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ELUCIDATION OF ADAPTIVE BEHAVIOUR OF SORGHUM [*SORGHUM BICOLOR* (L.) MOENCH] FOR FODDER YIELD AND ITS ATTRIBUTING TRAITS UNDER SALT STRESS

HIMANI PUNIA[1]*, JAYANTI TOKAS[1], ANJU RANI[1], PERNIKA GUPTA[1] AND SATPAL[2]

[1]Department of Biochemistry
[2]Forage Section, Department of Genetics & Plant Breeding
CCS Haryana Agriculture University, Hisar-125 004, Haryana, India
**(e-mail : himanipunia91@gmail.com)*

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SUMMARY

Salt stress has been considered a major limiting factor to crop productivity in arid and semi-arid regions. The present study was conducted to evaluate the sorghum genotypes superior in quality and yield under saline conditions. The two factor experiment was carried out in a completely randomized block design with three replications during the *kharif* season 2018 and 2019. Crude protein content and IVDMD decreased significantly under different salinity levels. The higher reduction being reported in PC-5 than SSG 59-3. Crude protein yield (CPY) and digestible dry matter (DDM) was maximum in SSG 59-3 and minimum in PC-5 at 10 dSm^{-1}. Salt stress showed an adverse effect on yield attributes and yield, so seed yield per plant, green fodder yield (GFY), and dry matter yield (DMY), decreased under salt stress. GFY and DMY were maximum in SSG 59-3 while minimum in PC-5. Better performance was maintained by SSG 59-3 than PC-5. This, SSG 59-3 (salt-tolerant) genotype acclimated better than PC-5 (salt-sensitive) genotype by maintaining the fodder quality and yield and may be exploited in plant breeding programs aimed at developing salt-tolerant sorghum genotypes for salinity prone areas.

Key words : Crude protein, fodder yield, HCN, IVDMD, salinity and sorghum

Salt stress is one of the major abiotic stresses, drastically affecting global agricultural productivity (Zhang *et al*., 2020). It affects crop productivity by inhibiting the absorption of water and minerals owing to the prevailing osmotic stress in soil profile. It has considerable effects on plant growth and development (Arya *et al.,* 2014) . Salt-affected soils are estimated to comprise 23 % of the cultivated land, approximately 3.5108 ha, the global extent of saline soils to be 412 mha, which closely agrees with the FAO (Corwin and Scudiero, 2019). It is especially worrisome as urban expansion drives farming into more or less dry land, 30 % of the cultivable soils will become unusable due to salt stress, and global food needs expecting to rise by 70 % to feed over 9.7 billion people by 2050 (http://www.fao.org/wsfs/world-summit/en), requiring agricultural productivity gains on smaller land areas and lower water resources (Shokat and Großkinsky, 2019).

Sorghum [*Sorghum bicolor* (L.) Moench] belongs to the family *Poaceae* and physiologically classified as C_4 plants (Punia *et al*., 2020a; Punia *et al*., 2021). It ranked fifth among the top five economically valuable cereal crops globally and a climate resilient crop (Punia *et al*., 2020b). It is a multi-purpose food crop used as a food source, fodder, fuel, and bioethanol (Ananda *et al*., 2020; Himani *et al*., 2018). Sorghum is well known for its adaptability in arid and semi-arid regimes, moderately drought tolerant, and highly biomass productive (Punia *et al*., 2020c; Krishnamurthy *et al*., 2007). India contributes 9.45 % of the world's sorghum production with 5.82 million hectares and 5.39 million tonnes of the total output (Gite *et al*., 2015).

Quality is an essential attribute towards the development of new cultivars (Punia *et al*., 2019). Sorghum forage quality depends on the interaction of several factors such as genotypic interactions, plant maturity, and other environmental factors, leading to variation in nutritional traits (Singh *et al*., 2014). Due to a lack of feed and demand for land with several other crops, livestock in semi-arid and tropical areas are underproductive and poor. Introduction of new varieties with improved quality and yield are the key determinants in breeding programmes for saline prone regions (Tokas *et al*., 2017; Satpal *et al*., 2018). Crops with high dry matter yield, low fiber, good energy, and better digestibility are some of the important good quality characters (Satpal *et al*., 2015). The primary criterion of plant breeders for selecting sorghum genotypes is the use of agronomically important traits with superior fodder quality and grain (Satpal *et al*., 2018). In sorghum, grain and fodder yield production are the complex traits regulated by several genes, which help in crop production (Mahajan *et al*., 2011). Thus, the present study was aimed to evaluate the fodder quality and agronomically important traits under saline environment.

