Salicylic Acid Enhances Growth and Productivity in Cabbage (Brassica oleracea var. Capitata L.) Grown Under Saline Condition

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Abstract

Introduction: This experiment was set up to investigate the beneficial effect of salicylic acid to reduce the harmful consequence of salinity on cabbage productivity where Salt stress severely limits plant growth, development and yield.

Methods: We had grown cabbage plants under different levels of NaCl salinity (0, 4, 8 dS m⁻¹) alone or supplemented with foliar spray of different concentrations of salicylic acid (SA, 0, 0.25 and 0.5 mM). This experiment was laid out in a randomized complete block design with three replications. Collected all data were statistically analyzed following the analysis of variance (ANOVA) technique using MSTAT-C program and the mean differences were adjudged by least significant difference (LSD) test at 5% level of significance.

Results: Results showed that, higher concentrated salt treated plants give the significant lower growth and head yield. Plant growth as well as yield of cabbage such as heads thickness, diameter and weight were decreased with increased level of salinity such as 8 dS m⁻¹ compared with other treatment. While, foliar application of SA increased growth and yield also hindered stress induced growth and production inhibition. The improvement in plant height, leaf number, leaf length and breadth, foliage coverage, number of root and weight, head thickness, diameter and weight were increased with increased concentration of SA and higher value were recorded from 0.50 mM SA.

Conclusions: It can be concluded that SA improve the plant defense system to resist the toxic effect of salinity.

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Abiotic Stress
Foliage Coverage
Osmotic Stress
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Plant Root

INTRODUCTION

Being one of the major environmental adversities, salt stress is considered as the most devastating abiotic stress for crops grown under irrigation. As a consequence crop growth and yield is reported to be reduced by more than double in many instances [1]. Salt stress is associated with both osmotic stress and ionic toxicity which lead to many abnormalities such as imbalanced metabolism, chlorosis, impaired photosynthesis, nutrient imbalance and yield loss [2]. One of the major consequences of salt stress at cellular level is the overproduction of reactive oxygen species (ROS which causes oxidative stress [3]. High concentration of salt often make the soils unsuitable for many crops those are sensitive and hence thus it is a serious concern for crop growers. Salinity not only disturbs normal plant growth and development by inhibits the cell division and expansion but also restricts nutrients uptake mechanism and enzymatic activities [4]. ROS causes cell death which is a consequence of membrane damage, metabolic enzymes deactivation, and nucleic acids damage. Antioxidant defense systems become activated under stress condition to scavenge the ROS molecules and enhanced the antioxidant enzyme activities viz. SOD, CAT, and POX [5]. Therefore, it is become most utmost demand to mitigate the deleterious effects of salt stress on plants through developing different methods and strategies. Increasing plant tolerance against stress to improve productivity for our extra world population is now best implications in agriculture. Hayat et al. [6] recognized salicylic acid (SA) as a plant hormone whose plays a vital physiological role on growth and development [7] and abiotic stress tolerance in plants. SA counters many abiotic stresses viz. heavy metal.
mechanism where SA increases K+ concentration in roots. Homeostasis is fundamental requirement for salinity tolerance as treatment variables. Cabbage plants were treated with 0, 0.25, 0.50 mM salicylic acid (SA, Wako, Japan) viz. 0, 4, 8 dS m-1 NaCl, (Wako, Japan) and three levels of salinity viz. 0, 40, 55 DAT. SA was applied as foliar spray in the same days after application of salt. The experimental design was randomized complete block design (RCBD) with three replications.

Crop Husbandry

Nutrient and pest management practices were done as recommended.

Data Collection

Different morphological and reproductive parameter as well as yield was recorded to evaluate the response of cabbage under saline condition and also the mitigating behavior of SA to salt toxicity.

Statistical Analysis

All the data collected on different parameters were statistically analyzed following the analysis of variance (ANOVA) technique using MSTAT-C [16] program and the mean differences were adjudged by least significant difference (LSD) test at 5% level of significance.

