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DRY MATTER PARTITIONING OF SORGHUM GENOTYPES AS INFLUENCED BY JASMONIC ACID SPRAY UNDER SALT STRESS

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SUMMARY

In contemporary era, salinization of soil is one of the challenging environmental concerns all over the world. Excessive salt adversely affects the productivity of agricultural crops in terms of quality and quantity of produce. Sorghum also known as jowar, is the fifth key crop among cereals, have a number of medicinal properties for human beings. Sorghum being comparatively tolerant to salinity; however its growth is also negatively affected by salinity by altering physiological and biochemical processes and elevating ROS-caused oxidative stress. Understanding responses of sorghum against salinity would be therefore helpful in adopting appropriate procedure to increase its productivity in stressed conditions. Salinity adversely affects all the growth-related traits like plant weight, fodder yield etc. Enormous strategies can be taken into account to alleviate salt stress in sorghum crop and one of these methods is the application of plant stress hormones like ABA, Brassinosteroids, Jasmonates etc. In response to various abiotic and biotic stresses jasmonic acid accumulates rapidly and transiently. Foliar application of jasmonic acid improve plant morphological characters, enhances vegetative growth by increasing fresh and dry weight under salt stress. The objective of the present study was to assess the effects of exogenous application of 4.5, 6.5 and 8.5 mM Jasmonic acid (JA), an endogenous plant growth regulator, on mitigation of oxidative and osmotic stresses caused by various levels of NaCl (control, 4, 6 and 8 dS m^{-1}) in sorghum genotypes (HJ 541 and CSV 21F). Salt stress negatively affected sorghum growth from the aspect of fresh weight of different plant parts and plant biomass. While, jasmonic acid helped sorghum to overcome the negative influence of salt stress to some extent, application of 8.5 mM of jasmonic acid proved most efficient at all levels of salinity in both the genotypes. CSV 21F performed better as compare to HJ 541 at all levels of salt stress under the influence of different spray of jasmonic acid.

Key words : Salinity stress, jasmonic acid, sorghum, fresh weight, dry weight

Sorghum (*Sorghum bicolor*) member of Poaceae family, commonly known as great millet, jowar, cholam, or Jonna in India, is grown globally for grain, fodder and ethanol production. Sorghum is a C_4 species plant, and the only cereal grain known to have starch in the mesocarp layer of the pericarp. Sorghum is a key component in gluten-free foods and also having medicinal importance. Sorghum is a rich source of various phytochemicals including tannins, phenolic acids, anthocyanins, phytosterols and policosanols and it's fractions possess high antioxidant activity in vitro relative to other cereals or fruits (Awika *et al*., 2004). Pigmented sorghum grain is a rich source of antioxidants like polyphenols, mainly tannins, which have multiple benefits on human health such as, antiproliferative properties associated with the prevention of certain cancers, antioxidant activities related to the prevention of associated diseases to oxidative stress, antimicrobial and anti-inflammatory effects, it also improves glucose metabolism (Espitia-Hernandez *et al*., 2020). Worldwide sorghum is mainly grown in hot and dry regions on large-scale for commercial operations and for small land holding farmers sorghum shows comparative advantages over other cereals. Due to high yield, resistance to drought and heat sorghum replacing maize in some regions. Moreover, sorghum is also broadly adapted to temperate, subtropical and tropical drylands, and irrigated environments. (Borrell *et al.,* 2021).

Among agricultural crops, sorghum is naturally drought and salt-tolerant crop that can produce high biomass yields with low input. Sweet sorghum biomass has rich fermentable sugars such as sucrose, glucose, and fructose, which could be an indicator for its salt tolerance (Nazar *et al.,* 2011). Excess salt in the soil may adversely affect plant growth either through osmotic inhibition of water uptake by roots or specific ion effects (Khan *et al.*, 2015). Major adverse effects of salinity stress include increased ion-toxicity, osmotic stress, nutritional acquisition, homeostasis, impaired stomatal conductance, increased cell-turgor loss, reduction in leaf water potential, altered physiological/biochemical processes and elevated ROS-caused oxidative stress. In addition to several chemical and biological methods, attention to various natural or synthetic substances that can reduce the impact of abiotic stress factors on crops was increased. When applied to plants, these substances enhance the processes stimulating the plant's tolerance to biotic and abiotic stresses. For example, the use of jasmonic acid has a specificity action in plants to improve the tolerance to biotic and abiotic stresses, because jasmonic acid interacts with other phytohormones, which are involved in plant immunity (Abdi *et al.*,2022).

