Full Length Research Paper

Effect of halopriming on germination and seedling vigor of tomato

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Accepted 16 May, 2011

The study was carried out to investigate the effects of halopriming on germination, seedling growth and biochemical responses of tomato seeds. Priming was done by exposing seeds of two tomato cultivars ‘Nagina’ and ‘Pakit’ to aerated solutions of 10, 25 and 50 mM NaCl and KNO₃ for 24 h. Halopriming with 25 mM KNO₃ increased final germination percentage, germination index, root length, shoot length and seedling fresh weight of both tomato cultivars as compared to all presowing seed treatments including control. Seeds of both tomato cultivars primed with 25 mM KNO₃ for 24 h, significantly reduced the time taken to 50% emergence and mean emergence, increased final seedling emergence percentage and seedling growth. Results indicated that halopriming with varying concentrations of KNO₃ improved germination potential and seedling establishment of both cultivars and it proved better option than NaCl which resulted in poor emergence and seedling growth. Maximum improvement was recorded in seeds primed with 25 mM KNO₃. The better performance of haloprimed seeds may be due to lower electrical conductivity (EC) of seed leachates, higher total and reducing sugars along with increased α-amylase activity.

Key words: Seed dormancy, α-amylase, halopriming, electrical conductivity, reducing sugars.

INTRODUCTION

Seeds of many species become dormant during development on the parent plant and this resistance to germination persists after the seeds are disseminated, and this ‘primary dormancy’ is considered to be a key tactic to survive during unfavorable conditions (Osborne, 1981). Primary dormancy is often, but not always, removed by exposure of dry seeds to high temperatures (after-ripening) or of imbibed seed to chilling temperatures (Bewley and Black, 1985; Hilhorst, 1995). However, dormancy has been reported in freshly harvested tomato seeds (Liu et al., 1996). Endosperm rupture is the main limitation for germination of tomato seeds. In these cases of endosperm-limited germination, weakening of the micropylar endosperm surrounding the radicle tip appears to be required for radicle protrusion and is likely to involve cell-wall hydrolysis by hydrolytic enzymes (Bewley, 1997).

Due to this problem, tomato production is badly affected all over the world. The physical strength of the endosperm, perisperm or seed coverings have been shown to restrict germination in cultivated crops like lettuce, tomato and cucumber (Dutta et al., 1994). The precocious germination in tomato was affected by reduced water potential and ABA contents on the fruit tissue that surrounds the embryo, prevented endosperm weakening and the subsequent penetration of the embryo through the seed coat (Black, 1991; Hilhorst and Karssen, 1992). Thus, degradation of the endosperm in tomato is essential to initiate the germination (Bradford et al., 2000). Priming increases respiratory activity of seeds (Halpin-Ingham and Sundstrom, 1992) and when applied to aged seeds, restores activities of enzymes involved in the cell detoxifying mechanisms such as superoxide dismutase; catalase and glutathione reductase (Bailly et al., 1997). Tomato is among the crops which are responsive to priming. The purpose of priming is to shorten the time between planting and emergence and to protect seeds from biotic and abiotic factors during critical phase of seedling establishment as to synchronize emergence, which leads to uniform stand and improved
yield (Khan, 1992). These priming treatments which enhance seed germination include hydropriming (Afzal et al., 2002) osmopriming (Hardegree and Van Vactor, 2000; Rouhi, 2011), solid matrix priming (Ghassemi-Golezani, 2010) halopriming (Afzal et al., 2009; Gandonou, 2011) and hormonal priming (Afzal et al., 2006).

In halopriming, the seeds are soaked in salt solutions, which help to invigorate the seed and facilitate the process of seed germination and seedling emergence even under adverse environmental conditions. Primed seeds perform better in a wider range of temperatures (Bray, 1995) and are less sensitive to oxygen deprivation (Corbineau et al., 1993) than unprimed ones. The favorable impact of priming has been associated with various, cellular, molecular and biochemical events including synthesis of DNA and proteins (Bewley and Black, 1994). Priming can also help to increase enzyme activity and neutralize the effects of seed ageing. According to Lee and Kim (2000), *de novo* synthesis of α-amylase is also known during priming. Thus, higher vigour of the primed seeds relates to metabolic activities in seeds due to increased α-amylase activity.

During priming with osmotica, ions from potassium nitrate and sodium chloride solutions accumulate within the seeds, reducing water potential and increasing water absorption (Parera and Cantliffe, 1994). It is very important to understand biochemical and physiological changes in tomato induced by halopriming. Therefore, this study was carried out to investigate the effect of halopriming on enhancing germination and seedling vigour of tomato species and to explore the possible biochemical basis of this enhancement.

**MATERIALS AND METHODS**

**Plant material**

Seeds of two tomato cultivars that is Nagina and Pakit, were collected from Ayub Agricultural Research Institute, Faisalabad, Pakistan. The initial seed moisture was 8.12 and 8.17%, respectively (dry weight basis).

