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Research Article

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Seed Germination and Vegetative Growth of Petunia (*Petunia hybrida*) Genotypes to Salt Stress

Niaz Ahmed Wahocho[1], Rais Mujeeb-ur-Rehman Laghari [1], Khalid Hussain Talpur[2], Muzamil Farooque Jamali[1], Waqas Ahmad[3], Ahmed Naqi Shah[4], Sohail Ahmed Otho[5], Piar Ali Shar[6], Safdar Ali Wahocho[1]

[1]Department of Horticulture, Sindh Agriculture University Tandojam, Pakistan
[2]Department of Soil Science, Sindh Agriculture University Tandojam, Pakistan
[3]College of Agriculture, Bahauddin Zakariya University Bahadur Campus Layyah, Pakistan.
[4]Department of Agronomy, Sindh Agriculture University Tandojam, Pakistan
[5]Department of Entomology, Sindh Agriculture University Tandojam, Pakistan
[6]Department of Plant Breeding and Genetics, Sindh Agriculture University Tandojam, Pakistan
Corresponding author email: nawahocho@sau.edu.pk

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Abstract

Salinity is a brutal threat to sustainability of crop production and exhibits injurious effect on major plant processes including protein synthesis, cell division and photosynthetic activity. Germination and early growth of plants are most susceptible to salinity effect in comparison to other growth stages. In this context, the seed emergence and early vegetative growth of flowers needs to be tested properly. The pot based study was conducted in Completely Randomized Design (CRD) with three replicates at Sindh Agriculture University Tandojam. The goal of this investigation was to explore the performance of petunia plants to salt stress environment at early growth stage. Two petunia varieties (V_1= Prism blue, V_2= Hala lop petunia rose) were evaluated against six levels of salt stress (T_1 = Canal irrigation water [Control], T_2 = 3 dS m^{-1}, T_3 = 5 dS m^{-1}, T_4 = 7 dS m^{-1}, T_5 = 9 dS m^{-1}, T_6 = 11 dS m^{-1}).The results showed that there was an inverse effect of salt stress on all the traits examined and with each increased level of salinity in irrigation water; the values of petunia plant traits were significantly decreased. The petunia grown in pots given only canal water (control) revealed better performance for germination and growth attributes. It was further noted that that salt stress up to 3 dS m^{-1} level was generally tolerated by petunia. Among petunia varieties, Hala lop petunia rose performance was better and showed relative tolerance to salt stress over Prism blue, but in most cases the differences were insignificant (P>0.05).

Keywords: *Salt stress, seed germination, vegetative growth, petunia genotypes*

Introduction

Floriculture is one of the high value industries in agriculture sector worldwide; and in developed nations this industry is more established as compared to developing or under developing world. Internationally, the cut flower annual trade is around US$ 11 billion and contributes 60 percent of total floriculture related trade. The export of cut flowers is increasing continuously and expected this pace of development in future (Singh *et al*., 2010). Production of cut flowers for few decades has shown rapid developments worldwide due to development in the marketing facilities including storage and classification (Torbaghan, 2012). In Pakistan, the cut flower industry has not been developed much due to instable policies for agriculture production and particularly for the floriculture and the flower production and marketing is limited up to big cities. However, media invasion have developed masses for the importance of flowers for different events (Manzoor *et al.* 2001). Petunias belong to Solanaceae family and in temperate climates these are cultivated as annual bedding and container plants (Gulser, 2019). Petunia are lovely, long flowering annual plants, which yield single or double, small or big flowers in striking colours (Gerats and Strommer, 2009). It is good pot, bed or border plant (Dubey *et al*., 2013). Diverse colours of petunias made them most famous bedding plants in the world (Kessler, 1998). In the United States (USA), it is very famous and more than 400 petunia cultivars are grown there (Kessler, 1998; USDA, 2010). Salinity is a major threat to sustainability of crop production (Alam *et al*., 2014; Porcel *et al*., 2012) and badly influences the physiological, biochemical and morphological activities of plants (Akbarimoghaddam *et al*. 2011). Available evidences revealed that salt stress environment around the plant caused highly bad influence on important plant parameters including germination, growth and yield attributed parameters (Ahanger *et al*., 2020; Mahajan and Tuteja, 2005). Salinity issue is increasing day by day because of regular application of salt contaminated water to plants (Zelm *et al*., 2020). Munns and Tester (2008) reported that salinity posed serious threat to 45 million hectares of agricultural land of which 1.5 million hectares soil showed significant reduction in crop yield. The past evidences showed that highly injurious consequence of salt stress is due to the buildup of $sodium^+$ and $chloride^-$ ions in the tissues of plants (Hnilickova *et al*. 2019). The induction of both ions in plant tissues results in major ion imbalance and toxicity that causes the failure of physiological activities in the plants (James *et al*. 2011). Moreover, salt stress condition also badly influences the respiration, transpirations, protein synthesis and lipid and energy metabolism processes (Zelm *et al*., 2020).This eventually led to poor growth, development and yield of plants (Guo *et al*., 2020 and Zhu, 2007). Furthermore, the long exposure of salt stress conditions to plants causes the low osmotic potential (Ahenger *et al*., 2019). This may led to decreased cell expansion and division as well as stomatal movement (Mubarak *et al*., 2022).The increased concentration of salts (Na and Cl) significantly influence the enzymatic activities that results in cell swelling, reduced energy production and occurrence of physiological changes in crop plants (Kaya *et al*., 2020). Most of plant species have evolved mechanism of salt adaptation. Osmotic stress tolerance is vital for salt stress adaptation mechanism of plants (Nikalje *et al*., 2017). Salinity has shown highly injurious effect on diverse crop species. Gu *et al*. (2016) stated that increased concentration of Na^+ in various plant parts was the main cause of yield reduction in cabbage. Similarly Jamali *et al*. (2021) also found injurious effect of salinity in marigold and stated that germination, vegetative and flowering attributed parameters significantly decreased. Likewise, Wahocho *et al*. (2021) reported major reduction of leaves, germination, seedling vigour index and other shoot and root attributed observations in chilli. Hnilickova (2019) assessed the impact of salt stress on selected plant species (lettuce, New Zealand spinach and purslane) and found diverse reactions of plant species to salt stress. He reported that lettuce was more sensitive to salt stress and revealed a marked decline of shoot biomass. Floriculture crop species are highly sensitive to salinity and have been generally applied salt free water for their healthy growth and development (Pizarro, 2011). Nevertheless, shortage of high quality irrigation water occurs worldwide which is major threat to floriculture crop species. The development of salt tolerant flower crop species is a promising approach for lucrative farming of flowers. Most of the flowers including petunia are tolerable from low to moderate salinity. It is generally believed that floriculture crop species are very sensitive to salt stress environment. It is well documented that past studies related to salinity were mainly performed on trees, shrubs and perennial herbaceous plants (Niu and Cabrera, 2011). However, only few studies were performed on cut flowers (Pizarro, 2011). Germination and early growth of any plant are known as most crucial stages (Wahocho *et al*., 2021). Available evidences reveals that these stages of plants are most susceptible to salinity effect in comparison to other growth stages especially in the case of floriculture crop species. (Jamali *et al*., 2021). Due to injurious effect of salinity and high value of floriculture crop species it is crucial to explore their performance to salinity during early growth stages. In view of above discussion and facts, the present study has been attempted to assess the seed germination, vegetative growth and determine the salt stress tolerance of petunia genotypes.