Jasmonates (JAs) an endogenous signaling molecule involved in diverse developmental processes that was originally considered a stress-related hormone in higher plants. Jasmonates modify growth and development through numerous linkages among various signaling pathways rather than a single simple mechanism (Prakriti *et.al*., 2022). In plants under abiotic stress, JA is usually involved in physiological and molecular responses. Physiological responses often include activation of the antioxidant system (superoxide anion radical, peroxidase, NADPH-oxidase), accumulation of amino acids (isoleucine and methionine) and soluble sugars and regulation of stomatal opening and closing (Ali *et al*., 2019). Exogenous application of JA amends several physiological responses to improve resistance against abiotic stresses (Wani *et al*., 2016).

MATERIALS AND METHODS

The screen house experiment was conducted during *kharif* season of 2021 at the screen house of the Department of Botany & Plant Physiology, CCS Haryana Agricultural University, Hisar (Haryana). Seeds of two sorghum genotypes (CSV 21F and HJ 541) were collected from Forage Section, Department of Genetics and Plant Breeding and were sown in plastic pots containing 10 kg of dune sand. Before sowing pots were saturated with desired levels of salt *i.e*., Control (0), 4, 6 and 8 dS m^{-1}. The control pots were irrigated with canal water. Nutrient solution was applied at different time intervals (Hoagland and Arnon, 1950). Jasmonic acid (0, 4.5, 6.5 and 8.5 mM) applied exogenously with the help of manual sprayer at 30 days after sowing (DAS). Observations for growth and yield characters were recorded at 40 DAS of sorghum. Fresh weight of root, stem and leaves was measured with the help of weighing machine immediately after harvesting. Dry weight of root, stem and leaves of sorghum cultivars were measured after drying the samples in an oven at 60°C for 96 h with the help of weighing machine. Percent contribution of different plant parts to total weight were calculated by:

$$\text{Percent contribution of leaf} = \frac{\text{Dry weight of leaf}}{\text{Total dry weight}} \times 100$$

$$\text{Percent contribution of stem} = \frac{\text{Dry weight of stem}}{\text{Total dry weight}} \times 100$$

$$\text{Percent contribution of root} = \frac{\text{Dry weight of root}}{\text{Total dry weight}} \times 100$$

Statistical Analysis

The data was analyzed statistically for ANOVA using complete randomized design (CRD) by using OPSTAT programme (Sheoran *et. al*., 1998). Treatments were compared with CD (critical difference) values at 5% level of significance.

RESULTS AND DISCUSSION

Fresh weight of leaf, stem and root (g)

Growth variables are valuable tool for assessing crop productivity in sorghum crop. Individually fresh weight (g) of stem, leaves and roots showed declining trend with every increment of salt stress. Fresh weight of stem is towards higher side as compared to leaf and root. (Table. 1) Maximum fresh weight of stem decreased significantly in both the genotype HJ 541 (44.2%) and CSV 21F (43.7%) at 8 dS m^{-1} of salt level over their respective control. Similar results were reported in sorghum by Punia *et al.* (2021b) and Nimir *et al. (*2015). A reduction in fresh and dry weight of shoot and root with increment in salt concentration due to loss of turgidity under salinity was observed by Neji *et al.* (2021). Jasmonic acid spray (4.5, 6.5 and 8.5 mM) increased the fresh weight of stem, but more increment was observed at 8.5mM of JA in both genotypes. Maximum enhancement was noticed at 4 dS m^{-1} of salt level *i.e.,* 49.3% and 30.3% in HJ 541 and CSV 21F over their respective control, at 40 DAS. Sheteiwy *et al*., (2021) also purported that application of 0.06 mM jasmonic acid improved the growth of plant (shoot height, fresh and dry weight) by regulating the interaction between plant hormones and hydrogen peroxide.

TABLE 1

Effect of salt stress on fresh weight (g/plant), dry weight (g/plant) and its alleviation by jasmonic acid on sorghum at 40 DAS (S_0 = 0 dS/m, S_1 = 4 dS/m, S_2 = 6 dS/m, S_3 = 8 dS/m, J_0 = 0 mM, J_1 = 4.5 mM, J_2 = 6.5 mM, J_3 = 8.5 mM)