MATERIALS AND METHODS

The seeds of two sorghum genotypes were procured from Forage Section, Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar, Haryana, India. The two factor experiment was conducted in plastic pots during two *kharif* seasons (2018 and 2019) in the screen house of Department of Biochemistry, CCS Haryana Agricultural University, Hisar. The physico-chemical properties of the soil used were also determined before sowing. Two forage sorghum genotypes *viz*. SSG 59-3 (salt tolerant) and PC-5 (salt susceptible) were grown in pots saturated with desired salt levels, *i.e*. control, 6, 8, 10, and 12 dS/m in three replicates. Samples were collected at the pre-flowering (35 days after sowing) and post-flowering (95 days after sowing) stage. Hydrocyanic acid (HCN) content was estimated at 35 days after sowing (DAS) in the innermost collar of fresh plant sample of sorghum by the method described by Gilchrist *et al.* (1967). The fresh weight of the plant/pot was taken at flower initiation stage and converted into green fodder yield (GFY) per hectare. The samples were first sun-dried for 15 days and then transferred in a hot air oven for drying at a temperature of 60±5 °C till constant weight was achieved and the dry fodder yield (DMY) was calculated. Dried samples were then ground in Willey mill using 2 mm sieve and stored in brown papers until analysis. Crude protein in the samples was estimated by conventional Kjeldahl's method. *in vitro* dry matter digestibility (IVDMD) was determined by the method of Barnes *et al.* (1971) Crude protein yield (CPY) and digestible dry matter (DDM) were calculated by multiplication of crude protein content and IVDMD (*in vitro* dry matter digestibility) with dry matter yield (kg/ha), respectively. Seed yield per plant was also recorded from each plant and expressed in grams.

Statistical analysis

The data was expressed as Mean ± SD (three replicates each). Three-way ANOVA was conducted to check the significance of main effects (genotypes, temperature, and salinity) and their interaction on growth indices followed by posthoc comparison (Tuckey's test) at 5% level (P≤0.05). Statistical analysis was performed using SPSS v23.0 software (SPSS for Windows, Chicago, IL, USA).

RESULTS AND DISCUSSION

Hydrocyanic acid (HCN) is a chief component among quality traits in sorghum (Sarfraz *et al*., 2012). HCN content (µg/g) showed a significant difference in sorghum genotypes at the vegetative stage (Fig. 1). The percent increase was higher in PC-5, *i.e*., 44.6 % and 62.8 %, and lower in SSG 59-3, *i.e*., 12.6 % and 23.8 % at 10 dS/m and 12 dS/m, respectively. Sorghum had maximum HCN content at the vegetative stage (35 DAS), but it diminished afterward. The accumulation of high HCN content might be due to the increase in nitrogen absorption by plants used to synthesize HCN (Abdel-Aziz and Abdel-Gwad, 2008; Arora *et al*., 1977). Punia *et al*. (2020c) observed a significant increase in HCN content with increasing salinity, diminishing plant physiological maturity.

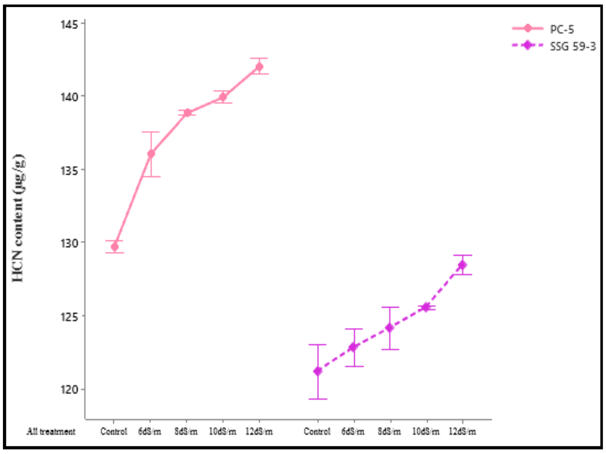

Fig. 1. Effect of salt stress on HCN content (µg/g) of sorghum genotypes at 35 DAS.

