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Effect of foliar application of Salicylic Acid and KNO_3 on growth and yield of Tomato (*Solanum lycopersicum* L.) under water stress condition

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ABSTRACT: Water deficit is one of the most limiting factor for plant survival since it regulates growth and development and limits plant productivity. The tolerance of plants to water stress can be increased through breeding and use of plant growth regulators. The field experiment was conducted during the *rabi* season of the year 2019-20 at AICRP on Vegetable crops, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, to evaluate foliar spray with Salicylic Acid & KNO_3 on growth and yield of Tomato (*Solanum lycopersicum* L.) under water stress condition. The experiment was laid down in randomize block design with three replications. The experiment comprised of ten treatments of different concentrations of Salicylic Acid (10 ppm, 25 ppm, 50 ppm, 75 ppm, 100 ppm) and KNO_3 (1%, 2.5%, 5%) along with one stress check treatment (Drought stress by withholding irrigation) and stress free check treatment (Irrigated up to field capacity). The yield 49.67 tonnes/ha and yield components such as No. of flower clusters/ plant, No. of fruits/ plant, Fruit yield/ha (t) were also higher from plants that were subjected to moisture stress at vegetative stage and the control. Hence, Application of Salicylic Acid 100 ppm and 5% KNO_3 indicated the efficacy of both in ameliorating the deteriorative effects of drought in tomato by improving the growth attributes by enhanced antioxidant enzyme activities and increased the stress tolerance of seedlings.

Keywords: Salicylic Acid, KNO_3, Growth attributes, antioxidant enzyme, moisture stress.

INTRODUCTION

Tomato is globally considered as 'Protective Food' both because of its special nutritive value and also because of its widespread production. Tomato is one of the most important commercial crops cultivated by small and medium-scale farmers. Tomato (*Solanum lycopersicum* L.) belongs to family solanaceae and it is world's largest grown vegetable crop after potato and onion (Gowda *et al*., 2015). Tomatoes are used for soup, salad, pickles, ketchup, puree, sauces and in many other ways. It tops the list of canned vegetables. Tomato and its products are used as preventive strategies against some diseases such as cancer and cardio vascular diseases. Tomato contains a rich source of vitamins, carotenoids, and phenolic compounds that are used for diet across the globe. The antioxidant compounds present in tomato fruits are used in anti- curative and anti-inflammatory properties (Frusciante *et al.*, 2007). They have high degree of lycopene and ascorbic acid content (Kaur and Kapoor 2008). It is a rich source of minerals, vitamins, and organic acids (Tiyagi *et al*., 2015).

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). Lower productivity of Tomato in Odisha is due to various incidences of biotic and abiotic stresses. The abiotic stress causes loss of hundred million dollars annually, because of Post harvest losses (Mahajan and Tuteja 2005). It has been observed that the water table of an area plays an important part in meeting the moisture needs of this crop. It is necessary to maintain an optimum moisture supply in Tomato crops from planting to final harvesting.

Drought is one of the major abiotic stresses that reduce plant growth and crop productivity worldwide. Water scarcity resulting from global climate change is accompanied by more frequent and more severe summer droughts in many regions (Hamdy *et al*., 2003). Abiotic stresses resulting from water deficit led to reduction in photosynthesis, transpiration and other biochemical processes associated with plant growth, development and crop productivity (Tiwari *et al*., 2010). Furthermore, abiotic stress lead to oxidative stress in the plant cell productivity resulting in a higher leakage of electrons towards O_2 during photosynthetic and respiratory processes which leading to enhancement of reactive oxygen species (ROS) generation (Asada, 2006). Much of the injury on plants under abiotic stress is linked to oxidative damage at the cellular level leading to cell death (Mittler, 2002). During optimal growth conditions, balance between ROS formation and consumption is tightly controlled by plant antioxidant defense system (Hameed *et al*., 2013). Plants containing high activities of antioxidant enzymes have shown considerable resistance to oxidative damage caused by ROS (Gapinska *et al*., 2008). General metabolic adaptation which enables plants to cope with water or osmotic stress, involves an increased synthesis of osmoprotectants, such as proline and soluble sugar.

