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Influences Induced by Salinity Stress on Germination, Growth and Proline Contents of Maize (*Zea mays* L.)

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ABSTRACT

Salinity is major obstacle in crop production throughout the globe. It retards plant growth and brings drastic losses in yield. Therefore, a pot experiment was executed at the research area of University of Agriculture Faisalabad to evaluate the influences caused by salinity stress on maize. Different levels of NaCl (Control, 4 dSm^{-1}, 8 dSm^{-1}, 12 $dSm^{-1}$and 16 dSm^{-1}) were used as treatments. Maize hybrid KS-85 was sown as trial crop and complete randomized design was used to allocate the treatments. Data for different parameters were recorded and analyzed statistically at 5% probability level which showed that plant germination and growth were reduced at higher salinity, while, proline contents exhibited the opposite trend. At salinity level 16 dSm^{-1}, the plumule and radical length was decreased by 89.86% and 92.65% respectively when these were in comparison to those from control. Plumule fresh was decreased by 86.79%, while, the fresh weight of radical was decreased by 84.61%. Similarly, shoot and root length was reduced by 54.28% and 59.72% respectively. The proline content was increased up to 369.23% as compared to control while at 16dSm^{-1}. In conclusion, maize is a moderately salt tolerant crop, but at higher salinity, growth of maize was impaired and proline contents were boosted up.

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INTRODUCTION

Maize (Zea mays L.) is one of the significant crops in Pakistan, which serves three main purposes as food and corn oil for human expenditures, feed for livestock and poultry, and raw material for agro-based industries. The regular yield of maize in Pakistan is low as compared to other maize growing regions of the world. Salinity is one of the serious environmental problems that cause osmotic stress and reduction in plant growth (Shrivastava and Kumar, 2015). Higher salt contents in the soil are limiting the global crop production. In addition, toxic concentration of single nutrient caueses yield reduction (Ahmad et al., 2018; Farooqi et al., 2019, Saleem et al., 2020). As out of 230 million hectares of irrigated agricultural land in world, approximately 45 million hectares are salt-affected (Athar and Ashraf, 2009). Maize which belongs to the plants with C_4 metabolism is considered as moderately salt sensitive (Carpici et al., 2009). For maize grown under salinity, reduction in growth characters and yield has been observed (Ouda et al., 2008). Salinity may cause significant reductions in the growth rate and percentage of germination, which in turn may lead to uneven stand establishment and reduced crop yields (Akram et al., 2007). Sub-cellular organs and biological membranes can be damaged in plant organs due to sodium accumulation at toxic levels (Hussain et al., 2013). Likewise, Hosseini et al., (2003) reported delayed germination in saline soils. Excessive presence of Na^+ negatively impacts on intracellular K^+ influx which results in ion imbalance and toxicity to enzymes in living cells. Proline is considered among the most significant indicators for salinity stress as it regulates the sequester-able nitrogen and is osmotically active. It also limits the salinity effects on disruption of cell membrane. Many other findings also indicate clearly that proline enhances plants growth against salt stress (Ashraf et al., 2004). Therefore, the current experiment was laid out to determine the maize tolerance to sodium and impacts of high salinity level on growth and biochemical components of maize.

MATERIAL and METHODS

Research design and trial location:

The experiment was executed at University of Agriculture Faisalabad to evaluate the salinity tolerance in maize and influences caused by salinity stress. Different levels of NaCl (Control, 4 dSm^{-1}, 8 dSm^{-1}, 12 $dSm^{-1}$and 16 dSm^{-1}) were used as treatments and complete randomized design was used to allocate the treatments.

Seed source:

Maize hybrid KS-85 was used as trial crop and the seeds were taken from Ayub Agriculture Research Institute Faisalabad.

Experimental material:

Thoroughly cleaned 20 pots of 35cm diameter were used for pot experiment. Each treatment was well mixed in 5 kg soil and then that treated soil was filled to each pot. Seeds were soaked in water overnight and then healthier ones were sown in pots containing respective salt + soil treatment. Following germination, plants were thinned to one plant per respective pot. Each treatment was replicated four times for accuracy.