RESULTS

Plant Height

The plant height varied significantly (P ≤ 0.05) by different levels of salinity stress at different days after transplanting (DAT) of cabbage (Fig 1). Plant height increased with increasing age but in here decreased with increasing salinity in cabbage where this pattern also increased with age. At 30, 40, 50, 60 and 70 DAT, highest plant height were observed from non-saline (0 dS m-1) condition where lowest values were recorded from at same age from highest salinity level (8 dS m-1). Salicylic acid significantly reduced the harmful effect of salt on plant height in cabbage at different DAT (Fig 1). SA significantly prompted plant height with various growth stages of cabbage under saline condition. From this experiment it was noticed that SA increased plant height as compared with the control where the best result was found from 0.25 mM concentration of SA. At, 40, 50, 60 and 70 DAT, highest plant height were recorded from 0.50 mM SA treated plant except at 30 DAT, where 0.50 mM SA produce highest plant height. SA has positive effect when used in combination with NaCl. Interaction effect between salinity and SA as alleviating agent on plant height was significant at different DAT (Table 1). At 30 and 40 DAT highest plant height were recorded from without salinity and 0.50 mM SA concentration and no salinity with without SA application respectively but in case of 50, 60 and 70 DAT highest plant height were shown from without saline condition with foliar application of 0.25 mM concentrated SA. Higher salinity in soil without application of SA decreased the plant height of cabbage.
Figure 1: Effect of Salinity and Salicylic Acid on Plant Height and Number of Leaf at Different Days After Transplanting of Cabbage. Effect of Salinity (A and C) and effect of salicylic acid (B and D). Here, LSD value = 1.372, 1.877, 1.128 and 1.286 for 30, 40, 50, 60 and 70 DAT respectively for plant height and LSD value = 2.12, 1.821, 1.916, 1.252 and 1.272 for 30, 40, 50, 60 and 70 DAT respectively for number of leaf.

Table 1: Combined Effect of Salinity and Salicylic Acid on Plant Height and Number of Leaf Plant⁻¹ at Different DAT of Cabbage

<table>
<thead>
<tr>
<th>Salinity</th>
<th>Salicylic Acid (mM)</th>
<th>Plant Height (cm) at</th>
<th>Number of Leaf Plant⁻¹ at</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 DAT</td>
<td>40 DAT</td>
<td>50 DAT</td>
</tr>
<tr>
<td>8 dSm⁻¹</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>21.5 ab</td>
<td>27.5 a</td>
<td>27.0 ab</td>
</tr>
<tr>
<td>0.25</td>
<td>18.0 d-f</td>
<td>26.0 ab</td>
<td>29.5 a</td>
</tr>
<tr>
<td>0.50</td>
<td>22.0 a</td>
<td>27.0 ab</td>
<td>25.5 bc</td>
</tr>
<tr>
<td>4 dSm⁻¹</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>21.0 a-c</td>
<td>24.5 ab</td>
<td>25.0 bc</td>
</tr>
<tr>
<td>0.25</td>
<td>20.0 a-d</td>
<td>25.0 ab</td>
<td>25.5 bc</td>
</tr>
<tr>
<td>0.50</td>
<td>19.0 c-e</td>
<td>26.0 ab</td>
<td>25.0 bc</td>
</tr>
<tr>
<td>8 dSm⁻¹</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>15.7 f</td>
<td>18.5 c</td>
<td>18.0 d</td>
</tr>
<tr>
<td>0.25</td>
<td>19.3 b-e</td>
<td>24.0 b</td>
<td>22.5 c</td>
</tr>
<tr>
<td>0.50</td>
<td>17.3 ef</td>
<td>19.0 c</td>
<td>18.0 d</td>
</tr>
<tr>
<td>CV%</td>
<td>7.11</td>
<td>7.77</td>
<td>8.14</td>
</tr>
</tbody>
</table>

Mean values having the dissimilar letter (s) indicate significant at $P \leq 0.05$.