Materials and Methods

Experimental Location: The pot based study was performed during winter, 2019-20 under nursery conditions at Sindh Agriculture University, Tandojam to test the response of petunia varieties to different salt stress levels. The pots were filled with canal sediment (canal silt) keeping one inch space at the top. The soil was sandy, and was not salt affected having EC 0.5 dSm^{-1}.

Experimental design: The study was executed using randomized complete block design with three replicates. Each replication comprises of three pots and in each pot five seeds were sown. Overall, 54 earthen pots were used in this study.

Experimental Factors: Two factors viz. varieties and treatments were used to evaluate the efficacy of each factor independently as well as on interaction basis. The factor A comprised of two varieties i.e. V1 prism blue and V2 Hala lop petunia rose and factor B consisted of six salt stress treatments that included (T_1 = Canal irrigation water [Control], $T_2 = 3$ dS m^{-1}, $T_3 = 5$ dS m^{-1}, $T_4 = 7$ dS m^{-1}, $T_5 = 9$ dS m^{-1}, $T_6 = 11$ dS m^{-1}).

Seed Source: The seeds of both varieties were purchased from skyseeds company.

Preparation of Salt Stress levels: The salt stress solutions were prepared under laboratory conditions. Sodium chloride (NaCl) was used to maintain electrical conductivity (EC) of each solution. The amount of salt used to prepare various salt levels was 1.5 grams (g), 3 g, 4.5 g, 6 g and 7.5 g, respectively. The solution were prepared in plastic bottles filled with canal water that was acquired from local Rohri canal.

Sowing of seeds and cultural practices: In each pot five seeds were sown. Before sowing seeds, the pots were supplied with saline water having different EC levels. Pots were irrigated with canal water twice a week , however saline water was applied to plants twice a week. All the required farming practices including hoeing, weeding, pests and disease attract were strictly followed. It is noteworthy that no pest infestation (insect pest and disease attack) was noted in petunia plants. After 45 days of exposure to salinity, five uniform size plants were selected randomly for recording data. The parameters including seed germination (%), germination index, seedling vigour index, root length (cm), shoot length (cm), leaves plant^{-1}, shoot biomass (g), root biomass (g), electrolyte leakage of leaf (%) were selected for recording the data.

Observations Recording Procedure

Germination Percentage (%): The following formula as described by Larsen (2004) was applied to calculate the germination%

$$\text{Germination \%} = \frac{\text{germinated seeds}}{\text{Seeds sown}} \times 100$$

Seedling vigour index: Seedling vigour index was found by a following formula as stated by Abdul-Baki and Anderson (1970)

Seedling vigor index (SVI) = [length of shoot (cm)× germination %]

Root length: The length of major primary root was calculated with the measuring scale.

Shoot length: The shoot length was measured by summing of the shoot lengths of all pieces of plant in which long path of plant is determined.

Leaves plant^{-1}: Leaves in selected each plant were counted and then average was taken out.

Fresh root biomass (g): Fresh root biomass was calculated by randomly selecting five plants in each treatment on digital weighing balance. Before weighing, root were properly washed and was kept on tissue paper for three hours in order to drain out the excess water.

Fresh shoot biomass (g): First of all, roots were separated. The fresh shoot biomass was calculated by summing up all patches (small and long). The digital balance was used to measure the shoot biomass.

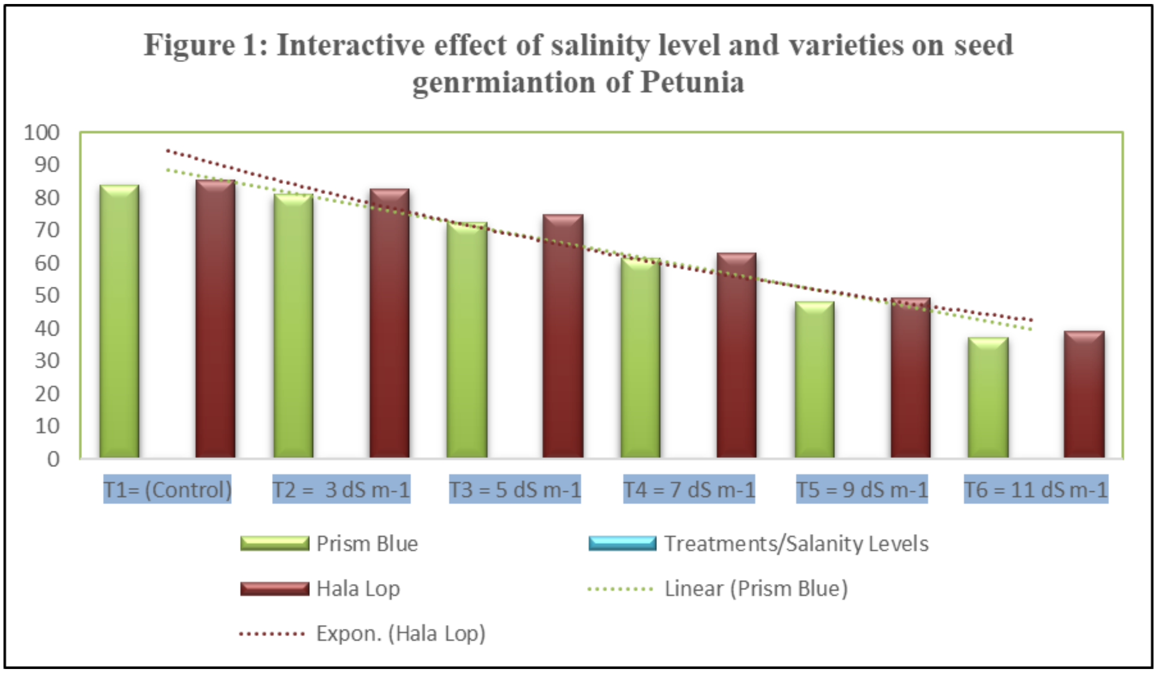
Electrolyte leakage of leaf %: For measuring electrolyte leakage, five discs from fresh fully expanded leaves from labeled plants having diameter 0.5 cm were cut. In order to remove the surface adhered electrolytes, the sample leaves were washed and cleaned thrice with deionized water. The leaf discs were kept in tubes containing 30 ml of deionized water and incubated over a course of 4 hours at room temperature. After that, the initial electrical conductivity (EC) of bathing solution was calculated with EC meter that was considered as value A. The leaf samples were again incubated in water bathing solution at a temperature of 95^{0}C for a course of 20 minutes to release all electrolytes. The samples were then cooled down at room temperature(25 ^{0}C) and final EC of solution was measure and that was considered as value B. The electrolyte leakage (EL) was measured by applying following formula.

