



## Effect of salt stress on morphological and yield attributing parameters of pepper (*Capsicum annuum*) genotypes

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### ABSTRACT

The present study was carried out during 2022 to 2024 at Punjab Agricultural University, Ludhiana, Punjab to determine the influence of salinity levels of 0, 2, 4 and 6 dS/m on morphological and yield characteristics of 16 highly tolerant pepper (*Capsicum annuum* L.) genotypes initially selected by testing 100 genotypes at nursery stage. The experiment was conducted using a split plot design (SPD) with salinity treatments as main factor and genotypes as sub factor. Artificial saline conditions in pot were created using NaCl, MgSO<sub>4</sub> and CaCl<sub>2</sub> in the ratio 2:1:1. The findings revealed that salinity caused a significant decrease in plant height, internode length, branch number, root weight, fruit characteristics, fruit number and yield. Additionally, it also delayed the onset of flowering in all genotypes. When compared to other genotypes, genotypes PAU-212, YL-581 and SL-474 performed superior in all parameters when exposed to salt stress. Maximum yield at highest salinity level was exhibited by PAU-212 (519.8 g/plant) and was followed by YL-581 (511.7 g/plant). In terms of percent decrease in yield at higher salinity levels in comparison to control conditions was minimum in GC-222, with only 16.9% reduction, followed by YL-581 (18.4%) and SL-474 (22.8%). Thus, it can be concluded that PAU-212, YL-581 and SL-474 proved to be the most suitable genotypes for salt tolerance in pot conditions and could be considered for future studies and cultivation in salt affected regions.

**Keywords:** Fruit number, Pepper, Salinity, Stress, Yield

Pepper (*Capsicum annuum* L.) is one of the important solanaceous crop, producing 44.9 mt from 4.16 mha, with Andhra Pradesh, Madhya Pradesh, Karnataka, Bihar and Tamil Nadu being the leading producers (PAU, 2024). Pepper crop faces many biotic and abiotic challenges during their growth period and among them major challenge in today's scenario has been imposed by salinity stress in some areas (Subramanyam *et al.* 2021). Approximately 632 mha of agricultural land, or 20% of all cultivated land worldwide, are classified as salt-affected in the current situation (Ghassemi *et al.* 1995, Kiferle 2022). The negative relationship between salinity and agricultural productivity has been emphasised by numerous studies, which demonstrates that yields decreases as salinity increases. Salinity affects growth by reducing osmotic potential, cell membrane stability, photosynthesis, enzyme activity and cell expansion along with disruption in ion absorption, ultimately, leading to decreased growth and economic performance (Munns and Tester 2008, Shahid *et al.* 2011). However, the extent to which salinity impacts depends on the plant species along with type and level of salts.

Pepper is moderately salt-sensitive plant species with threshold electrical conductivity (EC) of 1.5 dS/m (Kadir

*et al.* 2004, Machado and Serralheiro 2017). Maas and Hoffman (1977) reported yield reduction of the crop when electrical conductivity of soil saturation extract exceeds 1.5 dS/m. Being a glycophyte (Subramanyam *et al.* 2010), it undergoes noticeable morphological and physio-chemical changes as it progresses from seedling to the maturation stage (Aktas *et al.* 2006). Several measures including leaching, irrigation methods, salt scraping, surface flushing of salts have been employed to deal salinity but such corrective measures are often expensive and only offer short-term fixes. Therefore, it is crucial to develop a long term and sustainable solution under such circumstances. A more long-term and complementary strategy to lessen the impacts of salinity is to select and breed for salt tolerance (Ashraf and McNeilly 2004). A species' genetic diversity is a useful tool for breeding and screening against salt tolerance. Since, pepper germplasm exhibit a notable variation in response to salt stress (Niu *et al.* 2010), this study was carried out to examine tolerant lines that could serve as valuable genetic resource for breeding programmes.

### MATERIALS AND METHODS

The present study was carried out during 2022 to 2024 at Punjab Agricultural University, Ludhiana, Punjab using 100 different pepper genotypes. A mixture of sodium

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chloride, calcium chloride, and magnesium sulphate (2:1:1) were added to water to achieve desired salinity levels of 2 dS/m, 4 dS/m, and 6 dS/m in the pots. Based on evaluation at nursery stage, genotypes were categorised as 16 extremely tolerant (upto 6 dS/m), 9 tolerant (upto 4 dS/m), 15 moderately tolerant (upto 2 dS/m), and 60 sensitive. Highly tolerant genotypes were further evaluated for morphological parameters in pot conditions and various observations were recorded. Plastic poly bags measuring 12" × 12" (D × H) were used for pot growing. Pots were filled using mixture of 50% soil and 50% media (2:1:1 ratio of cocopeat, perlite, and vermiculite). Saline water was applied every other day for the first two months (one day regular water, the next salty water) and was adjusted further as per EC values, calculated on the basis of leaching fraction. Every other cultural practice was followed according to package of practices for Vegetable Crops (PAU, 2024). The experiment was laid out in a split plot design (SPD) where the salinity levels (Control, 2 dS/m, 4 dS/m, and 6 dS/m) were the main factor while the genotypes were the subplot factor. Data was recorded on various morphological and yield attributing parameters and was analysed at  $p=0.05$  significant level using SAS software.

