Original Research Article

Effect of different salinity levels on Morphological and Yield-related traits of tomato (*Solanum lycopersicum* L.)

ABSTRACT

Salinity stress arises from the accumulation of elevated salt levels in the soil, leading to the hindrance of plant growth and eventual crop loss. Compounds that induce stress tolerance exhibit a remarkable capacity to enhance growth and mitigate the impacts of salinity stress, all while maintaining a positive environmental impact by regulating plant activities. to investigate how varying levels of salinity in the irrigation water impact the morphological characteristics and yield of tomato plants. The experiment employed a complete randomized design with one plant per pot and three replicates per treatment, spanning from October 2021 to April 2022 and October 2022 to April 2023 at SVPUAT, Meerut. The objective was to investigate the impact of four NaCl levels (0, 50, 100, and 150 mM) on the Morphological traits of ten tomato cultivars (Arka Rakshak, Punjab Ratta, H-88-78-5, VRT-16-1, Pusa Ruby, Pant T-3, Arka Samrat, Kashi Aman, Kashi Anupam, Pusa Rohini) during the mature stage. Parameters such as average fruit weight, fruit diameter, fruit length, and TSS were also measured. The findings revealed that increasing NaCl salinity adversely affected the morphological properties of all examined tomato plants compared to the control group (tap water). Salinity was found to decrease morpho and yield related parameters, except for TSS in tomato fruit. Nevertheless, there was a variation in the response to salt stress among the studied varieties. Notably, the varieties Pusa Ruby and Pusa Rohini exhibited resilience both in the absence and presence of salt. "Pusa Ruby" and "Pusa Rohini" demonstrated greater tolerance and stability under salinity stress, followed by Arka Rakshak and Kashi Aman, while Punjab Ratta, followed by Pant T-3, proved to be sensitive to salinity. Water salinity significantly impacts the growth and production of crops, and the insights from this study can aid in the selection of salt-tolerant varieties in saline-affected areas.

Keywords: Salinity stress, Plant Growth, Crop loss, NaCl levels, Tomato

1. INTRODUCTION

Tomato (*Solanum lycopersicum*) is a member of the Solanaceae family and a crucial nutritional source for the global population. It ranks as the fourth most widely grown vegetable worldwide and stands as a nutrient-dense plant serving as a model for the development of ~~flavorful~~flavourful fruits. It follows closely behind potatoes and sweet potatoes in global vegetable production [1]. It is an annual crop predominantly undergoing self-pollination, with a chromosome number of 2n = 2x = 24. Believed to have originated in the New World, specifically the Andean region (now spanning parts of Bolivia, Chile, Colombia, Ecuador, and Peru), the diversity observed in cultivated tomatoes strongly suggests their domestication in Mexico. Following the discovery of the New World, tomatoes were introduced to Europe and gradually disseminated globally [2]. However, tomatoes have faced considerable damage in recent years, not only due to abiotic factors like drought or salinity stress but also due to different infections and pests such as fungi, insects, and nematodes [3]. Salt-affected soils span around 1.5 million hectares or roughly 10% of the country's total area. Many crops undergo morphological, physiological, and biochemical alterations as a result of salt,

according to several studies. Different species, variations, and even ecotypes have different levels of stress tolerance [4]. Salt stress represents a significant abiotic challenge impacting every aspect of a plant's physiology and biochemistry, ultimately leading to diminished yields. This poses a critical threat to agricultural productivity, particularly in arid and semi-arid regions. Soil salinity is categorized based on the pH of saturated soil paste, electrical conductivity of saturated paste extract (ECe), and exchangeable sodium percentage (ESP) [5].

Increasing tomato planting area is one of the keys to increasing tomato production. Expansion of planting areas to sub-optimal land including areas experiencing salinity stress can be an alternative for tomato plant development. Salinity is the concentration of dissolved salts in large quantities that can affect the growth of most plants. One of the main obstacles as a result of salinity stress is water deficit / water dehydration caused by low water potential of the growing medium. Throughout the plant life cycle seed germination is generally the most sensitive stage under various factors including salt stress.

Plants cultivated in saline conditions experience stress through three primary mechanisms: (1) a decrease in water potential within the root zone, leading to water deficit; (2) phytotoxic effects of ions, including Na+ and Cl-; and (3) disruption of nutrient balance due to reduced uptake and/or impaired shoot transport [6]. Salt stress induces hyperosmotic stress and disrupts ion equilibrium, causing impairment to essential cellular functions in plants. Consequences include decreased water availability, heightened respiration rates, altered mineral distribution, membrane instability, and the inability to maintain turgor pressure. In response to these challenges, plants employ strategies such as tolerance mechanisms or transitioning into a dormant stage to cope with the adverse effects of salt stress [7].

Based on several studies that Stress Salinity is a limiting factor for plant growth and development, affecting almost all physiological and biochemical processes and stages. It affects almost all physiological and biochemical processes and stages of plant growth. stages of plant growth. Under saline conditions, there is a decrease in chlorophyll content in leaves Content. Increased accumulation Proline accumulation in plant leaves under saline stress conditions.

Formatted: Space After: 12 pt

Therefore,
Based on this, it is considered necessary to conduct research on the physiological response of eggplant plants to salinity stress so that it can be useful to determine genotypes that are not only tolerant based on morphology, but also based on physiological data. not only tolerant based on morphology, but also based on physiological data. The results of this study are expected to provide knowledge about morphological and physiological characters that can be used as parameters of tolerance to salinity stress in eggplant plants and get potential genotypes to be used as parents in the program. genotypes that are potential to be used as elders in eggplant breeding programs. eggplant breeding program.

Formatted: Space After: 12 pt

understanding the impact of salinity on tomato plants and fruits is valuable for selecting and implementing appropriate crop practices to meet the demand in the tomato market. This study focuses on assessing the responses of tomatoes to salinity stress, highlighting the effects on morphology, physiology, and fruit quality under varying levels of soil salinity.

2. MATERIAL AND METHODS

2.1 EXPERIMENTAL DESIGN AND LAYOUT

The design used for this was Completely Randomized Design (CRD) with three replications. The tomato genotypes were grown in plastic pots and then they were exposed to four simulated soil salinity levels (0, 50, 100 and 150mM of NaCl) after attaining stability after transplantation (fig1). The diameter of each plastic pot was 18 × 20 cm^2, containing soil, compost and Manure in a 3:1:1 ratio.

2.2 Experimental site

The experiment was conducted at the Field Laboratory and Experiment Station within the Department of Agricultural Biotechnology at the College of Biotechnology, SVPUA&T, Meerut, India. This location resides in the semi-arid environment and agro-climatic plain zone of Uttar Pradesh state, situated in the North West Plain Zone of India, at 28.99°N latitude and 77.7°E longitude, with an altitude of 220 meters above sea level.

2.3 Nursery Raising and Seedlings Transplantation

All ten accessions were evaluated during *Rabi* season 2021-22 and 2022-23 at the Field Laboratory and Experiment Station within the Department of Agricultural Biotechnology at the College of Biotechnology, SVPUA&T, Meerut, India. Seedlings were raised in pro-trays having 50 cavities with coco peat, vermicompost, and soil (2:1:1) under intensive care and with a high survival percentage under shade net house during September and transplanted in the second week of October. The pots were filled with soil and seedling having a reasonable size of 3–4 leaves were transplanted in the pots. The pots were arranged randomly and repeated three times. One seedling per pot was planted. After the plant's establishment, they were subjected to salinity stress.

Figure 1. Assessment of Tomato genotypes under different levels of salinity (C-0mM, T1-50mM, T2-100mM, T3-150mM)

2.4 Morphological parameters measurement

2.4.1 Plant height (PH)

The height of three replicates for each treatment was determined with the help of a meter scale and recorded plant height in cm after one month of treatment and at maturity. The average plant height was calculated.

2.4.2 Number of branches per plant (NBP)

The number of branches arising on the main shoot was counted for each plant at the time of maturity and recorded as the number of branches per plant.

2.4.3 Number of flower trusses per plant

Recordings of all the flower trusses of a plant were taken at the time of flowering and at regular intervals till fruit setting took place. The total number of flower trusses was recorded for all the treatments.

2.4.4 Number of flowers per truss

Recordings of the number of flowers per truss were taken for three flower trusses of each plant at the time of flowering.

