Salt Stress Alleviation with Salicylic Acid on the Yield of Maize 
(Zea mays L. cultivar NMH-909)

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ABSTRACT
The present study was conducted to determine the effects of salicylic acid on the yield of salt stressed Zea mays L. cultivar NMH-909 plants. The application of salicylic acid was done as foliar spray, 40 days after sowing at the vegetative stage of maize plants. The effect of salicylic acid was observed at four different levels of salinity viz. control, 4dSm⁻¹, 8dSm⁻¹ and 12dSm⁻¹. The application of salicylic acid was found effective in the amelioration of detrimental effects of salt stress on maize plants. The plants with applied salicylic acid showed much better yield in comparison to those plants which were not treated with salicylic acid. Under non-saline conditions, salicylic acid application in 150 ppm concentration was the most effective. In saline conditions, the improvement increased with the increase in the salicylic acid concentration and 150ppm salicylic acid gave best results, proving to be the most effective concentration in mitigating the harmful effects of salinity on maize plants. The use of salicylic acid can considerably improve the yield parameters of Zea mays L. cultivar NMH-909, and hence it can be implicated to alleviate adverse effects of salinity on maize plants. From the present study, it is inferred that the exogenous application of 150ppm salicylic acid is very useful to control detrimental effects of salinity.

Key words: exogenous, corn, cob, grains, salicylic acid, salinity.

INTRODUCTION
Soil salinity is a serious problem of agriculture, especially in those countries located in semi-arid to arid zones (Croughan & Rains, 1982). In Pakistan, the saline area is 6.67 M ha out of the total 20 M ha land under cultivation (Khan et al., 2006). Salt stress is one of the most devastating conditions for crop growth and productivity (Ashraf et al., 2008). The processes that are affected by high salt concentrations include toxicity of ions, osmotic stress, minerals and nutrient deficiency and above all oxidative stress (Flower, 2004). Many studies conducted in this field have shown that the height (Rui et al., 2009), leaf area (Zhao et al., 2007) and index of growth (Bandeh-Hagh et al., 2008) are harmfully effected with increasing levels of salt.

Salinity stress may also lead to other secondary stresses, such as oxidative stress that is caused from the build up of reactive oxygen species (ROS) (Molassiotis et al., 2006, Panda & Upadhyay, 2004). Plants under stress conditions also evolve different responses to abate the detrimental effects of ROS. Plants have to adapt an explicit protective mechanism, such as production of non-enzymatic (salicylic acid, ascorbic acid, carotenoids, α-tocopherol, etc.) and/or enzymatic (peroxidase, superoxide dismutase and catalase) antioxidants to minimize the damage set off by ROS (Ashraf, 2009). Salicylic acid performs role as an antioxidant and a growth regulator in modulating various physiological processes including photosynthetic rate (Singh & Usha, 2003).

Maize (Zea mays L.) occupies third position as themost important cereal crop after wheat and rice. In many countries around the world, it is used as staple food (Frova et al., 1999). It is cultivated twice a year in both spring and autumn seasons. Among different types of cereal crops, maize has a key position because of its importance for consumption by humans and animals. It serves as a chief source of income to the farmers of developing countries (Tagne et al., 2008). In Pakistan, owing to its growing importance, various strategies for the improvement of agronomic characters of maize are receiving significant attention (Mehdi & Ahsan, 2000). The present study was intended to determine the effect of different levels of salinity on the yield of Zea mays L. and to evaluate the mitigating effect of different treatments of salicylic acid on the yield of Zea mays L.
MATERIALS AND METHODS

The experiment for determining the effects of salicylic acid on Zea mays L. grown under different concentrations of salinity was conducted in the Botanic Garden, Government College University, Lahore. This experiment was performed in a wire netting enclosure in which biotic factors were controlled. Certified seeds of Zea mays L. cultivar NMH-909 were collected from the Federal Seed Certification Department, Lahore. The healthy seeds were selected on the basis of evenness of size.

