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Response of Organic Biostimulants and Silicon to Growth, Yield and Quality of Tomato under Soil Salinity Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Abiotic stresses strongly affect plant growth, nutrient composition and quality of production; final crop yield can be really compromised if stress occurs in plants' most sensitive phenological phases. The present field study was conducted to evaluate the effect of biostimulants on improvement of tolerance and yield of tomato plants exposed to salinity. The tomato field soil condition with pH- 8.7 and EC- 4 dS m^{-1} was recorded. After the first fruit set of tomato, Organic biostimulant (Organic mix with high concentration of carboxylic acids, containing calcium oxide (CaO), ammonium ligninsulfonate and Zinc) were given by soil drenching and Orthosilicic acid as silicon source by foliar spray at every 10 – 15 days interval. The treatments include Organic biostimulant at 0.3ml/plant & 0.6ml/plant, Orthosilicic acid at 0.2% and 0.4%. The observations were taken during greener and red ripening stage. The biostimulants positively affected the plant height and chlorophyll fluorescence. Biostimulants were allowed to maintain the lower level of electrolyte

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leakage and osmotic potential within the plant. The activities of catalase (CAT) and superoxide dismutase (SOD) enzymes increased with the increases in salinity: biostimulants thereby kept the lower the level of reactive oxygen species. Under saline conditions due to the ionic imbalance, potassium and calcium content in both the shoots and roots were recorded lower, whereas the sodium content was found to be higher than the control plants. Similarly, a significant increase in total soluble solids and firmness of the fruit was recorded in tomato fruits. Yield characters like fruit number per plant, single plant yield, single fruit weight and flower to fruit ratio were positively affected by the application of biostimulants. The organic biostimulant and Orthosilicic acid administered at a greater dose appeared to be the most effective in our investigation.

Keywords: Biostimulants; morpho-physiological; biochemical; yield parameters.

1. INTRODUCTION

Tomato, *Solanum lycopersicum* L. Is one of the commonly grown and important vegetable crops with a global production of more than 120 million metric tonnes [1]. It is a fourth most popular fresh vegetable marketed after potato, lettuce and onion. Tomatoes are a good source of antioxidants and vitamins, which play a significant role in human diet. However, the tomato plant growth and yield are adversely affected by salinity stress. Abiotic stressor affects the quality of agricultural produce besides to lowering crop yield through morphological, physiological and biochemical alteration that can modify the visual appearance and nutritional value of the products to make it unmarketable. Though, the adaptation and mitigation strategies are required to enhance agricultural production under stress and to assure crop output and quality, according to future scenario.

Besides, salinity also affects the product quality, which considerable raise in agricultural product costs. All of these changes in plants caused by salt exacerbate the overproduction of reactive oxygen species (ROS), which interferes normal cellular metabolism and causes oxidative damage. Plants have an outstanding network of ROS detoxification system, which includes enzymatic antioxidant such as superoxide dismutase (SOD) and catalase (CAT) as well as non-enzymatic antioxidant such as ascorbic acid (AsA) and proline. Similarly, under saline conditions the significant decrease in leaf osmotic potential, chlorophyll b content, activities of CAT, and SOD as well as significant rise in leaf proline content was reported in carrot [2].

Bio-stimulants are defined as any substance or microorganisms applied to plants to improve nutrition uptake, stimulate plant growth, and improve crop quality [3], which are natural and environmentally friendly. It assists plant cope with biotic and abiotic stress besides to improving nutrient use efficiency. Humic compounds, seaweed extract, amino acid containing products and plant growth promoting microbes are the most prevalent biostimulants used to enhance plant growth and health. Because of the excessive accumulation of Na^+ and Cl^- in plants, salt stress causes ionic imbalance, which decreases the uptake of other mineral nutrients including K^+ and Ca^{2+}. Nutritional imbalance, membrane permeability and instability (due to Ca^{2+} displacement by Na^+) and an overproduction of reactive oxygen species (ROS) cause oxidative damage to cellular macromolecules are all consequences of excessive Na^+ build [4,5]. It is reported that plant derived protein hydrolysate increase lettuce plant tolerant to salinity, resulting in higher yield and dry weight [6]. Similar outcome was recently reported by Bulgari [7] in lettuce plants following the application of Organic Biostimulant, an organic commercial biostimulant. When compared to non-saline conditions, the improvement in fruit quality characteristics (TSS and Firmness of Fruit) in response to salinity stress has been attributed to decreased fruit water content and increased concentrations of reducing sugars and acids [8].

Silicon is a potential biostimulant that has been used to enhance the yield and quality of plant products. Silicon is one of the most prevalent elements in soil, however its availability to plant in the form of silicic acid may be limited, leads to reduction in agricultural productivity [9]. Plethora's of report confirmed that plant treated with silicon increased chlorophyll content, leaf photosynthetic activity, decreased plasma membrane permeability, cell formed structure maintenance due to increased antioxidant enzymes activity like SOD and CAT under salt stress. Silicon has been shown to reduce salt stress in varied crops includes rice [10], wheat [11], tomato [12], and cucumber [13]. With this background, the current study was emphasized to evaluate the potential effect of integrated application of organic biostimulant and silicon used as soil drenching and foliar spray to minimise the effect of soil salinity stress in morpho-physiological, growth and yield of tomato.