## RESULTS AND DISCUSSION

**Plant height (cm):** A key determinant of plant health is plant height, which reflects the nutritional content of the soil as well as the plant's capacity to absorb those nutrients. Plant height decreased significantly from the control to 6 dS/m at 45, 90, and 135 days, respectively, by 49%, 61%, and 59% (Table 1). Among the genotypes, CH-52 had the maximum plant height at 45-day interval (36.6 cm), considerably higher than all other genotypes except PAU-212 (34.4 cm). The maximum plant height at 90 and 135-day intervals respectively was recorded in SNP 755 (64.0 cm and 67.0 cm), which was statistically comparable to PAU-212 (63.6 cm and 66.3 cm) and CH-52 (62.7 cm and 65.7 cm). The interaction between genotype and salt levels at 45-day interval revealed that, under control conditions (0 dS/m), CH-52 showed the maximum plant height (48.2 cm) and was statistically comparable to YL-581 (43.5 cm) at the same level. Similarly, at 90 and 135-day intervals, CH-52 recorded the maximum plant height but was at par with genotype SNP 755 at control conditions.

Salinity stress showed negative impact on vegetative growth thereby leading to stunted growth. Plant height decreased significantly with increasing salinity and significant genotypic variation was observed in response to salt stress. Plant height reduction under salinity stress is primarily caused by osmotic stress, which inhibits water intake and cell elongation and division. Plant growth is inhibited by the accumulation of harmful ions like  $\text{Na}^+$  and  $\text{Cl}^-$ , which further disrupt nutrient uptake and metabolic processes (Munns and Tester 2008). Pepper and other solanaceous crops have shown comparable decrease in plant height under salinity stress (Himaya and Prapagar 2019, Ai *et al.* 2021). According to recent research, salinity lowers

*Capsicum annuum's* chlorophyll content, photosynthetic efficiency and biomass accumulation, which eventually results in decreased plant height and vegetative development (Yuce *et al.* 2025, Silva *et al.* 2025).

**Leaf area ( $\text{cm}^2$ ):** Maximum leaf area was reported at 0 dS/m (36.3  $\text{cm}^2$ ), followed by 2 dS/m (29.3  $\text{cm}^2$ ), indicating a considerable drop in leaf area as salt levels rose (Table 2). The maximum leaf area (40.3  $\text{cm}^2$ ) among the genotypes was observed in CH-27, significantly greater than the other genotypes. Genotype S-2530 recorded the smallest leaf area (20.1  $\text{cm}^2$ ). The interaction between genotype and salinity was significant with CH-27 having the largest area (57.8  $\text{cm}^2$ ) under control conditions, followed by the same genotype at 2 dS/m.

Leaf area (LA) is important in crop development models because it is linked to dry matter production via leaf area expansion, which affects light interception and photosynthesis. Osmotic imbalance and decreased leaf water potential, resulting in loss of leaf turgidity and limited leaf growth, are linked to a decrease in leaf area under salinity stress. A higher concentration of salt in the root zone lowers stomatal conductance, relative leaf water content and ultimately photosynthetic activity (Munns and Tester 2008). Bandooglu *et al.* (2004) and Nizam *et al.* (2017) found similar results with pepper. Recent studies have shown that oxidative stress caused by salinity damages chloroplast membrane and prevents cell growth, leading pepper plants to have smaller leaves and accelerated leaf senescence (Hasanuzzaman *et al.* 2020).

**Days to first and 50% flowering:** One important factor that directly affects a plant's earliness is the number of days to flowering. Among the salinity treatments, significantly lowest number of days were recorded at 0 dS/m (48.9) and days increased significantly with exposure to salt stress. Data also revealed that genotype SL-474 took significantly lower number of days till first flowering (47.7) in comparison to other genotypes, whereas YL-581 took the highest number of days (67.8) (Table 2). Genotype SL-474 was statistically comparable to PP-91-7195-1 (49.5) and Punjab Tej (47.8).

