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Assessment of Salicylic Acid and KNO_3 impacts on quality parameters of Tomato (*Solanum lycopersicum* L.) under water stress condition

Deeptimayee Sahoo[1], Dipika Sahoo[2], Gouri Shankar Sahu[3], Pradyumna Tripathy[4], Swarnalata Das[5] sand Rajkumari Bhol[6]

[1]Ph.D. (Veg. Sc.), DepartSment of Vegetable Science, College of Agriculture, OUAT, Bhubaneswar (Odisha), India.
[2]Associate Professor, Vegetable Science, College of Horticulture, Chiplima (Odisha), India.
[3]Professor and Head, Department of Vegetable Science,
College of Agriculture, OUAT, Bhubaneswar (Odisha), India.
[4]Professor, Department of Vegetable Science, College of Agriculture, OUAT, Bhubaneswar (Odisha), India.
[5]Seed Production Officer, AICRP on Vegetable Crops, OUAT, Bhubaneswar (Odisha), India.
[6]Assistant Professor, Department of Plant Physiology, College of Agriculture, OUAT, Bhubaneswar (Odisha), India.

(Corresponding author: Deeptimayee Sahoo)*
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ABSTRACT: The abiotic stresses such as temperature, drought and salinity and unusual warming trends during growth stage are causing yield and quality decline. Drought has been identified as a major threat restricting crop production worldwide. Drought or water deficit stress elicits many different physiological responses in plants. Hence, there are intensive efforts to improve plant tolerance to drought and other environmental stressors. The use of elicitors such as salicylic acid (SA) and KNO_3 is an emerging novel practice to improve the yield and quality of crops as they play an important role in the regulation of various physiological and metabolic processes. The objective of this research was to study the effect of the foliar application of SA and KNO_3 on the quality of tomato fruits under water stress condition. A completely randomized experimental design with 3 replications was used. The experiment comprised of ten treatments of different concentrations of Salicylic Acid and KNO_3 along with one stress check treatment and stress free check treatment. Treatments were applied at pre flowering stage and 50% fruiting stage through foliar sprays after transplantation. The response variables were fruit quality parameters (fruit length, fruit diameter, fruit weight, total soluble solids, and Ascorbic Acid content). The obtained results suggest that the foliar spraying of SA and KNO_3 improves the biosynthesis of phyto-chemical compounds in tomato fruits, compared to control plants. According to the results, it is advisable to use the dose of 100 PPM of SA since it has a higher content of bioactive compounds which gives highest quality outputs in stress condition without compromising yield. We suggest salicylic acid might be considered as a potential growth regulator to improve tomato plant drought stress resistance, in the current era of global climate change.

Keywords: Salicylic Acid, KNO_3, elicitors, Phyto-chemical compounds.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.), is the most consumed and cultivated horticultural species in the world. It belongs to the family Solanaceae. It is the world's largest vegetable crop after Potato. Tomato has become an important vegetable of the world in view of the increasing demand for fresh consumption as well as processing industry (Kerketta *et al.*, 2018). Horticultural applicability of the fleshy vegetable tomato has invigorated for its wide applications in food and feed ingredients. Major incorporations in salads and all varieties of dishes ranging from pasta, pizza, and other bakery products render them as an effective food supplement. Health-enhancing components in tomato comprise vitamins like C and E, beta-carotene, lycopene, flavonoids, and lutein. Adequate supply of plant nutrients is a very important factor to produce the best quality of fruits (Akladious and Mohamed 2018). Tomato is cultivated in India in an area of 789.2'000 hectares with a production of 19.75 MT and productivity is 25 MT/ha. Tomato production is highest in Andhra Pradesh (2.74 MT) followed by Madhya Pradesh (2.41 MT). The area and production of Tomato in Odisha is 0.091 million ha and 1.312 million tonnes respectively with a productivity of 14.42 MT/ha (Horticulture Statistics at a Glance-2018). The importance of tomato fruit for human health is justified by its very high consumption per capita worldwide, so the identification of tomato varieties that accumulate high levels of primary and secondary metabolites in their fruits is now a priority (Hou *et al.*, 2020). For a long time, changes in agricultural management practices have mostly sought to increase fruit yield, but interest in enhancing fruit quality, especially by augmenting the levels and composition of primary and secondary metabolites, has increased greatly in the last few years (Beauvoit *et al*., 2018). Rather recently, the proposed strategy had been to strengthen fruit quality by growing crop plants under controlled environmental stress conditions (Fanciullino *et al*., 2014). Thus, abiotic stress may improve the quality of tomato fruit by inducing higher levels of sugars, amino acids and organic acids, positively influencing its flavor and water content (Quinet *et al*., 2019).