2. MATERIALS AND METHODS

The field experiment was conducted during March to July 2021 at Tamil Nadu Agricultural University, Coimbatore to study the effect of Organic biostimulants and Orthosilicic acid on physiological, biochemical and yield traits of tomato. The tomato hybrid *COTH3* seeds were obtained from Department of Vegetable Science, Tamil Nadu Agricultural University, Coimbatore and seeds were sown in protrays. After 30 days, the seedlings were transplanted to the main field at the spacing of 60 x 45 cm. The field experiment was carried out by randomized block design (RBS) with six treatments and four replications. Treatments include, T1: (Control), T2: (Salinity stress), T3: Salinity stress + Organic Biostimulant (0.3ml/plant- 4 times), T4: Salinity stress + Organic Biostimulant (0.6ml/plant- 4 times), T5: Salinity stress + Orthosilicic acid (0.2 %), T6: Salinity stress + Orthosilicic acid (0.4 %).

The Organic Biostimulant is an organic mix with high concentration of carboxylic acids, containing calcium oxide (CaO) 8.0% (w/w) soluble in water and 1.4% complexed by ammonium ligninsulfonate, Zinc (Zn) 0.2% (w/w) soluble in water and 0.2% (w/w) chelated by EDTA. Calcium complexed by ammonium ligninsulfonate is stable in the pH comprised from 3 to 9, while the Zn chelated with EDTA is stable in pH comprised from 4 to 11.

The irrigation with saline water with 2.5dS m^{-1} EC used for treatments and normal irrigation water servers as control. The tomato field soil condition with pH- 8.7 and EC- 4 dS m^{-1} was recorded. After the first tomato fruit set, the treatments like Organic Biostimulant and Orthosilicic acid given. Two treatments of Organic Biostimulant (0.3ml/plant and 0.6ml/plant) were applied by soil drenching, every 10-15 days interval for times after the first fruit set occur. Similarly, the foliar spray of Orthosilicic acid (0.2% and 0.4%) as source of silicon were given by foliar spray after the first fruit set. The morpho-physiological parameters were observed both the greener and red ripening stages of tomato.

2.1 Morphophysiological Parameters

2.1.1 Plant height

Plant height was recorded by measuring the distance from base to tip of the plant at both greener and red stages was and expressed as cm $plant^{-1}$.

2.1.2 Chlorophyll fluorescence

Chlorophyll fluorescence was measured using chlorophyll fluorescence meter (Opti-Sciences OS1p). Light weight plastic clip was used for the achievement of dark adaptation of the plant physiologically active third leaf. For preventing the entry of the light, leaf clip provided with adjustable slit were used. Adjustable slit is left closed to attained the dark adaptation for around 30 minutes, so that leaf provided for dark adaptation. Slit is open for measuring observation and single press; value displayed automatically in instrument. The key fluorescence parameters Fo (Initial fluorescence), Fm (Maximum fluorescence), Fv (Variable fluorescence) and the ratio of Fv/Fm, ETR (Electron Transport Rate), Y(II) (Yield of PSII) were automatically calculated [14].

$$\frac{\mathrm{Fv}}{\mathrm{Fm}} = \frac{\text{Variable fluorescence}}{\text{Maximum fluorescence}}$$

Fv / Fm ratio has been proportional to quantum yield and show a high degree of relationship with photosynthesis.

2.1.3 Electrolyte leakage

Plant samples were cut into small pieces with sharp blade, rinsed briefly with de-ionized water and immediately placed in a test tube with 5 ml of de-ionized water. Electrolyte leakage was then measured before and after 4 h of rehydration and finally autoclaved. Electrolyte leakage was measured by following the method as described in [15] and expressed as per cent.

2.1.4 Osmotic potential

Vapour pressure osmometer (Vapour Model 5520 Wescor Inc., Logan, UT, USA) was used to determine osmotic potential. The osmotic potential (ψ_s) was calculated as per the method of [16] and expressed as mega pascal (MPa).

$$\text{Osmotic potential} = -c\,RT$$

Where, c - Concentration (mmol kg^{-1}), R - Universal gas constant (0.0832), T - Temperature in degrees Kelvin (310^{o} K)

2.1.5 Osmotic adjustment

Osmotic adjustment was calculated with the values of osmotic potential from drought and irrigated condition, using the formula as described [17].

Osmotic adjustment (OA) = Drought leaf Ψ_{S100} – Irrigated leaf Ψ_{S100}

$\Psi_{S100} = (\Psi_S \text{ x RWC})/100$

2.2 Biochemical Parameters

2.2.1 Estimation of proline

Free proline was extracted with sulphosalicylic acid and the amount of proline was estimated by ninhydrin method as described [18] and expressed in mg g^{-1}fresh weight.

2.2.2 Estimation of antioxidant

The antioxidant like Catalase and Superoxide dismutase (SOD) was estimated. Catalase activity was determined as per Gopalachari [19] method and expressed in enzyme unit µg H_2O_2 g^{-1} min^{-1}. SOD activity was assessed by measuring the reduction of nitro blue tetrazolium (NBT) salt and the procedure is followed as described by Beauchamp and Fridovich [20] and expressed in enzyme units mg^{-1} protein.