A similar pattern regarding the effect of salinity treatments on 50% flowering was observed where the lowest number of days were recorded in the control group (51.0 days) and was followed by 2 dS/m (57.1 days). Among the genotypes, SL-474 (49.8) took minimum number of days and was significantly lower from others except for Punjab Tej (49.9 days) and PP-91-7195-1 (51.7 days).

Interaction between genotype and salinity treatments was found to be significant where genotype PP-91-7195-1 (37.6 and 39.7) took minimum number of days to flower at 0 dS/m and was statistically comparable to DS-175 (38.2 and 40.3), SL-474 (41.5 and 43.6), and CH-27 (39.6 and 41.7) for first and 50% flowering, respectively, at the same salinity level.

The duration to first and 50% flowering is a crucial factor for determining yield potential, as it is directly linked to the earliness of crop plants. As salinity level

Table 1 Effect of salt stress on plant height at 45, 90 and 135 days interval under pot conditions

S. No. Variety	Plant height (45 days) (cm)					Plant height (90 days) (cm)					Plant height (135 days) (cm)				
	Control	2 dS/m	4 dS/m	6 dS/m	Mean	Control	2 dS/m	4 dS/m	6 dS/m	Mean	Control	2 dS/m	4 dS/m	6 dS/m	Mean
1. CH-52	48.2	41.8	32.5	23.9	36.6	91.2	79.1	52.0	28.8	62.7	94.1	82.0	54.9	31.7	65.7
2. YL-581	43.5	37.7	30.1	15.7	31.8	81.2	68.0	45.4	22.9	54.3	83.4	71.4	48.1	24.7	56.9
3. DS-175	29.6	21.6	11.6	9.2	18.0	73.5	63.6	43.5	21.3	50.4	77.0	66.6	46.0	24.0	53.4
4. Punjab Gucchehaar	31.6	26.8	21.7	20.1	25.1	71.6	59.8	50.9	34.1	54.1	74.3	62.8	53.8	36.3	56.8
5. PP-91-7195-1	27.6	21.3	19.5	11.7	20.0	69.5	56.2	39.6	19.1	46.1	73.8	59.0	42.3	21.3	49.1
6. PBC 362	33.6	26.0	17.9	14.7	23.1	76.2	62.4	47.0	32.6	54.5	78.8	65.8	49.4	35.5	57.3
7. GC-222	29.1	26.8	22.4	20.4	24.7	77.6	64.6	45.5	29.6	54.3	80.1	67.4	48.4	32.1	57.0
8. KH-314	30.8	25.6	20.3	19.4	24.0	72.3	77.7	42.8	12.3	51.2	75.6	80.6	45.3	14.6	54.0
9. SL-474	34.6	26.7	22.8	22.5	26.7	82.2	65.1	54.9	40.1	60.5	85.3	68.0	57.4	43.3	63.5
10. S-2530	38.5	31.1	23.1	22.1	28.7	69.9	65.2	50.4	32.6	54.5	73.4	67.8	53.3	35.5	57.5
11. Punjab Lal	32.2	28.1	20.5	11.6	23.1	73.6	53.6	40.6	27.4	48.8	75.3	56.2	43.4	30.9	51.4
12. Punjab Tej	37.9	30.3	23.0	19.4	27.7	84.9	68.8	53.1	34.0	60.2	87.3	71.6	56.7	37.3	63.2
13. SNP 755	40.2	36.0	26.8	22.9	31.5	87.4	70.0	60.1	38.5	64.0	90.2	73.2	63.2	41.4	67.0
14. PAU-212	41.6	37.8	30.1	28.2	34.4	82.2	72.3	58.4	41.8	63.6	84.6	74.7	61.3	44.6	66.3
15. PAU-217	29.7	28.4	19.7	13.4	22.8	73.5	69.2	51.3	36.0	57.5	76.2	72.2	53.8	38.5	60.2
16. CH-27	41.6	31.2	17.8	11.7	25.6	81.1	79.3	54.0	29.2	60.9	84.1	82.4	56.1	31.7	63.6
Mean	35.6	29.8	22.4	18.0		78.0	67.1	49.3	30.0		80.8	70.1	52.1	32.7	
CD ( $p=0.05$ )															
Salt			1.4				1.4					1.6			
Variety			2.4				2.9					2.9			
Salt × Variety			4.9				5.8					5.8			

Table 2 Effect of salt stress on leaf area, days to first flowering and days to fifty percent flowering under pot conditions

