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Interactive effects of vermicompost and polythene mulch alleviate salt stress in tomato

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Abstract
Soil salinity is a global problem, which is predicted to worsen in arid and semi-arid regions due to climate change. The aim of this study was to understand the remediation potential of different growing conditions (plain bed, ridge bed, polyethylene mulch and water hyacinth mulch) and organic amendments (no manuring, cowdung, vermicompost and poulty manure) in alleviating salt stress by studying its effects on the growth and yield parameters of the tomato. The experiment was arranged in a Randomized complete block design with three replications. Among the growing conditions, the highest plant height (148.67 cm), number of fruits/cluster (7.73), yield (4.45 kg/plant and 95.73 t/ha) were observed in polyethylene mulch. In the case of organic manures, the highest plant height (127.32 cm), number of fruits/cluster (6.59), and yield (3.70 kg/plant and 79.84 t/ha) were observed in vermicompost treatment. Furthermore, the highest plant height (153.10 cm), number of clusters/plant (16.13), number of fruits/cluster (8.06), and yield (4.83 kg/plant and 103.88 t/ha) were observed in the interaction of $GC_3 \times OM_3$. The benefit-cost ratio (BCR) was highest (2.48) in the interaction of polyethylend mulch with vermicompost. Therefore, it can be concluded that the treatment interaction of polythene mulch with vermicompost exhibited great potential for better growth and yield of tomato under saline stress conditions.

Keywords: Growing conditions, organic amendments, salt stress, tomato

Introduction
Tomato is a member of the Solanaceae family, which contains phenolics, flavinols, anthocyanins, and lipophilic antioxidants. It is also a reliable and good source of vitamins and minerals (Pinela *et al*., 2012) [23] those effects are positive for human health (Najla *et al*., 2009; Yahia *et al*., 2017) [21, 32]. Because of its flavor, and high nutritional value; tomato is one of the most popular vegetable that have grown to be extremely well-known around the world (Demirkaya, 2014) [10]. It is also a highly demanded crop grown round the year in Bangladesh, although the bulk of their production occurs in the winter.
The world's agriculture is seriously threatened by several abiotic environmental challenges, including metal toxicity, high or low temperatures, salt, drought, and flooding. Salinity is one of the harshest environmental conditions that limit agricultural productivity, including tomato production. Salinity poses a serious hazard to agriculture all across the world (Ahsan *et al*., 2022) [4]. Salinity affects nearly all physiological and biochemical aspects of plant development, which causes tomato output and quality to decline in terms of food safety and nutritional value (Alam *et al*., 2021) [5]. Tomatoes are grown in saline-prone areas using a combination of various growing conditions and manures. Mulch can change the soil microclimate by raising soil temperature. Several studies have demonstrated that it is a successful method for boosting crop emergence (Haque *et al*., 2018) [13]. The most common type of plastic mulch used in vegetable cultivation is black polyethylene mulch. Researchers have seen increased yield during early harvests when using black plastic as opposed to bare soil. The raised bed is becoming more important in many parts of the world. The salinity of the soil and moisture have opposite relationships (Bhowmik *et al*., 2019) [7]. Mulching with organic material, such as rice straw or water hyacinth, can also help to reduce soil salinity (Zhao *et al*., 2016) [34]. With the application of mulch materials on the surface of the soil, the soil EC values decreased significantly and all the mulch materials significantly reduced electrical conductivity (Temiz & Cayci, 2018) [28].
Organic manures, such as cowdung, poultry manure, and vermicompost enhance soil structure, aeration, and slowly release nutrients that encourage root development and increase tomato plant growth and yield.

Numerous bacteria and animals, such as earthworms, use organic manure as a food source to break down nutrients into micronutrients that are easily absorbed by plants. Poultry manure is an organic material source that enriches the soil; it not only boosts the nutrient content of soil but also strengthens the soil structure. For the proper growth of plants, poultry manure provides significant percentages of nitrogen and phosphorus (Kacprzak *et al*., 2023) [14]. Poultry manure has been demonstrated to increase the organic matter content, water holding capacity, oxygen diffusion rate, and aggregate stability of the soils, hence enhancing the fertility of the cultivated soil (Adekiya *et al*., 2019) [1].