2.3 Nutrient Content

2.3.1 Estimation of sodium and potassium in shoot and root

The oven dried samples were chopped separately (shoots and roots) and ground using willey mill. These sample used for sodium and potassium content estimation by triple acid digestion method using flame photometer in the tri-acid extract suggested by [21]. The content was calculated and expressed in mg/g of dry weight of sample.

2.4 Yield and Yield Components

The yield parameters observed by after the harvest of tomato fruits when it reaches the commercial maturity.

2.4.1 Fruit number per plant

The number of fruits per plant was recorded in the tagged plants from every replication of all the treatments and the mean value was expressed as number.

2.4.2 Single fruit weight

The fruit weight was calculated from randomly selected fruits from each treatment and the mean value was determined and expressed as g $fruit^{-1}$.

2.4.3 Single plant yield

Fresh weight of the fruits produced per plant was recorded at every harvest and yield per plant (g) was determined.

2.4.4 Flower to fruit ratio

The total number of flowers and fruits harvested from tagged plant in each replication and an average the number of flower and fruits per plants, flower to fruit ratio were calculated.

2.5 Quality Parameters

2.5.1 Total Soluble Solid (TSS)

TSS (total soluble solids content) was determined using an Erma hand refractometer (0-32^{o} C). The extracted tomato juice was placed on a refractometer prism and the ^{o}Brix value was calculated.

2.5.2 Firmness of Fruit by penetrometer

Fruit Hardness Tester (LT Lutron, FR-5120, Taiwan) was used to evaluate the firmness of the fruit. Penetrometry tests were determined using a 5 mm width stainless steel probe, penetrating 10 mm into sample. The test was performed with a trigger force of 10.01 N. The test was performed by recording at the equatorial surface for each individual fruit. Firmness was expressed in Newton (N).

2.6 Statistical Analysis

IBM SPSS Statistics (version 22.0) software was used for statistical analysis. The mean values of each character were examined using analysis of variance (ANOVA) to determine their significance difference between the treatments ($P \geq 0.05$).

3. RESULTS AND DISCUSSION

3.1 Morphophysiological Parameters

3.1.1 Plant height

The plant height was measured at both greener and red stage of tomato. In the present study, a significant reduction in plant height was observed among the different treatments (Table1). The maximum plant height was observed in control plants at both greener (59.21cm) and red (88.81 cm) stages compared to other treatments. However, the plant exposed to the salinity stress was recorded to minimum plant height in both greener (45.72 cm) and red (68.58 cm) stages. A significant increase in the plant height was observed in the treatment Organic biostimulant (0.6ml/plant) and Orthosilicic acid (0.4%) in both greener (58.21 and 57.26 cm) and red (87.69 and 85.59 cm) stages. It has been claimed that plant growth increased as salinity decline and the salt create an unfavourable environmental condition, which reduces the plant height as salinity increases. Salinity had a same effect as it reduced plant height and slow down the elongation rate of the main stem in tomato. In the present study, the application of biostimulants was significantly enhances the plant height whereas similar result was observed [22] that the application of Wuxal amino biostimulant were positively enhances the plant height in tomato plants.

3.1.2 Chlorophyll fluorescence

The functional condition of photosynthetic machinery was determined using chlorophyll fluorescence. To assess the direct impact of salts on PSII photochemistry, the measurement of chlorophyll fluorescence characteristics was tried. The chlorophyll fluorescence is a non-destructive approach for monitoring the progression of stress situation. In our study, a significant reduction in chlorophyll fluorescence was observed among the different treatments (Table1). However, the maximum chlorophyll fluorescence was observed in control plants at both greener (0.705) and red (0.686) stages than compared to other treatment. Combined salinity stress and biostimulant treated plants, the plants exposed to the salinity stress was recorded the minimum chlorophyll fluorescence in both greener (0.544) and red (0.533) stages. A significant increase in the chlorophyll fluorescence was observed in the treatment Organic biostimulant (0.6ml/plant) and Orthosilicic acid (0.4%) in both the greener (0.684) and red (0.676) stage. Under the saline treated plants, Fv'/Fm' was diminished, indicating the occurrence of photoinhibition, which could be caused by the stress damage to the PSII [23]. Biostimulants treatments like Organic Biostimulant and Orthosilicic acid at its higher dose may have been crucial in delaying the photoinhibition and ensuring proper function of the photosynthetic machinery, thus improving the final yield of tomato.