	Fresh Weight (g/plant)			Dry Weight (g/plant)		
	Leaf	Stem	Root	Leaf	Stem	Root
Salinity x Jasmonic Acid						
HJ 541						
S_0J_0	17.74	46.33	14.11	4.90	9.12	5.03
S_0J_1	23.23	56.93	16.86	5.06	11.70	5.52
S_0J_2	27.60	60.76	20.11	7.17	14.43	5.93
S_0J_3	28.50	62.93	20.13	7.80	14.73	6.04
S_1J_0	19.40	42.87	14.06	3.84	7.50	4.90
S_1J_1	21.37	55.13	15.61	4.07	10.70	5.02
S_1J_2	24.70	61.23	19.06	5.63	12.03	5.43
S_1J_3	24.96	62.70	19.10	6.50	13.13	5.93
S_2J_0	10.60	29.56	9.17	3.02	5.52	3.20
S_2J_1	11.24	32.56	10.81	3.39	7.10	3.66
S_2J_2	11.78	36.24	11.01	3.95	9.66	4.23
S_2J_3	11.99	37.88	11.06	4.26	10.36	4.81
S_3J_0	8.50	25.82	8.00	2.07	3.22	2.17
S_3J_1	9.01	28.83	8.61	2.40	4.26	2.87
S_3J_2	9.34	29.83	9.12	3.16	6.67	3.22
S_3J_3	9.48	30.06	9.23	3.22	6.78	3.46
CSV 21F						
S_0J_0	16.33	46.96	13.96	5.01	10.83	3.47
S_0J_1	25.20	59.01	15.96	5.67	12.47	4.96
S_0J_2	28.10	61.81	18.76	8.47	15.70	5.91
S_0J_3	29.03	63.93	18.92	9.00	16.03	5.97
S_1J_0	17.48	48.52	13.02	4.70	9.79	2.78
S_1J_1	23.30	53.21	15.04	4.91	11.80	3.94
S_1J_2	24.60	59.17	18.02	6.93	12.33	4.99
S_1J_3	25.83	61.11	18.23	7.56	15.07	5.01
S_2J_0	12.11	30.73	7.15	3.92	6.01	2.63
S_2J_1	14.90	31.12	8.11	4.70	8.98	2.70
S_2J_2	15.23	31.77	9.10	5.31	9.73	3.41
S_2J_3	15.38	31.92	9.17	5.42	10.01	3.43
S_3J_0	8.60	26.40	6.20	3.11	5.22	2.09
S_3J_1	10.00	27.20	7.10	3.99	8.01	2.31
S_3J_2	10.26	27.46	7.25	4.62	8.45	2.98
S_3J_3	10.41	27.81	7.31	4.91	8.98	3.02

Dry weight of Leaf, stem and root (g)

Similar trend was noticed in case of dry weight of different plant parts with salt stress, but the dry weight of stem contributes more towards the total weight as compared to leaf and root. Maximum dry weight of stem was decreased in both genotype HJ 541 (64.69%) and CSV 21F (51.80%) at 8 dS m^{-1} of salt level over their respective control (Table. 1). A substantial drop in forage dry biomass of two forage sorghum cultivars (Speedfeed and KFS4) from control (44.09 g/plant) to 15 dS m^{-1} (32.76 g/plant) of salt stress (Roy, 2017). Similar results were also reported by Devi *et al.* (2019) in sorghum genotypes under salt stress. Foliar application of jasmonic acid (4.5, 6.5 and 8.5 mM) increased the dry weight of stem, but more increment was observed at 8.5mM of JA in both genotypes. Maximum enhancement was noticed at 4 dS m^{-1} of salt level *i.e.,* 75.06% and 53.93% in HJ 541 and CSV 21F over their respective control, at 40 DAS. Similar outcomes were also noticed by Islam *et al*., (2019) in wheat genotypes after application of methyl jasmonate (MeJA) levels under salinity stress. Increased salt tolerance in plants is linked to higher antioxidant enzyme activities and cell membrane protection as a result of decreased lipid peroxidation, as well as improved leaf photosynthetic rate and stomatal conductance. Foliar application of JA on plants reduced the negative impact of salt stress while improving plant growth and yield *via* ROS scavenging by antioxidant enzymes and ion absorption (Qui *et al.* 2014).

Percent contribution of plant parts to total weight at 40 DAS

Leaf

At 40 DAS irrespective of salinity levels and jasmonic acid the percent contribution of leaf to total weight was significantly affected by genotypes and it was varied from 20.57 to 27.77% in case HJ 541 and 23.77 to 31.23% in case of CSV 21F (Fig. 1). Percent contribution of leaf to total weight was non-significantly affected by salt and jasmonic acid levels. Among salt concentrations maximum percent contribution of leaf to total weight was noticed 27.77 at 8 dS m^{-1} in HJ 541 and 31.23 at 6 dS m^{-1} in CSV 21F without the application of jasmonic acid. Sheokand *et al*., (2018) also advocated similar trend in *Glycine max* under salt stress after the application of jasmonic acid. The numerical decrease in percent contribution of leaf to total weight was recorded with application of JA from 4.5 to 8.5 mM in both the genotypes compare to control at 8 dS m^{-1} of salt level.