Number of Leaves Plant⁻¹

The results of this experiment disclosed that two different concentration of salt have significant effect on number of leaves plant⁻¹ of cabbage at different DAT (Fig 1). Salinity at 8 dS m⁻¹ produced lowest number of leaves plant⁻¹ at 30, 40, 50, 60 and 70 DAT, whereas highest number of leaves produced from without salt treated plant in all over the growth period. Thus, number of leaves plant⁻¹ was decreased with increasing salt stress was lower number compared to control plant. SA significantly improves the number of leaves plant⁻¹ of cabbage at different DAT which was found (Fig 1) in this experiment. At 30 and 40 DAT, highest leaves number were came from 0.25 mM SA treated plant where at 50 DAT highest value was came from without SA treatment and at 60 and 70 DAT, where highest leaves number came from 0.50 mM SA treated plant. From this study it was noticed that, the number of leaves plant⁻¹ was gradually increased with the increasing age with foliar addition of SA along with salt. The combined effect of salinity and SA on leaves initiation plant⁻¹ was significantly indicated at different stages of cabbage (Table 1). Exogenous supply of SA increased the leaf production under salinity.

Average Leaf Length and Leaf Breadth Plant⁻¹

Average leaf length and breadth plant⁻¹ of cabbage was significantly affected by salinity at different DAT (Table 2). AT 40, 50, 60 and 70 DAT highest value of average leaf length were recorded from without salt treated plant and lowest...
values were recorded from 8 dS m\(^{-1}\). Again, same result was also found for leaf breadth. Application of SA on cabbage plant has a significant role to salt mitigation (Table 2) and as well as it increase the leaf length and breadth ultimately increased the total leaf area, which also responsible for more photosynthesis through enlarging photosynthetic area. Among the two concentration of SA 0.25 mM showed the better result compare to other. Salinity and SA has a significant combined effect on average leaf length and breadth (Table 3) of cabbage at different DAT.

Foliage Coverage Plant\(^{-1}\)

Foliage coverage (cm) was decreased under saline condition significantly (Table 2) of cabbage and this trend was increased with increased level of salinity. Where 8 dS m\(^{-1}\) showed the lowest foliage coverage plant\(^{-1}\) at 40, 50, 60 and 70 DAT compared to other treatment. It’s may be due to the negative effect of salinity on leaf number and leaf area which were also decreased with increasing level of salinity. SA gradually increased the foliage coverage compare to without SA.
treated plant (Table 2) and where best result was found from 0.25 mM concentration treated plant compare to 0.50 mM SA. In interaction effect of salinity and SA on foliage coverage exhibited a significant effect (Table 3). The highest foliage coverage was recorded from 0.50 mM SA with without salinity treated plant. Increased salinity levels such as 4 and 8 dS m⁻¹ treated plants showed higher foliage coverage in 0.25 mM concentration of SA.

Whole Plant Weight and All Loose Leaf Weight

Plant weight as well as loose leaf weight of cabbage plant due to salinity stress at harvesting time has been studied in this experiment. It was found that whole plant and leaf weight decreased significantly with the increased level of salinity (Table 4). Highest value of whole plant weight was recorded control plant (0 dS m⁻¹) and lowest one was come from 8 dS m⁻¹ treated plant. So salinity reduces plant biomass production and from the result of this study, about 54.72% reduction of whole plant weight was recorded from 8 dS m⁻¹ salinity. Again lowest loose leaf weight was measured from 8 dS m⁻¹ salinity treated plant and thus 35.69% reduction of leaf weight was occurred due to this level of salinity. Significant effect of SA on plant and leaf weight was found (Table 4) and where 0.50 mM SA showed the better result compared to 0.25 mM treated plant. The interaction effect of SA and salinity on whole plant as well as all loose leaf weight was also affected where 0.50 mM SA showed the better response compare to 0.25 mM SA concentration.