3.1.3 Electrolyte leakage

Membrane permeability is based on the quantity of ion leakage from the tissue and electrolyte is the measure of membrane stability index. Current result shows that the significant increase in electrolyte leakage was observed in salinity treatments as compared to control (Table 1). The maximum electrolyte leakage was observed in salinity stress treatments at both greener (54.4%) and red (45.9%) stage than compared to other treatments. However, the lower value of electrolyte leakage was recorded in the control plant at both greener (42.84%) and red (37.85%) stage. Moreover, a significant decrease in the electrolyte leakage was observed in the treatment Organic biostimulant (0.6ml/plant) and Orthosilicic acid (0.4%) in both the greener (43.89%) and red (40.72%) stage. Due to excessive salt concentration induces the leaf damage, lowered the tissue water status and increased the electrolyte leakage in tomato. Plant that are exposed to salt stress have a decreased photosynthetic rate, which affect the CO_2 fixation, while light response and electron exchange are normally unaffected. Furthermore, oxygen can replace NADP electrons as an electron receptor, promoting the creation of additional ROS that resulted in an increasing of electrolyte leakage under the salt stress condition [24]. The enhanced electrolyte leakage was linked to increased peroxidation [25]. Salt stressed plants treated with the Organic biostimulant and Orthosilicic acid showed significant decrement in electrolyte leakage. Thus, the similar result obtained [26] by the application of lipoic acid with fulvic acid significantly decreases the electrolyte leakage in wheat plant grown under the salinity stress.

Table 1. Effect of organic biostimulants and silicon on plant height, chlorophyll fluorescence (Fv'/Fm') and electrolyte leakage during greener and ripening stage of tomato under salinity condition

Treatments	**Plant height (cm)**		**Chlorophyl fluorescence (Fv'/Fm' ratio)**		**Electrolyte leakage**	
	Greener stage	**Ripening stage**	**Greener stage**	**Ripening stage**	**Greener stage**	**Ripening stage**
T_1 - Control	59.2	88.81	0.705	0.686	42.84	37.85
T_2 - Salinity stress	45.7	68.58	0.544	0.533	54.44	45.94
T_3 - Salinity stress + Organic Biostimulant(0.3ml/plant)	52.8	80.51	0.626	0.640	49.33	44.14
T_4 - Salinity stress + Organic Biostimulant (0.6ml/plant)	58.2	87.69	0.684	0.676	43.89	40.91
T_5 - Salinity stress + Ortho silicic acid (0.2 %)	53.7	79.26	0.621	0.643	48.48	43.37
T_6 - Salinity stress + Ortho silicic acid (0.4 %)	57.3	85.89	0.654	0.646	45.64	40.72
Mean	54.5	81.79	0.639	0.637	47.44	42.16
SEd	2.0	2.96	0.0103	0.0124	1.32	0.5447
CD (P≥0.05)	4.3**	6.31**	0.022**	0.026**	2.94**	1.21**

3.1.4 Osmotic potential

Osmotic potential was significantly reduced due to saline stress (Table 2). Present result shows that the lower osmotic potential value was observed in salinity stress plants at both greener (-7.88 MPa) and red (-7.93 MPa) stage than compared to the other treatments. While the maximum osmotic potential was observed in the control plants in both greener (-4.89 MPa) and red (-5.58 MPa) stage. A significant increase in the osmotic potential was observed in Organic biostimulant (0.6ml/plant) and Orthosilicic acid (0.4%) in both the greener (-6.27 MPa and -6.41 MPa) and red (-6.78 MPa) stage. One of the most essential adaptation to the salt stress is the maintenance of water status as expressed by leaf osmotic potential [27]. Low osmotic potential and photo oxidative reaction causes the chlorophyll breakdown at high salt concentration [28]. Low osmotic potential trigger the plant stomata closure, which result in reduced CO_2 fixation, increases photorespiration and H_2O_2 synthesis in peroxisome [5]. With the salinity treatment, leaf osmotic potential decreased dramatically and was found to be related to the amount of salt applied. The application of biostimulants significantly increases the osmotic potential value compared to the salinity plant. [29] shows that similar result was found by the application of cyanobacteria based biostimulant in tomato plant under saline condition.

3.1.5 Osmotic adjustment

The accumulation of osmotic metabolites and sequestration of salt on vacuole, interfering with other substances, can be attributed to biostimulant improving osmotic adjustment in the cell. A significant increase in osmotic adjustment was observed at the different treatment (Table 2). A maximum osmotic adjustment was recorded at salinity stress in both greener (2.99 MPa) and red (2.35 MPa) stage than compared to other treatments. However, the lowest value was measured in Organic biostimulant (0.6ml/plant) and Orthosilicic acid (0.4%) in both greener (1.37 MPa and 1.20 MPa) and red (1.52 MPa and 1.20 MPa) stage. Maintaining the osmotic adjustment under the salt stress was good correlation with lower oxidative damage. The development of osmotic stress due to a low osmotic potential of saline solution, which restrict the plant access to the soil water. This osmotic stress induce water shortage can cause cell to lose turgidity and dehydrate, resulting in plant death [30]. Osmotic adjustment is a key mechanism that plant used to keep growing under saline environment [31]. Plant acquires the osmotic balance by accumulating inorganic ions and generating the suitable solutes [32].

3.2 Biochemical Parameters

3.2.1 Proline

Proline is an osmoprotectant, it can be used as non-enzymatic antioxidant and also it may be involved osmotic correction and the scavenging of reactive oxygen species. The concentration of proline increased as a salt level increased. The effect of salinity on the proline content of various treatments was shown (Fig.1). In this study, the maximum proline content was observed in salinity treatment (0.79 mg/g) than compared to other treatments. Whereas, the lower proline content was observed in the control plant (0.28 mg/g). Organic biostimulant (0.3ml/plant and 0.6ml/plant) treated plants showed higher (0.42 mg/g and 0.31 mg/g) proline level where as Orthosilicic acid (0.2% and 0.4%) treated plantsshowed higher of 0.46 mg/g and 0.33 mg/g proline level which indicates biostimulant and Orthosilicic acid treated plants used to maintain the lower level of proline. Many plant species develop proline in response to a variety of environmental stress [33]. In general, Organic Biostimulant and Orthosilicic acid allowed for reduced proline level to maintain despite salinity. These findings showed that treatments have a dose dependent effect on tomato and support the hypothesis that treatment (biostimulant and Orthosilicic acid) protected the plant against salinity stress.