Abiotic stress factors are on an alarming rise emphasizing the requirement for arresting the devastating predicaments of drought and soil contamination that accounts for vulnerability in sustainable agriculture which encounters major yield loss of key horticultural crops like tomato. Climate change and ever-increasing industrialization are attributed to high range of abiotic stresses that affect yield and productivity (Chandrasekaran *et al*., 2021). Therefore, studies to increase yield and quality under abiotic stress conditions are desirable. Future scenarios indicate that water shortages will affect 50% of agricultural land by 2050. Besides, water deficit is the biggest environmental constraint that limits growth of field crops and vegetables (Aires *et al*., 2022). Since tomato cultivation is mostly carried out in the open field, one of the factors that most affect its development is water availability. Thus, water deficit affects plant growth and development by negatively impacting cell division and elongation generating adverse effects on plant physiology, morphology, and ecology (Farooq *et al*., 2009).

Exogenous application of phytohormones and biostimulants is known as the effective adapting methods (El-Mageed *et al*., 2017). Among these salicylic acid (SA) can be mentioned, which is a phenolic compound with action on plant growth, ion absorption, and substance transport. SA is considered an important plant signaling molecule for the defense response of plants, increasing plant tolerance to biotic and abiotic stresses (Gorni *et al*., 2017). Positive effects of SA application were observed on the growth and biomass accumulation of Portulaca oleracea under water deficit due to the maintenance of photosynthetic pigments and increased CO_2 assimilation (Saheri *et al*., 2020). The exogenous salicylic acid application significantly increased the Antioxidative enzymes activities which in turn prevent the plants from ROS mediated membrane damage under drought stress (Ramakrishna *et al*., 2022). (Chavoushi *et al*., 2020) reported that treatment with SA in safflower (*Carthamus tinctorius* L.) under water deficit improved photosynthesis rate, anthocyanin content, and phenylalanine ammonium lyase (PAL) enzyme activity. The improvement of nutraceutical attributes through the application of biostimulants or elicitors, such as SA, is a response of plants to the stress caused by them, increasing the synthesis of phytochemical compounds (Sariñana-Aldaco *et al*., 2020). Recent results have shown that the foliar application of SA in grape tomatoes acts as water deficit mitigation (Chakma *et al*., 2021). In this context, previous studies have also demonstrated that potassium has a positive effect on WUE enhancement in crop plants (Trankner *et al*., 2018). Due to its essential role in adjusting stomatal conductance, K can minimize water loss by transpiration. Increasing concentration of K in guard cells leads to increased turgor thereby opening the stomata, but with the exclusion of K from guard cells stomatal closure occurs (Trankner *et al*., 2018). Rapid and effective measures of plant treatment are necessary so that deterioration of crops due to stresses can be countered successfully. Therefore, present research was designed with an objective to evaluate the changes in quality under the influence of salicylic acid and KNO_3 in Tomato plants, exposed to water stress condition.