Statistical Analysis

Data for different parameters were recorded and the results after data analysis at 5% probability level of LSD test are given below.

RESULTS and DISCUSSION

Germination Percentage: It is most pivotal parameter to determine the salinity impact on plant growth as plant population is dependent upon germination percentage. An elevated stress condition may encourage to less germination of seeds leading to poor stands establishment. Stress imposed by salinity significantly resulted in retarded germination of maize seeds. Data recorded is illustrated in Fig.1. Significantly, the highest germination was countered in the control treatment. Whereas, the lowest germination was completed by the seeds which encountered salinity levels of $16dSm^{-1}$. In addition, onset of germination was also delayed at higher salt concentration. Reduction in germination might be due to increased osmotic pressure under stress conditions which lowered the imbibition and reduced germination rate. Aliu et al. (2015) also presented similar results. Parvaiz and Satyawati (2008) also found that with increase in salt concentrations the percentage germination of seeds was decreased.

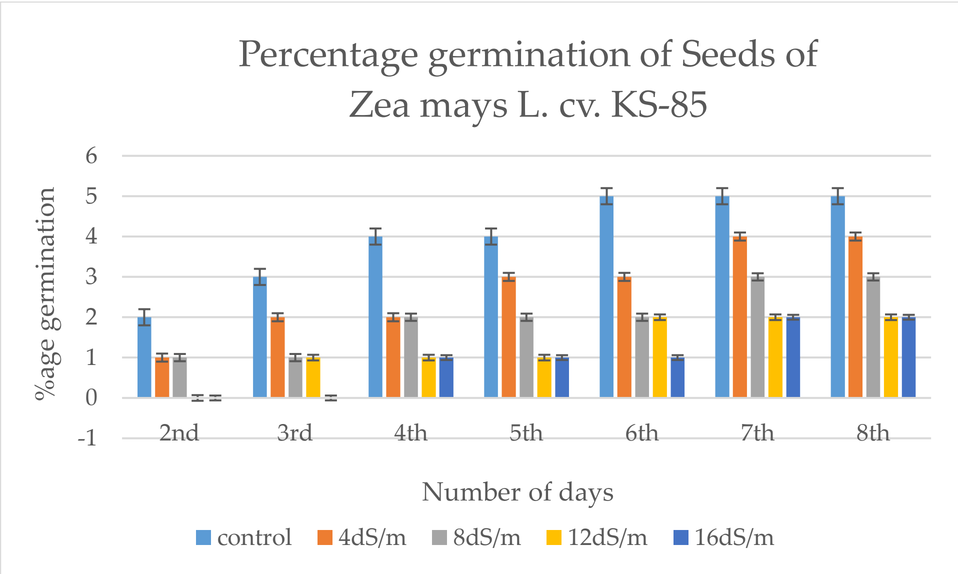

Figure 1**.** Influence of various salinity levels on germination of Zea mays

Plumule Length: Length of plumule was drastically influenced by salinity stress. The shortest plumule was noticed in treatment with $16dSm^{-1}$ salinity level. Dara recorded is presented in Fig.2 which indicated 89.86% reduction in plumule length with $16dSm^{-1}$ salinity level in comparison to control. Plumule length was shortened because of inhibition of water uptake during salinity stress. These results are endorsed by Rohnipoor et al. (2013) as they also reported decreased plumule length in maize seedlings when exposed to salinity.