2.4.5 Average fruit weight

The average fruit weight was estimated by weighing three fruits in each treatment, with the help of an electronic balance measuring in grams to the third decimal place and then converting to average fruit weight.

2.4.6 Fruit diameter (cm)

Three fruits per pot were taken and the diameter at the maximum point of fruit was measured by vernier caliper. The average diameter per fruit was calculated.

2.4.7 Fruit length (cm)

For Replication, three fruits of each genotype were selected randomly and the length was measured by vernier caliper and recorded in cm.

2.4.8 Number of fruits per plant

The total number of mature ripe fruits per plant ~~were~~ was calculated and recorded.

2.4.9 Total soluble solids (˚ Brix)

Total soluble solids (TSS) were determined on a portable refractometer (NC-1, Atago Co., Japan) standardized with distilled water. A hand refractometer was used for direct determination of total soluble solids (Brix) for fresh Juice. Three ripe fruits were selected at random from each picking of the sample plants and the refractometer reading from the juice of each of the three fruits was recorded separately and the average of these three readings was calculated. Three such averages were taken from three separate picking and the mean of these three averages was used for statistical analysis.

3. RESULTS AND DISCUSSION

The variance analysis revealed significant variability among the genotypes in response to salinity stress across various traits, including plant height, number of branches per plant, number of flowers per cluster, number of trusses per plant, number of fruits per plant, diameter, and length of fruit, total soluble solids, average fruit weight, and TSS. To discern the impact of salinity stress at concentrations of 50mM, 100mM, and 150mM, differences in growth parameters were observed by comparing the values obtained in the treatment with the corresponding controls for each parameter and variety. The table presents the mean performance of different genotypes for various traits and the grand mean for these traits under salinity stress.

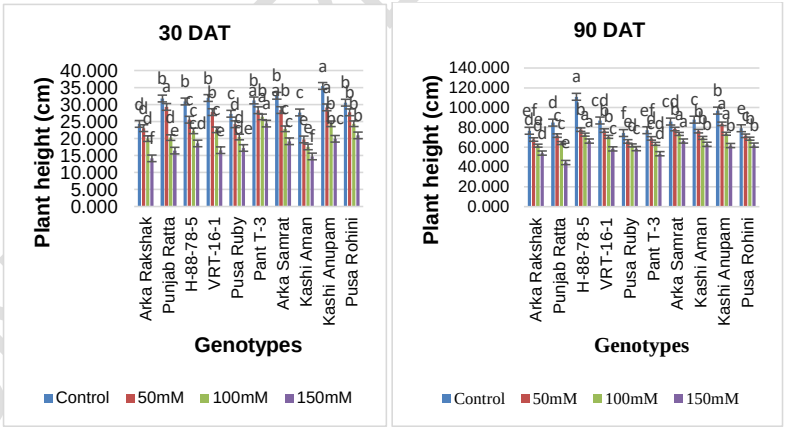
3.1 Plant height

At 30-day after treatment, the data presented in Figure 2 highlights a noteworthy decline in plant height (PLHT) due to salt stress at 50mM, 100mM, and 150mM NaCl concentrations. The most significant reduction in plant height was observed in plants subjected to 150mM concentration, followed by 100mM and 50mM. Comparatively, control plants exhibited greater height than their stressed counterparts. Plant height decreased with the application of elevated salt stress reported by Babu *et al.* (2012); and Ali *et al.* (2014) [7,8]. Taking into account the mean results over both years, the average plant height under control conditions was 30.36 cm, and in stress conditions, the mean plant heights were 26.31 cm, 22.09 cm, and 18.21 cm at NaCl concentrations of 50mM, 100mM, and 150mM, respectively. Plant height ranged from 24.3 ± 0.65 cm (Arka Rakshak) to 35.47 ± 0.75 cm (Kashi Anupam) for control, while stressed plants varied from 14.17 ± 0.6 cm (Arka Rakshak) to 24.39 ± 0.31 cm (Pant T-3) under the highest NaCl concentration (150mM). Among the different germplasms used in the experiment, Kashi Anupam displayed the highest height, with heights of 35.47 ± 0.75 cm, 29.16 ± 0.23 cm, 24.33 ± 0.66 cm, and 19.92 ± 0.36 cm for control and treatments (50mM, 100mM, and 150mM). Conversely, Arka Rakshak exhibited the lowest height, measuring 24.3 ± 0.65 cm, 23.05 ± 0.58 cm, 19.96 ± 0.98 cm, and 14.17 ± 0.6 cm, followed by Pusa Ruby with heights of 27.28 ± 0.71 cm, 24.2 ± 0.63 cm, 20.44 ± 0.79 cm, and 17.22 ± 0.7 cm for control and treatments (50mM, 100mM, and 150mM).

At the 90 days after treatment or maturity, the mean results over both years, the average plant height under control conditions was 86.09 cm and in stress conditions, the mean plant heights were 73.88 cm, 67.94 cm, and 58.84 cm at NaCl concentrations of 50mM, 100mM, and 150mM, respectively. Plant height ranged from 74.33 ± 0.64 cm (Pusa Ruby) to 110.92 ± 1.51 cm (H-88-78-5) for control, while stressed plants varied from 44.56 ± 0.98 cm (Punjab Ratta) to 66.25 ± 0.46 cm (Arka Samrat) under the highest NaCl concentration (150mM). Among the different germplasms used in the experiment, H-88-78-5 displayed the highest height, with heights of 110.92 ± 1.51 cm, 77.76 ± 0.61 cm, 72.73 ± 0.99 cm, and 66.23 ± 0.94 cm for control and treatments (50mM, 100mM, and 150mM) followed by Kashi Anupam with the height of 96.96 ± 1.17 cm, 83.62 ± 0.86 cm, 73.62 ± 0.42 cm and 61.73 ± 0.95 cm. Conversely, Pusa Ruby exhibited the lowest height, measuring 74.33 ± 0.64 cm, 65.87 ± 0.8 cm, 61.87 ± 0.26 cm, and 58.59 ± 0.37 cm for control and treatments (50mM, 100mM, and 150mM), followed by Arka Rakshak with heights of 76.62 ± 0.42 cm, 67.8 ± 0.79 cm, 61.59 ± 0.55 cm, and 54.11 ± 0.91 cm. observation tells the negative percent reduction for this character as shown in Fig 2. Ismail *et al.* (1994); and Umar *et al*. (2018) [9,10] also reported a comparable outcome, noting that an elevation in salinity is accompanied by a reduction in plant height.

Genotype Punjab Ratta (47.47%) exhibited the highest percentage reduction under stressed conditions, followed by H-88-78-5 (40.29%), while the lowest percentage reduction was observed in Pusa Ruby (21.17%) followed by Pusa Rohini (21.55%). The ANOVA results confirmed the significance of the plant height character outcomes.

Several studies have reported that eggplant plant height growth is inhibited. This is because salinity levels can interfere with the absorption of important nutrient ions. This situation is thought to be the cause of the disruption of the nutrient water absorption system into the plant, while water is the raw material needed by plants to carry out metabolic activities, so that plant cells continue to divide and develop. cells continue to divide and develop. absorption can cause cell division to be disrupted.



Data is represented as mean (±standard error) and the different letters are shown according to the Tukey's HSD test at $p < 0.05$

Figure 2. Effect of tomato genotypes on the plant height at different days after treatment (DAT).

3.2 Number of branches per plant (NBP)

The mean results over both years, the average NBP under control conditions was 11.7 and in stress conditions, the mean was 9.37 cm, 7.90 cm, and 6.00 cm at NaCl concentrations of 50mM, 100mM, and 150mM, respectively (Table 1). Recorded observations show that the number of branches per plant varied from 8.33 ± 0.33 (Pusa Rohini) to 14.67 ± 0.33 (VRT-16-1) in controlled conditions whereas in stressed conditions the number of branches varied from 3.33 ± 0.88 (Kashi Aman) to 8.67 ± 0.33 (Pusa Ruby) under the highest NaCl concentration (150mM) (Table 1). The observations showed a compelling reduction in the number of branches per plant under salinity stress conditions in all ten genotypes. VRT-16-1 displayed the highest NBP i.e 14.67 ± 0.33, 12.33 ± 0.33, 10 ± 0.58 and 7.33 ± 0.33 followed by Pusa Ruby with the number of 12.67 ± 0.33, 10.67 ± 0.33, 9 ± 0.58 and 8.67 ± 0.33 for control and treatments (50mM, 100mM, and 150mM). Conversely, Pusa Rohini exhibited the lowest height, measuring 8.33 ± 0.33, 6.67 ± 0.33, 6.33 ± 0.33 and 5.33 ± 0.33for control and treatments (50mM, 100mM, and 150mM), followed by Kashi Aman with the number of 8.67 ± 0.67, 6.67 ± 0.33, 5.33 ± 0.33 and 3.33 ± 0.88. Observation tells the negative percent reduction for this character. Similar results were also recorded by Khursheda *et al.* (2015) [11]. Uddin *et al*. (2005) [12] observed a decrease in the number of branches in *Brassica* species with increasing salinity, aligning with a similar finding in rice where salinity led to a reduction in tiller number, as reported by Mortazainezhad *et al.* (2006) [13].
Genotype Kashi Anupam (56.23%) exhibited the highest percentage reduction under stressed conditions, followed by Kashi Aman (61.59%), while the lowest percentage reduction was observed in Pusa Ruby (31.57%). The ANOVA results confirmed the significance of the character outcomes.