Electrolyte leakage of leaf % = (Value A/Value B)x 100

Statistical analysis: The collected data were subjected to statistical analysis using Statistix Ver.8.1 (Statistix, 2006). The LSD test at 0.05% was followed to assess difference between treatments, wherever required.

Results

Seed germination %: The effect of salt stress on the seed germination of petunia varieties was investigated and the data are presented in Figure 1. The statistical analysis (Figure-I) reveals that salt stress levels had major ($P<0.05$) effect on the seed germination of petunia; while interactive effect of petunia varieties and salt stress levels was insignificant ($P>0.05$). The data shown in (Figure 1) exhibited that the petunia genotype Hala lops petunia rose resulted in relatively higher seed germination (65.73 %) as compared to Prism blue (63.96 %). This indicates that variety Hala lop petunia rose has relative tolerance to salinity as compared to variety Prism blue. The effect of salt stress indicates that petunia seeds sown in media of 11 dS m^{-1} salt stress level caused lowest seed germination of 38.18 percent; while there was a linear increase in the seed germination with decreasing salt stress level up to 9 dS m^{-1} (48.73 %), 7 dS m^{-1} (62.16 %), 5 dS m^{-1} (73.50 %) and 3 dS m^{-1} (81.88 %), while the seed germination reached to its maximum (84.62 %) when soil media was irrigated with canal irrigation water. The data clearly suggested that 5 dS m^{-1} and above salt stress showed severe adverse effect on seed germination ($P<0.05$); while the differences in seed germination between control (canal water irrigation) and 3 dS m^{-1} salt stress level were insignificant ($P>0.05$) suggesting that petunia can be grown in media of 3 dS m^{-1} salinity without considerable adverse effect on seed germination.



Significance level	Varieties (V)	Salt stress levels (S)	V×S
S.E.	1.1482	1.9887	2.4616
LSD 0.05	NS	4.1242	NS
CV%	5.31		

Germination index: The germination index of petunia varieties was calculated under the impact of different levels of salt stress and the findings are given in Figure 2. The analysis of variance (ANOVA) suggested that germination index of petunia was significantly influenced by salt stress levels (P<0.05); but the effect of petunia varieties and interaction results were statistically insignificant (P>0.05). It is visible from the results (Figure 2) that germination index was higher (0.8717) in petunia variety Hala lop petunia rose as compared to Prism blue (0.8444); which shows that Hala lop petunia rose variety was more efficient to attain more germination under saline conditions as compared to variety Prism blue. The salt stress effect showed that the germination index was least (0.29) in media of 11 dS m^{-1} salt stress level; and the germination index was linearly increased with lessening salt stress level upto 9 dS m^{-1}, 7 dS m^{-1}, 5 dS m^{-1} and 3 dS m^{-1} with average germination index of 0.48, 0.655, 0.8767 and 1.3383, respectively. However, germination index was highest (1.5083) when soil media was irrigated with canal water. It is evident from the results that salt stress upto or above 5 dS m^{-1} cause harsh effect on seed germination and soil media or the water used for petunia irrigation must not be higher than 3 dS m^{-1} salinity. Statistically, the differences in germination index between canal water irrigation (control) and 3 dS m^{-1} salt stress level were insignificant (P<0.05) indicates that petunia can be grown in media of up to 3 dS m^{-1} salt level with minor negative effect on germination index

Seedling vigor index: The effect of salt stress on the seedling vigor index of petunia was determined and the findings are shown in Figure 3. The statistical analysis of the data revealed that salt stress levels and petunia varieties had significant (P<0.05) effect on the seedling vigor index of petunia; while seedling vigor index did not change significantly (P>0.05) due to interactive effect of petunia varieties and salt stress levels. The data (Figure 3) depicted that the calculated seedling vigor index was relatively higher in petunia variety Hala lop petunia (936.41) as compared to variety Prism blue (867.96). This indicates that variety Hala lop petunia rose possessed relatively more tolerance to salinity than variety Prism blue. The effect of salt stress indicates that petunia sown in pots irrigated with water of 11 dS m^{-1} salinity level resulted in lowest seedling vigor index of 362.4; and the seedling vigor index showed a linear increase under decreased salt stress level i.e. 9 dS m^{-1} (560.8), 7 dS m^{-1} (773.3), 5 dS m^{-1} (1052.9) and 3 dS m^{-1}