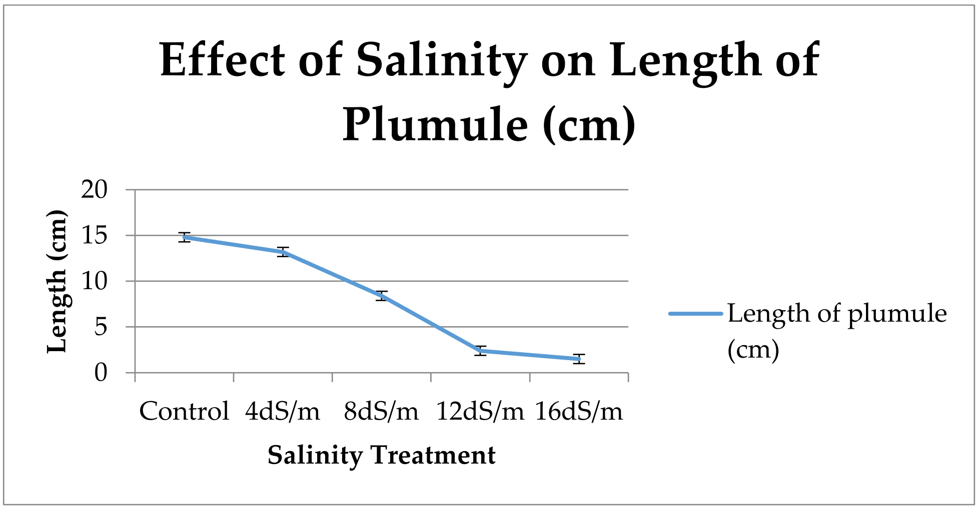

Figure 2. Influence of various salinity levels on plumule length of Zea mays

Radical length: Radical length also started a decline which was in direct relation to salinity level. Salinity obstructed radicle development. Data analysis is presented in Fig.3 which indicated that the highest radical length was recorded from control. While the lowest radical length was observed when salinity was its peak ($16dSm^{-1}$). There was 92.65% reduction in radical length at this salinity level when compared to control. Carpici et al. (2009) also found that radical length was reduced by the application of salt solutions and reported that high salinity concentration reduced the radical length due to lower water uptake by maize seedlings.

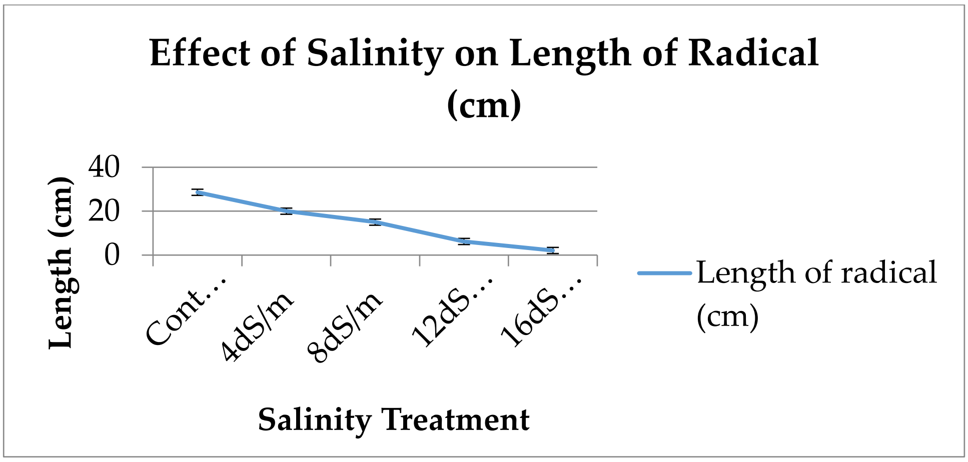

Figure 3. Influence of various salinity levels on radical length of Zea mays

Plant height: Escalated plants were observed from control in comparison to other treatments. However, it was decreased continuously with increasing in salinity level. It can be seen from Fig.4 and IMAGE 1 (Annexure-I) that plant was markedly reduced when there was an increase in salinity level in experimental soil. The reduction in height was 54.28% at $16dSm^{-1}$ salinity in comparison to the value recorded from the control. The decrease in plant height was mainly due to inhibition of shoot elongation in prevailing stress conditions. Yang et al. (2008) also observed reduction of plant height at increasing salinity levels. Similarly, Guan et al. (2009) concluded reduced plant height due to restriction of leaf expansion and shoot elongation.