Media High salinity media can also reduce the number of branches, where salinity stress affects agronomic traits and the number of productive branches. salinity stress affects agronomic traits and the number of productive branches. The number of branches is negatively correlated with plant height.

3.3 Number of flower trusses per plant

The number of leaves can also be used as an important variable to determine the growth rate of salinity-stressed plants. determine the level of plant growth that is affected by salinity, because in the leaf organ, many metabolic processes occur such as the rate of photosynthesis and a series of other physiological processes. a series of other physiological processes. In addition to inhibiting the entry process of water into the plant, the effect caused by salt can cause the plant to experience ion plants to experience ion poisoning, so that cells must pump more energy to avoid saline stress. to avoid saline stress, commonly known as the avoidance mechanism. avoidence mechanism. This can change some physiological reactions physiological reactions become unbalanced, so that the growth of the number of leaves is reduced and the percentage of dead leaves increases. reduced and the percentage of dead leaves increases

Salinity stress has an adverse effect on crop yield attributes causing a reduction in the number of flower trusses per plant in tomato plants Zhang *et al*. (2017) [14]. The detailed results were recorded and evaluated under control conditions as well as salinity stress conditions and represented. For all tomato genotypes, recorded observations for the number of flower trusses per plant were found to be in the range of 5.33 ± 0.33 to 10.67 ± 0.88 control plants in comparison to salinity stressed plants which showed the range of 1.33 ± 0.33 to 3.67 ± 0.67

when applied the highest concentration of NaCl i.e 150mM (Table 1). The observations showed a compelling reduction in number of flower truss per plant under salinity stress conditions in all ten genotypes. Results further indicated that under controlled conditions genotype Kashi Anupam showed the maximum number of flower trusses per plant i.e 10.67 ± 0.88, 5.67 ± 1.33, 4.67 ± 0.88 and 3.67 ± 0.67 followed by Pusa Ruby i.e 9.33 ± 0.33, 7 ± 1, 6.33 ± 0.33 and 4.67 ± 0.33 for control and treatments (50mM, 100mM, and 150mM) while a minimum number of flower trusses per plant were recorded in Arka Rakshak i.e 5.33 ± 0.33, 4.33 ± 0.33, 3.33 ± 0.33 and 1.67 ± 0.33 followed by Arka Samrat 5.67 ± 0.88, 3.67 ± 0.88, 3 ± 0.58 and 1.67 ± 0.67 for control and treatments (50mM, 100mM, and 150mM). Similar results were recorded by Leiva-Ampuero *et al.* (2020) [15]. One-way ANOVA analyses have shown that the results for the number of flower truss per plant are significant at $p < 0.05$.
Genotype Punjab Ratta (78.98%) exhibited the highest percentage reduction under stressed conditions, followed by Arka Samrat (75.99%), while the lowest percentage reduction was observed in Pusa Ruby (49.94%) followed by Pusa Rohini (59.97%).

3.4 Number of flowers per truss

Some studies state that the difference in the number of flowers per genotypes can occur due to genetic factors, besides that it can also be because the plant experiencing a deficiency of phosphorus nutrients which can suppress the number of flowers and fruit initiation

Age difference flowering age in each plant can occur due to the influence of temperature, light and nutrients absorbed by the plant. nutrients absorbed by the plant. Percentage of live buds and flowers as well as the number of fruits is getting lower as salinity levels increase. although not significantly influenced by variance analysis is not influenced by salinity levels. by salinity levels, but the number of flowers and fruit is more influenced by the nutrient nutrient element pospor

Salinity stress harms crop yield attributes causing a reduction in the number of flowers per truss in tomato plants (Zhang *et al.,* 2017) [14]. The detailed results recorded and evaluated under control as well as salinity stress conditions are represented in Table 1. Recorded observations corresponding to the number of flowers per truss were found to vary from 5.67 ± 0.33 (Pusa Ruby) to 7.83 ± 0.44 (VRT-16-1) in controlled plants while in salinity- stressed plants values varied from 2.17 ± 0.6 (Kashi Anupam) to 3.83 ± 0.44 (H-88-78-5) under the highest NaCl concentration (150mM). The observations showed compelling reduction in number of flowers per truss under salinity stress conditions in all ten genotypes. The tomato plant exhibited the highest floral count in the control condition, while the plant treated with salt showed the lowest counts also reported by Amini *et al.* (2007) [16]. Results also indicated that under controlled conditions genotype VRT-16-1 showed the maximum number of flower per truss i.e 7.83 ± 0.44, 6.43 ± 0.3, 5.6 ± 0.38 and 3.67 ± 0.33 followed by H-88-78-5 i.e 7.77 ± 0.39, 6.19 ± 0.24, 5.53 ± 0.29 and 3.83 ± 0.44 for control and treatments (50mM, 100mM, and 150mM) while a minimum number of flower per truss were recorded in genotype Pusa Ruby i.e. 5.67 ± 0.33, 4.5 ± 0.14, 4.92 ± 0.51 and 3.5 ± 1.89 followed by Pusa Rohini i.e 5.7 ± 0.44, 4.93 ± 0.3, 4.33 ± 0.44 and 2.83 ± 0.6 for control and treatments (50mM, 100mM, and 150mM). Furthermore, salinity negatively impacted flower production, with control plants exhibiting a higher rate compared to those subjected to salinity treatment. Likewise, Umar *et al.* (2018); and Gumi *et al* (2013) [10,17] observed a reduction in vegetative growth and the number of flowers in tomatoes under salinity.
Genotype Punjab Ratta (68.21%) exhibited the highest percentage reduction under stressed conditions, followed by Kashi Anupam (65.71%), while the lowest percentage reduction was

observed in Pusa Ruby (38.27%) followed by Pusa Rohini (50.35%). The ANOVA results confirmed the significance of the character outcomes.

According to some studies, the number of leaves of tomato plants decreases with increasing salinity concentration. salinity concentration, alinity can also reduce the weight of the roots. This has to do with the physiological processes of plants that are disrupted and cell division is inhibited, causing the growth of the plant. physiological processes are disrupted and cell division is inhibited, causing plant growth to be inhibited plant growth becomes inhibited as well

Table 1. Effect of different concentrations of salt (50mM, 100mM and 150mM) on Number of branches/plant, Number of trusses/plant and number of flowers/ truss