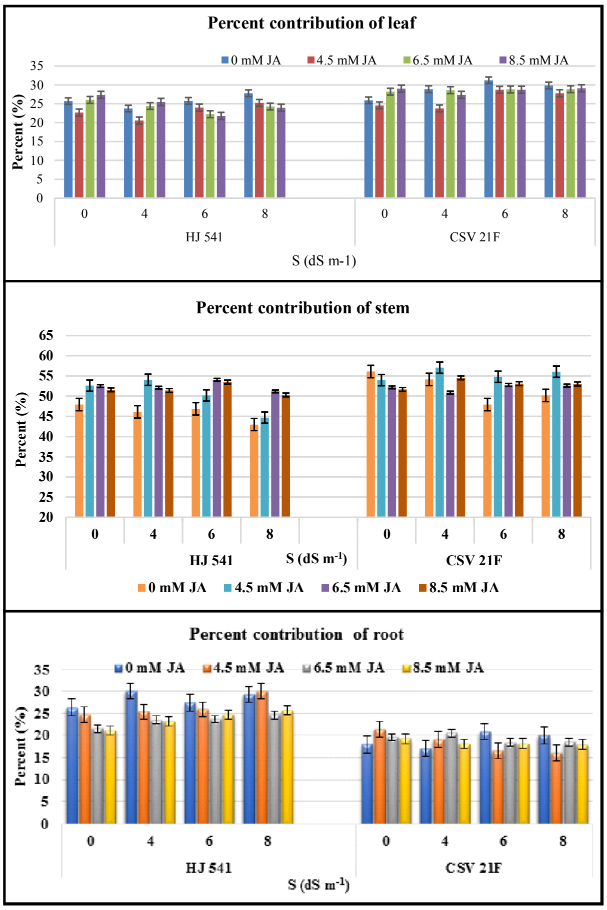

Fig. 1. Effect of salt stress on percent contribution of leaf, stem and root to total weight and its alleviation by jasmonic acid on sorghum at 40 DAS.

Stem

An inquisition to data (Fig. 1) strutted that percent contribution of stem to total weight was significantly affected by genotypes, salt levels and jasmonic acid levels. Irrespective of salt and jasmonic acid concentrations the percent contribution of stem to total weight was varied from 42.97 to 54.07% in case HJ 541. While, it was varied from 47.93 to 57.07% in CSV 21F. Among salt concentrations maximum mean percent contribution of stem to total weight was observed 51.15 at 6 dS m^{-1} in HJ 541 while, in CSV 21F it was maximum at 4 dS m^{-1} (54.15%). With the foliar application of JA (4.5, 6.5 and 8.5 mM) significant increase in percent contribution of stem to total weight was recorded in both the genotypes. Significantly higher percent contribution of stem to total weight was recorded at 6.5 mM in HJ 541 while, at 4.5 mM in CSV 21F. Similar pattern was observed in choysum plants upon application of jasmonic acid by Kamran *et al.* (2021).

Root

A disquisition to data in Fig. 1 exhibited that at 40 DAS the percent contribution of root to total weight was significantly affected by genotypes and jasmonic acid levels. Irrespective of salt and jasmonic acid levels the percent contribution of root to total weight was varied from 21.13 to 30.07% in case HJ 541. While, it was varied from 16.10 to 21.47% in CSV 21F. Among salt concentrations maximum percent contribution of root to total weight was observed 30.13% at 4 dS m^{-1} in HJ 541 while, in CSV 21F it was maximum at 6 dS m^{-1} (20.83%) at 0 mM of JA. Compare to control increase in salt levels from 4 to 8 dS m^{-1} numerically increased percent contribution of root to total weight was recorded in HJ 541 while, in CSV 21F percent contribution of root to total weight decreased with increasing levels of salt was observed. Among JA levels (4.5, 6.5 and 8.5 mM) significantly higher percent contribution of root to total weight (26.50%) was recorded at 4.5 mM in HJ 541 while it was highest at 6.5 mM in CSV 21F *i.e.*, 19.29%. Similar results were also reported by Fateme and Reza, (2020) and Sheokand *et al.* (2018).

CONCLUSION

It can be concluded that foliar application of JA mitigates the negative effects of salt stress in sorghum. The significant increase in growth parameters *viz.* fresh and dry weight of leaves, stem and root following foliar application of jasmonic acid. Fresh and dry weight of sorghum genotypes (HJ 541 and CSV 21F) declined with increasing levels of salt stress in both genotypes, however, application of jasmonic acid (0, 4.5, 6.5 and 8.5 mM) enhanced the growth parameters. The effects were more pronounced at 8.5 mM of jasmonic acid. Overall, CSV 21F showed more growth rate as compared to HJ 541. In case of percent contribution, maximum percent contribution to total dry weight was reported by stem followed by leaf and root. Percent contribution of root to total dry weight was recorded higher in case of HJ 541 (30.13%) while, leaf and stem percent contribution to total dry weight was higher in CSV 21F (11.34 and 54.15%) at 4 dS.

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