Bangladesh has 3 million hectares of land that is affected by salinity, mostly in the coastal and south-east districts, with electrical conductivity (EC) values that range from 4 to 16 dS/m (Naher *et al*., 2020) [20]. The low land used in saline areas is troublesome primarily because the soil salinity is adverse during the dry season. To attain optimum production instead of chemicals, organic manures, and different contemporary planting techniques might be used. Organic fertilizers enhance the soil's structure, aeration, and slow-release nutrients that encourage root development and increase tomato plants' growth and productivity. Production of tomato is insufficiently good in the saline-prone coastal region of Bangladesh. It is expected that the coastal region of Bangladesh can be included in tomato cultivation since tomato plants are being grown in salt-stress environments all over the world using various approaches. Very limited research works have been conducted to adapt tomato crop in the saline area of Bangladesh. Different kinds of growing conditions and organic manure can be used for the production of tomato in the coastal region of Bangladesh. Field crops rarely achieve their full yield potential as pot research doesn't represent the field properly and enormous yield gaps are found when comparing experimental pots with field data. Therefore, the research was thought to be carried out directly in the farmer's field to develop an advantageous combination of growing conditions and manure for tomato cultivation in saline soil.

Materials and Methods

The experiment was carried out at a farmers' field in the Mahipur upazilla of Patuakhali district whcih belongs to Latitude: 21.87° North, Longitude: 90.17° East, and 6.00 meter rise from sea level. The experiment was arranged in a factorial randomized complete block design with 3 replications. One factor represented four growing conditions *viz*., plain bed (GC_1), ridge bed (GC_2), polyethylene mulch bed (GC_3), and water hyacinth mulch bed (GC_4), while other factor included four types of organic manure denoted as no manure (OM_1), cowdung (OM_2), vermicompost (OM_3), poultry manure (OM_4). One of the popular and mega tomato variety (BARI Tomato-14) developed by Bangladesh Agricultural Research Institute was used as a test crop in this experiment. The number of seedlings per unit plot was 5 × 4 = 20 following a recommended spacing of 2 m × 2.5 m plant to plant and row to row respectively. A basal dose of chemical fertilizer was applied during the final land preparation recommended by Bangladesh Agricultural Research Institute (BARI). Ridge beds were prepared by lifting the soil about 40 cm from the soil surface. The breadth of each ridge and furrow was 50 cm. For the preparation of a polyethylene mulch bed, a 10 m^2 black polythene sheet having a thickness of 1.2 mm was used. Twenty holes of 6 cm diameter were made in each polythene sheet for seedling transplanting and intercultural operation. A water hyacinth mulch bed was prepared by spreading dried water hyacinth uniformly on the previously prepared bed with a thickness of about 10 cm. About 20 holes having a diameter of 6 cm were also prepared for facilitating the transplanting of seedlings and intercultural operation. About 20 cm topsoil of a bed was pulverized and mixed with specific organic manure for organic amendment treatment. Cowdung @ 20 t/ha, vermicompost @ 15 t/ha and poultry manure @ 20 t/ha was mixed with topsoil to prepare cowdung, vermicompost and poultry manure amended plot, respectively. Organic manures were collected from local farmers. Growth parameters were recorded at regular intervals. Data on yield and yield contributing characters were collected during the harvesting period of tomato. The data collected from the experimental plots were statistically analyzed through the computer-based statistical program STAR following the basic principles. The mean value for all the treatments was calculated and the analysis of variance (ANOVA) for most of the characteristics was accomplished by the F variance test. The significance of the difference between the pair of means lettering was tested with the help of Tukey's honestly significant differences (HSD).

Results and Discussion

Effect of different growing conditions and organic manures on growth parameters of tomato in saline-prone soil

Plant height

Plant height differed significantly due to different growing conditions at different growth stages of tomato. The tallest plant (148.67 cm) was observed in the polythene mulch bed as compared to the shortest (84.21 cm) from the bed treated with water hyacinth mulch. Mendonça *et al*. (2021) [17] also stated that polythene mulch increases tomato plant growth. The tallest plant was observed in black polyethylene mulch might be due to higher soil temperature inside the mulch as black color not only absorbs more heat but also reatains it to somc extent causing warm and humid conditions as compared to other mulch and no mulch treatment. Earlier study suggested that a two degree rise in temperature can result in a doubling of tomato seedling shoot growth (Tegen *et al*., 2016) [27]. Zhang *et al*. (2023) [33] also observed that organic mulches keep the soil cooler with retardation of tomato growth via slower cell division and cell maturation. Organic manures also had a significant impact on plant height. The beds treated with poultry manure had the tallest plant (127.32 cm), followed by vermicompost manuring had (102.44 cm), however, the shortest plant (94.83 cm) was recorded in control treatment (T-1). Adekiya *et al*. (2016) [2] also stated poultry manure increases plant height significantly.