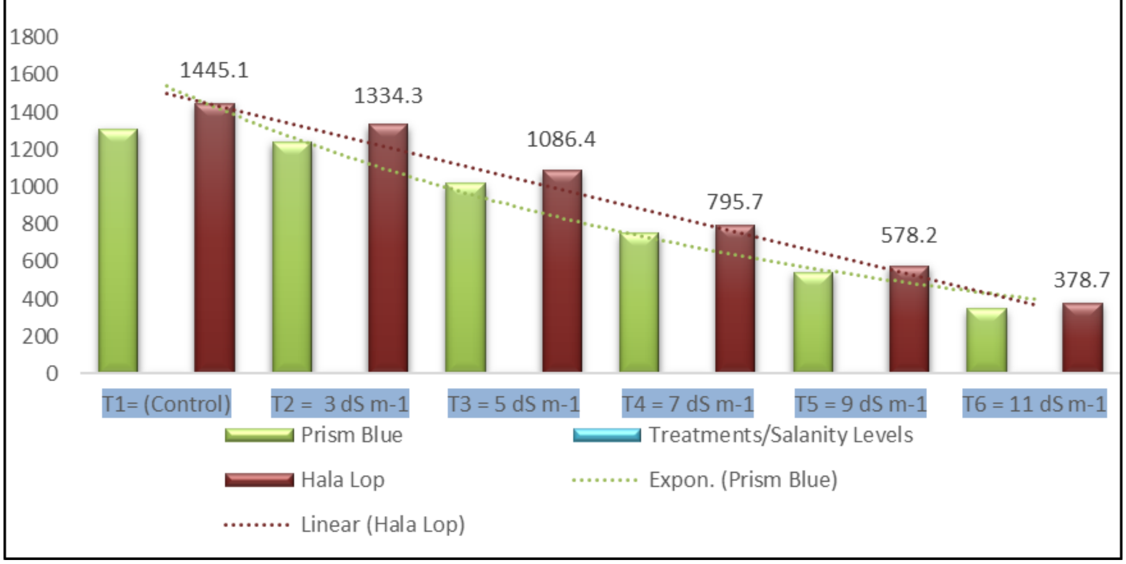
(1287.2), while the seedling vigor index was highest (1376.6) when pots were irrigated with canal irrigation water (control). The treatment interaction showed that variety Hala lop petunia rose irrigated with canal water resulted in maximum seedling vigor index (1445.1); while the least seedling vigor index (346.1) was calculated in variety Prism blue when supplied with water of 11dS m^{-1} salinity level. Statistically, the difference in seedling vigor index between control (canal water irrigation) and 3 dS m^{-1} salt stress level were insignificant (P<0.05) which indicates that saline water upto 3 dS m^{-1} salinity can be applied without significant damage to petunia plant growth as reflected by the calculated seedling vigor index.

Figure 2: Germination index of petunia varieties under the influence of varying salt stress levels

Significance level	Varieties (V)	Salt stress levels (S)	V×S
S.E.	0.0486	0.0842	0.1191
LSD0.05	NS	0.1747	NS
CV%	3.63		

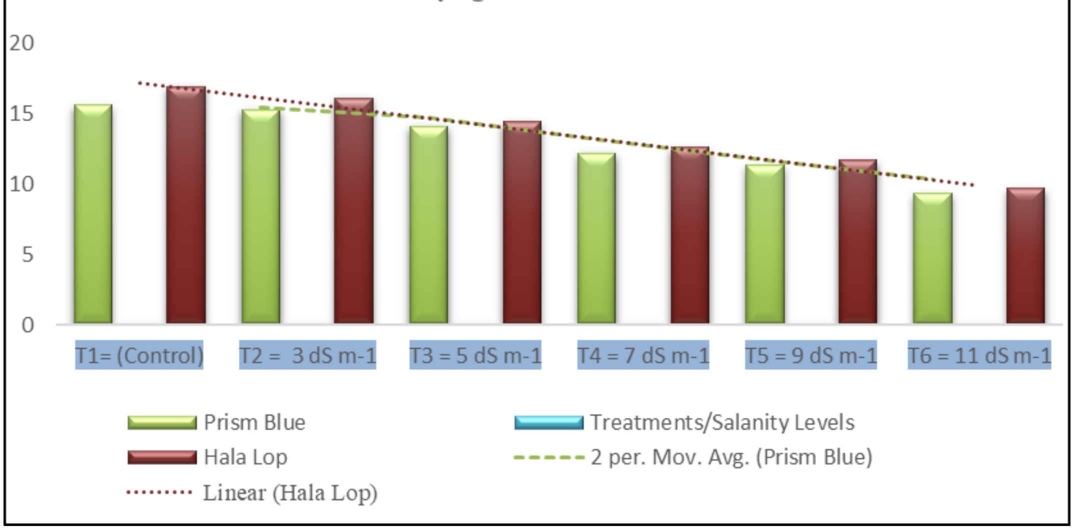
Shoot length (cm): The plant growth is manifested mainly through height of the plants. The influence of salt stress on the shoot length of petunia varieties was examined and the data are given in Figure 4. The ANOVA depicts that plant height of petunia was significantly influenced by salt stress levels (P<0.05); while shoot length did not reflect significant change (P>0.05) due to varieties and by interaction between petunia varieties and salt stress levels. It is obvious from the results (Figure 4) that petunia variety Hala lop petunia grew relatively taller (13.582 cm) than its counterpart Prism blue (12.985 cm). This showed that variety Hala lop petunia rose may be genetically better in height than Prism blue. The treatment effect on plant height indicates that pots sown with petunia and supplied with saline water of 11 dS m^{-1} produced plants of lowest in height (9.487 cm); and with decrease in salt stress level i.e. 9 dS m^{-1}, 7 dS m^{-1}, 5 dS m^{-1} and 3 dS m^{-1}, the plant height enhanced by 11.502 cm, 12.435 cm, 14.313 cm and 15.703 cm, respectively. However, the pots irrigated with canal water (control) produced plants of maximum height (16.260 cm). The treatment interaction showed that variety Hala lop petunia rose irrigated with canal water resulted in maximum plant height (16.920 cm); while the shortest plants (9.30 cm) were recorded in pots sown with variety Prism blue and irrigated with water of 11dS m^{-1} salinity level. Statistically, the difference in plant height between 7 dS m^{-1} and 9 dS m^{-1} salt stress levels were insignificant (P>0.05) and significant (P<0.05) when compared with rest of the treatments.