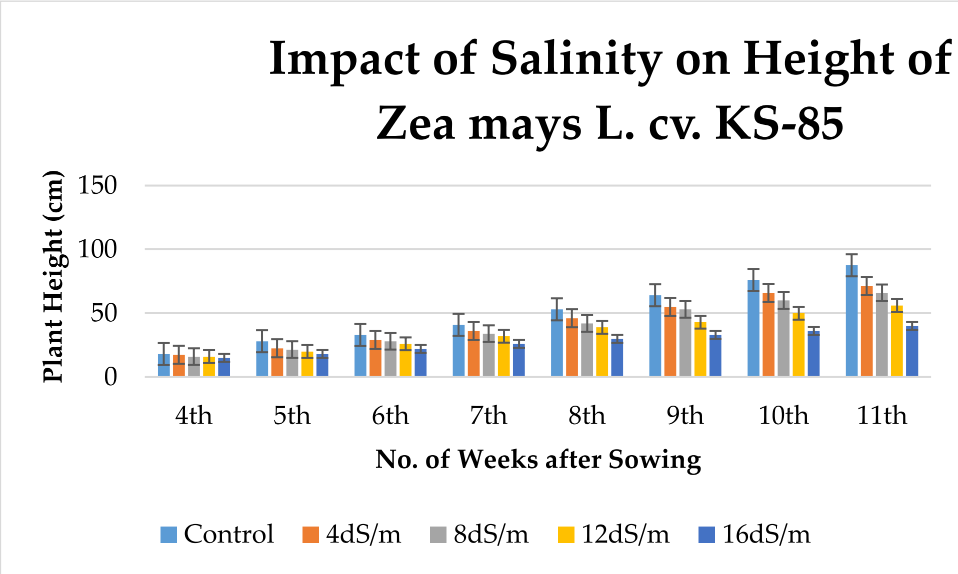

Figure 4. Influence of various salinity levels on Height of Zea mays

Image I. Growth of Zea mays seedlings under different salinity levels

Leaves plant^{-1}: Leaves of a plant are the main source of photosynthesis and food accumulation in plant. These have direct impact on plant biomass and yield. Increasing salinity level in soil resulted in significant abatement of leaves plant^{-1}. Data demon stared in Fig.5 and IMAGE II (Annexure-II) revealed the response of plants to salinity levels. Significantly, the greatest No.of leaves were counted in control, while, the least leaves were found in treatment receiving 16dSm^{-1} salinity. Beltagi (2008) also reported declined leaves plant^{-1} at high salinity levels. Tester and Davenport (2003) also found that salinity stress initiated a significant decrease in the leaf number.

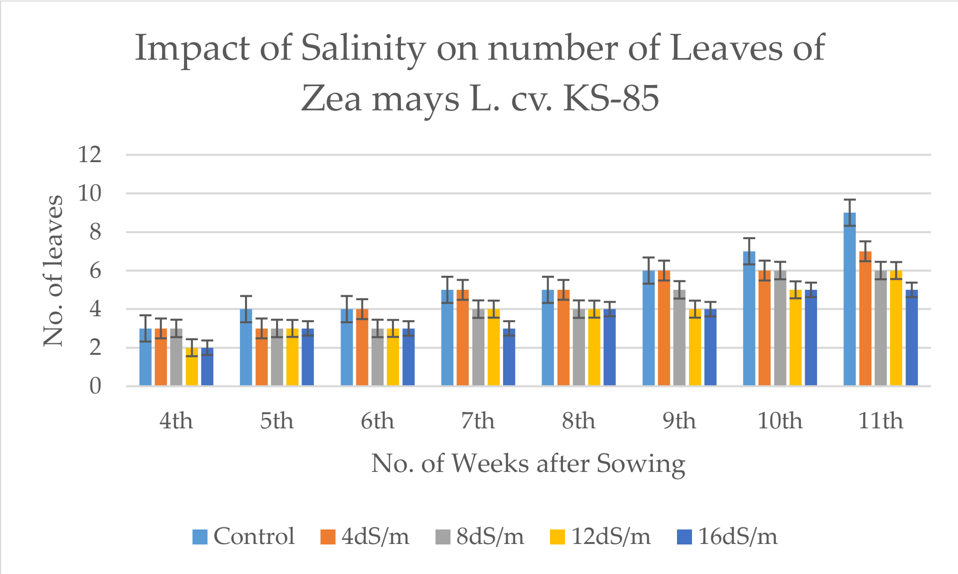

Figure 5. Influence of various salinity levels on leaves plant^{-1} of Zea mays

Image II. Comparison of growth of Zea mays under different salt concentrations

Root length: It remained the highest in non-saline situations (control) but it tended to decrease when salinity levels were increased. Results presented in Fig.6 depicted that 59.72% reduction in root length at salinity 16dSm^{-1} in comparison to control. Savvas et al. (2007) observed reduced root length during salt stress. Ghoulam et al. (2001)

concluded that the increase in NaCl concentration restricted the root length of maize because of the higher accumulation of Na^+ and Cl^- in the root zone.