<table>
<thead>
<tr>
<th>Salinity</th>
<th>Salicylic Acid (mM)</th>
<th>No. of Loose Leaf</th>
<th>Average Loose Leaf Length (cm)</th>
<th>Average Loose Leaf Breadth (cm)</th>
<th>No. of Root</th>
<th>Root Length (cm)</th>
<th>Root Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 dS m⁻¹</td>
<td>0</td>
<td>16.67 b</td>
<td>18.50 ab</td>
<td>19.00 a</td>
<td>48.33 b</td>
<td>14.33 c</td>
<td>27.33 cd</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>16.00 b</td>
<td>19.50 a</td>
<td>16.00 b</td>
<td>65.00 a</td>
<td>18.33 a</td>
<td>28.33 bcd</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>11.67 c</td>
<td>20.00 a</td>
<td>16.00 b</td>
<td>68.33 a</td>
<td>16.50 abc</td>
<td>31.00 bcd</td>
</tr>
<tr>
<td>4 dS m⁻¹</td>
<td>0</td>
<td>21.00 a</td>
<td>18.33 abc</td>
<td>15.00 bc</td>
<td>66.00 a</td>
<td>18.00 ab</td>
<td>24.00 cd</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>18.00 ab</td>
<td>16.67 bc</td>
<td>13.83 cd</td>
<td>65.67 a</td>
<td>16.67 abc</td>
<td>20.67 de</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>15.33 b</td>
<td>16.00 cd</td>
<td>12.83 de</td>
<td>65.00 a</td>
<td>17.33 abc</td>
<td>54.00 a</td>
</tr>
<tr>
<td>8 dS m⁻¹</td>
<td>0</td>
<td>14.67 bc</td>
<td>14.17 d</td>
<td>11.50 e</td>
<td>45.33 b</td>
<td>15.33 abc</td>
<td>32.33 b</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>15.67 b</td>
<td>13.83 d</td>
<td>11.50 e</td>
<td>34.33 c</td>
<td>17.33 abc</td>
<td>14.00 e</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>17.00 b</td>
<td>16.83 bc</td>
<td>11.00 e</td>
<td>52.00 b</td>
<td>15.00 bc</td>
<td>21.00 de</td>
</tr>
</tbody>
</table>

CV%:

12.37 8.25 8.44 10.3 11.33 16.81

Mean values having the dissimilar letter (s) indicate significant at P ≤ 0.05 and similar letter (s) indicate non-significant.

Figure 2: Effect of Salinity and Salicylic Acid on Number of Roots, Root Weight, Head Thickness and Head Diameter of Cabbage Effect of Salinity (A and C) and effect of salicylic acid (B and D). Here, LSD value = 5.833 and 4.715 for no. of roots and root weight respectively and LSD value = 2.267 and 1.529 for head thickness and head diameter respectively.
### Table 6: Combined Effect of Salinity and Salicylic Acid on Whole Plant Weight, All Loose Leaf Weight, Head Thickness, Head Diameter and Marketable Head weight Plant⁻¹ of Cabbage