S. No.	Variety	Leaf area (cm <sup>2</sup> )					Days to first flowering					Days to fifty percent flowering				
		Control	2 dS/m	4 dS/m	6 dS/m	Mean	Control	2dS/m	4 dS/m	6 dS/m	Mean	Control	2dS/m	4 dS/m	6 dS/m	Mean
1.	CH-52	34.1	25.9	17.3	14.1	22.9	47.5	49.3	51.1	68.6	54.1	49.7	51.5	53.2	70.7	56.3
2.	YL-581	40.8	34.1	25.1	23.1	30.8	57.8	64.9	69.2	79.4	67.8	59.9	67.0	71.3	81.5	69.9
3.	DS-175	33.1	21.0	17.0	10.8	20.5	38.2	53.2	58.0	60.4	52.5	40.3	55.3	60.2	62.6	54.6
4.	Punjab Guechedaar	24.1	20.7	20.7	15.1	20.1	57.4	62.6	66.2	69.4	63.9	59.6	64.7	68.3	71.5	66.0
5.	PP-91-7195-1	29.7	27.5	22.2	10.8	22.6	37.6	49.8	51.3	59.4	49.5	39.7	52.0	53.4	61.6	51.7
6.	PBC 362	27.7	23.9	19.4	12.2	20.8	45.6	51.4	57.8	58.1	53.2	47.7	53.6	59.9	60.2	55.4
7.	GC-222	39.7	29.4	28.9	22.7	30.2	56.1	57.4	60.0	75.2	62.2	58.2	59.5	62.2	77.3	64.3
8.	KH-314	44.9	27.2	26.6	25.6	31.1	52.5	54.5	63.6	71.8	60.6	54.7	56.7	65.7	74.0	62.8
9.	SL-474	38.9	28.2	23.4	19.5	27.5	41.5	47.1	50.6	51.5	47.7	43.6	49.2	52.7	53.7	49.8
10.	S-2530	28.7	25.1	15.8	10.9	20.1	49.8	54.2	55.3	67.1	56.6	51.9	56.3	57.4	69.3	58.7
11.	Punjab Lal	43.4	37.2	25.9	14.0	30.2	48.7	54.9	58.2	61.1	55.7	50.8	57.0	60.4	63.3	57.9
12.	Punjab Tej	30.9	27.2	21.0	17.3	24.1	44.0	44.9	49.7	52.4	47.8	46.2	47.0	51.8	54.6	49.9
13.	SNP 755	34.1	31.9	29.6	15.1	27.7	56.3	59.5	68.4	79.7	66.0	58.4	61.6	70.5	81.8	68.1
14.	PAU-212	39.1	30.9	29.5	17.1	29.2	60.2	66.7	66.9	77.1	67.7	62.3	68.8	69.0	79.3	69.9
15.	PAU-217	33.8	30.4	18.1	13.1	23.9	49.6	51.8	58.1	68.8	57.1	51.7	54.0	60.2	71.0	59.2
16.	CH-27	57.8	49.0	32.9	21.5	40.3	39.6	57.4	58.9	64.3	55.1	41.7	59.6	61.0	66.4	57.2
	Mean	36.3	29.3	23.3	16.5		48.9	54.9	58.9	66.5		51.0	57.1	61.1	68.6	
	CD ( <i>p</i> =0.05)															
	Salt			1.3					1.7					1.7		
	Variety			2.1					2.4					2.4		
	Salt × Variety			4.2					4.8					4.9		

increased, the number of days required for both first and 50% flowering also increased (Kripkoun *et al.* 2019). This delay in flowering was due to salinity induced negative impacts on growth parameters, which impaired the plant's ability to produce flowers as a result of reduced growth and metabolic activity. Salinity inhibits microsporogenesis, stamen filament elongation, promotes programmed cell death in specific tissues, causes ovule abortion, and causes senescence of fertilised embryos (Shrivastava and Kumar 2015). Studies have demonstrated that salinity delays flowering in stressed plants by changing the expression of genes linked to flowering and interfering with the distribution of carbohydrates to reproductive organs (Bigot *et al.* 2025).

*Number of branches, internode length (cm) and pericarp thickness (mm)*: The data presented in Table 3 clearly shows that salinity stress had a considerable impact on branch number, internode length, and pericarp thickness. With increasing salinity, the number of branches gradually declines (0–6 dS/m). The control condition (8.03) showed a considerably higher number of branches, followed by 2 dS/m (7.28), 4 dS/m (6.36) and 6 dS/m (4.91). When genotypes were compared, genotype DS-175 had the highest number of branches (9.38) and was followed by Punjab Guchedaar (8.14). Salinity levels and genotype were found to interact significantly, with genotype DS-175 (12.53) recording the maximum number of branches under control conditions.

As salinity rose from 0 dS/m to 6 dS/m, internode lengths tended to decrease, suggesting that salt stress has a detrimental effect on internode elongation. Among the salinity treatments, the longest internode length was observed under controlled conditions (3.95 cm), followed by 2 dS/m (3.29 cm), and the shortest was recorded under 6 dS/m (2.29 cm). SL-474 (4.04 cm) exhibited the longest internode length among the genotypes, and it was noticeably higher than others. Interactions were found significant between genotype and salinity treatments with maximum internode length in SL-474 (5.13 cm) under no salt conditions.