Cultivar/ Treatment	Number of branches / plant				Number of trusses / plant				Number of flowers / truss			
	Control	50mM	100mM	150mM	Control	50mM	100mM	150mM	Control	50mM	100mM	150mM
Arka Rakshak	12.67 ± 0.33^{bc}	9.33 ± 0.33^{cd}	7.67 ± 0.33^{bc}	6.67 ± 0.33^{bc}	5.33 ± 0.33^{f}	4.33 ± 0.33	3.33 ± 0.33^{bcd}	1.67 ± 0.33^{cd}	6.53 ± 0.29^{cd}	5.2 ± 0.2^{bcd}	4.17 ± 0.17^{c}	2.83 ± 0.17
Punjab Ratta	13.33 ± 0.33^{ab}	10.33 ± 0.33^{bc}	9.33 ± 0.33^{a}	6.33 ± 0.33b^{cd}	6.33 ± 0.33^{def}	4.33 ± 0.67	2.67 ± 0.33^{d}	1.33 ± 0.33^{d}	7.33 ± 0.33^{bc}	6.0 ± 0.29^{abc}	4.5 ± 0.29^{bc}	2.33 ± 0.33
H-88-78-5	11.33 ± 0.33^{cd}	9.00± 0.58^{d}	7.33 ± 0.67^{c}	5.33 ± 0.33^{cde}	7.33 ± 0.33^{cde}	4.33 ± 0.88	3.33 ± 0.33^{bcd}	2.33 ± 0.33^{cd}	7.77 ± 0.39^{ab}	6.19 ± 0.24^{ab}	5.53 ± 0.29^{ab}	3.83 ± 0.44
VRT-16-1	14.67 ± 0.33^{a}	12.33 ± 0.33^{a}	10.00 ± 0.58^{a}	7.33 ± 0.33^{ab}	8.33 ± 0.33^{bc}	5.00 ± 0.58	4.33 ± 0.67^{bc}	2.33 ± 0.33^{cd}	7.83 ± 0.44^{a}	6.43 ± 0.3^{a}	5.6 ± 0.38^{a}	3.67 ± 0.33
Pusa Ruby	12.67 ± 0.33^{bc}	10.67 ± 0.33^{b}	9.00 ± 0.58^{ab}	8.67 ± 0.33^{Aa}	9.33 ± 0.33^{ab}	7.00 ± 1.00	6.33 ± 0.33^{a}	4.67 ± 0.33^{a}	5.67 ± 0.33^{d}	4.5 ± 0.14^{d}	4.92 ± 0.51^{bc}	3.5 ± 1.89
Pant T-3	14.00 ± 0.58^{ab}	11.33 ± 0.33^{ab}	10.33 ± 0.88^{a}	7.33 ± 0.88^{ab}	8.00 ± 0.58^{bcd}	4.67 ± 0.88	4.33 ± 0.33^{bc}	2.67 ± 0.33^{bc}	5.87 ± 0.47^{d}	4.5 ± 0.29^{d}	4.13 ± 0.32^{c}	2.83 ± 0.44
Arka Samrat	10.67 ± 0.88^{d}	8.67 ± 0.33^{d}	7.00 ± 0.58^{c}	5.00 ± 0.58d^{e}	5.67 ± 0.88^{ef}	3.67 ± 0.88	3.00 ± 0.58^{cd}	1.67 ± 0.67^{cd}	6.6 ± 0.4^{cd}	5.27 ± 0.15^{bcd}	4.07 ± 0.56^{c}	2.6 ± 0.31
Kashi Aman	8.67 ± 0.67^{e}	6.67 ± 0.33^{e}	5.33 ± 0.33^{d}	3.33 ± 0.88^{f}	8.33 ± 0.88^{bc}	5.67 ± 0.33	3.67 ± 0.33^{bcd}	2.00 ± 0.58^{cd}	7.4 ± 0.7^{bc}	5.10 ± 0.67^{cd}	4 ± 0.29^{c}	2.73 ± 0.37
Kashi Anupam	10.67 ± 0.33^{d}	8.67 ± 0.33^{d}	6.67 ± 0.33^{cd}	4.67 ± 0.33^{ef}	10.67 ± 0.88^{a}	5.67 ± 1.33	4.67 ± 0.88^{b}	3.67 ± 0.67^{ab}	6.33 ± 0.33^{cd}	5.0 ± 0.58^{cd}	4.83 ± 0.27^{bc}	2.17 ± 0.6
Pusa Rohini	8.33 ± 0.33^{e}	6.67 ± 0.33^{e}	6.33 ± 0.33^{cd}	5.33 ± 0.33^{cde}	6.67 ± 0.33^{cdef}	4.33 ± 0.33	3.67 ± 0.88^{bcd}	2.67 ± 0.33^{bc}	5.7 ± 0.44^{d}	4.93 ± 0.3^{d}	4.33 ± 0.44^{c}	2.83 ± 0.6
Gen. Mean	**11.7**	**9.37**	**7.9**	**6**	**7.6**	**4.9**	**3.93**	**2.5**	**6.7**	**5.31**	**4.61**	**2.93**
F Prob.	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.21**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.78**
S.E.M.	**0.48**	**0.37**	**0.53**	**0.52**	**0.58**	**0.79**	**0.55**	**0.45**	**0.43**	**0.35**	**0.37**	**0.72**
C.D. 5%	**1.42**	**1.08**	**1.55**	**1.52**	**1.7**	**NS**	**1.62**	**1.32**	**1.26**	**1.05**	**1.09**	**NS**
C.V.	**7.15**	**6.75**	**11.56**	**14.91**	**13.16**	**27.88**	**24.12**	**30.98**	**11.05**	**11.57**	**13.88**	**42.48**

Note: Value are means of 3 independent replicates± Standard error, means followed by different letters are significantly different at p ≤ 0.05 according to HSD.

3.5 Average fruit weight

The data presented in Table 3 highlights a noteworthy decline in average fruit weight due to salt stress at 50mM, 100mM, and 150mM NaCl concentrations. Considering the overall mean

result of both years the mean average fruit weight at the control condition was 49.15g and at stress 43.89, 40.21 and 35.48g for 50mM, 100mMand 150mM respectively. It ranged between 23.76 ± 0.55 (Punjab Ratta) to 108.73 ± 1.29 g (Kashi Anupam) among control plants whereas, among treatments, it was 18.79 ± 0.45 g (Punjab Ratta) to 78.53 ± 0.71g (Kashi Anupam) under the highest NaCl concentration (150mM). The Highest fruit weight was recorded by Kashi Anupam i.e 108.73 ± 1.29, 97.13 ± 1.03, 91.58 ± 0.47 and 78.53 ± 0.71g followed by Pusa Rohini i.e 54.16 ± 0.85g, 47.72 ± 0.68g, 42.64 ± 0.37 and 35.24 ± 0.34, Arka Rakshak i.e 51.59 ± 1.02, 45.87 ± 0.46, 42.71 ± 0.48 and 39.45 ± 0.56g for control and treatments (50mM, 100mM and 150mM). The Lowest average fruit weight was recorded by Punjab Ratta i.e 23.76 ± 0.55, 22.05 ± 0.3, 20.37 ± 0.2 and 18.79 ± 0.45g for control and treatments (50mM, 100mM and 150mM). Giannakoula *et al.* (2013); Umar *et al.* (2018); Ali *et al.* (2014); and De Pascale *et al.* (2012) [18,11,8,19], findings also indicated a notable impact of NaCl on fruit fresh weight, with an observed reduction in plants subjected to NaCl treatment.

Genotype Pant T-3 (35.80%) exhibited the highest percentage reduction under stressed conditions, followed by Pusa Rohini (34.93%), while the lowest percentage reduction was observed in Pusa Ruby (19.59%). The ANOVA results confirmed the significance of the Average fruit weight character outcomes.

Several studies reported that salinity treatment affected the wet weight of eggplant fruit, 100% NaCl (high concentration). The decrease is caused by low water supply to the leaves during growth, and lack of mineral nutrient supply, because the water supply is disrupted, the photosynthesis process is inhibited so that the photosynthate produced for growth and fruit formation is also small, so that the fruit formed is not optimal.

3.6 Fruit diameter (cm)

The fruit diameter is one of the characteristics that helps to measure the size of tomato fruit produced by the plant. The fruit diameter experienced significant alterations under different salinity stress levels (Fig 3). This could be attributed to the detrimental impact of salt stress on water availability and uptake, resulting in a reduction in water content within plant tissues. This, in turn, induces changes in metabolic processes within the cell, as suggested by Latif and Mohamed *et al.* (2016) [20]. The Overall mean of both the years the mean fruit width among control and treatments (50mM, 100mM and 150mM) plants recorded was 4.46, 4.24, 4.01 and 3.71 cm respectively. It ranged from 2.55 ± 0.03 cm (H-88-78-5) to 6.97 ± 0.10 cm (Kashi Anupam) by control and treatments ranged between 1.95 ± 0.02 cm (H-88-78-5) to 4.7 ± 0.02 cm (Pusa Rohini) under the highest NaCl concentration (150mM). The highest fruit diameter recorded by Kashi Anupam was 6.97 ± 0.1, 6.54 ± 0.03, 6.26 ± 0.03 and 5.96 ± 0.03cm followed by Pusa Rohini i.e 5.26 ± 0.02, 5.05 ± 0.04, 4.89 ± 0.04 and 4.7 ± 0.02cm while lowest fruit diameter was shown by H-88-78-5 i.e 2.55 ± 0.03, 2.39 ± 0.03, 2.27 ± 0.03 and 1.95 ± 0.02cm followed by Punjab Ratta 3.7 ± 0.09, 3.54 ± 0.03, 3.22 ± 0.1 and 2.17 ± 0.06cm for control and treatments (50mM, 100mM and 150mM) represented in Table 2.Ali *et al.* (2014) [8] reported that NaCl significantly decreased fruit diameter. Elevated salinity stress, particularly at a concentration of 8.0 dS/m, resulted in a reduction in the radius of tomato fruit and cell size. This effect can be attributed to a decrease in water influx, as documented by Saito *et al.* (2009) [21]. The findings of this study align with the conclusions of Akladious and Mohamed (2018) [22], who observed a significant reduction in fruit length and diameter of pepper plants when irrigated with high saline water (200mM).