The interaction effect of different growing conditions and organic manures showed significant differences among others. The highest plant height (153.10 cm) was observed in polythene mulch with vermicompost ($GC_3 \times OM_3$) which was statistically identical to ($GC_2 \times OM_2$, 152.10cm), ($GC_3 \times OM_4$, 147.70cm) and ($GC_3 \times OM_1$, 141.80cm) respectively (T-2). Salt ions greatly reduce the growth of plants by altering the physiological activity of plants. The interaction effect of plain bed and control manuring showed the lowest plant height (77 cm). Tomato plants grown in

combination with polythene mulch with vermicompost produced 49.70% taller plants than plants grown in plain beds with control manuring practices. It might be due to the high salinity level of that soil**.** The heights of all plants were observed best in the treatment interaction of $GC_3 \times OM_3$ than all others. Vermicompost with polythene mulch provides better soil health as it is rich in essential nutrients. It facilitates better root growth which helps in increasing plant height under saline stress. Vermicompost is rich in macro and micronutrients and beneficial soil microbes which improves plant growth (Rekha *et al*., 2018) [24].

Number of leaves per plant

The number of leaves per plant varied with both factors. In different growing conditions, the maximum number of leaves per plant (23.35) was recorded in a polythene mulch bed while the lowest number of leaves (18.26) was recorded in a plain bed (T-1). Furthermore, the number of leaves per plant (21.38) was the maximum with vermicompost manuring and the minimum number of leaves per plant (17.85) was found in control manuring. Wang *et al*. (2017) [31] experimented and determined that vermicompost significantly increases the number of leaves of tomato.

Different growing conditions and organic manuring practices significantly influenced the number of leaves per plant. It was observed that the maximum number of leaves (23.93) were found from the treatment interaction of ($GC_3 \times OM_3$) polythene mulching with vermicompost manuring (T-2). On the other hand, the minimum number of leaves (17.43) was recorded from the treatment interaction of ($GC_1 \times OM_1$) plain bed with control manuring. The number of leaves per plant was observed 27.16% higher in this interaction than $GC_1 \times OM_1$.

Number of branches per plant

The number of branches is also regulated by the salinity level of the soil. Total branch numbers were varied with the variation of growing conditions and organic manures. The maximum number of branches (14.39) was observed in the Polythene mulch bed while the minimum number of branches (8.8) was observed in the plain bed. Similar results were also advocated by Tegen *et al*. (2016) [27]. For organic manuring treatments, the maximum number of branches (15.35) was observed in poultry manure manuring while the minimum number of branches (9.02) was observed in control manuring (T-1). Chisom *et al*. (2021) [8] and Mehdizadeh *et al*. (2013) [16] also stated similar findings.

Soil salinity leads to changes in the morphological and physiological characteristics of plants. A significant effect on the number of branches per plant was observed due to the interaction of different growing conditions and organic manures. It was observed that the highest number of branches per plant (13.3) were in the interaction of ($GC_3 \times OM_4$) polythene mulch with poultry manuring, whereas the lowest (6.33) were recorded in the interaction of ($GC_1 \times OM_1$) plain bed with control manuring (T-2).

Length of root

In the experiment, the root length of tomato plant (41.56 cm) showed the highest result in the polythene mulch bed. The minimum root length (27.35 cm) was recorded in plain bed (T-1). An experiment was done by Tesfaye *et al*. (2016) [29] and observed better root growth of plants by using polythene mulch. Again, the maximum root length (32.40 cm) was obtained from vermicompost manuring though, poultry manuring practices produced (32.30 cm) which was statistically similar to this. On the other hand, control manuring produced the smallest root (31.29 cm). From the findings, it can be concluded that vermicompost manuring produced the highest root length.

The root length of tomato plants was observed significant due to the interaction effect of different growing conditions and organic manuring. The largest root length (42.23 cm) was observed in the interaction of ($GC_3 \times OM_3$) polythene mulch with vermicompost manuring which was statistically identical to ($GC_3 \times OM_4$, 41.56 cm), ($GC_4 \times OM_3$, 41.63 cm) and ($GC_4 \times OM_4$,40.83) respectively but significantly different with others (T-2). The smallest root length (17.83 cm) was observed in a plain bed with control manuring.