Crude protein content decreased significantly under increasing salinity levels (Fig. 2A). A significant reduction was observed at 12 dS m^{-1}, but at 10 dS/m, the decline was less prominent in both genotypes, *i.e*., 6.22 % in SSG 59-3 and 5.72 % in PC-5. The decrease in crude protein was less in SSG 59-3 (11 %) and more in PC-5 (34.3 %) at 10 dS/m, while further increase in salt concentration had a profound effect on crude protein content. With plant development, the protein concentration increased from 35 to 95 DAS. Similar results were observed at 95 DAS. The decrease in crude protein under salt stress may be due to less absorption of nitrogen by plants, which causes a reduction in protein synthesis, thus resulting in stunted plant growth (Punia *et al*., 2020c). *In-vitro* dry matter digestibility (IVDMD) is an important indicator of fodder quality (Sher *et al*., 2016). Forage with high IVDMD is superior in fodder quality. The results presented in Fig. 2B shows the IVDMD content which decreased significantly with the increase in salt concentration at $p<0.05$. IVDMD content was more at the vegetative stage. At 35 DAS, the percent decline in IVDMD content was less in SSG 59-3 (19.2 %) while more prominent in PC-5 (50.6 %) at 10 dS/m which further reduced to 28.8 % and 64.3 % in SSG 59-3 and PC-5, respectively at 12 dS/m. Several researchers also supported these observations (Petropoulos *et al*., 2009; Tokas *et al*., 2017; Himani *et al*., 2019). Satpal *et al*. (2015) observed that nitrogen application increased the crude protein (10.15%), *in vitro* dry matter digestibility (53.0 %), and digestible dry matter (60.3 q/ha) in sorghum and may reduce the harmful effect of salinity on quality traits. Gupta *et al*. (2009) have suggested that the reduction in crude protein might be due to more oxidative damage in plant cells under stress conditions. Similar results were obtained in guar (Sumanlata *et al*., 1999) and sorghum (Kumar *et al*., 2010; Sihag and Joshi, 2018).

Results depicted in Fig. 3A demonstrated significant differences in crude protein yield (CPY) among sorghum genotypes at $p<0.05$. At 35 DAS, SSG 59-3 (86.36 kg/ha) attained maximum CPY while PC-5 (32.15 kg/ha) had low CPY at 10 dS/m. At 12 dS/m, a further reduction was observed in SSG 59-3 (54.26 kg/ha), which was more prominent in PC-5 (21.62 kg/ha). Similar results were obtained at 95 DAS. At 35 DAS, SSG 59-3 (593.86 kg/ha) had maximum digestible dry matter (DDM) while PC-5 (198.36 kg/ha) had low CPY at 10 dS m^{-1} (Fig. 3B). Similar results were obtained at 95 DAS. But the overall mean value of DDM was maximum at 95 DAS as compared to 35 DAS due to increased dry matter content at physiological maturity. Significant differences were observed among the developmental stages and the genotypes. Furthermore, the digestibility rate and the energy-synthesized decline sharply once the heading starts. These results are also corroborating with many researchers' findings (Bali *et al*., 2003; Malik and Paynter, 2010; Mlaik *et al*., 2021; Satpal *et al*., 2015) who supported the findings of the present study.

Seed yield per plant declined significantly with the increasing levels of salt from control to 12 dS/min sorghum genotypes (Fig. 4). At physiological maturity, the harvested seeds showed a higher percentage reduction in seed yield in PC-5 (42 %) while lower was noted in SSG 59-3 (13 %) at 10 dS/m. SSG 59-3 was found superior in retaining seed yield at different salinity levels. Interaction between treatments was significant in all genotypes. Our results are also concomitant with Manchanda *et al*. (1991) and Sharma and Sharma (1993), who reported that low plant water status adversely affects the yield attributes