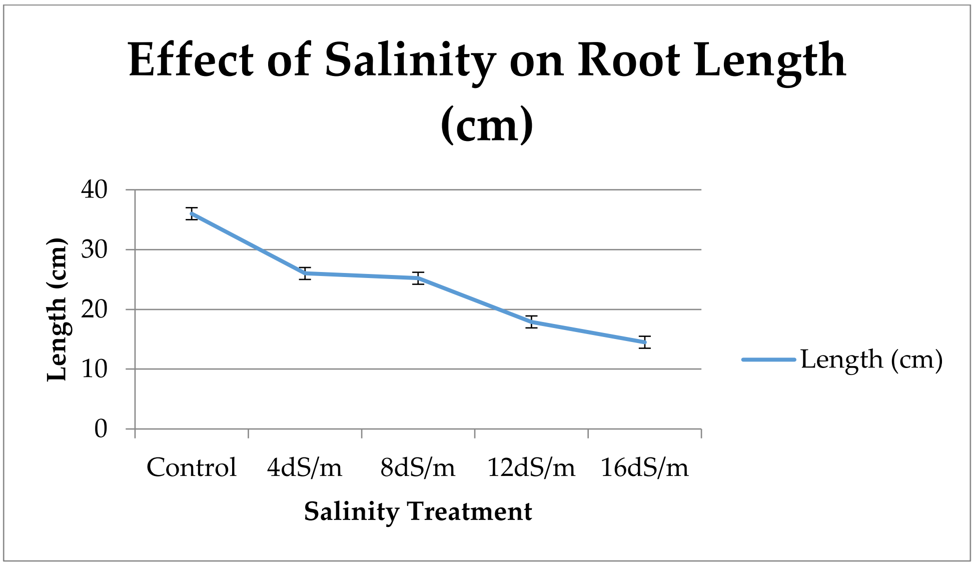

Figure 6. Influence of various levels of salinity on length of roots in Zea mays

Shoot length: Shoot length tended to decrease with increasing salinity level. The data observed is given in Fig.7. Significantly, the highest shoot length was observed from the control. Whereas, the lowest was indicated by the treatment with the highest salinity level. This reduction is shoot length might be due to accumulation of high Na^+ in plant body which restricted the osmoses and thereby resulted in stunted growth. These findings are in support of Abrol et al. (2004) as they have also stated a decline in shoot length with higher levels of Na^+.