The highest percent Induction for fruit diameter was recorded by Punjab Ratta (41.35%) followed by H-88-78-5 (23.52%). The lowest percent reduction was reported by Pusa Ruby (9.54%) followed by Pusa Rohini (10.64%).

that salinity can affect photosynthesis in both the short and long term. In the short term, salinity affects photosynthesis withstomatal limitation, which leads to decreased carbon assimilation. plant growth is limited by plant growth is limited by an excessive decrease in photosynthesis rate due to salt uptake.

3.7 Fruit length (cm)

Overall results indicated that control plants have bigger-sized fruits as compared to treatment plant fruits, hence, control showed more fruit length than plants under stress in this study (Table 2). This result is reported by Ali *et al.* (2014) [8] in their study. Considering the overall mean result of both years the mean average fruit length at the control condition was 4.34 cm and at salinity treatments (50mM, 100mM and 150mM) was 4.08, 3.76 and 3.43cm respectively. The range shown by control plants was 2.92 ± 0.03cm (Pant-T3) to 6.11 ± 0.07cm (Kashi Aman), and that of treatment plants was 2.04 ± 0.08cm (Pant-T3) to 5.32 ± 0.02 cm (Kashi Anupam). Among the different germplasms used in the experiment, Kashi Anupam displayed the highest fruit length, with lengths of 6.11 ± 0.07, 5.74 ± 0.04, 5.58 ± 0.03 and 5.32 ± 0.02cm followed by Arka Samrat i.e 5.31 ± 0.05, 4.84 ± 0.02, 4.7 ± 0.01 and 4.51 ± 0.02cm conversely, Pant-T3 exhibited the lowest fruit length, measuring 2.92 ± 0.03, 2.73 ± 0.03, 2.4 ± 0.01 and 2.04 ± 0.08 cm followed by Punjab Ratta i.e 3.46 ± 0.03, 3.27 ± 0.08, 3 ± 0.01 and 2.79 ± 0.03cm for control and treatments (50mM, 100mM, and 150mM).

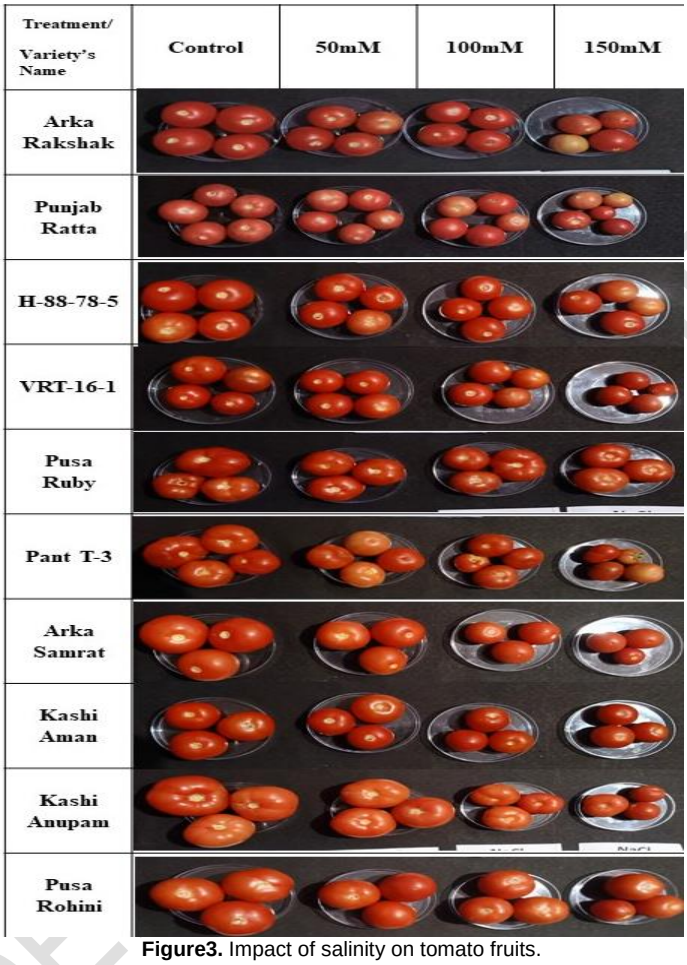


Figure3. Impact of salinity on tomato fruits.

Distinct salinity levels led to differences in the length of tomato plant fruits as shown in fig 3. Notably, substantial fruits were harvested from control plants, while plants subjected to high salinity stress produced smaller fruits. This phenomenon could be attributed to the adverse impact of salinity on cell expansion, as reported by Parvin *et al.* (2015) [23].

The highest percent Induction for fruit length was recorded by H-88-78-5 (42.29 %). followed by Pant T-3 (30.13%). The lowest percent reduction was reported by Kashi Aman (12.92%) followed by Pusa Rohini (14.37%).

Table 2. **Effect of different concentrations of salt (50mM, 100mM and 150mM) on Fruit diameter and length.**

Cultivar/ Treatment	Fruit diameter				Fruit length			
	Control	50mM	100mM	150mM	Control	50mM	100mM	150mM
Arka Rakshak	4.46 ± 0.05^{d}	4.22 ± 0.07^{e}	3.96 ± 0.04^{de}	3.56 ± 0.17^{e}	4.81 ± 0.03^{c}	4.66 ± 0.02^{c}	3.9 ± 0.02^{e}	3.67 ± 0.03^{d}
Punjab Ratta	3.7 ± 0.09^{g}	3.54 ± 0.03^{h}	3.22 ± 0.1^{g}	2.17 ± 0.06^{g}	3.46 ± 0.03^{f}	3.27 ± 0.08^{h}	3 ± 0.01^{h}	2.79 ± 0.03^{f}
H-88-78-5	2.55 ± 0.03^{h}	2.39 ± 0.03^{i}	2.27 ± 0.03^{h}	1.95 ± 0.02^{h}	3.83 ± 0.03^{e}	3.48 ± 0.03^{g}	2.93 ± 0.04^{h}	2.21 ± 0.01^{g}
VRT-16-1	4.12 ± 0.05^{e}	3.94 ± 0.02^{f}	3.76 ± 0.03^{ef}	3.54 ± 0.02^{e}	3.83 ± 0.02^{e}	3.64 ± 0.03^{f}	3.22 ± 0.03^{g}	2.77 ± 0.06^{f}
Pusa Ruby	4.82 ± 0.02^{c}	4.6 ± 0.01^{c}	4.49 ± 0.01^{c}	4.36 ± 0.02^{c}	3.88 ± 0.08^{e}	3.64 ± 0.02^{f}	3.5 ± 0.05^{f}	3.27 ± 0.04^{e}
Pant T-3	4.14 ± 0.02^{e}	3.97 ± 0.03^{f}	3.54 ± 0.01^{f}	3.67 ± 0.02^{e}	2.92 ± 0.03^{g}	2.73 ± 0.03^{i}	2.4 ± 0.01^{i}	2.04 ± 0.08^{h}
Arka Samrat	4.7 ± 0.02^{c}	4.41 ± 0.01^{d}	4.14 ± 0.06^{d}	3.93 ± 0.03^{d}	5.31 ± 0.05^{b}	4.84 ± 0.02^{b}	4.7 ± 0.01^{b}	4.51 ± 0.02^{b}
Kashi Aman	3.94 ± 0.04^{f}	3.7 ± 0.01^{g}	3.53 ± 0.03^{f}	3.31 ± 0.01^{f}	6.11 ± 0.07^{a}	5.74 ± 0.04^{a}	5.58 ± 0.03^{a}	5.32 ± 0.02^{a}
Kashi Anupam	6.97 ± 0.1^{a}	6.54 ± 0.03^{a}	6.26 ± 0.03^{a}	5.96 ± 0.03^{a}	4.52 ± 0.07^{d}	4.31 ± 0.02^{e}	4.1 ± 0.04^{d}	3.71 ± 0.1^{d}
Pusa Rohini	5.26 ± 0.02^{b}	5.05 ± 0.04^{b}	4.89 ± 0.04^{b}	4.7 ± 0.02^{b}	4.73 ± 0.02^{c}	4.46 ± 0.03^{d}	4.23 ± 0.02^{c}	4.05 ± 0.04^{c}
Gen. Mean	**4.46**	**4.24**	**4.01**	**3.71**	**4.34**	**4.08**	**3.76**	**3.43**
F Prob.	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
S.E.M.	**0.05**	**0.03**	**0.1**	**0.06**	**0.05**	**0.04**	**0.03**	**0.05**
C.D. 5%	**0.15**	**0.1**	**0.29**	**0.18**	**0.14**	**0.11**	**0.09**	**0.15**
C.V.	**1.99**	**1.35**	**4.21**	**2.81**	**1.89**	**1.6**	**1.4**	**2.53**