MATERIALS AND METHODS

The present experiment was conducted to find out the effect of different levels of Salicylic Acid (10 ppm, 25 ppm, 50 ppm, 75 ppm, 100 ppm) and KNO_3 (1%, 2.5%, 5%) on growth and yield in Tomato variety BT-10 at AICRP on Vegetable Crops, College of Agriculture, OUAT, Bhubaneswar during Rabi season of year 2019-20. The experiment was laid out in Randomized Block Design with three replications. The seeds of BT-10 Variety were procured from AICRP on Vegetable Crops, College of Agriculture, OUAT, Bhubaneswar. Healthy seeds were surface sterilized with 5% sodium hypochlorite followed by repeated washing with water. 30 plots were divided into 10 treatments as T1: Drought stress + Foliar spray of 10 PPM S.A, T2: Drought stress + Foliar spray of 25 PPM S.A, T3: Drought stress + Foliar spray of 50 PPM S.A, T4: Drought stress + Foliar spray of 75 PPM S.A, T5: Drought stress + Foliar spray of 100 PPM S.A T6: Drought stress + Foliar spray of 1% KNO_3, T7: Drought stress + Foliar spray of 2.5% $KNO_{3,}$ T8: Drought stress + Foliar spray of 5% $KNO_{3,}$ T9: Drought stress (With holding irrigation), T10: Control (Irrigated up to field capacity). The drought stress treatment was imposed by withholding irrigation. The seeds were sown in nursery beds filled with sandy loam soil and farmyard manure in the ratio of 6:1. Seedlings of 10 cm height having sturdy stems were carefully uprooted and transplanted into the main field; taking into account the appropriate environmental conditions. The foliar application of salicylic acid and potassium nitrate was taken at pre-flowering stage and 50% fruiting stage of transplanted tomato plants. The uniform stress treatment was ensured. The fruits after harvesting were used for estimation of the levels of TSS, Ascorbic Acid Content, Fruit length, Fruit diameter and single fruit weight. The statistical analysis was done following the procedure described by Panse and Sukhatme (1989).

Total Soluble Solids (TSS). The total soluble solids (TSS) were measured in ^{O}Brix; for this purpose, a drop of juice was extracted from the fruit and the reading was taken in a manual refractometer from 0 to 32% (Master-_2311, Atago®, Tokyo, Japan).

Ascorbic Acid Content. The content of vitamin C was determined by the titration method based on fresh weight (FW). Fresh fruit samples of 10 g were taken, crushed together with 10 mL of 2% hydrochloric acid, filtered, and made up to 100 mL with distilled water in an Erlenmeyer flask. A volume of 10 mL of the dilute was titrated with 2.6 dichlorophenolindophenol (1×10^{-3} N) and the vitamin C content was determined with the following equation:

$$\text{Vit C (mg per 100 g FW)} = \frac{\text{ml of 2.6 dcf} \times 0.088 \times \text{total volume} \times 100}{\text{volume of aliquote} \times \text{weight of sample}}$$

Fruit length (mm). Five fruits were selected randomly from each treatment and the length of the fruit was measured with the help of vernier caliper and mean length was calculated.

Fruit Diameter (mm). Five fruits were selected randomly from each treatment and diameter was measured with the help of vernier caliper and mean diameter was calculated.

Single Fruit Weight (gm). Five fruits were selected randomly from each treatment and weight was measured with weighing machine and mean weight was calculated.

Statistical analysis. Randomized block design (RBD) was used to do analysis of data statistically.

RESULTS AND DISCUSSION

Total Soluble Solids (TSS). Foliar application of salicylic acid (SA) and KNO_3 and drought stress had a significant impact on TSS content of Tomato fruits (Table 1). Maximum TSS (5.32) was recorded in T5 (100 ppm SA) followed by (5.02) in T4 (75 ppm SA). The results are in close line with (Qadir *et al*., 2019) who also observed greatest magnitude of TSS on application of SA in cherry tomato. (Naeem *et al*., 2018) also reported similar results in Tomato. Sugar synthesis is directly associated with osmoprotection (Sadeghi and Shekafandeh 2014) which is facilitated by SA. The increase in TSS by the application of salicylic acid might be due to further synthesis and accumulation of photosynthetic activities (Jamali *et al*., 2015). Foliar application of salicylic acid had a valuable effect on this parameter and elevated the harmful effect from stressed plant which possibly may lead to an increase of quality parameters such as TSS (Moustafa-Farag *et al*., 2020). Similarly, TSS of (4.72) has been recorded in T8 (5% KNO_3) which is significantly higher than control. This result is also in line with (Ali *et al*., 2020) who revealed that the biochemical attributes, e.g., total soluble sugars and phenolic content, of tomato plants were enhanced by seed priming with KNO_3.

