2-}-S) from the above extract, the Acacia-$BaCl_2$ method of Tendon (1993) was used.

The data for the respective experiments was analyzed for variance analysis separately for both the soil types. Least Significant Difference (LSD) test was used for the comparison of treatment means. The letters have been applied to the data values, where three factor (clones, EC/SAR and seasons) interactions were significant ($P<0.05$). All the statistical analyses were made using Statistix 8.1 computer software.

Results

Bud Sprouting and Sprouts Growth

Under control condition there was non-significant difference in the clones for sett sprouting in both the seasons and simulated and natural soil. However, increased salinity/sodicity (EC/SAR of 5/25 and 6/30) in simulated saline soil consistently reduced this parameter in both the clones although CPF-246 (tolerant clone) exhibited significantly greater sprouting than S-2003-US-778 (sensitive clones). In natural saline/sodic both the clones showed sprouting at EC/SAR of 4/26 being significantly higher in CPF-246 than S-2003-US-778, while no sprouting was observed at EC/SAR of 5/30 in both the clones over the seasons. A comparison of both the soil types and seasons revealed that natural saline/sodic soil was more damaging to sprouting than simulated saline soil, while autumn season was more adverse than spring season (Fig. 1a).

The number of nodal roots in simulation study in control set was similar in both the clones, but at increased EC/SAR treatments it was reduced marginally in Spring season but substantially in Autumn season, although CPF-246 performed much better by showing a lower reduction in the number of roots. In natural control fields both the clones exhibited greater number of root in Spring season but slightly reduced one in Autumn season. At EC/SAR of 4/26 both the clones indicated a similar number of nodal roots in both the seasons, while at EC/SAR of 5/30 no root production was noticed in any clone (Fig. 1b).

The shoot length in simulation study in control sprouts was similar in both the clones, but it was greatly reduced under EC/SAR treatments, although it was greater in Spring season and much reduced in Autumn season. In natural control field, CPF-246 followed by S-2003-US-778 exhibited greater number of root in Spring season but considerably reduced one in Autumn season. At EC/SAR of 4/26 significantly longer shoots were measured in CPF-246 than S-2003-US-778, while the Spring season was far more favorable for shoot length than Autumn season. At EC/SAR of 5/30 in natural field no sprouting was noticed in any clone (Fig. 1c). Root length in simulation study in control sprouts was higher in CPF-246 than S-2003-US-778. Under EC/SAR treatments in the simulation study, root length Spring season and much reduced in Autumn season, while CPF-246 excelled in both the seasons. In natural control field, CPF-246 compared to S-2003-US-778 exhibited greater increase in root length under control or at EC/SAR of 4/26 and a similar trend was observed in both the seasons. Nonetheless, at EC/SAR of 5/30 no root production was seen in any clone (Fig. 1d).

In the simulation study in control sprouts, shoot dry weight was greater in S-2003-US-778 than CPF-246. However, under EC/SAR treatments the shoot dry weight was more reduced in S-2003-US-778 in both the seasons. Spring season was considerably less damaging to the shoot dry weight of both the clones than Autumn season. In natural control field, CPF-246 exhibited greater shoot dry weight than S-2003-US-778 in both the seasons. At EC/SAR of 4/26, although reduction in both the clones shoot dry weight was more in CPF-246 than S-2003-US-778, while the Spring season was far more favorable for shoot length than Autumn season (Fig. 1e). As for root dry weight in simulation study in control sprouts, the root dry weight was higher in CPF-246 than S-2003-US-778 in both the seasons. Under EC/SAR treatments in the simulation study, root dry weight consistently declined irrespective of the season, nonetheless Spring season was quite favourable than Autumn season, whereas CPF-246 performed better than S-2003-US-778 in both the seasons. In natural field, under control condition, CPF-246 compared to S-2003-US-778 exhibited markedly increased root dry weight under control or 4/26 EC/SAR treatments and similar trend was observed in both the seasons. Nonetheless, at EC/SAR of 5/30 no root production took place in any clone (Fig. 1f).