First flowering days

The first flowering days varied significantly due to different growing conditions. The maximum days (23.54) to first flowering was observed in polythene mulch growing conditions while the minimum days (19.70) to first flowering was observed in plain bed (t-1). Plants tend to complete their lifecycle early in stressful conditions. In plain bed conditions, salinity stress for tomato plants might be high that's why they produce flowers very early to complete their lifecycle and vice versa. In organic manuring, the tabulated result showed that the shortest period (20.27 days) was required for first flowering in control manuring conditions whereas the longest period (21.04 days) was required for vermicompost manuring.

The interaction effect between different growing conditions and manuring on days required for first flowering was observed significantly. Maximum days required for the appearance of the first flower was observed (24.90 days) in the interaction of ($gc_3 \times om_3$) polythene mulch with vermicompost manuring which was statistically identical to ($gc_3 \times om_4$, 24.03) interaction (t-2). The plain bed with control manuring gave the earliest flowering (16.16 days) which is also supported by the findings of sabijon & sudaria (2018) [25].

First fruiting days

The first fruiting days were significantly varied among the different growing conditions. The earliest fruiting (29.87 days) was observed in plain bed growing conditions where the maximum time required (32.70 days) was in a polythene mulch bed. In organic manuring, the maximum days required for first fruiting (33.07 days) was observed in vermicompost manuring which was statistically identical to poultry manuring beds. The minimum required days (28.91 days) for the first fruiting of tomato plant was observed in control manuring (T-1).

Table 1: Effect of different growing conditions and organic amendents on growth of tomato plant

Treatments	Plant Height	Number of Leaves/plant	Number of Branches/plant	Length of Root (cm)	Days to 1st Flowering	Days to 1st Fruiting
Growing Conditions						
GC_1	102.10 b	18.26 c	8.80 c	27.35 c	19.70 d	29.87 b
GC_2	88.94 c	19.15 c	9.37 c	29.74 c	20.20 c	30.31 b
GC_3	148.67 a	23.35 a	14.39 a	41.56 a	23.54 a	32.70 a
GC_4	84.21 c	20.10 b	11.95 b	35.13 b	21.60 b	31.91 a
LS	**	**	*	**	**	**
CV (%)	4.85	3.86	6.21	2.16	1.96	4.15
Organic Amendents						
OM_1	94.83 c	17.85 c	9.02 c	31.29 c	20.27 c	28.91 c
OM_2	99.34 bc	20.21 b	10.07 bc	31.34 b	20.29 c	31.03 b
OM_3	102.44 b	21.38 a	15.35 a	32.40 a	23.45 a	33.07 a
OM_4	127.32 a	21.12 a	11.07 b	32.30 a	21.04 ab	31.78 ab
LS	*	*	*	**	**	**
CV (%)	4.85	3.86	6.53	2.16	1.96	4.15

Here, means in a column followed by the different letter (s) differ significantly but with same letter (s) do not differ significantly at 5% level of probability analyzed by Tukey HSD test. ** = Significant at 1% level of probability, LS= Level of significance, DAT= Days after transplanting. GC_1 = Plain bed, GC_2 = Ridge bed, GC_3 = Polythene mulch bed, GC_4 = Water hyacinth mulch bed and Manuring, OM_1 = No manure, OM_2 = Cow dung, OM_3 = Vermicompost, OM_4 = Poultry manure.

Interaction effect on days to first fruiting was observed significantly due to different growing conditions and organic manures. The earliest fruiting (25.50 days) was observed in the interaction of plain bed and control manuring while the maximum time (35.00 days) was required for the appearance of first fruiting in polythene mulch with vermicompost manuring and that was statistically identical to the interaction effect of polythene mulch with poultry manure manuring (T-2).

Table 2: Interaction effect of different growing conditions and organic manures on growth parameters of tomato plant in saline-prone soil