Table 1: Effect of Salicylic Acid and KNO_3 on quality of tomato.

Treatments	1. TSS (Brix)	2.Ascorbic Acid (mg 100 g^{-1} FW)	3. Fruit length (mm)	4. Fruit dia (mm)	5. Fruit wt (gm)
T1(10 PPM S.A)	4.92	19.61	4.54	5.07	39.8
T2 (25 PPM S.A)	5.02	21.46	4.79	5.23	41.5
T3 (50 PPM S.A)	5.32	24.53	5.32	5.32	47.6
T4 (75 PPM S.A)	4.57	18.86	4.4	4.84	40.32
T5 (100 PPM S.A)	4.61	20.03	4.37	5.21	42.32
T6 (1% KNO_3)	4.72	20.48	4.72	5.26	45.19
T7 (2.5% KNO_3)	4.21	17.21	3.94	4.64	37.64
T8 (5% KNO_3)	4.32	17.76	4.52	4.77	38.72
T9 Stress Check	4.21	17.21	3.94	4.64	37.64
T10 Stress Free Check	4.92	19.61	4.54	5.07	39.8
SEm (±)	5.02	21.46	4.79	5.23	41.5
CD (0.05)	0.15	0.33	0.38	0.08	0.52

Ascorbic Acid Content. Vitamin C was significantly affected by salicylic acid concentration. Table 1 shows that the maximum vitamin C content (24.53 mg·100 g^{-1}) was noted with T5 (SA 100 ppm) followed by (21.46 mg100 g^{-1}) in T4 (SA 75 ppm) and (20.48 mg 100 g^{-1}) in T8 (5% KNO_3), while the minimum vitamin C content (17.21mg·100 g^{-1}) was recorded in stress check control plot. Salicylic acid application significantly increased ascorbic acid concentration as compared to control. These findings are also in line with the work of (Naeem *et al*., 2020). The concentration of alpha-carotene and vitamin C increased in carrot with SA application (Tari *et al*., 2015). This condition could be recognized by the defensive effects of phenolic substances such as salicylic acid on Ascorbic Acid content of tomato fruits (ElBeltagi *et al*., 2020). (JAN *et al*., 2019) reported that the biosynthesis of ascorbic acid (AsA) was significantly increased by potassium. Ascorbic Acids are non-enzymatic antioxidant in higher plants and are also conducive to alleviate oxidative injuries resulted from water deficit. Ascorbic Acid plays an essential role in removing hydrogen peroxide, which has been shown to be involved in the resistance to drought stress in several plants.

Fruit quality. Fruit length was significantly influenced by salicylic acid concentration and their interaction (Table 1). Maximum fruit length (5.32 mm) was recorded in T5 with application of salicylic acid at 100 ppm followed by (4.79 mm) in T4 with application of Salicylic acid at 75 ppm and (4.72 mm) in T8 with application of 5% KNO_3, while the minimum fruit length (3.94 mm) was recorded at stress check control. Fruit diameter was significantly surged by the application of osmo-protectants, especially SA @ 100 ppm sprayed on plants compared to control. Maximum fruit diameter (5.32 mm) was recorded in T5 with application of salicylic acid at 100 ppm followed by (5.26 mm) in T4 with application of 5% KNO_3, while the minimum fruit length (4.64 mm) was recorded at stress check control. Similarly, maximum fruit weight (47.6 g) was recorded in T5 (100 ppm SA) followed by (45.19 g) in T8 (5% KNO_3) while minimum fruit weight (37.64 g) was recorded in T9 in stress check control plot. Salicylic acid application increases the diameter of fruit in tomato, since it triggers cell division thus ameliorates fruit size (Qadir *et al*., 2019).