Sprouts Tissue Elemental Relations

In simulated experiment under control condition, the Na^+ content was the lowest in the shoot of both the clones. With an increase in EC/SAR of 5/25 and 6/30, a concomitant increase in shoot Na^+ was noticed in both the clones although

Table 1: Physico-chemical properties of soil at Soil Salinity Research Institute Farm, Pindi Bhattian (after Arshadullah *et al.*, 2012)

Soil characteristics	EC/SAR (2.4/19)*	EC/SAR (4/26)	EC/SAR (5/30)	Garden soil**
Color	Light brown	Dark brown	Blackish brown	Brown
Textural class	Sandy clay loam	Sandy clay loam	Sandy clay loam	Loam
ECe (dS m^{-1})	2.4	4.0	5.0	2.50
SAR (mmol L^{-1})	19.0	26.0	30	13
pH	8.7	9.21	9.34	7.28
Organic matter (%)	0.80	0.64	0.59	0.95
Sand (%)	63.0	60.0	60.0	43.5
Silt (%)	17.0	18.0	18.0	27.5
Clay (%)	20.0	22.0	22.0	29.0
Available N (mg kg^{-1})	6.5	5.8	5.4	7.3
Available P (mg kg^{-1})	4.3	4.1	3.9	5.3
Available K (mg kg^{-1})	23.8	20.4	19.2	26.3

*used as control soil for natural saline/sodic fields
**used to develop required EC/SAR levels in soil simulated study

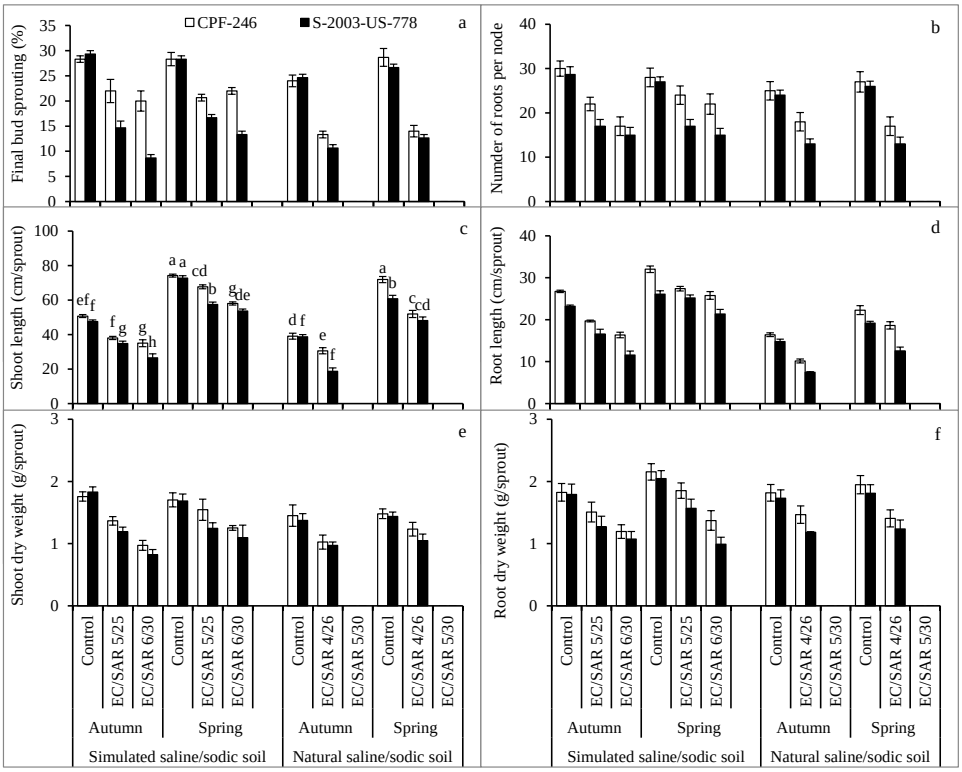

Fig. 1: Sprouts growth attributes of CPF-246 and S-2003-US-778 sugarcane clones grown in two planting seasons; Autumn and Spring seasons in both simulated conditions and natural field conditions. Missing bars in this and subsequent figures in this section indicate the mortality of lines under given levels of salinity/sodicity