<table>
<thead>
<tr>
<th>Salinity</th>
<th>Salicylic Acid (mM)</th>
<th>Whole Plant Weight (kg)</th>
<th>All loose leaf Weight (g)</th>
<th>Head Thickness (cm)</th>
<th>Head Diameter (cm)</th>
<th>Marketable Head Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 dS m⁻¹</td>
<td>0</td>
<td>1.420 a</td>
<td>377.0 a</td>
<td>16.33 a</td>
<td>9.500 bcd</td>
<td>1.043 a</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>1.113 bc</td>
<td>340.3 abc</td>
<td>14.00 ab</td>
<td>11.33 ab</td>
<td>0.780 bc</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>1.210 b</td>
<td>346.7 ab</td>
<td>13.50 ab</td>
<td>12.50 a</td>
<td>0.860 b</td>
</tr>
<tr>
<td>4 dS m⁻¹</td>
<td>0</td>
<td>1.073 bc</td>
<td>303.0 bc</td>
<td>14.17 ab</td>
<td>11.50 ab</td>
<td>0.770 bc</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>0.9767 c</td>
<td>312.0 bc</td>
<td>10.33 bcd</td>
<td>10.33 abc</td>
<td>0.663 c</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>0.9633 c</td>
<td>298.3 cd</td>
<td>12.67 abc</td>
<td>11.83 ab</td>
<td>0.663 c</td>
</tr>
<tr>
<td>8 dS m⁻¹</td>
<td>0</td>
<td>0.6033 d</td>
<td>213.3 e</td>
<td>9.500 cd</td>
<td>7.667 d</td>
<td>0.390 d</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>0.4633 d</td>
<td>216.0 e</td>
<td>8.167 d</td>
<td>8.333 cd</td>
<td>0.250 d</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td>0.6300 d</td>
<td>255.0 de</td>
<td>8.500 d</td>
<td>8.500 cd</td>
<td>0.373 d</td>
</tr>
<tr>
<td>CV%</td>
<td></td>
<td>12.72</td>
<td>9.2</td>
<td>19.05</td>
<td>15.05</td>
<td>16.45</td>
</tr>
</tbody>
</table>

Mean values having the dissimilar letter (s) indicate significant at $P \leq 0.05$ and similar letter (s) indicate non-significant.

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**Figure 3:** Effect of Salinity and Salicylic Acid on Marketable Head Weight Plant⁻¹ of Cabbage. Effect of Salinity (A) and Effect of Salicylic Acid (B). Here, LSD value = 0.1048.

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**Number of Loose Leaf and Root**

Number of loose leaf (Table 4) and number of roots (Fig 2) at harvesting time of cabbage showed significant variation for different salinity level such as 4 and 8 dS m⁻¹. The highest number of loose leaf and root were found from 4 dS m⁻¹ treated plant and lowest number of roots was recorded from 8 dS m⁻¹. Supplementation of SA on cabbage for number of loose leaf (Table 4) and root (Fig 2) has a significant effect where 0.25 mM SA gave the higher loose leaf than 0.50 mM SA and highest root number (61.78) was recorded from 0.50 mM SA treated plant. The highest number of loose leaf was found from 4 dS m⁻¹ salinity condition with without SA treatment combination (Table 5). On the other hand the highest number root was found from non-saline condition with 0.50 mM SA treatment combination (Table 5).

**Root Length and Root Weight Plant⁻¹**

Salinity reduces the root length (Table 4) and weight plant⁻¹ of cabbage (Fig 2) where highest root length and weight were found from 4 dS m⁻¹ salinity level and whereas lowest value was recorded from 8 dS m⁻¹ saline condition. Result of this experiment showed that, foliar application of SA increases the root length as well as weight. The greater root length and weight were recorded from 0.25 mM and 0.50 mM SA treated plant respectively. The highest root length plant⁻¹ was found from non-saline condition with 0.25 mM SA combination whereas the highest root weight was recorded from 4 dS m⁻¹ saline condition with 0.50 mM SA treatment combination (Table 5).

**Average Loose Leaf Length and Breadth**

Significant variation was recorded for average loose leaf length and breadth plant⁻¹ of cabbage due to salinity (Table 4). Salinity at 8 dS m⁻¹ resulted in lowest loose leaf length and loose leaf breadth where highest value was recorded from without salt treated plant. The highest leaf length was found from 0.50 mM SA treatment and highest breadth was recorded from non SA treated plant. Again the highest leaf length was found from non-saline condition with 0.50 mM SA treatment combination. Besides, the highest leaf breadth was recorded from control treatment combination.