Treatment Combinations		Plant Height (cm)	Number of Leaves/plant	Number of Branches/plant	Length of Root (cm)	Days to 1st Flowering	Days to 1st Fruiting
GC_1	OM_1	77.00 c	17.43 c	6.76 d	17.83 d	16.16 d	25.50 c
	OM_2	79.57 c	18.43 c	7.00 d	19.80 d	18.13 c	30.93 b
	OM_3	105.86 b	19.54 c	7.80 b	25.16 c	18.53 c	31.40 a
	OM_4	136.00 b	19.32 c	9.63 c	21.90 d	20.90 d	31.66 a
GC_2	OM_1	85.90 b	18.06 c	8.06 c	25.26 d	18.50 c	30.23 b
	OM_2	90.80 b	18.23 c	8.23 c	29.73 c	19.73 b	31.26 a
	OM_3	97.30 b	20.66 b	8.83 bc	32.60 b	22.43 b	31.16 a
	OM_4	101.76ab	19.06 c	9.16 c	27.93 c	22.16 a	28.60 b
GC_3	OM_1	141.80 a	22.73 a	9.30 c	30.93 c	22.36 a	31.13 a
	OM_2	152.10 a	23.3 a	10.90 b	36.03 b	22.86 a	31.23 a
	OM_3	153.10 a	23.93 a	11.30 ab	42.23 a	24.90 a	36.73 a
	OM_4	147.70 a	23.46 a	13.30 a	41.56 a	24.03 a	35.00 a
GC_4	OM_1	84.63 b	20.12 b	8.33 c	29.76 b	22.26 a	31.56 a
	OM_2	85.90 b	21.34 b	10.90 b	31.96 b	20.36 b	33.23 a
	OM_3	119.50 ab	21.57 b	11.80 a	41.63 a	21.03 b	30.26 ab
	OM_4	123.83 ab	22.21 a	12.76 a	40.83 a	22.23 a	32.30 a
LS		**	**	**	**	**	**
CV (%)		4.85	3.86	4.64	2.16	1.96	4.15

Here, means in a column followed by the different letter (s) differ significantly but with same letter (s) do not differ significantly at 5% level of probability analyzed by Tukey HSD test. ** = Significant at 1% level of probability, LS= Level of significance. GC_1 = Plain bed, GC_2 = Ridge bed, GC_3 = Polythene mulch bed, GC_4 = Water hyacinth mulch bed and Manuring, OM_1 = No manure, OM_2 = cow dung, OM_3 = vermicompost, OM_4 = poultry manure.

Effect of different growing conditions and organic ammendents on yield and yield components of tomato in saline-prone soil

Number of clusters per plant

The number of clusters per plant was observed significant due to differences in growing conditions and organic manuring both individually and in interaction. In the experiment, the number of clusters per plant (14.70) was observed highest in the polythene mulch bed. The water hyacinth mulch bed showed the second highest result while the minimum clusters per plant (8.28) were recorded in plain bed. This difference might be due to the positive effect of polythene mulching against the salinity stress of tomato plants. Furthermore, in organic manuring, the number of clusters per plant was observed highest in vermicompost manuring along with poultry liter manuring practices. In the vermicompost manuring bed, the number of clusters per plant was (12.56) while in the control manuring bed it showed (10.25), the lowest result (T-3). Ahirwar & Hussain (2015) [3] stated that the addition of vermicompost had significant positive effects on the growth, yield, and

elemental content of the plant as compared to control.
In the interaction effect, maximum clusters per plant (16.13) were observed in ($GC_3 \times OM_3$) interaction of polythene mulch with vermicompost which was identical to ($GC_3 \times OM_4$) interaction (T-4). Minimum clusters per plant (4.83) were observed in the interaction of the plain bed with the control manuring bed. The higher number of clusters per plant is an important parameter that shows the possibility of higher production. Flowers of tomato is produced in cluster which after fertilization becomes fruit. A higher number of clusters represents better developmental growth. Nutrient supply is a prerequisite for the development of plants which may result in a higher number of clusters. Patel *et al*. (2018) [22] stated that the application of organic fertilizer increases the number of clusters per plant.

Number of flowers per cluster
In the experiment, the number of flowers per cluster (6.97) was shown to be highest in the polythene mulch bed. The lowest number of flowers per cluster (5.08) were observed in plain bed. Ambadi *et al*. (2023) [6] observed significantly higher number of flowers per cluster in the mulch-treated plots than in the control treatment. Different organic manuring also showed significant differences among them. The number of flowers per cluster (6.10) was observed highest in vermicompost manuring while the lowest number of flowers per cluster (5.52) was observed in control manuring (T-3).
Flowers per cluster were also significantly different due to the interaction effect of different growing conditions and organic manuring. The highest number of flowers per cluster (7.43) was observed in ($GC_3 \times OM_3$) interaction of polythene mulch with vermicompost manuring which was identical to ($GC_3 \times OM_4$) interaction. The lowest number of flowers per cluster (4.03) were observed in the plain bed and control manuring bed (T-4). El-Mogy *et al*. (2018) [11] conducted an experiment taking different levels of salinity and reported that salinity affects growth and yield in cherry tomato which partially support our study.