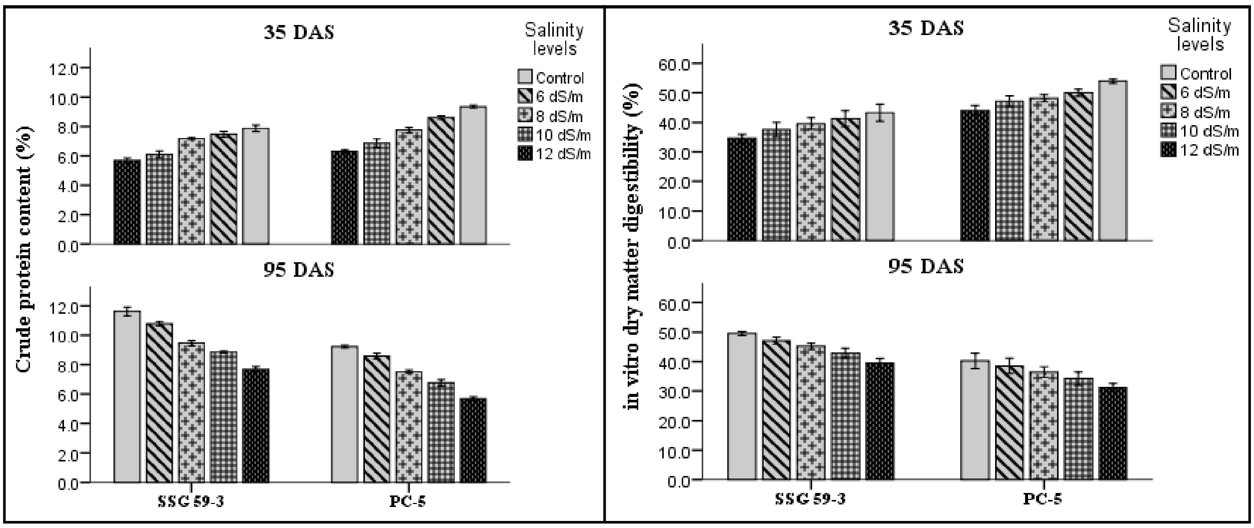

Fig. 2. Effect of salt stress on crude protein content (A) and IVDMD content (B) of sorghum genotypes at 35 and 95 DAS.

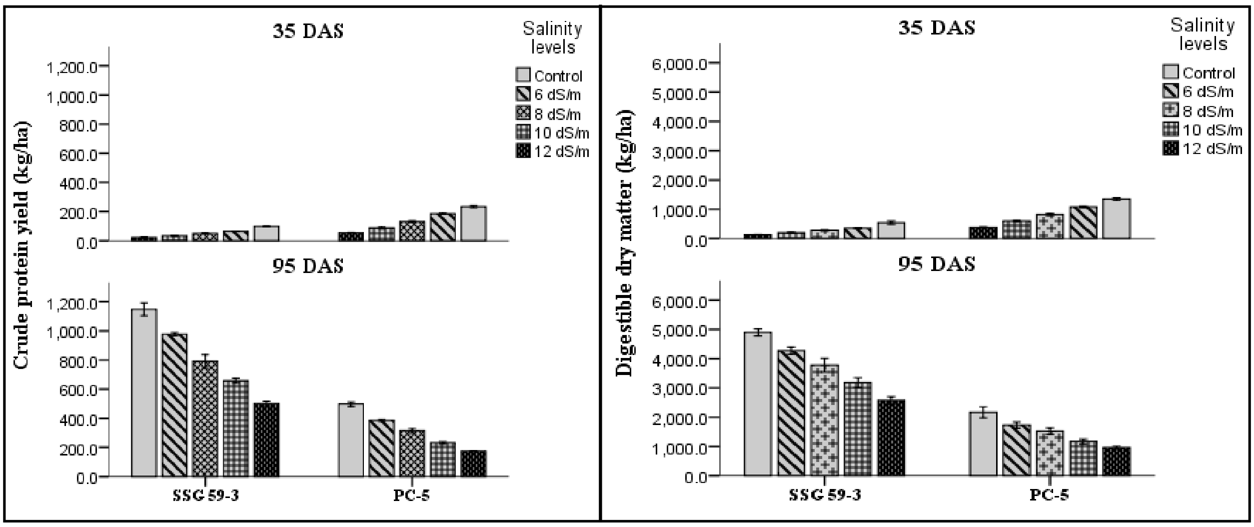

Fig. 3. Effect of salt stress on crude protein yield (A) and digestible dry matter (B) of sorghum genotypes at 35 and 95 DAS.

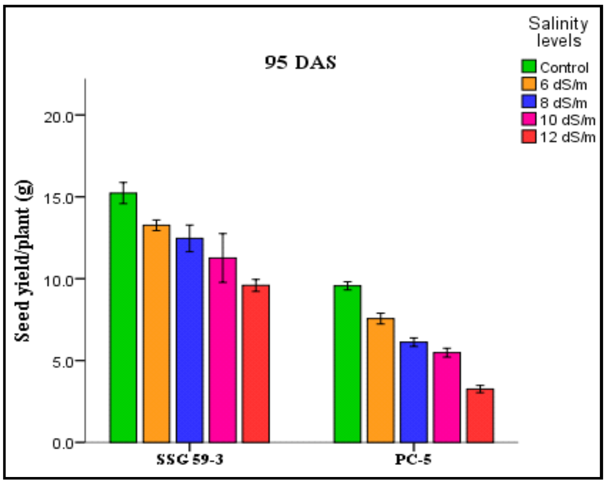

Fig. 4. Effect of salt stress on seed yield per plant (g) of sorghum genotypes at 95 DAS.

and yield. Seed yield was affected due to pollen sterility, abortion, pollen germination, and in-compatible fertilization, which directly reduced yield attributes and yield under salt stress (Hussain *et al.*, 2009).