**Head Diameter and Thickness**

There was a significant effect of salinity on head diameter (cm) and head thickness (cm) of cabbage (Fig 2). Lowest head thickness and diameter were recorded from 8 dS m⁻¹.
level of salinity where highest value was come from without salt treated plant. Again head diameter was increased with the foliar spray of SA and higher value was found from 0.50 mM SA treated plant over control treatment. But in case of thickness where higher value was recorded from control treated plant and the comparative higher value was recorded from 0.50 mM SA treated plant than 0.25 mM SA. The highest head diameter was found from non-saline condition with 0.50 mM SA treatment combination whereas the highest head thickness was recorded from control treatment (Table 6).

**Marketable Head Weight Plant**

Significant variation was found for marketable head weight plant of cabbage due to salinity stress (Fig 3) and the increasing level of salinity reduces the head weight gradually. Where the highest head weight was recorded from control treated plant and lowest value was found from 8 dS m⁻¹ salinity. Thus, 8 dS m⁻¹ salinity reduced 62.23% of yield per plant. The highest head weight was also found from without SA treated plant and 0.50 mM SA treatment gave the higher value compare to 0.25 mM SA. There was a non-significant combined effect of salinity and SA on marketable head yield of cabbage but 0.50 mM SA treatment gave the higher result compare to 0.25 mM treatment under both saline and non-saline condition (Table 6).

**DISCUSSION**

Results showed that, plant height was decreased under saline condition which was also found in tomato with increased levels of salinity mostly at 6 and 8 dS m⁻¹ [17]. Similar results were also recorded in tomato [18], lettuce [19] and coriander [20]. The reduction of plant height may be due to suppressive behavior of salt stress particularly on cell [21]. So, inhibition of plant growth is a common feature under saline condition. Our results remind of Ibn Maauouia [22] which showed that the growth of stem decreases when the salinity exceeds 4 g L⁻¹. This depressive effect can have two causes first, difficulties of water supply and nutriments and second the toxicity of ions accumulated in excess in the plant [23]. Indeed, the delay of development allows the plant to combat stress where damage is irreversible. In fact, reducing growth can result from the increase of abscisic acid concentration in the air part or a reduction in cytokinin concentration [24]. Application of SA increased the plant growth such as plant height under saline condition and similar result was also found from Agamy et al. [25] in tomato. Leaf is the main photosynthetic organ and as well as indicator of plant growth and development. Salinity negatively affected leaf production in cabbage. Similar observation was also observed by Ewase [20] who reported that number of leaves production decreased with the increasing concentration of NaCl in coriander. Saberi et al. [26] also obtained reduced number of leaves plant⁻¹ under salt stress. Leaf number was decreased under saline condition mostly at 6 and 8 dS m⁻¹ in tomato [17]. So it is suggested that the SA application improved leaves production by reducing the effect of salt. Agamy et al. [25] also obtained increased leaf number with the application of SA in tomato.

Results revealed that, salinity reduces the leaf length and breadth as well as leaf area and this reduction rate is gradually increased with higher level of salinity. Similar result was also found by Sixto et al., Munns and Tester, Saberi et al. [26]. According to Hernandez et al. [21] salt stress deprived the normal cell behavior and reducing leaf expansion as well as reduced leaf area. Salinity also adversely affected leaf area mostly at 8 dS m⁻¹ in tomato [17]. Salinity reduces the plant growth resulting foliage coverage was decreased. From this study it was showed that SA successfully reduced the detrimental effect of salinity and prompted the plant growth and development through increasing the whole foliage coverage may be the result of increased individual leaf area and plant height. Salt treated plant gave lower fresh plant weight which due to reduce response on all morphological features whereas SA showed that successful recovery reports on this behave and this also forecast that higher concentration of SA will be more successful in case of growth and developmental stage. This result also supported by Agamy et al. [25] who also found that, 0.50 mM SA increase the fresh weight of tomato plant.