Number of fruits per cluster
The number of fruits per cluster (7.73) was shown to highest in the polythene mulch bed while the lowest number of fruits per cluster (5.08) was observed in the plain bed. Mukherjee *et al*. (2018) [18] stated that mulching significantly increased the total number of fruit/plant of tomato over bare plants. Again, in organic manuring, the highest number of fruits per cluster (6.59) were obtained from vermicompost manuring though, poultry manuring practices produced (6.48) which was statistically similar to this (T-3) and control manuring produced the lowest number of fruits per cluster (5.97). From the findings, it can be concluded that vermicompost manuring beds produced the maximum number of fruits per cluster. The higher number of fruits per cluster indicates better fruit setting. Thus, the converging from flower to fruit rate is higher. A similar finding was also observed by Wako & Muleta (2022) [30].
Significant variation was found among the different interactions of growing conditions and organic manures. The maximum number of fruits per cluster (8.06) was observed in ($GC_3 \times OM_3$) interaction of polythene mulch with vermicompost which was statistically identical to ($GC_4 \times OM_3$, 7.90), ($GC_4 \times OM_4$, 7.86) and ($GC_3 \times OM_4$, 7.63) respectively but significantly different with others (T-4).
The lowest number of fruits per cluster (3.86) was observed in in interaction of plain bed with control manuring. Plant with better vegetative growth produces stout and viable reproductive organs. Which helps in a better fruit setting. Organic manure such as vermicompost and poultry manure supplies the required nutrients for reproductive development on the other hand it improves the soil's physical and chemical properties which improve nutrient uptake. Organic manure also provides various micronutrients and hormones which altogether may help for better reproductive growth, thus higher fruit settings for tomato.

Individual fruit weight
Individual fruit weight was observed significantly different due to different growing conditions and also in organic manuring. In different growing conditions, the highest individual fruit weight (0.15 kg) was observed in polythene mulch growing conditions while the lowest individual fruit weight (0.11 kg) was observed in plain bed. This might be due to the negative effect of polythene mulch on soil salinity. Ferdous *et al*. (2017) [12] observed that plant individual fruit weight was significantly higher in the mulch-treated plots than in non-mulched control treatment. In the case of organic manuring practices, the highest individual fruit weight (.13 kg) was observed in vermicompost manuring whose performance is statistically identical to poultry liter manuring (T-3). The lowest individual fruit weight (0.10 kg) was observed by control manuring. This difference might be due to the ability of crops to develop against salt stress by using poultry liter and vermicompost. On the other hand, organic matter supplies hormones and enzyme (Kováčik *et al*., 2014) [15], which is responsible for the transport of food material from the production point to the storage location which ultimately results in larger fruit.
Individual fruit weight was significantly different due to the interaction effect of different growing conditions and organic manuring. The maximum fruit weight was observed (0.15 kg) in ($GC_3 \times OM_3$) interaction of polythene mulch with vermicompost manuring which was identical to ($GC_3 \times OM_4$, 0.15 kg) interaction. The minimum individual fruit weight was observed (0.09 kg) in ($GC_1 \times OM_1$) interaction of plain bed with control manuring (T-4).

Fruit weight per plant
The maximum fruit weight per plant (4.45 kg) was observed in polythene mulch growing conditions while the minimum fruit weight per plant (3.01 kg) was observed in plain bed growing conditions (T-3). In the case of organic manuring, the highest fruit weight per plant (3.70 kg) was observed in vermicompost manuring whose performance is statistically identical to poultry liter manuring, and the lowest fruit weight per plant (3.22 kg) was observed by control manuring.
Fruit weight per plant was significantly different due to the interaction effect of different growing conditions and organic manuring. Maximum fruit weight per plant (4.83 kg) was observed in the interaction of polythene mulch with vermicompost manuring which was identical to the interaction of polythene mulch with poultry manure manuring. The minimum individual fruit weight (2.30 kg) was observed in the interaction of plain bed with control manuring (T-4).