Note: Value are means of 3 independent replicates± Standard error, means followed by different letters are significantly different at $p \leq 0.05$ according to HSD.

3.8 Number of fruits per plant

The results were significant for the important yield contributing character number of fruits per plant for both experiments. Due to abiotic stress, the fruit yield was reduced drastically in treated plants than the control for both the years (Table 3). The result is also reported by Umar *et al.* (2018); Amini et al. (2007); Babu *et al.* (2012) [10,16,7]. Considering the overall mean of both years the mean number of fruits per plant among control and treatments (50mM, 100mM and 150mM) recorded were 26.47, 20.17, 15.93 and 9.73 respectively. Control plants ranged from 17.33±0.88 (Pusa Rohini) to 35 ± 1.15 (H-88-78-5) and stress applied was from 6 ± 0.58 (VRT-16-1) to 11.67 ± 0.88 (Pusa Ruby) under the highest NaCl concentration (150mM) for number of fruits. Among the different germplasms used in the experiment, H-88-78-5 displayed the highest number of fruits, with the number of 35 ± 1.15, 28.67 ± 0.88, 21 ± 1.15 and 14 ± 1.15 followed by Kashi Aman i.e. 31 ± 1.15, 24.67 ± 0.88, 18.67 ± 0.88 and 9.67 ± 0.88 for control and treatments (50mM, 100mM, and 150mM). Conversely, Pusa Rohini exhibited the lowest number of fruits, measuring 17.33 ± 0.88, 13.33 ± 0.88, 10.67 ± 0.88 and 7.00 ± 1.15, followed by Arka Rakshak with the numbers of 23.33 ± 1.2, 17.67 ± 0.88, 14.67 ± 0.88 and 9 ± 0.58 for control and treatments (50mM, 100mM, and 150mM). The decrease in fruit number could be associated with salt-induced factors leading to a reduction in the number of flowers, as indicated by Magan *et al.* (2008) and Cuartero and Fernandez (1999) [24,25]. Zhang and colleagues (2017) [14] noted a decrease in tomato plant yield under NaCl stress (Control = 0.8 dS m−1 and sodium chloride solution with EC = 2.0 dS m−1) when salt stress was applied individually during the vegetative, flowering, and fruiting stages. In contrast, our study employed various salt concentrations from transplanting to harvest.

The overall percent reduction signifies the severity of stress and its importance. The highest percent reduction was indicated by genotype Punjab Ratta (74.65 %) followed by Kashi Aman (68.80%). The least affected genotypes were Pusa Ruby (49.97 %) followed by Arka Rakshak (54.11 %). The ANOVA results indicated significant results for this character.

Table 3. Effect of different concentrations of salt (50mM, 100mM and 150mM) on Number of fruits/ plant and Average fruit weight

Cultivar/ Treatment	Number of fruits per plant				Average fruit weight			
	Control	50mM	100mM	150mM	Control	50mM	100mM	150mM
Arka Rakshak	23.33 ± 1.2^{d}	17.67 ± 0.88^{cd}	14.67 ± 0.88^{d}	9.00 ± 0.58^{bc}	51.59 ± 1.02^{c}	45.87 ± 0.46^{c}	42.71 ± 0.48^{b}	39.45 ± 0.56^{b}
Punjab Ratta	23.67 ± 0.88^{d}	15 ± 0.58de	9.33 ± 0.88^{e}	6.00 ± 0.58^{d}	23.76 ± 0.55^{g}	22.05 ± 0.3^{h}	20.37 ± 0.2^{f}	18.79 ± 0.45^{h}
H-88-78-5	35 ± 1.15^{a}	28.67 ± 0.88^{a}	21.00 ± 1.15^{ab}	14.00 ± 1.15^{a}	36.37 ± 0.89^{f}	32.61 ± 0.66^{g}	29.12 ± 0.44^{e}	25.73 ± 0.29^{f}
VRT-16-1	26.67 ± 0.88^{c}	16.67 ± 0.88^{cd}	14.33 ± 0.88^{d}	8.67 ± 0.88^{cd}	34.53 ± 0.66^{f}	31.01 ± 0.19^{g}	28.67 ± 0.52^{e}	24.21 ± 0.38^{g}
Pusa Ruby	23.33 ± 0.88^{d}	18.67 ± 0.88^{c}	15.67 ± 0.88^{cd}	11.67 ± 0.88^{ab}	45.77 ± 0.61^{e}	43.21 ± 0.49^{d}	40.69 ± 0.34^{c}	36.80 ± 0.3^{c}
Pant T-3	28.67 ± 0.88^{bc}	23.67 ± 0.88^{b}	18.33 ± 0.88^{bc}	9.00 ± 1.15^{bc}	48.77 ± 0.73^{d}	40.71 ± 0.58^{e}	35.63 ± 0.46^{d}	31.31 ± 0.34^{e}
Arka Samrat	28.33 ± 0.88^{bc}	25.67 ± 0.88^{b}	21.33 ± 0.88^{a}	13.00 ± 0.58^{a}	43.6 ± 0.49^{e}	39.76 ± 0.46^{ef}	35.43 ± 0.52^{d}	32.45 ± 0.26^{e}
Kashi Aman	31 ± 1.15^{b}	24.67 ± 0.88^{b}	18.67 ± 0.88^{ab}	9.67 ± 0.88^{bc}	44.24 ± 0.42^{e}	38.82 ± 0.32^{f}	35.27 ± 0.26^{d}	32.28 ± 0.36^{e}
Kashi Anupam	27.33 ± 0.88^{c}	17.67 ± 1.45^{cd}	15.33 ± 0.88^{d}	9.33 ± 1.2^{bc}	108.73 ± 1.29^{a}	97.13 ± 1.03^{a}	91.58 ± 0.47^{a}	78.53 ± 0.71^{a}
Pusa Rohini	17.33 ± 0.88^{e}	13.33 ± 0.88^{e}	10.67 ± 0.88^{e}	7.00 ± 1.15^{cd}	54.16 ± 0.85^{b}	47.72 ± 0.68^{b}	42.64 ± 0.37^{b}	35.24 ± 0.34^{d}
Gen. Mean	**26.47**	**20.17**	**15.93**	**9.73**	**49.15**	**43.89**	**40.21**	**35.48**
F Prob.	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
S.E.M.	**0.98**	**0.93**	**0.91**	**0.94**	**0.79**	**0.57**	**0.42**	**0.42**
C.D. 5%	**2.88**	**2.75**	**2.69**	**2.76**	**2.34**	**1.67**	**1.24**	**1.24**
C.V.	**6.4**	**8**	**9.92**	**16.67**	**2.79**	**2.23**	**1.81**	**2.05**

Note: Value are means of 3 independent replicates± Standard error, means followed by different letters are significantly different at p ≤ 0.05 according to HSD.

study results reported that the number of fruits is not directly proportional to the fruit weight. The number of fruits formed is influenced by the content of elements P (phosphorus) and K (potassium), element P helps the formation of flowers and fruit, and element K helps in the development of reinforcing tissue on the fruit stalk so as to reduce the fall of fruit.