Exogenous application of phytohormones and biostimulants is known as the effective adapting methods (Abd El-Mageed *et al*., 2017). 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). For example, water deficit reduced stomatal conductance, transpiration, and CO_2 assimilation in rice plants, while SA application increased gas exchange characteristics in plants under water deficit (Shemi *et al*., 2021). 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). (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 however, it did not affect the accumulation of plant dry matter. Recent results have shown that the foliar application of SA in grape tomatoes acts as water deficit mitigation (Chakma *et al*., 2021).

Potassium plays an important role in balancing membrane potential and turgor, activating enzymes, regulating osmotic pressure, stomatal movement, and membrane polarization (Kaya *et al*., 2007). Potassium is well reported to reduce drought stress effects in plants (Gilani *et al*., 2020). It is observed that K application improves stomatal function allows carbohydrates synthesis, thus, enhancing plant growth under water stress (Bahrami-Rad & Hajiboland 2017). Plants mostly use Na and K for osmotic adjustments. Exogenous application of KNO_3 as treatment can increase multiple physiological and biochemical mechanisms (Moaaz *et al*., 2020). Additional KNO_3 increases the photosynthetic pigment contents, potassium content, and enhances plant growth and decreases sodium in moisture-stressed plants. The water deficiency causes lipid peroxidation (measured as MDA) in leaves. Applying KNO_3 to plants maintains or even reduces MDA contents, thus suggesting a crucial role of K^+ in improving the antioxidant system and ameliorating drought stress conditions (Fayez *et al*., 2014).

Therefore, based on the research reports, our research hypothesizes that foliar application of different levels of Salicylic Acid and KNO_3 can reduce the deleterious effects of water deficit in Tomato and thus enhancing fruit yield.

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.

Treatment details

T1-	10 ppm Salicylic Acid	(0.05 g in 5 lit water)
T2-	25 ppm Salicylic Acid	(0.125 g in 5 lit water)
T3-	50 ppm Salicylic Acid	(0.25 g in 5 lit water)
T4-	75 ppm Salicylic Acid	(0.37 g in 5 lit water)
T5-	100 ppm Salicylic Acid	(0.5 g in 5 lit water)
T6-	1% KNO_3	(20 g KNO_3 + 2 lit water)
T7-	2.5% KNO_3	(50 g KNO_3 + 2 lit water)
T8-	5% KNO_3	(100 g KNO_3+ 2 lit water)
T9-	Stress Check	Drought stress by withholding irrigation
T10-	Stress Free Check	Irrigated up to field capacity

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. Observations were taken in five randomly selected plants in each treatment for plant growth and yield attributes. Data were taken at 60 DAT. The statistical analysis was done following the procedure described by Panse and Sukhatme (1989).

RESULTS AND DISCUSSION

A. Growth Parameters

Maximum plant height (101.4 cm) was recorded in T5 (100 ppm SA) followed by (99.2 cm) in T8 (5% KNO_3). Maximum number of primary branches (9.66) was observed in T5 (100 PPM SA) followed by (9.06) in T4 (75 ppm SA). Highest leaf area (103.99 sqcm) was recorded with T5 (100 PPM Salicylic Acid) followed by (102.28 sqcm) in T8 (5% KNO_3). The intensity of growth processes of plants treated with Salicylic acid and KNO_3 was noticeably significant than in control. Similar result was also found in cherry tomato by (Qadir *et al*., 2019) i.e. Plant height was significantly influenced by SA exhibited more plant height than other treatments. (Bano & Qureshi 2017) described similar results in strawberry plant i.e. the maximum plant height and leaf area was were obtained in SA treated plants of stress level 225ml. (Alam *et al*., 2020) also reported similar result in Okra where in case of exogenous application of salicylic acid at 240mgl^{-1} had maximum plant height (130.75 cm), maximum number of leaves (30.39) and maximum number of pods (24.24) per plant. This might be due to application of higher dose of Salicylic Acid as Auxin is synthesized in the meristem of the plant which is responsible for plant height, while their function is regulated by salicylic acid. Application of Salicylic acid promotes the accumulation of auxin and cytokinin which consequently increases the mitotic index of the apical meristems. The increase in the mitotic activity subsequently leads to enhanced growth (Hayat *et al*., 2007). Plants cannot complete a normal life cycle without sufficient potassium. Plants grown for food use large quantities of potassium. Phosphorus and potassium deficient plants often have slow growth, poor drought resistance, weak stems, and are more susceptible to lodging and plant disease. The possible reason was that potassium application improves the Plant height of tomato and increased the number of branches per plant (Kazemi, 2014). Similar result were obtained by (Abdelaziz and Taha 2018). They indicated that supplementary spraying of K caused significant increase in terms of plant height, leaf area, number of leaves and dry weight of water-stressed tomato. These positive effects may be explained that foliar spraying increases available K uptake by plants. Potassium are needed essential elements for enzymes utilization; IAA formation, regulating plant water status and optimizing plant growth performance (Abdelaziz and Taha 2018).