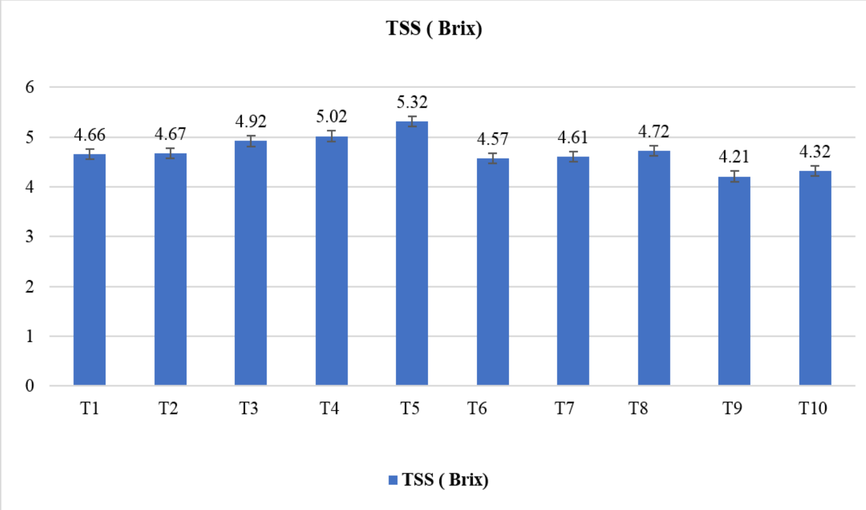

Fig. 1. Effect of salicylic acid and KNO_3 on TSS in tomato exposed to drought stress.

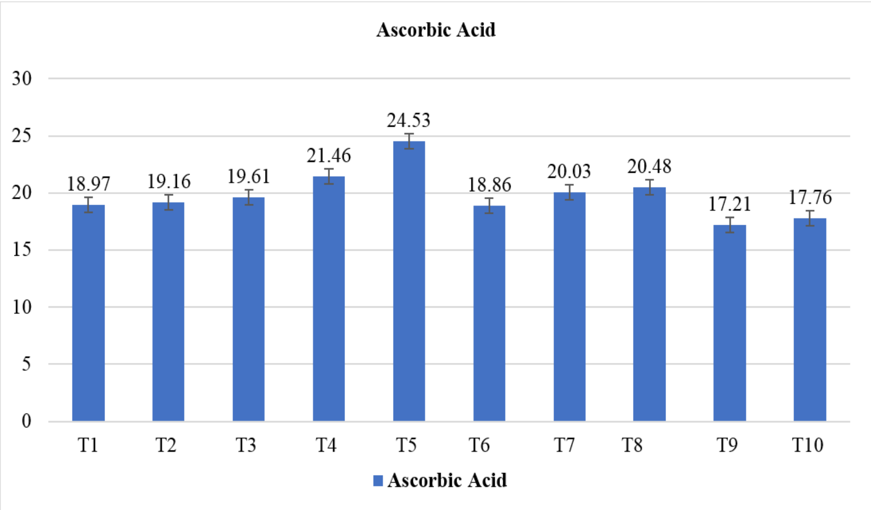

Fig. 2. Effect of salicylic acid and KNO_3 on Ascorbic acid in tomato exposed to drought stress.

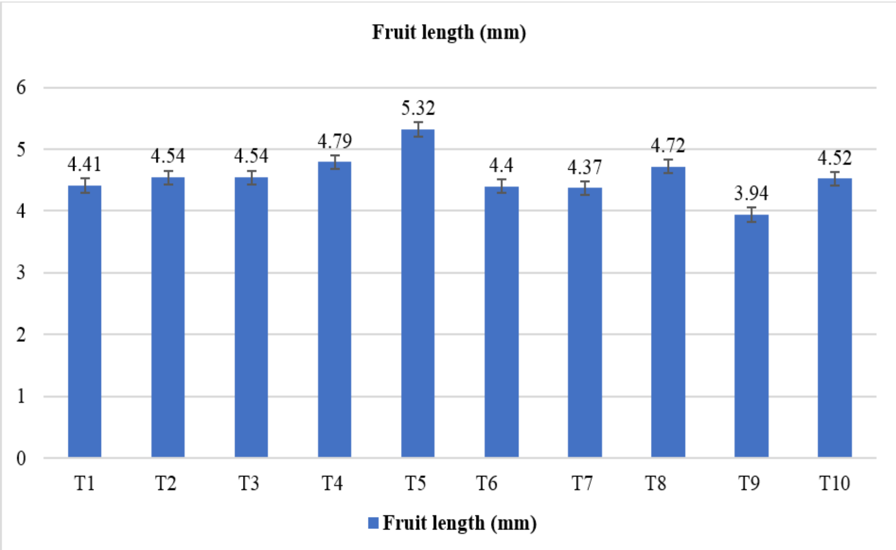

Fig. 3. Effect of salicylic acid and KNO_3 on Fruit length in tomato exposed to drought stress.