3.2.2 Catalase (CAT) and Superoxidase Dismutase Activity (SOD)

The activity of antioxidant enzyme increased dramatically in a gradual direction with increasing the salt stress. In the present study shows that significant increase in catalase and Super Oxidase Activity were observed in salinity treatments as compared over a control (Fig.2). The maximum value was observed in salinity treatment (8.46µg H_2O_2 g^{-1} min^{-1} and 45.01units mg^{-1} protein) compared to other treatments. Whereas, the lowest value was observed in control plant (1.55µg H_2O_2 g^{-1} min^{-1} and 20.04units mg^{-1} protein) on CAT and Super Oxidase Activity respectively. Furthermore, Organic biostimulant treated plants (0.3ml/plant) (3.69µg H_2O_2 g^{-1} min^{-1} and 31.50units mg^{-1} protein) showed to increase Catalase and SOD activities followed by (0.6ml/plant) (2.60 µg H_2O_2 g^{-1} min^{-1} and 26.56units mg^{-1} protein), whereas Orthosilicic acid treated plants (0.2%) (3.88µg H_2O_2 g^{-1} $min^{-1}$and 33.66units mg^{-1} protein) showed to increase Catalase and SOD activity followed by (0.4%). SOD provides the first line of defence against ROS accumulation in plants, which facilitating the conversion of superoxide or singlet oxygen radical into hydrogen peroxides and molecular oxygen [34]. In this case, salinity stress increases in SOD activity and clear indicator of its role in the defence mechanism that responsible for neutralizing the oxidative stress. CAT is another crucial antioxidant enzyme of plants, which play a defence against oxidative stress. Moreover, catalase contributes to the scavenging of ROS by collaborating with SOD to degrade H_2O_2 into water and oxygen [35].

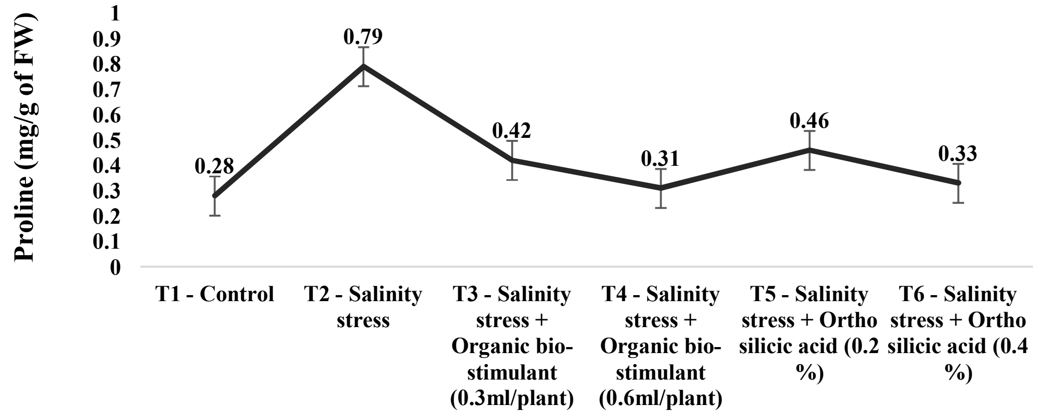

Fig. 1. Effect of organic biostimulants and silicon on Proline content of tomato under salinity condition

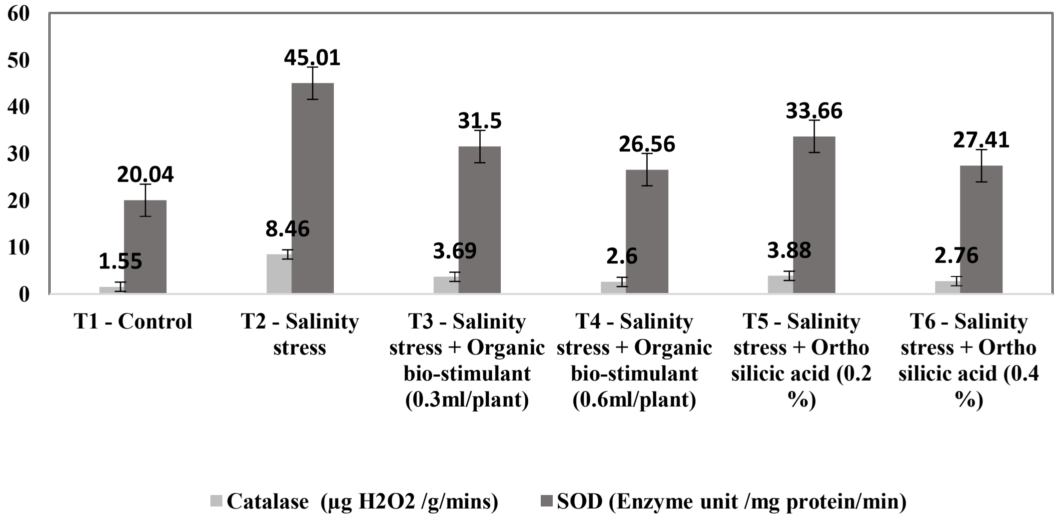

Fig. 2. Effect of organic biostimulants and silicon on activity of Catalase and Superoxide Dismutase in tomato under salinity condition