the accumulation was greater in S-2003-US-778 as compared to CPF-246 whilst this increase was greater in Autumn season. In natural control field, no difference was noticed in the clones in the seasons. However, EC/SAR of 4/26 enhanced the shoot Na^+ level almost equally in the clones in both the seasons (Fig. 2a). As regards root Na^+ content, in simulation control plot, a lowest Na^+ was noted in the root of both the clones, while enhanced EC/SAR substantially increased this ion although more in the S-2003-US-778 than CPF-246, and was greater in Autumn than in Spring season. In natural control field, although both the clones displayed the root Na^+ accumulation trend similar to the simulation study, a markedly increased root Na^+ was noticed in S-2003-US-778 at EC/SAR of 4/26 in Autumn planting season than in the Spring season (Fig. 2b). In simulated and natural control treatments, shoot K^+ was higher and it decrease with the increase in EC/SAR of 5/25 and 6/30 and EC/SAR of 4/26 in natural fields, respectively for Autumn

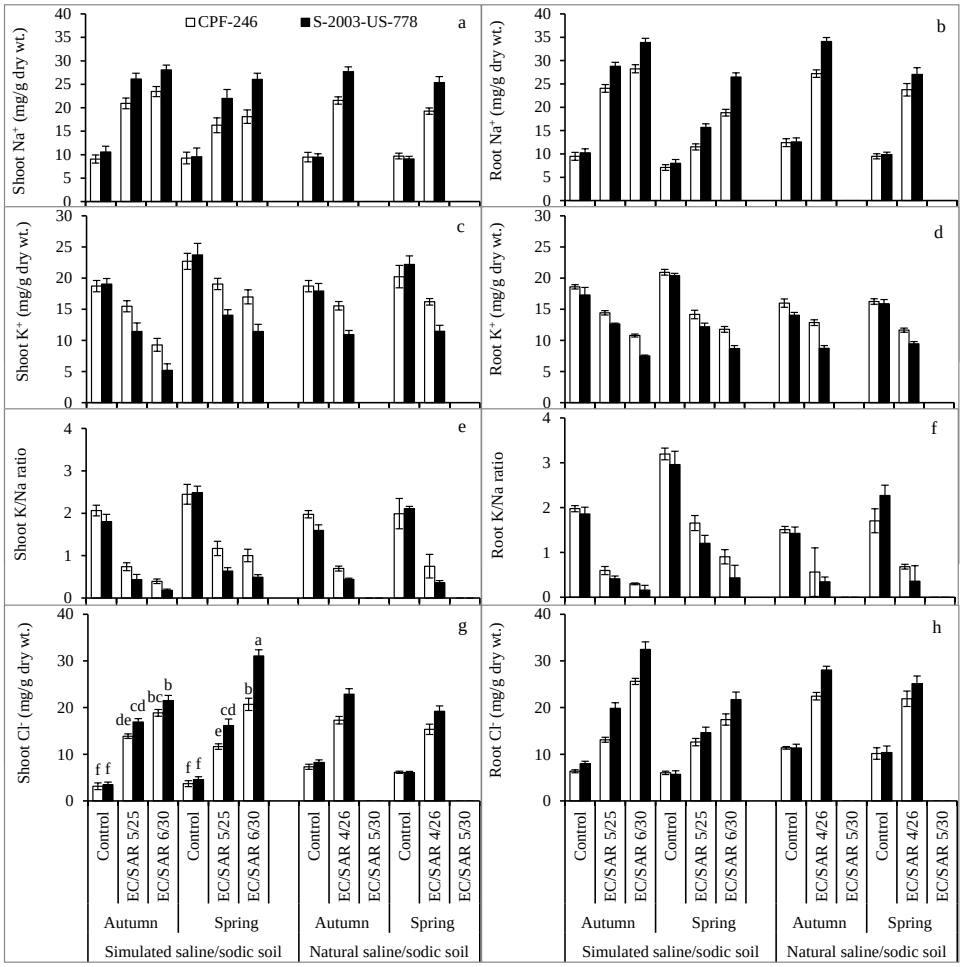

Fig. 2: Sprouts shoot and root ionic contents of CPF-246 and S-2003-US-778 sugarcane clones grown in two planting seasons; Autumn and Spring, in both simulated conditions and natural field conditions

and Spring seasons. However, in simulated and natural saline/sodic soil shoot K^+ was markedly reduced in both sugarcane clones at both EC/SAR treatments and in both planting seasons, nevertheless CFP-246 accumulated greater K^+ in the shoot (Fig. 2c). The root tissue also followed the pattern of K^+ accumulation similar to shoot, although both the clones accumulated the highest K^+ in Spring season in normal simulated soil but not in the natural fields in both the seasons (Fig. 2d).