Figure 3: Seedling vigor index of petunia varieties under the influence of varying salt stress levels



Significance level	Varieties (V)	Salt stress levels (S)	V×S
S.E.	33.480	57.989	82.009
LSD0.05	69.434	120.26	NS
CV%	11.13		

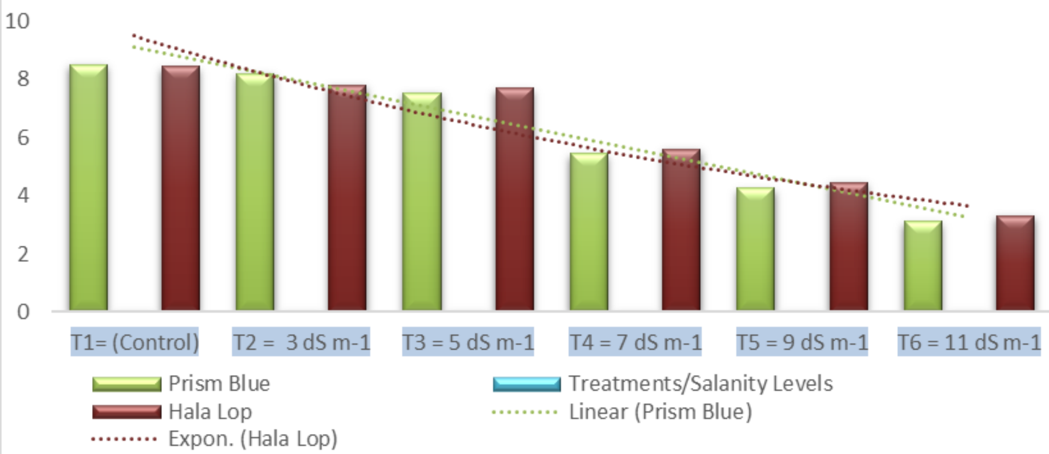
Table 4: Shoot length (cm) of petunia varieties under the influence of varying salt stress levels



Significance level	Varieties (V)	Salt stress levels (S)	V×S
S.E.	0.3645	0.6314	0.8929
LSD0.05	NS	1.3094	NS
CV%	8.23		

Leaves plant^{-1}: The number of leaves plant^{-1} is another important trait that signifies the growth of the plant. The effect of salt stress on the leaves per plant of petunia varieties was scrutinized and the results are presented in Figure 5. The statistical analysis described that leaves per plant of petunia was significantly affected by salt stress levels ($P<0.05$); while varieties and interaction between varieties and salt stress levels did not affect leaves number per plant significantly (P>0.05). The results in Figure 5 revealed that the plants of petunia variety Hala lop petunia rose possessed slightly more leaves (6.2167) than variety Prism blue (6.1778); this suggested a similar trend of foliage development in both the varieties tested. The treatment effect on leaves per plant indicates that pots irrigated with saline water of 11 dS m^{-1} produced plants with lowest number of leaves (3.2083); while the leavers number increased with decreasing the salt stress level; and use of water with decreased salinity level i.e. 9, 7, 5 and 3 dS m^{-1}, resulted in increased leaves number upto 4.3650, 5.5250, 7.6167 and 8.3167 per plant, respectively. However, the pots irrigated with canal water (control) produced plants with maximum leaves number per plant (8.1517). The treatment interaction revealed that variety Prism blue irrigated with canal water resulted in maximum leaves per plant (8.5); while the plants with least number of leaves (3.1167) were recorded in pots sown with variety Hala lop petunia rose and supplied water of 11dS m^{-1} level of salt stress. Statistically, the difference in leaves per plant was linear and significant (P<0.05) and inversely proportional to salt stress levels.

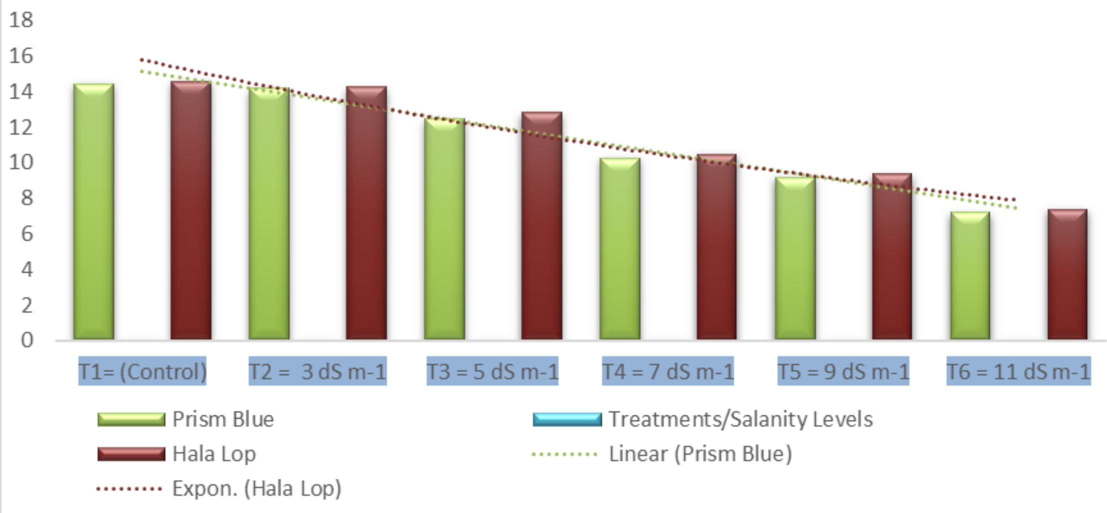
Figure 5: No. of Leaves plant^{-1} of petunia varieties under the influence of varying salt stress levels



Significance level	Varieties (V)	Salt stress levels (S)	V×S
S.E.	0.1676	0.2903	0.4105
LSD0.05	NS	0.6020	NS
CV%	8.11		

Root length (cm): The root length in plants is generally related with the genetic makeup of varieties, but the soil fertility and soil salinity also influence this trait markedly. In this study, the influence of salt stress on the root length of petunia varieties was investigated and the data are given in Figure 6. The ANOVA illustrates that the root length of petunia was significantly influenced by salt stress levels (P<0.05); while this plant trait showed similarity (P>0.05) for different petunia varieties and interaction between varieties and salt stress levels. It is visible from the findings (Figure 6) that the roots of petunia variety Hala lop petunia were slightly (P>0.05) longer (11.468 cm) than companion variety Prism blue (11.279 cm). The treatment effect on root length indicates that the petunia roots in pots irrigated with saline water of 11 dS m^{-1} were minimum in length (7.277 cm); and with decrease in salt stress level i.e. 9, 7, 5 and 3 dS m^{-1}, the root length enhanced by 9.263 cm, 10.363 cm, 12.628 cm and 14.213 cm, respectively. However, the pots irrigated with canal water (control) produced plants with maximum root length (14.497 cm). The treatment interaction indicates that variety Hala lop petunia rose irrigated with canal water resulted in maximum root length (14.563 cm); while the plants with shortest roots (7.182 cm) were recorded in pots sown with variety Prism blue and supplied with water of 11 dS m^{-1} salinity level. Statistically, the difference in root length between 3 dS m^{-1} salt stress level and canal irrigation (control) were not pronounced (P>0.05). This suggested that salinity up to 3 dS m^{-1} level did not affect the root length of petunia adversely; but salt stress beyond this level showed severe negative effect on root length.