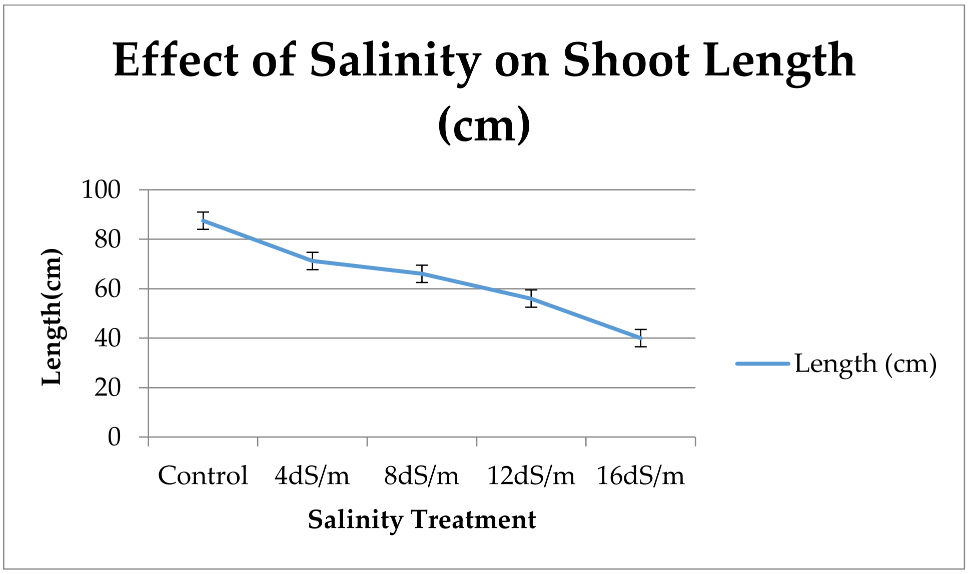

Figure 7. Influence of various levels of salinity on length of shoot in Zea mays

Seedling biomass accumulation: The effects of salinity on root and shoot dry weight can be seen in Fig.8 and Fig.9, respectively. It is clear from the illustrations that root dry weight gradually reduced with escalation in the salinity level. Significantly, the maximum root and shoot dry weights were obtained in control, whereas, the minimum values were observed from the treatment where highest salinity level ($16dSm^{-1}$) was present. Data presented indicated that there was 45.14% and 93.38% reduction in weights of root and shoot, respectively. Lohaus et al. (2000) also documented a reduction of root dry weight due to reduced length with elevated salinity level. Similarly, Kishor et al., (2005) concluded significant reduction in dry weight of shoots in highly saline soils. Ashraf and Harris (2004) also found high absorption of Na^{+} and Cl^{-} by the roots which inhibited the absorption of K, Ca and N and ultimately caused reduction in shoot dry weight.