In natural control field, a lower K^+/Na^+ ratio was noticed in shoot of both clones under control condition in Spring season. EC/SAR of 4/26 suppressed K^+/Na^+ ratio of both the clones more in S-2003-US-778 in both the seasons (Fig. 2e). Results for root K^+/Na^+ ratio were non-significant ($P>0.05$) for both the clones at both EC/SAR treatments as well as conditions. In simulated study root K^+/Na^+ ratio was high under control condition that considerably decline at EC/SAR of 5/25 more in Autumn season as compared to Spring season (Fig. 2f).

There was non-significant difference for shoot Cl^- of both CPF-246 and S-2003-US-778 for both EC/SAR treatments. Shoot Cl^- increased with under EC/SAR of 6/30 of which highest shoot Cl^- was noticed in Spring as compared to Autumn in simulated saline/sodic study. In natural saline/sodic fields shoot Cl^- increase with increase in EC/SAR of 4/26 in Autumn season as compared to Spring season (Fig. 2g). Under control, root Cl^- was non-significant for both sugarcane clones as well as seasons Root Cl^- of CPF-246 and S-2003-US-778 were non-significant ($P>0.05$) for both saline/sodic treatments and both growing seasons. Under simulated EC/SAR treatments root Cl^- was significantly higher at EC/SAR of 6/30 in Autumn season as compared to Spring season. Under natural saline/sodic condition, S-2003-US-778 showed significant greater root Cl^- at EC/SAR of 4/26 in both planting seasons (Fig. 2h).

Data revealed that under simulated or natural fields, generally the shoot nutrient contents were greater than root (Fig. 3a-j). Under different EC/SAR treatments, the contents of N, P, S Ca^{2+} and Mg^{2+} were higher under control conditions, while simulated or natural conditions,