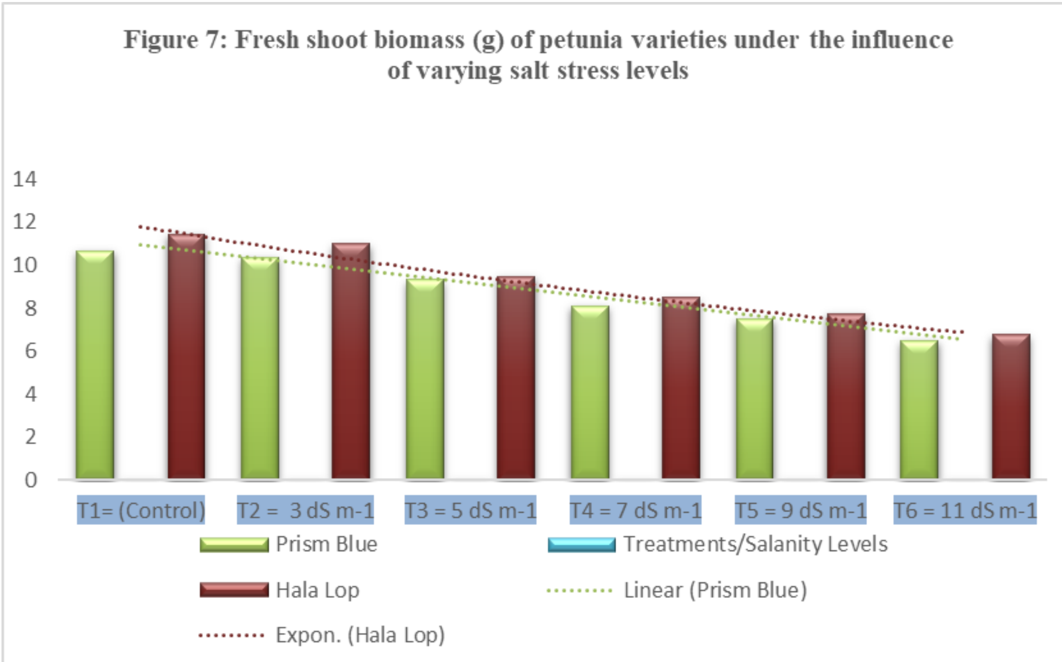
Figure 6: Root length (cm) of petunia varieties under the influence of varying salt stress levels



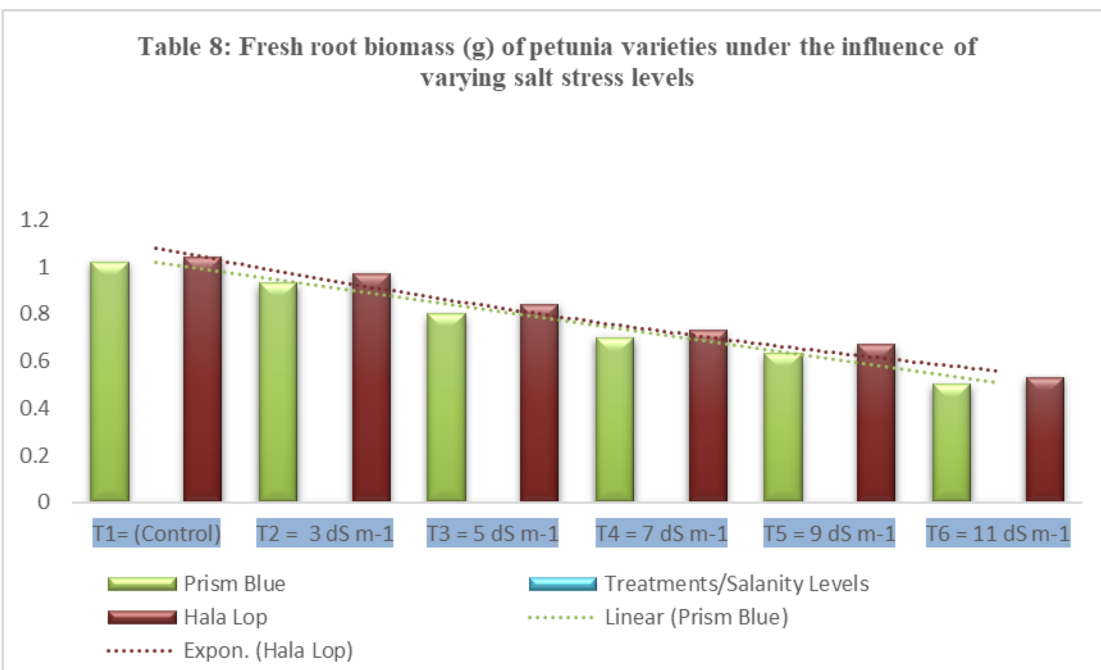
Significance level	Varieties (V)	Salt stress levels (S)	V×S
S.E.	0.0962	0.1665	0.2355
LSD0.05	NS	0.3454	NS
CV%	2.54		