Days taken to 1st flowering and 50 per cent flowering were also found to be significantly reduced with the application of Salicylic acid. Minimum days to first and 50% flowering were observed in T5 (100 ppm Salicylic Acid). These findings were corroborated by (Alam *et al*., 2020) in Okra. It is believed that plants has the ability to produce flowers under un-favoured (stressed) condition, such as low nutrition, low or high temperature, more or low moisture levels, or high or low light intensity are responsible as stressed induced flowering. SA have oxygen, carbon and hydrogen at their particular ratio which play a specific role in the production of fruits and flowers. On the other hand the salicylic acid make the plant capable to abiotic and biotic stresses (Alam *et al*., 2020).

B. Yield Parameters

Significant effect were observed with respect to number of flower clusters per plant in comparison with different concentration of Salicylic acid and KNO_3 used in the present study. The maximum number of flower clusters (8.73) per plant was observed in T5 (100 ppm SA) followed by (7.46) in T4 (75 ppm SA) and minimum flower clusters i.e 5 per plant were reported in Stress Check Plot. The effect of salicylic acid on plant and flower yield could be due to increased vegetative growth, photosynthetic pigments, minerals, and some bio constituents that affect plant growth. Similarly, plants treated with doses of potassium nitrate also showed comparatively higher flower clusters per plant (6.13 and 6) in accordance to Stress Check and Stress Free Check plots. The obtained results may be due to the role of potassium in shoot elongation, enzyme activity, protein synthesis, photosynthetic transport, and chlorophyll content (Abd-El-Hamied & Abd El-Hady 2018). Similar results i.e increasing trend of this variable as KNO_3 and SA levels increased the highest flowering rate was observed in Saffron (Khayyat *et al*., 2018). KNO_3 also provides potassium and nitrogen for plant growth and is considered as a flowering stimulator in plants such as saffron (Jabbari *et al*., 2017).

Number of fruits per plant was maximum in T4 (75 ppm SA) followed by T5 (100 ppm SA). Maximum number of fruits per plant in KNO_3 treated plots was 24 in T8 (5% KNO_3) and 23 in T7 (2.5% KNO_3) which was higher than control plots.

Fruit yield of 49.67 t/ha was recorded in T5 (100 ppm SA) per hectare followed by 45.46 t/ha in T8 (5% KNO_3) and 38.62 t/ha in T4 (75 ppm SA). Number of fruits per plant and fruit yield per hectare was significantly influenced by exogenous application of Salicylic Acid as depicted in (Table 1). Similar results were reported by Chakma *et al.* (2021). Application of KNO_3 also significantly increased yield parameters of tomato in accordance to control plots in water stress condition. Similar results were obtained by (Abdelaziz and Taha 2018) in Tomato where single foliar K application recorded the highest number of fruits with control under water stress treatment.

Table 1: Effect of Salicylic Acid and KNO_3 on growth and yield parameters of tomato.