Table 2. Effect of organic biostimulants and silicon on osmotic potential and osmotic adjustment during greener and ripening stage of tomato under salinity condition

Treatments	Osmotic potential (MPa)		Osmotic adjustment	
	Greener stage	Ripening stage	Greener stage	Ripening stage
T_1 - Control	-4.89	-5.58	0.00	0.00
T_2 - Salinity stress	-7.88	-7.93	2.99	2.35
T_3 - Salinity stress + Organic Biostimulant (0.3ml/plant)	-6.918	-7.21	2.02	1.62
T_4 - Salinity stress + Organic Biostimulant (0.6ml/plant)	-6.27	-6.78	1.37	1.20
T_5 - Salinity stress + Ortho silicic acid (0.2 %)	-6.80	-7.09	1.90	1.51
T_6 - Salinity stress + Ortho silicic acid (0.4 %)	-6.41	-6.78	1.52	1.20
Mean	-6.53	-6.90	1.63	1.31
SEd	0.35	0.37	0.34	0.37
CD (P≥0.05)	0.73**	0.79**	0.74**	0.79**

Table 3. Effects of organic biostimulants and silicon on Na^+ and K^+ in shoot of tomato under salinity condition

Treatments	Na (mg/g DW)	K (mg/g DW)	Na/K ratio
T_1 - Control	3.67	6.34	0.58
T_2 - Salinity stress	11.58	4.06	2.89
T_3 - Salinity stress + Organic Biostimulant (0.3ml/plant)	9.47	4.89	1.94
T_4 - Salinity stress + Organic Biostimulant (0.6ml/plant)	7.58	5.70	1.33
T_5 - Salinity stress + Ortho silicic acid (0.2 %)	9.58	4.97	1.93
T_6 - Salinity stress + Ortho silicic acid (0.4 %)	7.93	5.41	1.47
Mean	8.30	5.23	1.69
SEd	0.371	0.233	0.093
CD (P≥0.05)	0.792**	0.497**	0.199**

3.3 Nutrient Composition

3.3.1 Sodium and potassium content

A very important mechanism of salinity tolerance is the ability to minimize the amount of Na^+ entering the plant via the root. In our study, sodium content in both the shoots and roots increased gradually following the increase of salt concentrations with a more pronounced manner in shoot (11.58) than in roots (6.28). Conversely, potassium content in both the shoots and roots decreased gradually following the increase of salt concentration with a more pronounced manner in roots (2.33) than in shoot (4.06) which is shown in Table 3 and 4. Furthermore, Na^+ toxicity typically leads to a K^+ shortage [36]. A decrease of K^+ can exacerbate Na^+ toxicity by interfering with various important physiological processes such as stomatal movement, photosynthetic performance, metabolism of secondary metabolites, maintenance of membrane potential and osmotic balance, water status and enzyme activation [37]. However, the lesser Na/K ratio was maintained under the treatment of higher dose of organic bio stimulant (T4) and Orthosilici acid (T6) compared to salinity stress treatment. Plant survival under salt stress, on the other hand, is directly linked to the ability of plants to retain Na^+ and K^+ homeostasis in cellular compartments [38]. In agreement with this strategy, a lower Na^+ content but higher K^+ content in both roots and shoots of organic biostimulants applied in salt-stressed plants clearly indicate that these biostimulants improved the capability of tomato plants to restrict Na^+ uptake through roots, while maintaining a better level of K^+ in both roots and shoots.

3.4 Yield and Yield Components

3.4.1 Fruit number per plant (Number/plant)

Fruit number per plant was measured at different salinity treatments. The plant exposed to the salinity, which has the lower number of fruits as compared to control plants. A significant reduction in fruit number was observed among the treatments (Fig.3). However, the maximum fruit number per plant was observed in control plant (51.76) than compared to the other treatments. The plant exposed to salinity stress was recorded the minimum fruit number per plant (22.58). The significant increase in fruit number per plant was observed in the treatment Organic biostimulant (0.6ml/plant) and Orthosilicic acid (0.4%) registered 45.83 and 43.14 respectively compared to un-treated salinity plants. Similar results were observed [39] in strawberry.

3.4.2 Single fruit weight (g /fruit)

A significant reduction in the single fruit weight was observed among all the treatments (Fig.3). The maximum single fruit weight was observed in control plants (34.0 g/fruit) than compared to other salinity treatments. However, the plants exposed to salinity stress was recorded the minimum single fruit weight (19.0). A significance increase in the single fruit weight was observed in the Organic biostimulant (0.6ml/plant) and Orthosilicic acid (0.4%) and recorded 31.0 g/fruit and 29.0 g/fruit, respectively compared to un-treated plants subjected to salinity.