Fresh shoot biomass: The salt stress effect on fresh shoot biomass of petunia varieties was investigated in this experiment and the results are given in Figure 7. As demonstrated by the analysis of variance, the fresh shoot biomass was significantly influenced by salt stress levels and varieties ($P<0.05$); while the interactive effect of varieties × salt stress levels on shoot biomass was statistically insignificant ($P>0.05$). The data (Figure 7) exhibited that fresh shoot biomass was relatively heavier in petunia variety Hala lop petunia rose (9.1583 g) as compared to variety Prism blue (8.7711 g); suggesting genetic advantage to Hala lop petunia rose being heavier shoots than companion variety. The effect of salt stress indicated that petunia plants irrigated with highly saline water of 11 dS m^{-1} produced least fresh shoot biomass of 6.630 g; and the fresh shoot biomass linearly increased with decrease in salinity level i.e. 9 dS m^{-1} (7.630 g), 7 dS m-1 (8.382 g), 5 dS m^{-1} (9.407 g) and 3 dS m^{-1} (10.680 g); while the fresh shoot biomass was highest (11.060 g) when pots were irrigated with canal irrigation water (control). The treatment interaction showed that variety Hala lop petunia rose irrigated with canal water revealed highest shoot biomass (11.450 g); while the minimum shoot biomass (6.497 g) was recorded in variety Prism blue when irrigated with water of 11 dS m^{-1} salinity level. This suggests that there was an inverse impact of salinity on fresh shoot biomass and with each increase in salt stress level in water; the fresh shoot biomass was significantly decreased.

Fresh root biomass: The impact of salinity on the fresh root biomass of petunia varieties was examined and the data are presented in Figure 8. As described by ANOVA the fresh root biomass of petunia was markedly affected by salt stress levels ($P<0.05$); while the effect of varieties and interaction of varieties × salt stress levels on fresh root biomass was statistically insignificant ($P>0.05$). It is evident from the findings (Figure 8) that fresh root biomass was slightly higher in petunia variety Hala lop petunia rose (0.7628 g) as compared to variety Prism blue (0.7628 g). It looks that genetically the Hala lop petunia rose petunia variety is relatively heavier in root fresh weight than Prism blue. The effect of salt stress indicated that petunia plants supplied saline water (11 dS m^{-1}) resulted in lowest fresh root biomass of 0.5167 g; and the fresh root biomass showed a linear increase under decreased salt stress level i.e. 9 dS m^{-1} (0.6483 g), 7 dS m^{-1} (0.7183 g), 5 dS m^{-1} (0.8217 g) and 3 dS m^{-1} (0.9483 g), while the fresh root biomass was maximum (1.0283 g) when pots were irrigated with canal irrigation water (control). The treatment interaction showed that variety Hala lop petunia rose irrigated with canal water resulted in highest fresh root biomass (1.04 g); while the lowest root biomass (0.5023 g) was found in variety Prism blue when given water of 11 dS m^{-1} salinity level. The results showed that with each augmented salinity level in canal water, the fresh root biomass was significantly decreased.

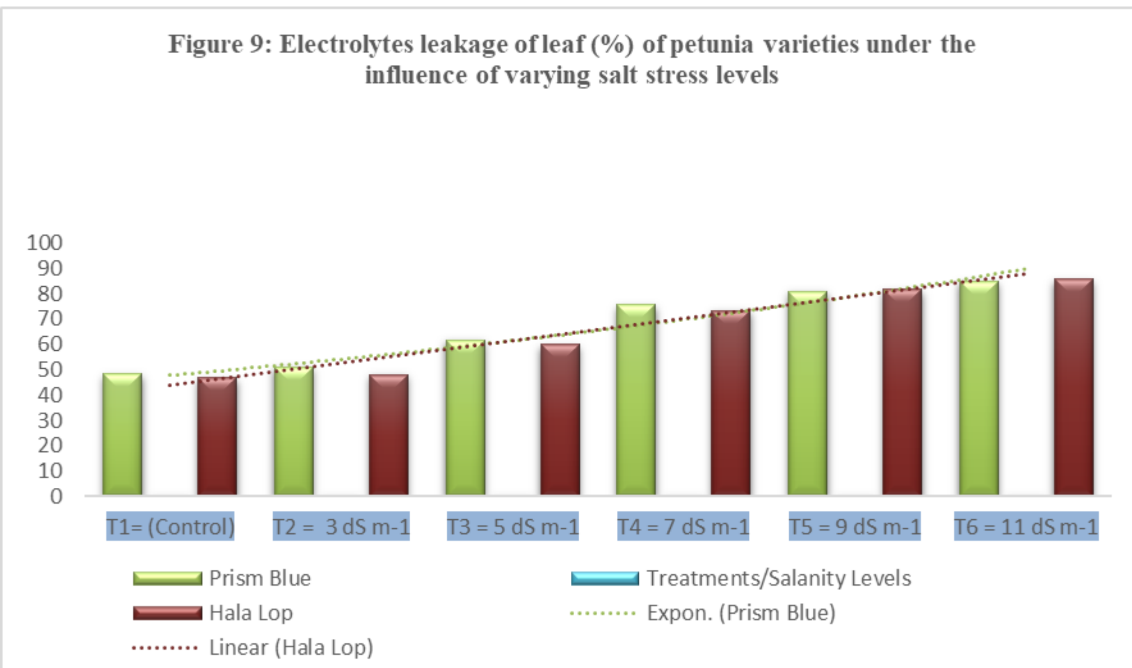


Significance level	Varieties (V)	Salt stress levels (S)	V×S
S.E.	0.1862	0.2225	0.4560
LSD0.05	0.3861	0.6688	NS
CV%	6.23		



Significance level	Varieties (V)	Salt stress levels (S)	V×S
S.E.	0.0363	0.0629	0.0889
LSD0.05	NS	0.0753	NS
CV%	13.96		

Electrolyte leakage of leaf (%): The salt stress effect on percentage of electrolyte leakage of petunia was examined and the results are presented in Figure 9. As described by the analysis of variance, the percentage of electrolyte leakage was markedly affected by salt stress levels (P<0.05); while the influence of varieties and interactive effect of varieties × salt stress levels on percentage of electrolyte leakage was statistically insignificant (P>0.05). The results (Figure 9) displayed that percentage of electrolyte leakage was relatively lower in petunia variety Hala lop petunia rose (65.92 %) as compared to variety Prism blue (67.10 %). The effect of salt stress indicated that petunia plants irrigated with highly saline water of 11 dS m^{-1} resulted in highest percentage of electrolyte leakage (85.36 %); and the percentage of electrolyte leakage linearly decreased with decrease in salt stress level i.e. 9 dS m^{-1} (81.21 %), 7 dS m^{-1} (74.46 %), 5 dS m^{-1} (60.73 %) and 3 dS m^{-1} (49.61 %); while the percentage of electrolyte leakage was lowest (47.59 %) when pots were irrigated with canal irrigation water (control). The treatment interaction showed that variety Hala lop petunia rose irrigated with canal water resulted in least percentage of electrolyte leakage (46.86 %); while the highest percentage of electrolyte leakage (85.76 %) was also recorded in variety Hala lop petunia rose when irrigated with water of 11 dS m^{-1} salinity level. This suggests that increased salinity showed severe negative effect on petunia plants in terms of electrolyte leakage and with each increased level of salinity in irrigation water; the percentage of electrolyte leakage was significantly increased.