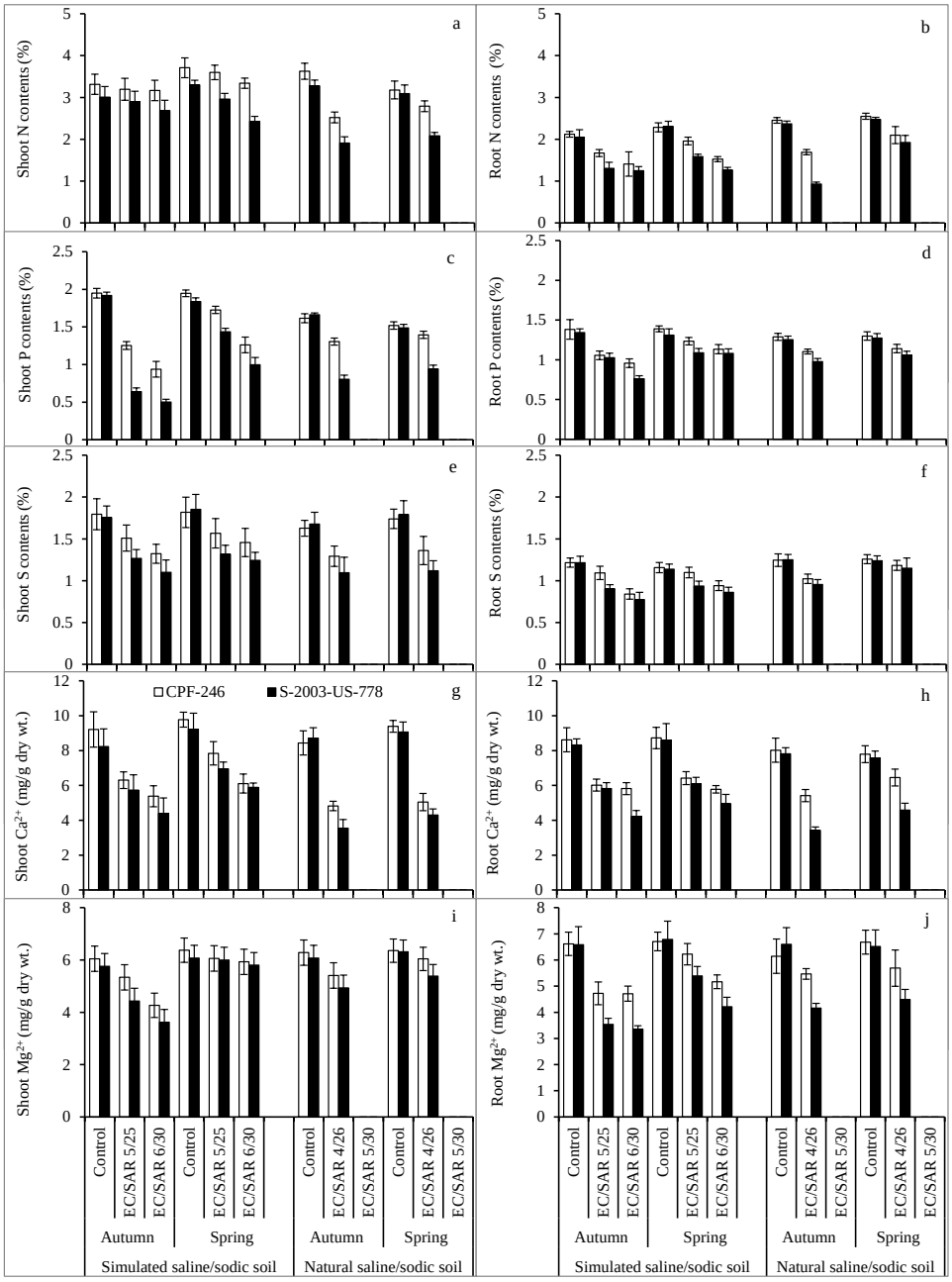

Fig. 3: Sprouts shoot and root nutrient contents of CPF-246 and S-2003-US-778 sugarcane clones grown in two planting seasons; Autumn and Spring, in both simulated conditions and natural field conditions

EC/SAR treatments reduced their contents to a great extent, although with differences among the contents of the nutrients (Fig. 3a–j). Spring season was quite more supportive in acquiring all the essential nutrients in shoot and root of sprouts of both the sugarcane clones under control or EC/SAR treatments irrespective of simulation or natural experimental arrangement. However, a comparison of shoot and root tissues revealed that shoot tissue exhibited greater essential nutrient contents than the root tissue under control condition, although N, P and S contents were greater than the others. However, EC/SAR treatments were more adverse to these nutrient in the shoot than root (Fig. 3a–f).

Discussion

Testing sugarcane materials in simulated or natural saline/sodic field conditions may yield different results in different clones. The excess of ions in the saline/sodic fields are known to antagonistically interact and tangibly reduce the

essential nutrient contents (Akhtar *et al.,* 2003; Gupta and Huang, 2014; Mahmood and Ali, 2015). In the present study, both simulated and natural saline/sodic soils reduced the sprouting, elongation and dry mass of sprouts shoot and root. The extent of such a reduction was greater in the natural saline/sodic fields as compared to simulated ones, although the EC/SAR treatments were comparable in both the type of soils. This revealed that in the natural saline/sodic fields there are certain critical factors that impede the sprouts development in natural fields, although tolerant clone (CPF-246) indicated substantially greater growth of sprouts (Fig. 1). A likely factor in differential growth of sprouts in both the soils may be greater compactness of the soil of natural fields while the simulated soil was more pulverized while mixing the salts to attain the required EC/SAR treatments. In addition, the conditions of temperature, relative humidity and precipitation were not much suitable for sprouting in Autumn than in Spring season.

Another factor of great importance is that sugarcane being a tropical to subtropical crop needs relatively higher temperature as the growth progresses. In the Spring season, the temperature and humidity conditions during sugarcane planting is relatively lower and increases as the growth progresses, which favors the sugarcane growth. At this time the sugarcane sprouts have been fully established and can better tolerate the adverse conditions like salinity/sodicity of soil and showing better growth, as has been better manifested by the tolerant clone in this study (Fig. 1). Contrarily, in Autumn season, the temperature is about similar to Spring season at the time of sprouting, which later on declines thus becoming adverse from sugarcane growth, while if soil is saline/sodic, it is an added adversary.