Treatments	1. Plant ht (cm)	2. No. of branches/ plant	3. Leaf Area (sqcm)	4. Days to 1st Flowering	5. Days to 50 % Flowering	6. No. of flower clusters/ plant	7. No. of fruit/ plant	8. Fruit yield/ha (t)
T_1(10 PPM S.A.)	95.16	8.33	94.57	30.53	44.66	6.66	17.13	34.39
T_2 (25 PPM S.A.)	97.57	8.66	99.28	31.46	45.73	7	20.13	36.36
T_3 (50 PPM S.A.)	98.42	8.6	95.98	29.06	42.8	7.26	22.66	37.17
T_4 (75 PPM S.A.)	99.4	9.06	99.2	28.66	43.06	7.46	24.66	38.62
T_5 (100 PPM S.A.)	101.4	9.66	103.99	25	38.2	8.73	22.06	49.67
T_6 (1% KNO_3)	97.74	7.93	95.54	26.13	39.26	4.2	19.26	36.21
T_7 (2.5% KNO_3)	97.54	8.4	93.1	26.06	39.73	6.13	23	36.83
T_8 (5% KNO_3)	99.92	9	102.28	26.13	39.4	6	24	45.46
T_9 Stress Check	94.56	7.26	93.93	34.13	48	5	16.6	30.6
T_{10} Stress Free Check	97.98	7.66	97.16	32.33	46.2	5.33	19.13	34.11
SEm (±)	0.12	0.14	1.12	0.53	0.29	0.65	1.16	4.95
CD (0.05)	0.37	0.43	3.32	1.6	0.87	1.95	3.45	14.72

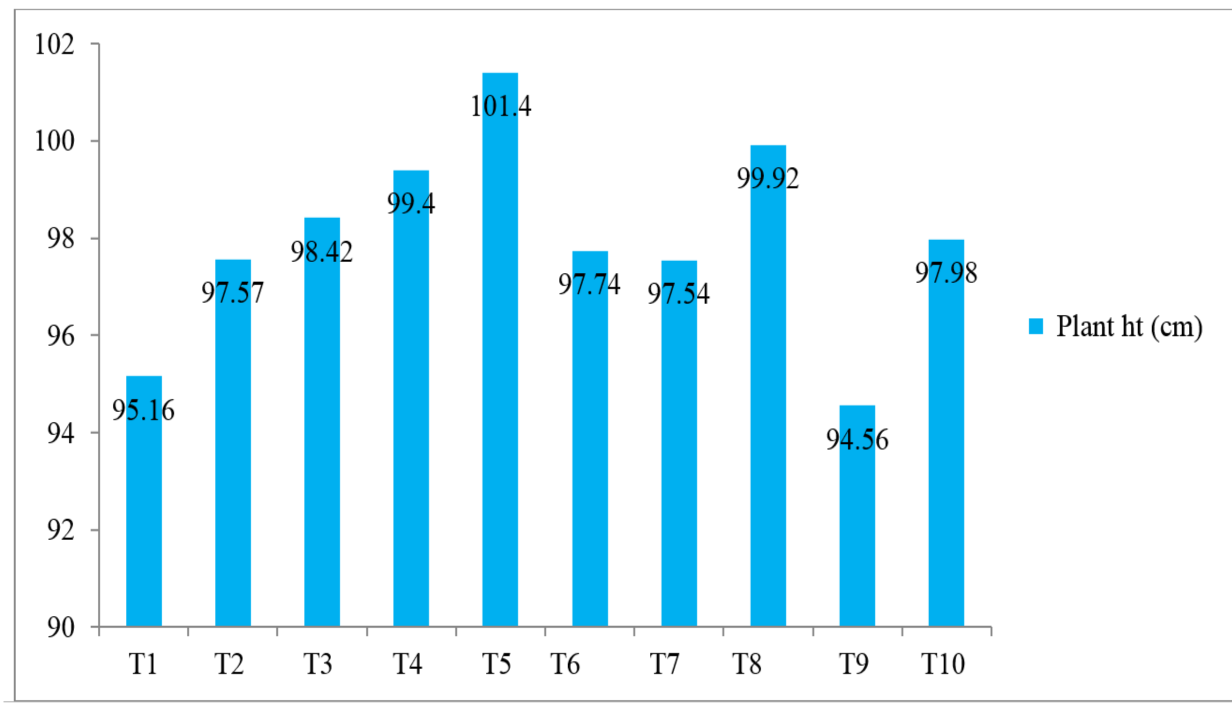

Fig. 1. Plant height (cm).