Significance level	Varieties (V)	Salt stress levels (S)	V×S
S.E.	1.0049	1.7406	2.4616
LSD0.05	NS	3.6099	NS
CV%	4.53		

DISCUSSION

Production of cut flowers has achieved a worldwide importance and hasty changes in storage and marketing processes have been noticed (Singh *et al.*, 2010). Floriculture has always been remained a neglected field in Pakistan and public and private sector has not yet created awareness among farming communities about the importance of this important field (Manzoor *et al.*, 2001). The pot based study was conducted to explore the performance of petunia plants to salt stress environment. Salinity issue is increasing day by day and is atrocious threat to food security as well as sustainable crop production (Guo *et al*., 2020). Salt stress conditions adversely affect all the physiological process including photosynthesis, protein synthesis and cell division and elongation (Zelm *et al*., 2020). It jeopardizes plant survival and at later stages, plant growth and yields are reduced considerably (Ahenger *et al*., 2019). Germination and early growth of any plant are known as most critical stages. Available evidences reveals that these stages of plants are most susceptible to salinity effect in comparison to other growth stages (Wahocho *et al*. 2021). The findings of the study showed that the impact of salt stress on petunia was injurious for all the studied plant traits; and there was bad impact of rising salt stress on germination parameters and other scored traits. The effect of salt stress indicates that petunia seeds sown in media of 11 dS m^{-1} salt stress level caused lowest seed germination and index; while there was a linear increase in the seed germination and germination index with decreasing salt stress. The lowest germination under salt stress conditions might be due to less imbibition of water in to seeds due to ion toxicity caused by sdium and chloride salts and osmotic stress (Hnilickova *et al*., 2019). The similar trend of poor germination under highest salinity level was also observed by Jamali *et al*. (2021) in marigold. Similar results have also been found by Wahocho *et al*., (2021) in chili to salinity conditions. The growth traits of petunia were also adversely affected by salinity. Seedling vigour index is one of the main traits that determines early plant growth and rapid crop establishment (Tabrizian and Osareh, 2007). It is generally based on shoot length and seed germination percentage. The seedling vigour decreasesd when salinity level increased to 3 dm^{-1}. The salt stress conditions also induced reduction in the root and shoot related traits. The adverse impact of salt stress conditions on shoot and root associated traits might be attributable to more accumulation of salts in the soil solution (Miunns and Tester, 2008). Moreover the application of saline water to the plants might have disturbed the metabolic processes and reduced water uptake efficiency of plants, consequently plants with shorter root and shoot biomass were produced. Moreover, the initial reduction in growth might be due to the osmotic influence caused by high concentration of salt at the root outside and consequent growth reduction attributed to failure of plants to inhibit the salt at injurious level in the leaves (Zelm *et al*., 2020). Locke *et al.* (2004) and Lee and Lersel (2008) also found the adverse impact of salinity on growth traits of petunia. Likewise, Kaouther *et al*. (2012) stated that application of saline water showed injurious effect on shoot biomass of chili pepper. In the present study, more leaves were produced in plants that were supplied only with canal water. In contrast plants that were irrigated with saline water showed less leaves. Leaves are the photosynthetic organ of green plants and generally known as food factory of plants. Healthier and more leaves are essential for photosynthetic activity of plant. The salt stress conditions might have caused toxic conditions in the leaves that led to poor leaf growth. Moreover enzymatic activity in plants might be also badly affected (Li *et al*., 2017), thus plants with less leaves were produced. These finding are in accord with Di Mola *et al*. (2017) who reported that leaf area, leaves number as well as shoot biomass were heavily affected due to irrigating the plants of lettuce with saline water. The adverse impact of salinity is also recorded by Zhani *et al*. (2014). Pizarro (2011), Sardoei *et al*. (2014) also argued that saline water application has deteriorating effect on petunia growth and flowering. Nguyen *et al.* (2017) found that increased salinity had severe adverse effects on morphological and physiological parameters of petunia and the flowering production and quality are adversely affected. Ferraz *et al.* (2016) reported that ornamental plants are mostly salt sensitive and their production and quality is deteriorated with increased salt stress. In the present investigation, the electrolyte leakage was considerably increased with the increased salt stress. This demonstrated that higher concentration of salt influenced the stability of membrance that led to increase in electrolyte leakage of leaf (Hnilickova, 2019). Similar trend is also noted by Hassen *et al*., (2013) who described that salt stress conditions resulted in the failure of plants to avoid dehydration of water that led to more electrolyte leakage in leaf. The electrolyte leakage of leaf is the indicator of cell membrane injury (Zhu *et al*., 2004). As NaCl concentration increased, the cell membrane became more permeable as shown by increasing electrolyte leakage in leaves. In this investigation, better performance was noted in Hala lop petunia for most of the examined traits over prism blue. This reflects more tolerance of Hala lop petunia to salt stress. This might be due to genetic potential of each cultivar regarding salt stress tolerance. Baratha *et al*. (2015) also described that large range of salt tolerance occurred in various cultivars of same crop species.

Conclusions

Petunia seed emergence and growth is decreased with increasing exposure to salinity. Salt stress up to 3 dS m^{-1} level was generally tolerated by petunia and the differences in overall performance under 3 dS m^{-1} salt stress level and canal irrigation (control) were insignificant (P>0.05). The findings of the study would be highly beneficial for the grower related to petunia cultivation and offers new insights regarding the tolerance of petunia to salt stress at early stage. This study was performed at seedling stage and explored the performance of petunia at initial stage. However, it is noteworthy that most the floriculture plants are more sensitive to salinity at early stage. In this context further study needs to be conducted up to flowering stage to determines the tolerance of petunia to salt stress.

Conflict of interest

The authors have declared no conflict of interest.

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