The green fodder yield (GFY) (kg/ha) varied significantly among the sorghum genotypes under different salt concentrations (Fig. 5A). The biomass accumulation was less at vegetative stage, so the quantum of fodder yield was also less. At vegetative stage, SSG 59-3 (4135.28 kg/ha) had maximum biomass accumulation so had higher GFY as compared to PC-5 (2753.16 kg/ha) at 10 dS m^{-1}. Further increase in salt concentration reduced the GFY significantly, *i.e.*, 1841.49 kg/ha in PC-5 and 3668.16 kg/ha in SSG 59-3. A similar trend was observed at physiological maturity (95 DAS). Increased accumulation of fresh

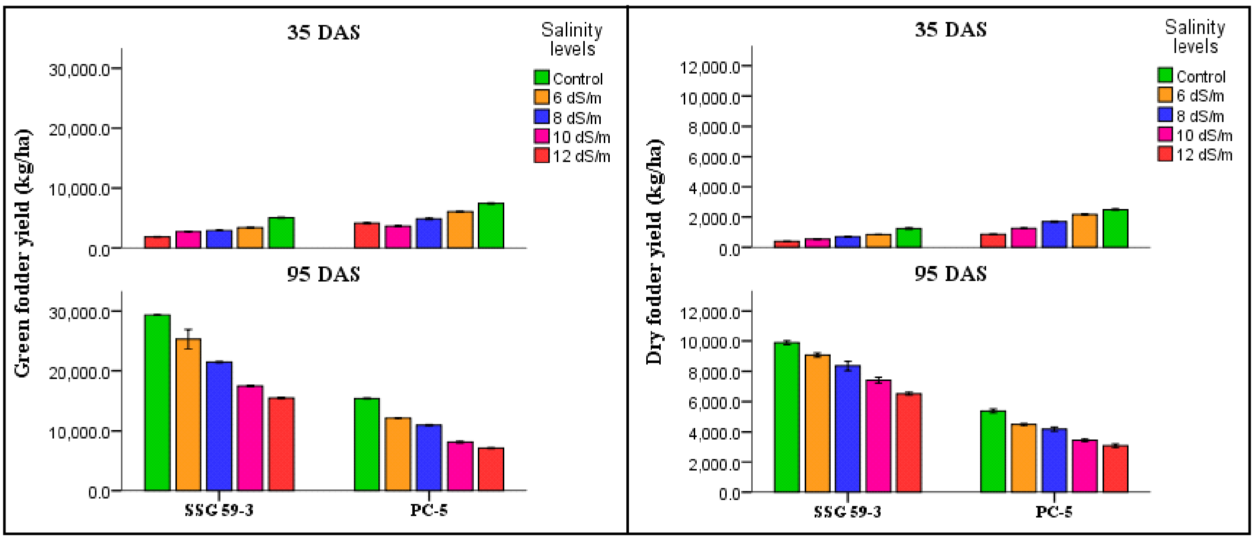

Fig. 5. Effect of salt stress on green fodder yield (A) and dry fodder yield (B) of sorghum genotypes at 35 and 95 DAS.

biomass in tolerant cultivars might be due to an increase in protoplasmic components and rapid cell division and elongation, leading to the luxury of vegetative growth, resulting in increased production of fresh biomass and dry matter (Satpal *et al.*, 2015).

The dry matter yield (DMY) (kg/ha) varied significantly among the sorghum genotypes under different salt concentrations (Fig. 5B). The dry matter accumulation was less at vegetative stage, so the quantum of DMY was also less. At vegetative stage, SSG 59-3 (1260.0 kg/ha) had maximum dry matter so had maximum DMY as compared to PC-5 (528.0 kg/ha) at 10 dS/m. Further increase in salt concentration reduced the DMY significantly, *i.e.*, 381.26 kg/ha in PC-5 and 862.86 kg/ha in SSG 59-3. A similar trend was observed at physiological maturity (95 DAS). Interactions were statistically significant between treatments in all the genotypes. The decrease in biomass might be a reason for higher Na^+ ions, which results in delayed maturity of the crop (McConnell *et al.*, 2008). Rana *et al.* (2013) reported that GFY, DMY, DDM, and the number of tillers were higher in multi-cut sorghum genotypes and might be utilized in salinity-prone areas. These results are also corroborating with many researchers' findings (Bali *et al.*, 2003; Malik and Paynter, 2010).

CONCLUSION

It is evident from present study that forage sorghum genotype SSG 59-3 performed better under high salinity (up to 10 dS/m) and may be grown as a potential green fodder crop for livestock management in salinity prone areas.

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