Salt stress also had a considerable impact on pericarp thickness, as seen in Table 3. With the lowest reported at 6 dS/m (1.04 mm) and the maximum under control conditions (1.81 mm), pericarp thickness dramatically decreased at high salt concentrations. Among the genotypes, CH-27 had the thickest pericarp (1.66 mm) among all, and was statistically comparable to KH-314 (1.60 mm), Punjab Guchedaar (1.57 mm), PAU-212 (1.55 mm), SL-474 (1.52 mm), and CH-52 (1.50 mm). The findings showed that all genotypes showed a decrease in pericarp thickness, with genotype DS-175 exhibiting the largest decline of about 66%.

Salinity stress reduces branching and internode length by lowering cell turgor pressure and inhibiting cell division and elongation. Salinity interferes with the intake of nutrients, especially calcium and potassium, which are necessary for fruit structure and cell wall growth (Parvin *et al.* 2015). Pepper plants subjected to salinity have shown similar results (Ibn Maouia-Houimli *et al.* 2008, Rhim *et*

*al.* 2012). As per studies conducted, plant architecture and fruit structural characteristics in vegetable crops are greatly impacted by salinity-induced oxidative damage to cellular membranes and hormonal imbalance (Hasanuzzaman *et al.* 2020, Kumar *et al.* 2022).

*Fruit length and width (cm)*: Data shown in Table 4 clearly shows that salinity had a substantial effect on fruit length and width across genotypes. All genotypes showed a general decrease in fruit length and width as salinity rose. At 6 dS/m, the mean fruit length and breadth decreased to 4.6 and 1.02 cm, respectively, indicating a decline of 19.0 and 44.0% from the control. The maximum fruit length of all was displayed by genotypes PAU-212 and CH-52 (6.6 cm each) and were statistically greater than the others. In terms of fruit width, PAU-212 (1.07 cm) showed significantly maximum width and was followed by genotype CH-27 (1.02 cm).

Fruit growth is impacted by salinity because it upsets the water balance and nutrient uptake in plant tissues. Fruit growth is restricted in saline environments because of decreased photosynthesis and poor assimilate transfer. Comparable observations were documented by Huez-Lopez *et al.* (2011) and Chartzoulakis and Klapaki (2000) in pepper. Salinity may also affect hormone control and the distribution of carbohydrates to developing fruits, which could lead to smaller and lower-quality fruits, according to recent studies (Kumar *et al.* 2022, Aizaz *et al.* 2024).

*Root fresh and dry weight (g)*: The data shown in Table 4 and Table 5 demonstrate that salinity stress significantly reduces root development. Fresh weight of roots consistently decreased for all genotypes as salinity increased from control (no salt) to 2 dS/m, 4 dS/m, and 6 dS/m. Significant stunting of root growth occurs under extreme salt stress, as seen by the mean root fresh weight dropping from 68.0 g at control to 42.2 g at 2 dS/m, which further decreases to 26.7 g at 4 dS/m and 16.7 g at 6 dS/m. Genotype SL-474 recorded the highest root weight (49.1 g) and was statistically comparable to GC-222 (46.9 g) whereas KH-314 exhibited the lowest root fresh weight (25.3 g). Salinity treatments and genotypes interacted significantly, with genotype SL-474 (86.5 g) exhibiting the highest root fresh weight under control conditions and statistically being comparable with S-2530 (86.0 g) under similar treatment.

The dry weight of the roots dropped significantly at 6 dS/m, from 35.8 g under control conditions to 12.8 g. Genotypic comparison revealed that SNP 755 displayed the highest root dry weight (31.7 g) and was statistically similar to YL-581 (31.2 g). Genotype KH-314 showed the lowest root dry weight, at 10.1 g. In terms of interaction, the maximum was seen in genotype YL-581 at no salt conditions (47.3 g) and was statistically comparable with SNP 755 (46.2 g), Punjab Tej (45.0 g), and CH-27 (44.8 g) at the same salt level.