Yield per hectare

Significant variation was found among the different growing conditions and organic manure both in interaction and in individual effect. Polythene mulch growing condition produced (95.73 ton) maximum yield, while the minimum yield (65.11 t) was observed by the plain bed (T-3). Therefore, yield decreased with the increase in salinity. De Cássia Alves *et al*. (2018) [9] in an experiment also found that the yield of tomato is drastically affected when the salt concentration was increased in the root zone. For organic manuring, it was observed that the vermicompost manuring bed showed (79.84 t) the highest calculated yield per hectare, and the control manuring bed showed (69.42 t) the calculated yield per hectare which was the lowest. Mukta *et al*. (2015) [19] also stated similar findings. Adequate nutrient supply along with favorable soil environment induces proper root and shoot growth. Later proper reproductive growth results in better flower and fruit setting. Better nutrition transportation and stage of food material results in bigger and healthier fruit altogether resulting in a higher yield.

Table 3: Effect of different growing conditions and organic amendents on the yield and yield components of tomato

Treatments	Number of Clusters/plant	Number of Flowers/cluster	Number of Fruits/cluster	Average fruit Weight (kg)	Yield (kg/plant)	Yield (t/ha)
Growing Conditions						
GC_1	8.28 d	5.08 c	5.08 d	0.11 b	3.01 c	65.11 d
GC_2	10.39 c	5.40 bc	5.74 c	0.12 b	3.35 c	72.11 c
GC_3	14.70 a	6.97 a	7.73 a	0.15 a	4.45 a	95.73 a
GC_4	13.07 b	5.67 b	6.76 b	0.12 b	4.06 b	85.98 b
LS	**	**	**	**	**	**
CV (%)	4.04	5.37	4.97	4.68	4.42	4.47
Organic Amemdents						
OM_1	10.25 c	5.52 c	5.97 b	0.10 c	3.33 b	69.42 c
OM_2	11.39 b	5.59 bc	6.27 ab	0.12 b	3.22 b	72.07 b
OM_3	12.56 a	6.10 a	6.59 a	0.13 a	3.70 a	79.84 a
OM_4	12.20 a	5.90 ab	6.48 a	0.13 a	3.60 a	77.62 a
LS	**	**	**	**	**	**
CV (%)	4.04	5.37	4.97	4.68	4.42	4.47

Here, means in a column followed by the different letter (s) differ significantly but with same letter (s) do not differ significantly at 5% level of probability analyzed by Tukey HSD test. ** = Significant at 1% level of probability, LS= Level of significance, DAT= Days after transplanting. GC_1 = Plain bed, GC_2 = Ridge bed, GC_3 = Polythenemulch bed, GC_4 = Water hyacinth mulch bed and Manuring, OM_1 = No manure, OM_2 = cow dung, OM_3 = vermicompost, OM_4 = poultry manure

In the interaction effect, maximum yield per hectare (103.88 t) was observed in the interaction of polythene mulch with vermicompost which was statistically identical to polythene mulch with poultry manuring (99.80 t), water hyacinth mulch with vermicompost manuring (90.41 t) and water hyacinth mulch with poultry manure manuring (88.90 t) respectively but significantly different with others (T-4). The lowest yield per hectare (49.43 t) was observed in the interaction of plain beds with control manuring. Yield per hectare in the interaction of polythene mulch with vermicompost manuring was 52.41% higher than yield per hectare produced in plain bed and control manuring. Saeed & Ahmad (2009) [26] also support our study.

Table 4: Interaction effect of different growing conditions and organic manures on yield and yield components of tomato plant in saline prone soil