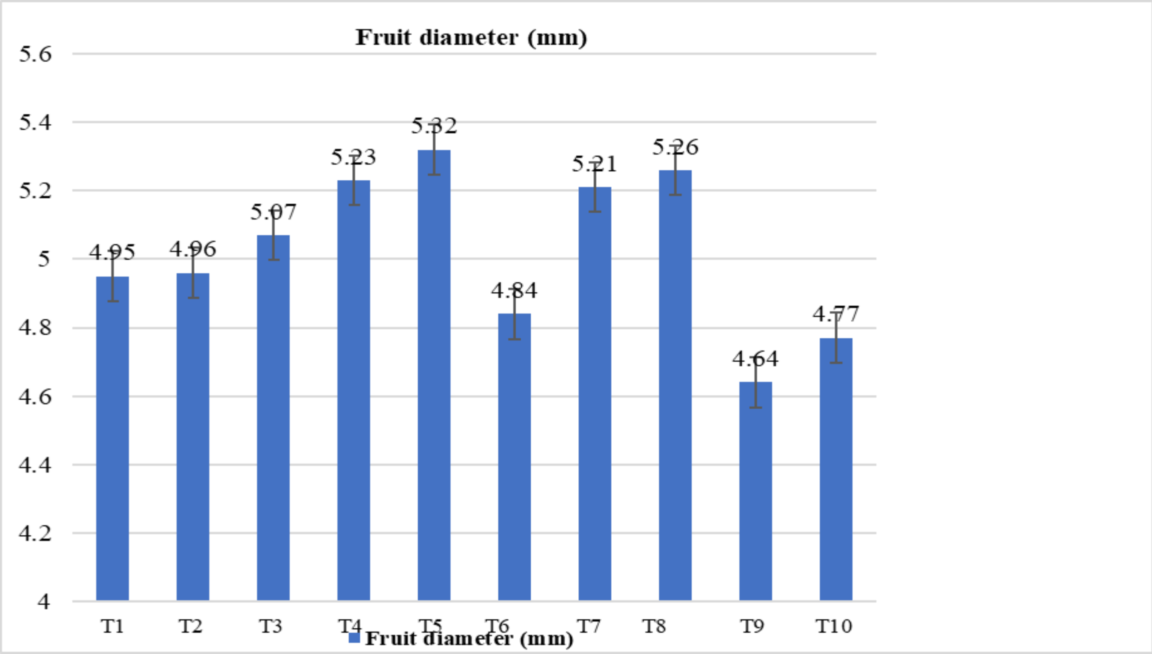

Fig. 4. Effect of salicylic acid and KNO_3 on Fruit diameter in tomato exposed to drought stress.