An important finding of the study is an inability of the sprouts to acquire the essential nutrients in requisite amounts. Sprouts shoots of sugarcane lacked this tendency due to higher uptake of Na^+ and Cl^- ions and reduced K^+ uptake and declined K^+/Na^+ ratio (Fig. 2). A greater tissue K^+/Na^+ ratio, as manifested by the tolerant clone in this study, has been established as a criterion of salinity/sodicity tolerance (Porcelli *et al.,* 1995; Kuşvuran, 2012). These toxic ions compete with the uptake of other essential nutrients including N, S, P, Ca^{2+} and Mg^{2+} (Wakeel, 2013; Wang *et al.,* 2013; Gul *et al.,* 2016). All these nutrients are both structurally and functionally involved, and the plant materials capable of acquiring greater amounts of these nutrients under subversive conditions are on an advantage and therefore are promising for growing in saline sodic soils (Taiz *et al.,* 2015). A comparison of two clones showed greater uptake of Na^+ and Cl^- by S-2003-US-778 (sensitive clone), whilst CPF-246 had essential nutrient contents especially N, P and S under EC/SAR treatments (Figs. 2 and 3). These data indicated the inherent tendency of the tolerant clone to acquire greater amounts of essential nutrients and withstand better under salinity/sodicity stress.

In the present study it was found that two differentially salt resistant clones not only exhibited hampered sprouting (more in S-2003-US-778) but also showed reduced expansion of bud shoots and production of roots from the nodal root primordia. Rasheed *et al.* (2016) attributed the reduced and delayed sprouting of sugarcane buds to the enhanced accumulation of toxic ions and production of hydrogen peroxide, a reactive oxygen species (Wahid *et al.,* 2014). We noted that subjecting the sugarcane nodal growing tissues to the salinity/sodicity conditions was more toxic to the shoot bud expansion and production of roots from root primordia most likely due to dual stress of the applied treatments. As nodal bud nutrients decisively determine the success of sprouts production in sugarcane clones (Wahid *et al.,* 2009), declined tissue nutrient contents can be regarded as important criteria of salinity/sodicity sensitivity in sugarcane. Since roots are the first organs to emerge, the explorations on the microanatomical changes in the root initials would be helpful in understanding the mechanism of salinity/sodicity tolerance.

In the studies conducted under artificial or simulated system, the plant behavior is not like that observed in the natural conditions. Since sugarcane is a long-duration crop, it was deemed imperative to study the comparative behavior of the selected tolerant and sensitive varieties by sowing the buds in the selected natural saline/sodic fields with an EC/SAR of 5/25 and 6/30, and to simulate the garden soil closer to these levels using the combination of salts (Richards, 1954; Mahmood *et al.,* 2009). The current study revealed that in simulated soil, both the sugarcane clones in both the seasons sprouted and showed the growth of sprouts shoot and root at all the EC/SAR treatments whilst in the natural fields the sprouting and growth of sprouts was observed only at EC/SAR of 5/25 (Fig. 1). This showed that there are certain interacting factors in the natural saline/sodic fields that were apparently missing in the simulated soil. From the sampling for physico-chemical analysis from the natural field and simulated soil, it was noticed that the soil pan in the natural fields was much harder and less pulverized. On the contrary, the simulated soil was mixed well when the EC/SAR treatments were developed. The physico-chemical properties of the natural field soils, being clayey loam also support this notion (Table 1). Thus more hampered sprouting and growth of sugarcane clones in the natural fields compared to simulated soil is due to the soil compactness, which did not allow sufficient leaching of the toxic ions in the natural field. Further to it, as reported for other crops (Horneck *et al.,* 2007; Kumar and Khare, 2014), both salinity and sodicity damaged the sugarcane sprouts, as compared to alone salinity grown clones (Akhtar *et al.,* 2003).

Conclusion

Although both the clones behaved individualistically under the combined menace of salinity/sodicity. Spring season was much more favorable to the sugarcane sprouting, acquisition of essential nutrients than the Autumn season. Among the nutrients the greater content of N, P and S was more critical

in conferring salinity/sodicity tolerance. Thus for better exploitation of marginally saline/sodic soils, the sugarcane sowing in Spring season can lead to better sprouting and survival of sprouts.

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