3.9 Total soluble solids (˚ Brix)

Total soluble solids (TSS) are mainly composed of a blend of sucrose, hexose, citrate and malate that all together reach 78% of the total content (Beckles *et al*.,2012) [26]. Total soluble solids (TSS) content is one of the most important quality parameters in tomato fruits, But the most interesting results were the significant TSS increases induced by salinity in ripe fruits of all genotypes. In all genotypes, 50mM and 100mM NaCl treatment caused significant increases in fruit °Brix which is consistent with our results. A significant decrease in fruit Brix under high salinity (150mM) has also been observed (Fig 4). These results are also reported by Habibi *et al*., (2021) [27]. Fruit °Brix ranged from 6.4 ± 0.06 (Arka Rakshak) to 9.13 ± 0.09 (VRT-16-1) for control, while stressed plants varied from 5.1 ± 0.06 (Pant T-3) to 8.43 ± 0.03 (VRT-16-1) under the highest NaCl concentration (150mM) (Table 4). The findings of Johkan

et al. (2014) [28] indicate that moderate salinity (50 mM) can enhance the Brix level of tomato fruit, aligning with our results.

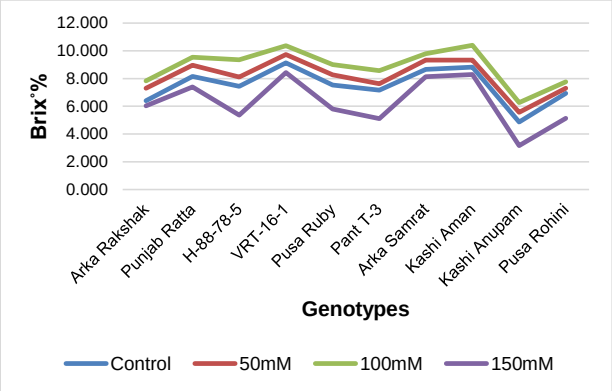


Figure 4. The TSS percent of tomato fruits grown in different salinity levels

Conversely, a notable reduction in fruit Brix was observed under high salinity (150 mM), consistent with previous observations. Additionally, studies by Lu *et al*. (2010) [29] reported that treatments with 150 mM and 200 mM resulted in a decrease in sucrose, while Carvajal *et al.* (2000) [30] found that 60 mM NaCl salinity increased sugars in tomato fruits, supporting the outcomes of our study.

Some studies reported that an increase in soil salinity above above 2 - 6 dS/m reduced yield and vegetative growth in tomato and vegetative growth in tomato, indicating that the need for indicates that there is a need for processing soil saline to maintain low soil salinity or introduce varieties that are tolerant varieties to salinity to maximum production.

4. CONCLUSION

Salinity, widespread abiotic stress due to soil salinization and suboptimal irrigation water quality, poses a significant threat to global yields, especially in arid and semiarid regions. This study delves into the complex responses at the plant level that are crucial for enhancing and safeguarding tomato crops against soil salinization. Results reveal varied responses to salinity among different tomato cultivars, with notable reductions in growth, flowering, and fruiting as salinity levels increase. Specific cultivars, such as Pusa Ruby, Pusa Rohini, and Arka Rakshak, demonstrate high tolerance to salt stress, providing valuable insights for in vitro screening of tomatoes under high salinity conditions. The study emphasizes the importance of field trials for validating cultivar performance in real-world conditions. In conclusion, the findings offer valuable information for plant breeders, suggesting the potential inclusion of salt-tolerant cultivars like Pusa Ruby in tomato breeding programs. This approach contributes to sustainable tomato production, especially in coastal areas, addressing the challenges posed by high salinity and guiding future breeding efforts.

5. Statistical analysis

Data are presented in terms of mean (±standard error). All data were subjected to analyses of variance (ANOVA) and then statistically analyzed using Windostat (version 9.3).

Statistical differences between treatment means were established using Tukey's HSD test at $p < 0.05$.

REFERENCES

1. Hasan MN, Hasan MM, Haque MZ, Howlader MH, Shanta UK. Adaptibility of tomato genotypes suitable for coastal region of Patuakhali in Bangladesh. Progressive Agriculture. 2017;28(2):84-91.
2. Salim MM, Rashid MH, Hossain MM, Zakaria M. Morphological characterization of tomato (Solanum lycopersicum L.) genotypes. Journal of the Saudi Society of Agricultural Sciences. 2020;19(3):233-40.
3. Jin JF, Wang ZQ, He QY, Wang JY, Li PF, Xu JM, Zheng SJ, Fan W, Yang JL. Genome-wide identification and expression analysis of the NAC transcription factor family in tomato (Solanum lycopersicum) during aluminum stress. BMC genomics. 2020; 21:1-4.
4. Bacha H, Tekaya M, Drine S, Guasmi F, Touil L, Enneb H, Triki T, Cheour F, Ferchichi A. Impact of salt stress on morpho-physiological and biochemical parameters of Solanum lycopersicum cv. Microtom leaves. South African Journal of Botany. 2017; 108:364-9.
5. Richards LA, editor. Diagnosis and improvement of saline and alkali soils. US Government Printing Office; 1954.
6. Gama PB, Inanaga S, Tanaka K, Nakazawa R. Physiological response of common bean (Phaseolus vulgaris L.) seedlings to salinity stress. African Journal of biotechnology. 2007;6(2).
7. Babu MA, Singh D, Gothandam KM. The effect of salinity on growth, hormones and mineral elements in leaf and fruit of tomato cultivar PKM1. Journal of Animal and Plant Sciences. 2012 ;22(1):159-64.
8. Ali HE, Ismail GS. Tomato fruit quality as influenced by salinity and nitric oxide. Turkish Journal of Botany. 2014;38(1):122-9.
9. Ismail MR, Burrage SW. Effects of salinity on growth, water relations and photosynthetic rate of tomatoes grown in nutrient film technique. Pertanika Journal of Tropical Agricultural Science. 1994; 17:73-9.
10. Umar J, Aliyu A, Shehu KK, Abubakar L. A study on effects of salinity on growth and yield of tomato genotype (Solanum lycopersicum). Sustainable Food Production. 2018; 3:16-24.
11. Khursheda P, Ahamed KU, Islam MM, Haque MN. Response of tomato plant under salt stress: role of exogenous calcium. Journal of Plant Sciences. 2015;10(6):222-33.
12. Uddin MN, Islam MT, Karim MA. Salinity tolerance of three mustard/rapeseed cuitivars. Journal of the Bangladesh Agricultural University. 2005;3(452-2018-3826):203-8.
13. Mortazainezhad F. Study of some parameters of yield and proline in rice plants under NaCl salinity stress. Journal of New Agricultural Science.2006;2:93-98.
14. Zhang P, Senge M, Dai Y. Effects of salinity stress at different growth stages on tomato growth, yield, and water-use efficiency. Communications in Soil Science and Plant Analysis. 2017; 48(6):624-34.
15. Leiva-Ampuero A, Agurto M, Matus JT, Hoppe G, Huidobro C, Inostroza-Blancheteau C, Reyes-Díaz M, Stange C, Canessa P, Vega A. Salinity impairs photosynthetic capacity and enhances carotenoid-related gene expression and biosynthesis in tomato (Solanum lycopersicum L. cv. Micro-Tom). PeerJ. 2020 ;8: e9742.
16. Amini F, Ehsanpour AA, Hoang QT, Shin JS. Protein pattern changes in tomato under in vitro salt stress. Russian Journal of Plant Physiology. 2007; 54:464-71.
17. Gumi AM, Aliero AA, Shehu K, Danbaba A. Salinity stress: Effects on growth, biochemical parameters and ion homeostasis in Solanum lycospersicum L (cv. Dan eka). Central European Journal of Experimental Biology. 2013;2(3):20-5.