The pots having a diameter of 35cm were used in the experimental set-up. The pots were thoroughly cleaned. For closing the holes at the bottom of the pots, pebbles were used and lining of the pots was done with polythene bags for preventing excessive water loss through drainage. Filling of pots was done with 10 kg soil taken from GCUBotanic Garden. Treatment and replicate number were labelled on each pot. In this experiment, the salinity levels 4dSm\(^{-1}\), 8dSm\(^{-1}\) and 12dSm\(^{-1}\) were used with control and these levels of salinity were made by adding the required NaCl amount in the soil. The different treatments of salicylic acid were 0ppm (0.1% Tween-20), 50ppm, 100ppm and 150ppm (Table 1). Salicylic acid solutions of different concentrations were applied to the plants in the form of foliar spray when they were at their vegetative stage. In order to ensure salicylic acid penetration into the leaf tissues, solution of 0.1% Tween-20 was used that acted as a surfactant. A manual sprayed was used for spraying 5ml volume of solution per plant.

Table 1: Preparation of different concentrations of salinity and salicylic acid (SA) for use in the experiment

<table>
<thead>
<tr>
<th>Salinity (T) Salicylic Acid (SA)</th>
<th>Control</th>
<th>4dSm(^{-1})</th>
<th>8dSm(^{-1})</th>
<th>12dSm(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>T(_0)</td>
<td>T(_1)</td>
<td>T(_2)</td>
<td>T(_3)</td>
</tr>
<tr>
<td>SA(_0) Tween-20 (0.1%)</td>
<td>T(_0)SA(_0)</td>
<td>T(_1)SA(_0)</td>
<td>T(_2)SA(_0)</td>
<td>T(_3)SA(_0)</td>
</tr>
<tr>
<td>SA(_1) (50ppm)</td>
<td>T(_0)SA(_1)</td>
<td>T(_1)SA(_1)</td>
<td>T(_2)SA(_1)</td>
<td>T(_3)SA(_1)</td>
</tr>
<tr>
<td>SA(_2) (100ppm)</td>
<td>T(_0)SA(_2)</td>
<td>T(_1)SA(_2)</td>
<td>T(_2)SA(_2)</td>
<td>T(_3)SA(_2)</td>
</tr>
<tr>
<td>SA(_3) (150ppm)</td>
<td>T(_0)SA(_3)</td>
<td>T(_1)SA(_3)</td>
<td>T(_2)SA(_3)</td>
<td>T(_3)SA(_3)</td>
</tr>
</tbody>
</table>

On complete maturation of plants, harvest was carried out. The harvested plants were placed in labelled plastic bags. For conducting further studies, these plants were taken to the Physiology Laboratory and the parameters studied were: cob length (cm); seeds number per plant; seeds weight per plant (g) and 1000 seeds weight (g). Statistical analysis was carried out by using software co-stat version 3.03 (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

The harvest was carried out when life cycle of maize plants was completed for the evaluation of their yield. Length of Cob

Figure 1 illustrated the effects of salinity and salicylic acid on the length of cob. Salicylic acid treatments proved beneficial to the length of cob in all salinity levels. Length of cob in control without salinity was 26.55cm and with salicylic acid treatment, the cob length was 29.40cm which showed 10.73% increase with 150ppm salicylic acid. Reduction in length of cob was gradual with the increase in salinity. The reduction in length was 9.23% at 4dSm\(^{-1}\) and 12.42% at 8dSm\(^{-1}\). 23.54% reduction was observed at 12dSm\(^{-1}\). Application of 150ppm salicylic acid increased length of cob to 12.24% and 14.84% at 4dSm\(^{-1}\) and 8dSm\(^{-1}\).
respectively. 150ppm salicylic acid was also very effective in plants under 12dSm$^{-1}$ salinity conditions. 150ppm salicylic acid was also very effective in plants under 12dSm$^{-1}$ salinity conditions. Similar observations were noted by Khan et al. (2010) that decline in the number of seeds was induced by salinity in mungbean and this decrease was overcome by the use of salicylic acid. Arfan et al. (2007) observed similar result that the yield of wheat was increased with the foliar application of salicylic acid.