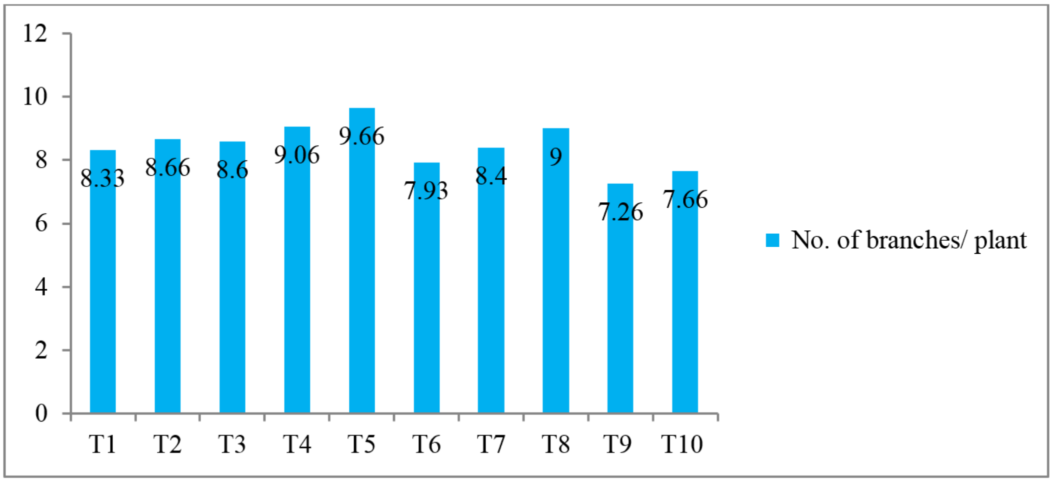

Fig. 2. Number of Primary branches/Plant.

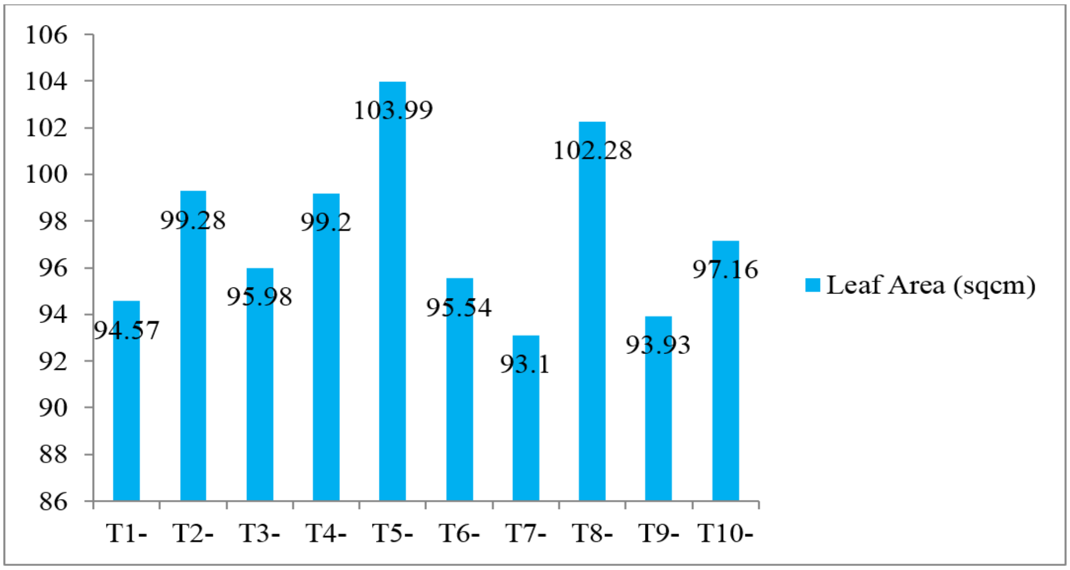

Fig. 3. Leaf Area (sqcm).