18. Giannakoula AE, Ilias IF. The effect of water stress and salinity on growth and physiology of tomato (Lycopersicon esculentum Mil.). Archives of Biological Sciences. 2013;65(2):611-20.
19. De Pascale S, Orsini F, Caputo R, Palermo MA, Barbieri G, Maggio A. Seasonal and multiannual effects of salinisation on tomato yield and fruit quality. Functional Plant Biology. 2012; 39(8):689-98.
20. Latif HH, Mohamed HI. Exogenous applications of moringa leaf extract effect on retrotransposon, ultrastructural and biochemical contents of common bean plants under environmental stresses. South African journal of botany. 2016; 106:221-31.
21. Saito T, Fukuda N, Matsukura C, Nishimura S. Effects of salinity on distribution of photosynthates and carbohydrate metabolism in tomato grown using nutrient film technique. Journal of the Japanese Society for Horticultural Science. 2009;78(1):90-6.
22. Akladious SA, Mohamed HI. Ameliorative effects of calcium nitrate and humic acid on the growth, yield component and biochemical attribute of pepper (Capsicum annuum) plants grown under salt stress. Scientia Horticulturae. 2018; 236:244-50.
23. Parvin K, Ahamed KU, Islam MM, Haque MN, Hore PK, Siddik MA, Roy I. Reproductive behavior of tomato plant under saline condition with exogenous application of calcium. Middle East Journal of Scientific Research. 2015; 23:2920-6.
24. Magan JJ, Gallardo M, Thompson RB, Lorenzo P. Effects of salinity on fruit yield and quality of tomato grown in soil-less culture in greenhouses in Mediterranean climatic conditions. Agricultural water management. 2008; 95(9):1041-55.
25. Cuartero J, Fernandez-Muñoz R. Tomato and salinity. Scientia horticulturae. 1998; 78(1-4):83-125.
26. Beckles DM. Factors affecting the postharvest soluble solids and sugar content of tomato (Solanum lycopersicum L.) fruit. Postharvest Biology and Technology. 2012; 63(1):129-40.
27. Habibi N, Sediqui N, Terada N, Sanada NT, Koshio K. Effects of salinity on growth, physiological and biochemical responses of tomato. Journal of the International Society for Southeast Asian Agricultural Sciences. 2021;27(2):14-28.
28. Johkan M, Nagatsuka A, Yoshitomi A, Nakagawa T, Maruo T, Tsukagoshi S, Hohjo MA, Lu N, Nakaminami A, Tsuchiya K, Shinohara Y. Effect of moderate salinity stress on the sugar concentration and fruit yield in single-truss, high-density tomato production system. Journal of the Japanese Society for Horticultural Science. 2014;83(3):229-34.
29. Lu S, Li T, Jiang J. Effects of salinity on sucrose metabolism during tomato fruit development. African journal of Biotechnology. 2010;9(6):842-9.
30. Carvajal M, Cerda A, Martinez V. Modification of the response of saline stressed tomato plants by the correction of cation disorders. Plant Growth Regulation. 2000; 30(1):37-47.

APPENDIX

Table. Effect of different concentrations of salt (50mM, 100mM and 150mM) on Plant height.

Cultivar/ Treatment	Plant Height							
	30DAT				90 DAT			
	Control	50mM	100mM	150mM	Control	50mM	100mM	150mM
Arka Rakshak	24.3 ± 0.65^{d}	23.05 ± 0.58^{d}	19.96 ± 0.98^{d}	14.17 ± 0.6^{f}	76.62 ± 0.42^{ef}	67.8 ± 0.79^{de}	61.59 ± 0.55^{d}	54.11 ± 0.91^{d}
Punjab Ratta	31.77 ± 0.95^{b}	29.3 ± 0.35^{a}	20.27 ± 0.37^{d}	16.44 ± 0.49^{e}	84.84 ± 1.11^{d}	71.74 ± 0.94^{c}	64.24 ± 1.03^{c}	44.56 ± 0.98^{e}
H-88-78-5	30.89 ± 0.95^{b}	25.54 ± 0.33^{c}	22.26 ± 0.66^{c}	18.55 ± 0.9^{cd}	110.92 ± 1.51^{a}	77.76 ± 0.61^{b}	72.73 ± 0.99^{a}	66.23 ± 0.94^{a}
VRT-16-1	31.91 ± 0.96^{b}	27.77 ± 0.4^{b}	22.56 ± 0.3^{c}	16.56 ± 0.29^{e}	87.01 ± 1.04^{cd}	76.86 ± 1.28^{b}	70.48 ± 0.6^{b}	58.35 ± 0.9^{c}
Pusa Ruby	27.28 ± 0.71^{c}	24.2 ± 0.63^{d}	20.44 ± 0.79^{d}	17.22 ± 0.7^{de}	74.33 ± 0.64^{f}	65.87 ± 0.8^{e}	61.87 ± 0.26^{d}	58.59 ± 0.37^{c}
Pant T-3	31.2 ± 0.61^{b}	28.33 ± 0.34^{ab}	26.36 ± 0.38^{a}	24.39 ± 0.31^{a}	77.23 ± 0.99^{ef}	68.93 ± 0.23^{d}	63.42 ± 1.08^{cd}	53.47 ± 0.58^{d}
Arka Samrat	32.58 ± 0.63^{b}	28.37 ± 0.45^{ab}	22.86 ±0.19b^{c}	19.19 ± 0.56^{c}	85.91 ± 0.69^{cd}	78.38 ± 0.48^{b}	73.42 ± 0.49^{a}	66.25 ± 0.46^{a}
Kashi Aman	27.66 ± 0.66^{c}	19.73 ± 0.26^{e}	17.53 ± 0.41^{e}	14.73 ± 0.26^{f}	87.83 ± 0.99^{c}	76.24 ± 1.22^{b}	69.44 ± 0.64^{b}	62.95 ± 0.74^{b}
Kashi Anupam	35.47 ± 0.75^{a}	29.16 ± 0.23^{a}	24.33 ± 0.66^{b}	19.92 ± 0.36^{bc}	96.96 ± 1.17^{b}	83.62 ± 0.86^{a}	73.62 ± 0.42^{a}	61.73 ± 0.95^{b}
Pusa Rohini	30.54 ± 1.07^{b}	27.71 ± 0.36^{b}	24.35 ± 0.39^{b}	20.92 ± 0.51^{b}	79.2 ± 1.05^{e}	71.57 ± 0.4^{c}	68.63 ± 0.59^{b}	62.13 ± 0.74^{b}
Gen. Mean	30.36	26.31	22.09	18.21	86.09	73.88	67.94	58.84
F Prob.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
S.E.M.	0.81	0.41	0.56	0.53	1	0.83	0.71	0.78
C.D. 5%	2.39	1.21	1.67	1.58	2.96	2.44	2.11	2.31
C.V.	4.62	2.69	4.43	5.08	2.02	1.94	1.82	2.31

TABLE. Effect of different concentrations of salt (50mM, 100mM and 150mM) on Average fruit weight and Total soluble solid (brix˚).

Cultivar/treatment	Control	50mm	100mm	150mm
Arka rakshak	6.4 ± 0.06^{h}	7.30 ± 0.06^{f}	7.83 ± 0.03^{f}	6.03 ± 0.09^{c}
Punjab ratta	8.15 ± 0.08^{d}	8.97 ± 0.07^{c}	9.53 ± 0.03^{c}	7.40 ± 0.06^{b}
H-88-78-5	7.43 ± 0.03^{e}	8.10 ± 0.06^{d}	9.37 ± 0.03^{c}	5.37 ± 0.03^{d}
Vrt-16-1	9.13 ± 0.09^{a}	9.73 ± 0.12^{a}	10.37 ± 0.09^{a}	8.43 ± 0.03^{a}
Pusa ruby	7.53 ± 0.03^{e}	8.27 ± 0.09^{d}	9.00 ± 0.06^{d}	5.80± 0.40^{c}
Pant t-3	7.17 ± 0.03^{f}	7.63 ± 0.12^{e}	8.57 ± 0.07^{e}	5.10 ± 0.06^{d}
Arka samrat	8.67 ± 0.03^{c}	9.33 ± 0.09^{b}	9.80 ± 0.06^{b}	8.13 ± 0.09^{a}
Kashi aman	8.83 ± 0.03^{b}	9.33 ± 0.07^{b}	10.4 ± 0.15^{a}	8.30 ± 0.06^{a}
Kashi anupam	4.87 ± 0.03^{i}	5.57 ± 0.09^{g}	6.27 ± 0.07^{g}	3.17 ± 0.03^{e}
Pusa rohini	6.93 ± 0.03^{g}	7.30 ± 0.10^{f}	7.77 ± 0.09^{f}	5.13 ± 0.03^{d}
Gen. Mean	7.51	8.15	8.89	6.29
F prob.	<0.001	<0.001	<0.001	<0.001
S.e.m.	0.05	0.09	0.08	0.14
C.d. 5%	0.15	0.26	0.22	0.41
C.v.	1.15	1.87	1.48	3.83