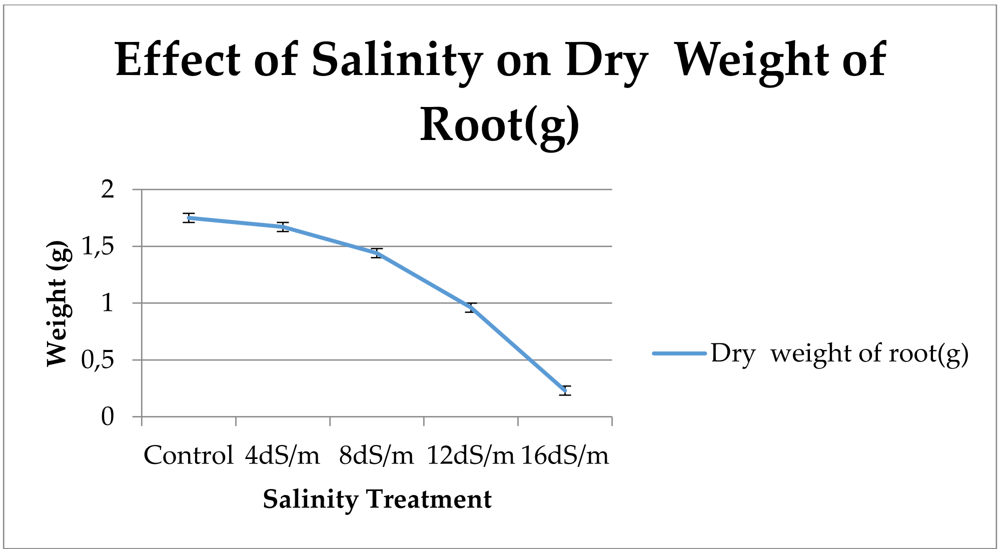

Figure 8. Influence of various salinity levels on root dry weight of Zea mays

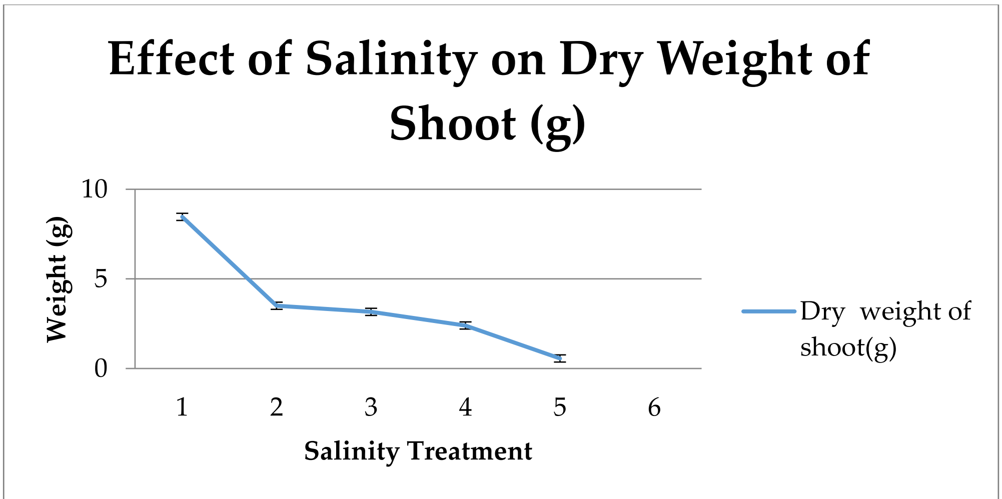

Figure 9. Influence of various salinity levels on shoot dry weight of Zea mays

Chlorophyll contents: These are key indicators of photosynthetic rate and amount of photosynthates produced. Salinity level imposed drastic changes in chlorophyll contents. These contents were reduced with increasing the salinity level. Data recorded for chlorophyll contents are provided in Table 1. Data indicated that significantly the maximum value for chlorophyll contents was found in control. In contrast, the lowest chlorophyll contents were cemented in treatment with the highest salinity level. There was 92.89% reduction in chlorophyll contents at salinity level 16dSm^{-1} when compared to control. Lohaus et al. (2000) also reported a significant reduction in chlorophyll contents of maize during stressed conditions. Pinheiro et al. (2008) found reduces chlorophyll and carotenoids when exposed to saline conditions.

Table 1. Impact of various salinity levels on chlorophyll content of zea mays

Treatment	Chlorophyll a mg/g	Chlorophyll b mg/g	Total Chlorophyll mg/g
S_0	2.080^a	4.220^a	14.400^a
	±0.028	±0.042	±0.084
S_4	1.615^b	3.925^b	4.335^b
	±0.021	±0.021	±0.049
S_8	1.410^c	1.810^c	2.710^c
	±0.014	±0.056	±0.028
S_{12}	0.625^d	1.045^d	1.415^d
	±0.049	±0.035	±0.021
S_{16}	0.355^e	1.040^d	1.055^e
	±0.007	±0.014	±0.035
LSD	0.0816	0.1066	0.1335

Values sharing same letter are non-significant at 5% probability of HSD test

Proline contents: Proline plays a pivotal part in plants to cope up with stress for their survival. Concentration of proline was increased along with the salinity level. Data recorded for proline contents are illustrated in Table 2 which demonstrated that the highest proline contents were found in treatment receiving the highest salinity level. While the lowest proline contents were recorded from control. Data showed 266.6% and 369.23% increase in root and leaves proline contents, respectively, at salinity level 16dSm^{-1}. Ashraf et al. (2004) have also documented an increase in proline contents with increasing salinity level.

Table 2. Influence of various salinity levels on proline content of zea mays

Treatment	Proline Content in Roots mg/100mg	Proline Content in Leaves mg/100mg
S_o	0.122^a	0.135^a
	±0.003	±0.0077
S_4	0.200^a	0.225^b
	±0.014	±0.0070
S_8	0.255^b	0.415^c
	±0.021	±0.0077
S_{12}	0.415^c	0.59^d
	±0.021	±0.0141
S_{16}	0.430^d	0.625^e
	±0.010	±0.021
LSD	0.047	0.01724

Values sharing same letter are non-significant at 5% probability of HSD test

Conclusion: Salinity is among the most destructive environmental and soil problem which is bringing significant yield losses in agricultural crops and other plants as well. Additionally, salinity interrupts water uptake and ionic balance resulting in stunted plant growth. Contents of proline increase during stress which help the plant to cope with the stress conditions. Reduction of saline stress is recommended to achieve higher plant growth.

Conflict of Interest Statement

The authors have declared that there is no competing interest.

Authors' Contributions

All authors have equally contributed.

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