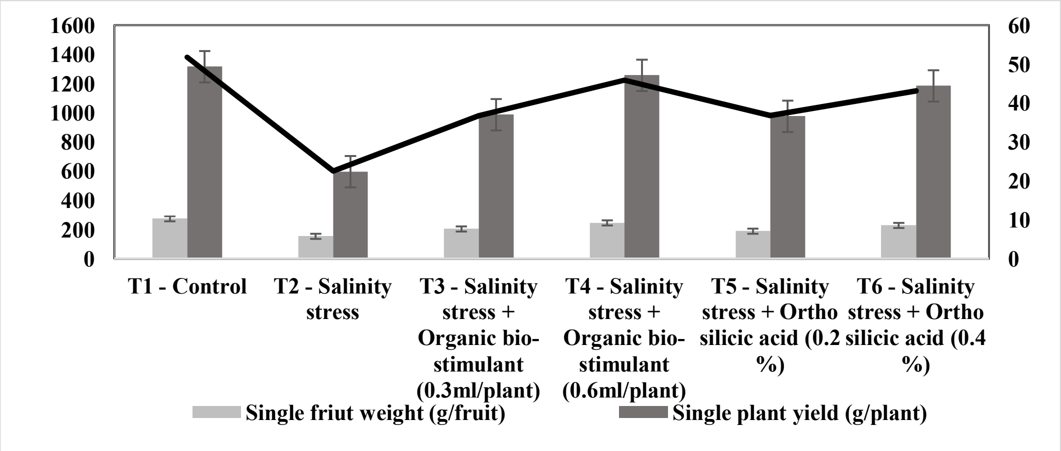

Fig. 3. Effect of organic biostimulants and silicon on Single fruit weight, single plant yield and fruit number per plant in tomato under salinity condition

Table 4. Effects of organic biostimulants and silicon on Na$^+$ and K$^+$ in root of tomato under salinity condition

Treatments	Na (mg/g DW)	K (mg/g DW)	Na/K ratio
T_1 - Control	3.00	5.52	0.55
T_2 - Salinity stress	6.28	2.33	2.70
T_3 - Salinity stress + Organic Biostimulant (0.3ml/plant)	5.18	3.35	1.55
T_4 - Salinity stress + Organic Biostimulant (0.6ml/plant)	4.33	4.52	0.96
T_5 - Salinity stress + Ortho silicic acid (0.2 %)	5.61	3.13	1.79
T_6 - Salinity stress + Ortho silicic acid (0.4 %)	4.65	4.24	1.10
Mean	4.84	3.85	1.44
SEd	0.155	0.121	0.066
CD (P≥0.05)	0.331**	0.259**	0.142**

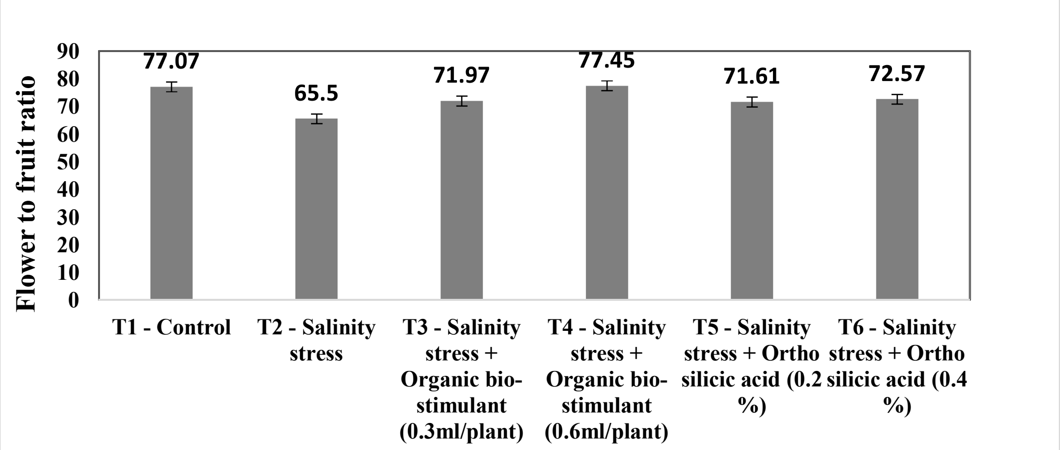

Fig. 4. Effect of organic biostimulants and silicon on flower to fruit ratio in tomato under salinity Condition