Osmotic stress, ion toxicity, and decreased root meristem cell division are the main causes of the decrease in root biomass in saline environments. In addition to decreasing nutrient intake, high salt concentrations lead to

Table 3 Effect of salt stress on number of branches, internode length and pericarp thickness under pot conditions

S.No.	Variety	Number of branches					Internode length (cm)					Pericarp thickness (mm)				
		Control	2 dS/m	4 dS/m	6 dS/m	Mean	Control	2 dS/m	4 dS/m	6 dS/m	Mean	Control	2 dS/m	4 dS/m	6 dS/m	Mean
1.	CH-52	8.93	7.97	6.10	3.93	6.73	3.93	3.20	2.67	1.93	2.93	1.83	1.60	1.40	1.17	1.50
2.	YL-581	7.37	7.20	6.23	4.43	6.31	3.67	3.30	3.07	2.60	3.16	1.80	1.43	1.27	0.93	1.36
3.	DS-175	12.53	10.40	8.10	6.47	9.38	3.80	3.47	2.70	2.03	3.00	1.40	0.87	0.67	0.47	0.85
4.	Punjab Guechedaar	9.37	8.50	8.20	6.50	8.14	3.40	2.83	2.33	2.07	2.66	2.00	1.70	1.47	1.10	1.57
5.	PP-91-7195-1	8.33	7.03	6.97	5.50	6.96	3.47	2.03	1.83	1.07	2.10	1.47	1.17	1.07	0.87	1.15
6.	PBC 362	6.47	6.40	6.37	5.33	6.14	3.77	3.40	3.23	2.67	3.27	1.77	1.47	1.27	1.00	1.38
7.	GC-222	7.20	7.00	6.80	5.90	6.73	3.87	3.37	3.03	2.73	3.25	1.83	1.27	1.27	1.00	1.34
8.	KH-314	7.80	7.70	5.90	4.47	6.47	2.63	2.30	1.83	1.87	2.16	2.20	1.53	1.43	1.23	1.60
9.	SL-474	7.47	6.53	6.30	3.87	6.04	5.13	4.70	3.60	2.73	4.04	1.73	1.60	1.57	1.17	1.52
10.	S-2530	7.37	7.40	6.67	4.43	6.47	3.30	3.10	2.87	2.57	2.96	1.77	1.63	1.50	1.07	1.49
11.	Punjab Lal	7.50	6.67	4.60	4.00	5.69	5.00	3.60	2.17	1.83	3.15	1.60	1.40	1.33	0.93	1.32
12.	Punjab Tej	7.27	6.57	6.87	5.57	6.57	4.23	3.27	3.10	2.47	3.27	1.87	1.47	1.40	1.17	1.48
13.	SNP 755	7.80	6.47	4.97	3.70	5.74	4.53	3.80	3.67	3.33	3.83	1.73	1.27	1.20	1.00	1.30
14.	PAU-212	7.50	5.60	5.67	4.87	5.91	4.90	4.60	3.37	2.53	3.85	1.97	1.57	1.50	1.17	1.55
15.	PAU-217	8.03	7.80	4.97	4.63	6.36	3.50	2.57	2.27	1.73	2.52	1.90	1.50	1.47	1.10	1.49
16.	CH-27	7.53	7.30	6.90	5.00	6.68	4.07	3.13	2.83	2.53	3.14	2.07	1.67	1.60	1.30	1.66
	Mean	8.03	7.28	6.35	4.91		3.95	3.29	2.78	2.29		1.81	1.45	1.34	1.04	
	CD ( $p=0.05$ )															
	Salt			0.19				0.04						0.11		
	Variety			0.29				0.06						0.16		
	Salt × Variety			0.59				0.11						NS		

Table 4 Effect of salt stress on fruit length, fruit width and fresh weight of roots under pot conditions