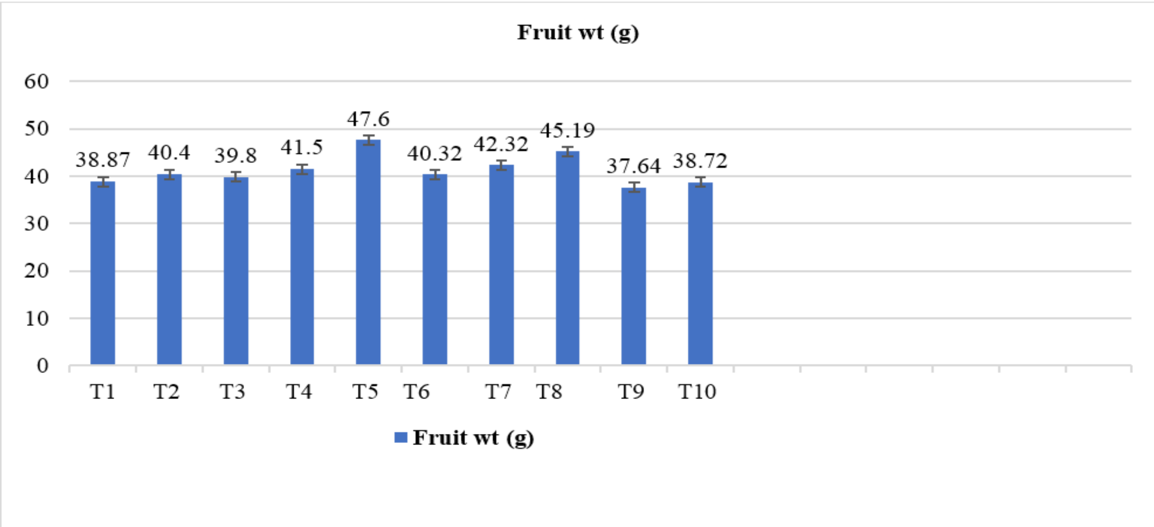

Fig. 5. Effect of salicylic acid and KNO_3 on Fruit weight in tomato exposed to drought stress.

This may be due to its role as antioxidant and anti-diseases substances which keep plant healthy and consequently increases its productivity, fruit traits and quality. The positive effect of salicylic acid reduces stress leading to more availability of carbohydrates to the fruits and enhances cell elongation which ultimately increases the fruit length and diameter (Naeem *et al.*, 2020). SA aids in improving photosynthetic capacity due to stimulation of the Rubisco enzyme and increases photosynthetic pigments. On the other hand, foliar application of SA also increases stomatal conductance and transpiration. This increase results in a better distribution of photo-assimilates to flowers and fruit. Thus, floral abortion was reduced, and the fruits accumulated mass and thus obtained maximum fruit quality (Aires *et al.*, 2022). Potassium (K) is one of the most demanded cationic minerals for vegetative growth (Kanai *et al.*, 2011) and is closely related to fruit yield and quality. These results were in agreement with (Ahmad *et al.*, 2015) who reported that potassium application increased the fruit weight from 68.11 to 83.24 g fruit^{-1}, minimum in control and maximum in treatment where 120 kg ha^{-1} potassium was applied at transplanting as single dose. Results was also in line with the results of (Afzal *et al.*, 2015) who found that the fruit weight of variety Roma increased from 57.30 g (control) to 72.0 g with the foliar application of 0.6 % potassium solution.

CONCLUSIONS

The tomato (*Solanum lycsopersicum* L.) is one of the most important vegetables in the world due to its nutritional, economic, and social values; it is particularly important in human nutrition due to its antioxidant properties (Stoleru *et al.*, 2020). Environmental stress, such as water limitation, adversely influence the quality attributes of Tomato. In this predicament, plants, alone, can't mitigate the damaging effects. Therefore, Tomato plants need exogenous support to cope drought stress which is facilitated by the osmo-protectants such as Salicylic Acid to carry out various process of osmo-protection to enhance yield and quality. Based on the results of the study, it can be said that Tomato variety BT-10 responded favourably in terms of quality-attributing traits. In terms of quality attributing features, the treatment combination T5 (100 ppm S.A) showed higher performance in water stress condition. So, Salicylic Acid can be considered as an important source that can improve various quality parameters under water stress conditions resulting in higher yield and ultimately the higher return.

FUTURE SCOPE

Climate Change has become a challenge for global food security, as rising temperatures and reduced water availability decrease crop productivity. Exogenous application of phytohormones and biostimulants is known as the effective adapting methods. Hence Both Salicylic Acid and Potassium Nitrate applications to foliage should be investigated to increase crop growth, yield and quality. The crops can be successfully grown by the exogenously applied solutes that induce stress tolerance. Osmoprotectants' assemblies in plants assist directly or indirectly to hold water and guard cells from damage created by dehydration, hence create turgidity during limited supply of water. Research should be conducted in the future to examine various osmoprotectants and their efficiency in stress management.

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Conflict of Interest. None.

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