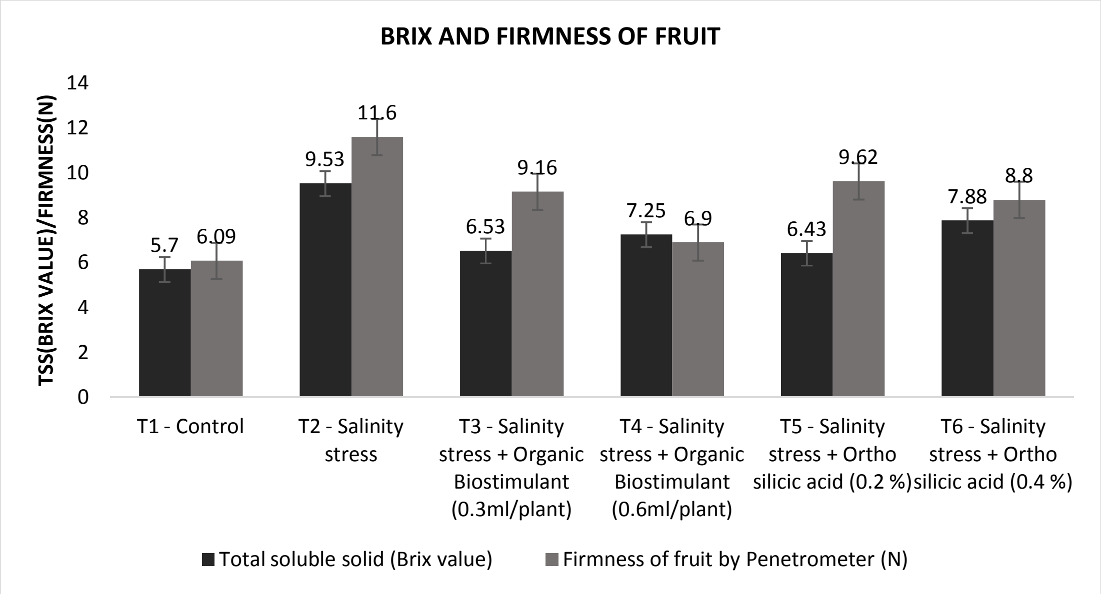

Fig. 5. Effect of organic biostimulants and silicon on total soluble solid (TSS) and Firmness of fruit

3.4.3 Single plant yield (g/plant)

The single plant yield was significantly influenced by the different level of treatments (Fig.3). Although, the maximum single plant yield was observed in control plant (1318 g/plant) compared over other salinity treatments. Moreover, the plants exposed to salinity stress recorded the minimum single plant yield (598 g/plant). A significant increase in single plant yield was observed in the treatment Organic biostimulant (0.6ml/plant) and Orthosilicic acid (0.4%) and recorded 1258 g/plant and 1186 g/plant respectively compared to un-treated plants exposed to salinity stress. Similarly, [40] observed that the most sensitive plant may experience physiological damage resulting in severe production loss, while tomato plants are moderately sensitive to tolerant can still generate acceptable yield. Thereby both treatments (Organic biostimulant & Orthosilicic acid) can positively increase the fruit yield compared to the un-treated salinity plants.

3.4.4 Flower to fruit ratio

In our study, the variation in the Flower to Fruit ratio was measured in different level of treatments. The significant reduction in flower to fruit ratio was observed among all the treatments (Fig.4). The maximum ratio was observed in control plant (77.07%) than other salinity treatments. The plant exposed to salinity stress was recorded the minimum ratio (65.5%). However, a significant increase in Flower to fruit ratio was observed in the treatment Organic biostimulant (0.6ml/plant) and Orthosilicic acid (0.4%) and recorded 77.45% and 72.57% respectively compared to non-treated salinity plants. The tomato plant was exposed to the salinity; it was observed that their flower to fruit ratio was decreased. These findings could indicate that tomato plant respond positively to salinity.

3.5 Quality Parameters

3.5.1 Total soluble solids (TSS)

Total soluble solids (TSS) significantly increased by salinity. Total soluble solid (TSS) was measured for different level of treatments. In this study, a significant increase in the Total soluble solid was observed among the different treatments shown in Table 3. The maximum Total soluble solid content was observed in a salinity treated plants (9.53). However, the lower value of Total soluble solid was recorded in the control plant (5.70). The significant increase in the Total soluble solid was observed in T4 and T6 is 7.25 and 7.88 respectively compared to the control plant. Salinity raises the osmotic potential in plants, resulting in decreases in water absorption and decreases in water flux into the fruit [41]. As well as, the accumulation of solute and organic molecules that is generally produced when plant is stressed by salt.

3.5.2 Firmness of fruit

Fruit external firmness directly indicates the shelf life of the fruit. Fruit external firmness was measured for different level of treatments. A significant increase in the fruit external firmness was observed among the different treatments shown in Table 3. The maximum firmness of fruit was observed in a salinity treated plants (11.90). However, the lower value of firmness of fruit was recorded in the control plant (6.09). The significant increase in the Total soluble solid was observed in T4 and T6 is 6.90 and 8.80 respectively compared to the control plant. [41] observed that increases in the firmness was observed under the stress owing to salt, less water in the fruit and higher dry weight was observed, which increases the firmness of fruit.

4. CONCLUSION

The present study indicated that, the use of organic biostimulant and orthosilicic acid in tomato presents a promising approach to improve growth, physiology, yield, quality and impart saline tolerance. Soil drenching with Organic Biostimulant and Foliar spray with orthosilicic acid could protect the tomato plants against disadvantages by saline stress. In our study, the organic biostimulant and Orthosilicic acid used at its higher dose appears to the most effective. Therefore, used combination of Organic biostimulant and Orthosilicic acid as soil drenching and foliar spray to stimulate plant growth and productivity under soil salinity stress may have higher significant effective application.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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