**Number of Grains per Plant**

The combined effects of salinity and salicylic acid on grain number per plant are represented in Figure 2. Plants from non-saline conditions had maximum number of grains. Maximum increase in grain number was shown by plants which were treated with 150ppm salicylic acid. Salt stress caused substantial decrease in number of grains per plant in comparison with the control. The reduction in number of grains was 27.84%, 42.75% and 52.94% at 4dSm$^{-1}$, 8dSm$^{-1}$ and 12dSm$^{-1}$ salinity respectively. Application of salicylic acid resulted in the increase in number of grains and best results were obtained with the use of 150ppm salicylic acid.

**Weight of Grains per Plant**

Figure 3 illustrates the effects of salinity and salicylic acid on grains weight per plant that signify the yield potential of plants and their success. Under control conditions with no salinity, weight of the grains recorded was exceptional and it was increased with the foliar application of salicylic acid.

Salt stress greatly caused reduction in the weight of maize grains per plant but salicylic acid
thwarted this decrease to some extent. Weight reduction of grains was 29.43%, 51.77% and 59.35% at 4dSm⁻¹, 8dSm⁻¹ and 12dSm⁻¹ salinity respectively. Adverse effects of salt stress were vanquished by foliar application of salicylic acid to some level. At all levels of salinity, 150ppm salicylic acid application showed to be the best in the alleviation of detrimental effects of salinity stress and caused improvement in the grains weight per plant.

Weight of 1000 Grains

The interactive effect of different levels of salts and salicylic acid on 1000 grains weight is shown in Figure 4. Exogenous application of salicylic acid significantly caused improvement in this parameter in both saline and non-saline conditions. 150ppm salicylic acid showed maximum improvement in weight of 1000 grains at all the salinity treatments. In non-saline condition, the increase in 1000 grains weight with 150ppm salicylic acid was 22.15% followed by 15.23% and 6.99% increase with 100ppm and 50ppm salicylic acid respectively.

Salt stress conditions decreased the 1000 grains weight which was counteracted by the application of salicylic acid exogenously. The reduction in weight of 1000 grains was up to 6.19%, 12.77%, and 13.63% at 4dSm⁻¹, 8dSm⁻¹ and 12dSm⁻¹ salinity respectively. The application of 150ppm salicylic acid exhibited the best results. 150ppm salicylic acid improved weight up to 23.90% at 8dSm⁻¹. Same concentration of salicylic acid increased weight up to 22.45% at 12dSm⁻¹. These results relate with the findings of Sahu et al. (1993) in which application of ascorbic acid improved yield of maize grains to 26.30%.

Yield of plants is actually final manifestation of photosynthetic process and growth. Khan et al. (2010) also reported increase in yield of mungbean plants that was negatively affected by salt stress. Salicylic acid had positive impact on these plants because of its effects on ion content, nutrients, glutathione content and antioxidant enzyme activities. Salicylic acid induced increase in growth promotes yield of crops since salinity stress conditions limit growth of plants by negatively affecting different biochemical and physiological processes which include photosynthetic process, balance of ions and antioxidant capacity (Ashraf, 2004).

It was reported by El-Tayeb (2005) that the increase in growth of plants induced by salicylic acid could be due to increased antioxidant activity that provides protection to plants from damage by ROS. Therefore, salicylic acid might cause enhancement of photosynthetic process which is the main control factor in growth and productivity of crops (Natr & Lawlor, 2005). Gunes et al. (2007) and Arfan et al. (2007) reported similar results in their experiments about the alleviating effects of salinity by using salicylic acid in maize and wheat plants respectively. However, Maqsood et al. (2008) observed that salinity substantially affected weight of 1000 grains in maize. The highest yield had been observed in the treatments of T₁SA₃, T₃SA₁, T₂ SA₃ and T₃SA₃ as compared to other treatments in the respective group.

Conclusion

The present study revealed that salt stress conditions badly affected the yield of Zea mays L. cv. NMH-909. However, the exogenous application of salicylic acid promoted all the yield attributes to a considerable extent. Cob length, number and weight of grains were increased as a result of salicylic acid application. At all levels of salinity improvement was observed by treatment of salicylic acid. Moreover, effectiveness increased with the increasing the concentration of salicylic acid. Hence, it can be inferred that exogenous application of salicylic acid can serve as a useful approach for increasing salt tolerance and improving the productivity of maize.

REFERENCES