S. No.	Variety	Fruit length (cm)						Fruit width (cm)						Fresh weight of roots (g)								
		Control		2 dS/m		6 dS/m		Control		2 dS/m		6 dS/m		Control		2 dS/m		6 dS/m		Mean		
		7.2	7.2	6.3	5.7	5.7	6.6	0.73	0.70	0.60	0.50	0.63	0.90	0.70	0.60	0.50	0.63	58.2	44.2	22.4	13.2	34.5
1.	CH-52	7.2	7.2	6.3	5.7	5.7	6.6	0.73	0.70	0.60	0.50	0.63	0.90	0.70	0.60	0.50	0.63	58.2	44.2	22.4	13.2	34.5
2.	YL-581	6.3	6.1	5.7	5.4	5.4	5.9	0.90	0.70	0.60	0.50	0.68	0.90	0.70	0.60	0.50	0.68	73.4	49.5	33.2	24.7	45.2
3.	DS-175	4.5	4.5	4.2	3.5	3.5	4.2	0.40	0.40	0.30	0.27	0.34	0.40	0.40	0.30	0.27	0.34	77.2	40.7	21.1	18.2	39.3
4.	Punjab Guccchedaar	5.8	5.4	5.2	4.9	4.9	5.3	0.90	0.53	0.47	0.30	0.55	0.90	0.53	0.47	0.30	0.55	79.1	37.5	28.6	19.8	41.3
5.	PP-91-7195-1	4.7	4.6	4.5	4.3	4.3	4.5	0.80	0.70	0.60	0.50	0.65	0.80	0.70	0.60	0.50	0.65	59.6	39.4	28.0	20.7	36.9
6.	PBC 362	6.3	6.0	5.9	5.4	5.4	5.9	0.63	0.57	0.50	0.40	0.53	0.63	0.57	0.50	0.40	0.53	54.8	37.6	26.1	10.8	32.3
7.	GC-222	4.1	4.2	3.9	3.5	3.5	3.9	0.63	0.60	0.50	0.37	0.53	0.63	0.60	0.50	0.37	0.53	70.4	50.6	44.6	22.1	46.9
8.	KH-314	4.9	4.5	4.1	3.7	3.7	4.3	1.10	0.80	0.80	0.60	0.83	1.10	0.80	0.80	0.60	0.83	55.0	24.3	12.1	9.7	25.3
9.	SL-474	6.0	5.8	5.6	5.4	5.4	5.7	0.70	0.53	0.47	0.33	0.51	0.70	0.53	0.47	0.33	0.51	86.5	49.3	38.2	22.4	49.1
10.	S-2530	6.3	5.9	5.5	4.8	4.8	5.6	0.63	0.60	0.50	0.37	0.53	0.63	0.60	0.50	0.37	0.53	86.0	46.2	21.8	12.4	41.6
11.	Punjab Lal	4.8	4.7	4.2	3.5	3.5	4.3	0.73	0.60	0.50	0.40	0.56	0.73	0.60	0.50	0.40	0.56	62.6	28.5	16.2	9.6	29.2
12.	Punjab Tej	5.3	5.0	4.6	4.0	4.0	4.7	0.50	0.40	0.30	0.20	0.35	0.50	0.40	0.30	0.20	0.35	62.0	36.1	22.1	19.4	34.9
13.	SNP 755	4.7	4.4	3.7	3.3	3.3	4.0	0.70	0.63	0.60	0.50	0.61	0.70	0.63	0.60	0.50	0.61	66.1	57.5	35.9	18.3	44.5
14.	PAU-212	7.2	7.1	6.4	5.8	5.8	6.6	1.33	1.10	1.00	0.83	1.07	1.33	1.10	1.00	0.83	1.07	64.2	51.9	35.1	21.8	43.3
15.	PAU-217	6.3	5.9	5.8	5.3	5.3	5.8	0.80	0.60	0.50	0.40	0.58	0.80	0.60	0.50	0.40	0.58	57.2	37.4	19.7	13.6	32.0
16.	CH-27	6.2	5.8	5.3	5.2	5.2	5.6	1.31	1.07	1.00	0.70	1.02	1.31	1.07	1.00	0.70	1.02	76.3	44.8	22.3	10.7	38.5
	Mean	5.7	5.4	5.1	4.6	4.6		0.80	0.66	0.58	0.45		0.80	0.66	0.58	0.45		68.0	42.2	26.7	16.7	
	CD ( $p=0.05$ )																					
	Salt			0.1					0.01					0.01						1.3		
	Variety			0.2					0.02					0.02						2.8		
	Salt × Variety			NS					0.05					0.05						5.6		

Table 5 Effect of salt stress on dry weight of roots, fruit number per plant and total yield under pot conditions