Treatments	Clusters/ Plant	Flowers/ Cluster	Fruits/ Cluster	Individual fruit Weight (kg)	Fruit Weight/Plant (kg)	Yield (t/ha)
$GC_1 \times OM_1$	4.83 d	4.03 c	3.86 d	0.09 c	2.30 d	49.43 d
$GC_1 \times OM_2$	6.76 d	4.16 c	4.06 d	0.12 b	2.90 c	62.52 c
$GC_1 \times OM_3$	8.20 c	5.50 b	5.70 c	0.13 b	3.20 b	67.45 bc
$GC_1 \times OM_4$	8.86 c	5.33 b	6.73 ab	0.13 b	3.06 c	63.04 c
$GC_2 \times OM_1$	9.23 c	4.53 c	5.46 c	0.12 b	3.13 bc	66.01 c
$GC_2 \times OM_2$	11.90 b	5.26 b	5.06 c	0.12 b	3.20 b	68.88 b
$GC_2 \times OM_3$	11.83 b	5.60 b	6.56 b	0.13 b	3.53 b	71.04 b
$GC_2 \times OM_4$	12.76 b	5.83 bc	6.16 b	0.13 ab	3.46 b	69.57 b
$GC_3 \times OM_1$	10.86 c	6.53 a	6.36 bc	0.13 b	3.33 b	75.34 b
$GC_3 \times OM_2$	13.83 b	6.83 a	7.10 a	0.13 b	3.86 b	76.06 b
$GC_3 \times OM_3$	16.13 a	7.43 a	8.06 a	0.15 a	4.83 a	103.88 a
$GC_3 \times OM_4$	16.10 a	7.30 a	7.63 a	0.15 a	4.63 a	99.80 a
$GC_4 \times OM_1$	12.30 b	5.43 b	6.03 c	0.13 b	3.30 b	68.88 b
$GC_4 \times OM_2$	13.63 b	6.23 b	6.70 b	0.13 b	3.50 b	74.62 b
$GC_4 \times OM_3$	14.63 a	6.30 a	7.90 a	0.14 a	4.20 a	90.41 a
$GC_4 \times OM_4$	13.80 b	6.13 b	7.86a	0.14 a	4.13 a	88.90 a
LS	**	**	**	**	**	**
CV (%)	4.04	5.37	4.97	4.68	4.42	4.47

Here, means in a column followed by the different letter (s) differ significantly but with same letter (s) do not differ significantly at 5% level of probability analyzed by Tukey HSD test. ** = Significant at 1% level of probability, LS= Level of significance. GC_1 = Plain bed, GC_2 = Ridge bed, GC_3 = Polythene mulch bed, GC_4 = Water hyacinth mulch bed and Manuring, OM_1 = No manure, OM_2 = cow dung, OM_3 = vermicompost, OM_4 = poultry manure.

Soil nutrient status

Soil samples from all treatment combinations were analyzed to determine the difference between before and after treatment. No or very few differences were observed in most of the interactions except (GC_3×OM_3), (GC_3×OM_4), (GC_4×OM_3) and (GC_4×OM_4). In various interaction effects, a maximum difference of pH was observed (-0.6) and EC was observed (-1.3 ds/m) in (GC_3×OM3). The maximum difference of potassium was also observed (+0.06 meq/100ml) in the treatment combination of (GC_3×OM3). Total nitrogen content was maximum increased (+0.03%) in the interaction effect of (GC_3×OM_4). In case of phosphorus and sulphur, maximum difference was observed (+0.19) and (+7) respectively (T-5).

Table 5: Soil nutrient status as influenced by different growing conditions and organic amemdents

Treatments	Period	pH	EC (ds/m)	K (meq/100 ml)	Total N (%)	P (mg/kg)	S (mg/kg)
GC_3×OM_3	Initial	6.3	6.1	0.27	0.07	0.82	58
	After Treatment	5.7	4.6	0.33	0.08	0.93	64
	Increase/Decrease	-0.6	-1.5	+0.06	+0.01	+0.11	+8
GC_3×OM_4	Initial	6.4	6.3	0.31	0.05	0.79	57
	After Treatment	5.9	5.0	0.37	0.08	0.92	68
	Increase/Decrease	-0.5	-1.	+0.06	+0.03	+0.13	+11
GC_4×OM_3	Initial	5.7	6.0	0.29	0.05	0.74	62
	After Treatment	5.4	5.4	0.34	0.07	0.93	69
	Increase/Decrease	-0.3	-0.6	+0.05	+0.02	+0.19	+7
GC_4×OM_4	Initial	6.7	5.9	0.34	0.04	0.81	63
	After Treatment	6.3	5.3	0.39	0.06	0.93	68
	Increase/Decrease	-0.4	-0.6	+0.05	+0.02	+0.12	+5

Here, GC_3 = Polythene mulch bed, GC_4 = Water hyacinth mulch bed, OM_3 = vermicompost and OM_4 = poultry manure.

Conclusion

Crop production in the coastal saline areas particularly during the Rabi season (dry season) is very limited due to the rise in soil salinity. From this study, it is revealed that polythene mulch bed and manuring with vermicompost minimize the rise in soil salinity significantly. Besides, the use of polythene mulch with poultry manure and water hyacinth mulch along with vermicompost or an extra amount of poultry manure helps to reduce soil salinity and increase crop yield. Thus, treatment comprised of Polythene and water hyacinth mulching with vermicompost and poultry manure produced a higher yield of tomato in a coastal saline environment. Farmers of coastal saline areas can adopt the technology for higher yield and economic return from tomato.

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