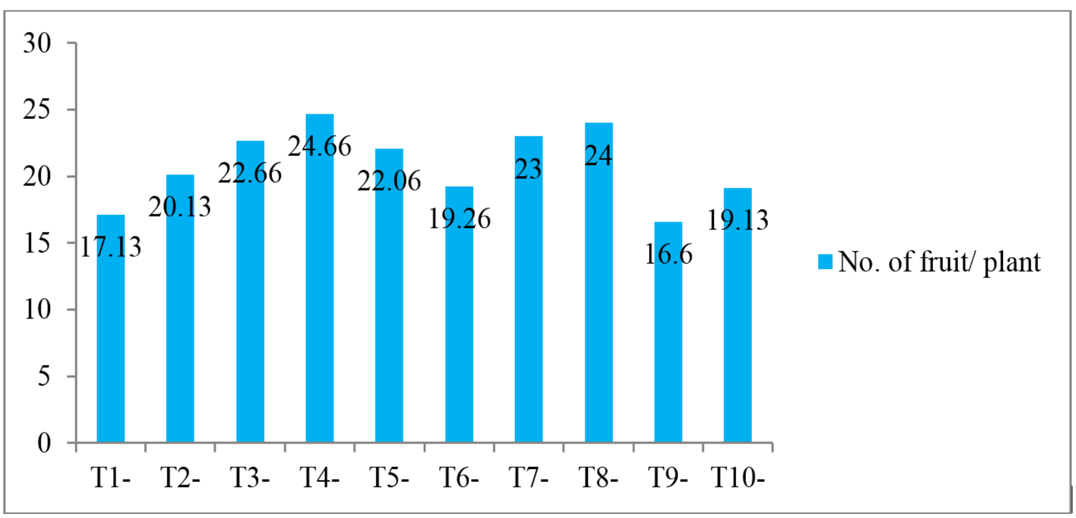

Fig. 4. Number of fruits/ plant.

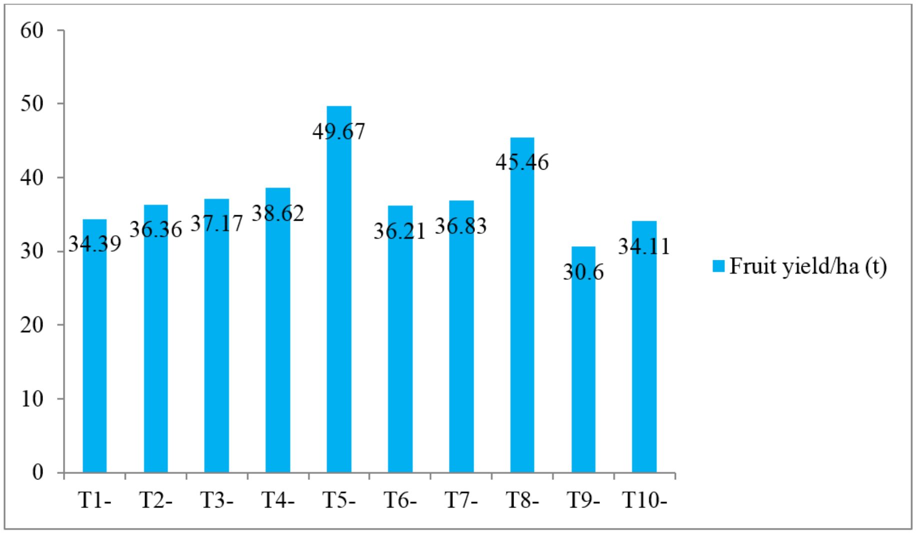

Fig. 5. Fruit yield/hectare (tonnes).

CONCLUSIONS

Salicylic Acid is known as natural endogenous signaling molecule that plays a key role in governing and mediating the responses of plants in diverse environmental stresses such as drought (Hayat *et al*., 2010). On the basis of the result obtained in the present investigation it is concluded that foliar application of SA (100 ppm) at pre flowering and fruiting stage proved to be best among other treatments and significantly increased the growth and yield of Tomato under deficit moisture content. So, Salicylic Acid can be considered as an important source that can improve various growth and yield parameters under water stress conditions resulting in higher yield and ultimately the higher return.

FUTURE SCOPE

To cope with climate change and rise in demand, Tomato has to be studied for its response to water stress conditions so as to increase productivity. Both Salicylic Acid and Potassium Nitrate applications to foliage should be investigated. Research should be conducted in the future to examine quality factors, including seed yield.

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Conflict of Interest. None.

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