S. No. Variety	Dry weight of roots (g)					Fruit number/plant					Fruit yield (g/plant)				
	Control	2 dS/m	4 dS/m	6 dS/m	Mean	Control	2 dS/m	4 dS/m	6 dS/m	Mean	Control	2 dS/m	4 dS/m	6 dS/m	Mean
1. CH-52	36.2	24.4	19.9	16.0	24.1	261.9	201.1	172.5	151.9	196.9	584.1	444.1	378.5	331.1	434.4
2. YL-581	47.3	37.2	21.3	19.0	31.2	240.8	216.7	204.0	198.1	214.9	627.2	561.9	527.6	511.7	557.1
3. DS-175	39.0	22.3	12.5	11.3	21.3	246.5	214.6	195.2	168.2	206.1	408.0	353.7	320.7	274.8	339.3
4. Punjab Guchedaar	32.0	20.8	19.7	17.3	22.4	169.0	148.1	113.3	105.1	133.9	433.2	376.7	282.7	260.8	338.3
5. PP-91-7195-1	32.7	29.8	23.0	13.9	24.8	173.9	169.2	124.1	109.6	144.2	430.3	418.0	300.7	263.2	353.0
6. PBC 362	32.0	13.1	10.7	4.5	15.0	179.0	169.1	137.1	123.4	152.2	426.9	402.1	322.0	287.8	359.7
7. GC-222	29.1	20.7	15.6	10.5	19.0	217.5	222.3	195.8	181.9	204.4	420.3	429.9	376.8	349.1	394.0
8. KH-314	16.0	9.5	9.2	5.6	10.1	184.4	161.4	149.6	129.2	156.1	405.9	353.0	325.8	278.8	340.9
9. SL-474	34.0	20.9	19.2	18.1	23.0	256.5	239.2	215.2	199.7	227.7	596.1	554.7	496.9	459.9	526.9
10. S-2530	33.4	26.2	17.3	15.2	23.0	227.2	188.2	169.5	151.2	184.0	461.2	379.3	340.1	301.7	370.6
11. Punjab Lal	34.9	22.2	15.8	18.6	22.9	172.8	169.9	132.3	116.6	147.9	330.8	325.2	249.9	218.5	281.1
12. Punjab Tej	45.0	23.5	12.8	6.3	21.9	223.9	155.1	157.9	146.5	170.9	433.1	295.5	301.2	278.4	327.1
13. SNP 755	46.2	33.6	30.8	16.0	31.7	254.9	237.0	209.9	191.6	223.3	567.9	526.7	464.4	422.4	495.3
14. PAU-212	38.6	29.5	20.9	18.2	26.8	214.4	199.5	193.5	178.2	196.4	747.9	632.2	584.4	519.8	621.1
15. PAU-217	31.1	16.4	10.3	4.5	15.6	202.5	197.3	166.9	154.0	180.2	599.8	583.8	489.5	449.4	530.6
16. CH-27	44.8	22.2	15.0	10.4	23.1	217.1	197.5	173.2	155.1	185.7	583.4	528.7	460.6	410.1	495.7
Mean	35.8	23.2	17.1	12.8		215.1	192.9	169.4	153.8		503.5	447.8	388.9	351.1	
CD ( $p=0.05$ )															
Salt			1.3					4.5					11.1		
Variety															22.6
Salt × Variety															45.2

mineral imbalance in the rhizosphere (Rehman *et al.* 2005). salinity limits root growth and nutrient uptake by decreasing root hydraulic conductivity and damaging root membrane stability (Hasanuzzaman *et al.* 2020). Sharma *et al.* (2012) showed similar decrease in pepper root development under saline stress.

*Fruit number and fruit yield (g/plant)*: The reproductive capability of a plant is indicated by the quantity of fruits it produces. Fruit production significantly decreased under control conditions (0 dS/m), from 215.1 fruits per plant to 153.8 fruits per plant at 6 dS/m (Table 5). Comparison between genotypes revealed that SL-474 was statistically similar to SNP 755 (223.3) and had the greatest fruit count (227.6) among all (Table 4). Interaction between genotype and salinity treatments was significant where CH-52 produced the most number of fruits per plant under control conditions (261.9) and was significantly high compared to others except for DS-175 (246.5), SL-474 (256.5) and SNP 755 (254.9) at the same salt level.

As salinity increased, yield consistently decreased, with the control conditions producing the maximum yields (Table 4). The average yield was 503.5 g/plant under the control treatment and 351.1 g/plant at the maximum salinity level (6 dS/m). PAU-212 showed the maximum yield of any of the genotypes (621.1 g/plant) and was followed by YL-581 (557.1 g/plant). Significant genotype  $\times$  salinity interactions were observed where genotype PAU-212 exhibited the maximum yield (747.9 g/plant) at control conditions and was higher among all. In terms of percent decrease in yield with increasing salt stress, GC-222 experienced the smallest decrease, with only 16.9% reduction and was followed by YL-581 (18.4%) and SL-474 (22.8%) genotype.

Yield reduction under saline conditions may be attributed to reduced photosynthetic activity, decreased assimilate production and impaired reproductive development. Additionally, salinity leads to generation of reactive oxygen species (ROS), which lowers metabolic efficiency and destroys cellular components (Hussain *et al.* 2018). Pepper plants eventually have lower fruit set and output due to reduced photosynthesis, chlorophyll degradation, and poor water relations (Neocleous and Vasilakakis 2007, Zörb *et al.* 2019). According to recent research, salinity stress reduces *Capsicum annuum* yield by adversely affecting carbon absorption, stomatal conductance, and reproductive development (Kumar *et al.* 2022).

Thus, it can be concluded that pepper genotypes exhibited significant reductions in growth, yield, and fruit characteristics under salt stress, with notable variation among lines. Genotypes PAU-212, YL-581, and SL-474 consistently performed better across all measured traits, with higher yields and better tolerance suggesting as the most promising genotypes for cultivation in salt-affected regions and for further research on salinity tolerance.

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