Higher level of salinity greatly reduces the root length as well as weight. Salinity may affect also the roots growth. Jbir et al. [27] showed that salt affected the size of the main root meristem (mitotic index, the process of cell division and the size of cortical cells) in wheat roots of two species differed in their sensitivity to salt. The root system seems to be much affected in the presence of even a low NaCl concentration but the addition of phytohormone alleviates the harmful effect of salt on the root development. Results consigned in table 5 showed an increase in the weight of roots fresh matter after the addition of these plant hormones. This is a proof in line with the fact that phytohormones stimulate the root growth. The nutrient status of the plant is very important as it has a potent effect on successfully crop production. It is likely that the reduction in the shoot and root growth under salt stress conditions might be due to several reasons. One possibility is that salinity reduces photosynthesis, which limits the supply of carbohydrates which is essential for growth [28]. Second possibility is that salinity reduces shoot and root growth by lowering turgor pressure in developing tissues resulting from lowered water potential in growth medium [28]. Third one is that the root response to salt was to down-regulation of shoot and root growth via a long distance signal [27]. Matsubara and Tasa-ka [29] noted a reduction of 50% of the fresh root weight of carrot with NaCl concentrations ranging from 68 to 102 mM. Similarly, the length of the root decreases with increasing salinity confirming the study of Unlukara et al. [30] on carrot. As well as the salinity has further reduced the growth of the aerial parts of carrot compared to the roots, this is in agree with the results of the work of Ibn Maaoouia [22]. On the other hand, accession L10 shows the most sensitive since the rate of reduction is 85% for the aerial part and 89% for the roots. These results resemble those obtained by Kaya and Higgs [31] on cucumber; Rode and Nothnagel [32] on carrot. Salt affects more producing root biomass than the aerial parts, because usually it is the absorption bodies how show greater sensitivity to salt stress as photosynthetic organs stress. Furthermore, reduced dimensions of the plant (length and diameter of the stem) and biomass (root and aerial part) is a result of a reduction in the number of cells or chlorophyll content, or both causing a decrease in the synthesis of dry matter [31]. Agamy et al. [25] reported that, root weight increased in tomato af-
ter application of SA. From this it is clear that SA can mitigate the salinity effect on cabbage and also can improve its growth and development. The results showed that, the increased level of salinity showed the decreasing trend of average loose leaf length and breadth. On the other hand, gradually head diameter and thickness were decreased with increased level of salinity and without salt treated plant gave the highest value which ensure that salinity reduce the formation of head and as well as growth. From the result of this experiment it was also found that SA application increased the head diameter and thickness under saline condition.

Cucumber and tomato fruit yield was enhanced significantly when the plants were sprayed with lower concentrations of SA [33]. The total yield was significantly reduced by salinity (NaCl) due to a significant decrease in average fruit weight; these results are also observed by Unlukara et al. [30]. In this experiment, there was increased in total marketable yield of cabbage at 0.50 mM of SA compared to 0.25mM and was not become more than without SA sprayed plant may be the concentration sprayed in here were not sufficient enough to overcome salinity toxicity in this species of cabbage which can be enhanced by increased head diameter and as well as thickness. It is also a make possible phenomenon to do more experiments in regarding higher concentration of SA to make more tolerant of cabbage to salinity which will give sufficient amount of production.

In conclusion, considering the above mentioned results, it may be concluded that, salinity retards the cabbage plant growth and development as well as reduces the yield. SA as a mitigating agent reduces the detrimental effect of salinity on cabbage. From where 0.25 mM concentration of SA shows the better result in plant height, leaf number, leaf length and breadth with higher foliage coverage. On the other hand 0.50 mM SA enhance the yield of cabbage in better value compare to 0.25 mM concentration. So, SA successfully can ameliorate the salt effect and reduce the reduction rate of plant growth development and yield under salinity.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

K.P., M.F. and M.H. conceived and designed the experiments; K.P. performed the experiments; M.H. analyzed the data and contributed reagents/materials/analysis tools; K.P. and M.H. wrote the manuscript. M. F. and M.H. edited the manuscript. All authors read and approved the final manuscript.

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