**Priming treatment**

Seeds were surface sterilized by dipping in sodium hypochlorite (5%) solution for 5 min and dried on filter paper. These surface sterilized seeds were soaked in aerated solution of 10, 25 and 50 ppm NaCl and KNO3 for 24 h at 25°C. After respective priming treatment for specific period, seeds were washed with distilled water and dried at room temperature on filter paper in shade for 24 h (Bennett and Waters, 1987). Seeds were then packed in polythene bags and stored in a refrigerator 4 ±2°C for further use.

**Germination test**

Twenty five seeds with each replicate per treatment were germinated in an incubator at 25°C under continuous fluorescent light (photosynthetic active photon flux density of 330 m mol m⁻² S⁻¹) in a growth chamber (Vindon, England) in 9 cm Petri dishes on two layers of Whatman No.1 filter paper and moistened with 4 ml distilled water for seven days. Time to 50% germination (T50) was calculated according to the formulae of Coolbear et al. (1984). Mean germination time (MGT) was calculated according to Ellis and Roberts (1981). Germination index (GI) was calculated as described by the Association of Official Seed Analysts (1983). Energy of germination was recorded on the 4th day after planting. It is the percentage of germinating seeds on the 4th day after planting relative to the total number of seeds tested.

**Emergence test**

The haloprimed and control (unprimed) seeds were sown in plastic trays (25 in each) having moist sand, replicated thrice were placed in growth chamber (Vindon, England) maintained at 25°C under continuous fluorescent light for seven days. Emergence was recorded daily according to the seedling evaluation of the Handbook of Association of Official Seed Analysts (1983). Seedlings were harvested after two weeks and washed with deionized water after harvest. Afterwards they were separated into root and shoot for the determination of their fresh and dry weight. Dry weight was determined after oven drying the samples at 65°C for 48 h in oven.

**Electrical conductivity of seed leachates**

All priming treatments were helpful in reducing the electrical conductivity of seed leachates (Figure 1). In general, the electrolyte leakage increased with increasing imbibition period including all treatments and control. After a longer period of imbibition from 1 to 24 h, all the priming treatments lowered down the electrolyte leakage in the seeds of both cultivars. After washing in distilled water, five seeds were weighed and soaked in 10 ml of distilled water at 25°C. Electrical conductivity of seed leachates was measured 0, 3, 6, 12 and 24 h after soaking using a conductivity meter (Twin Conductivity Meter, B-173, Horiba Ltd., Miyanohigashi, Kishoshin, Kyoto, Japan) and expressed as μS cm⁻¹ g⁻¹.

**α-Amylase and sugar contents analysis**

The activity of α-amylase was measured by taking 1 g of ground tomato seeds mixed with 10 ml distilled water and kept at 4°C for 24 h. The supernatant was taken and the α-amylase activity was measured by the DNS method (Bernfeld, 1955).

**Total soluble sugars**

The quantification of total soluble sugars in tomato seed samples was done by taking (0.1 g each) after grinding with the help of mortar pestle followed by hydrolysis with 2.5 N HCl and then neutralized by sodium carbonate. The mixture was filtered using Whatman filter paper42 and distilled water was added to make the final volume upto 10 ml. The prepared sample was centrifuged at 10000 rpm for 10 min and the supernatant was taken to measure total soluble sugars following phenol-sulphuric acid method (Dubois et al., 1956).

**Reducing sugars**

The measurement of reducing sugars was done by DNS method (Miller, 1959) and Sadasivam and Manickam (1992) from the tomato sample (0.1 g) extracted in 80% ethanol using 5 ml volume each time.
Table 1. Effect of halopriming on the germination of tomato cultivars.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Priming</th>
<th>FGP</th>
<th>GI</th>
<th>MGT (days)</th>
<th>T50 (days)</th>
<th>Root length (cm)</th>
<th>Shoot length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>61.33c</td>
<td>7.76e</td>
<td>7.31a</td>
<td>6.13b</td>
<td>5.30c</td>
<td>4.93b</td>
</tr>
<tr>
<td></td>
<td>Hydropriming</td>
<td>69.33b</td>
<td>9.54de</td>
<td>7.18abc</td>
<td>6.52a</td>
<td>5.30c</td>
<td>5.58a</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 10 mM NaCl</td>
<td>70.66b</td>
<td>10.60cd</td>
<td>7.00bc</td>
<td>6.28ab</td>
<td>5.50bc</td>
<td>5.24ab</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 25 mM NaCl</td>
<td>69.33b</td>
<td>9.02de</td>
<td>7.25ab</td>
<td>6.22b</td>
<td>4.20d</td>
<td>5.13ab</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 50 mM NaCl</td>
<td>72.00b</td>
<td>9.43de</td>
<td>7.24ab</td>
<td>6.38ab</td>
<td>5.56bc</td>
<td>5.27ab</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 10 mM KNO₃</td>
<td>74.66b</td>
<td>12.15bc</td>
<td>6.93cd</td>
<td>6.13b</td>
<td>6.06a</td>
<td>5.18ab</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 25 mM KNO₃</td>
<td>81.33a</td>
<td>16.99a</td>
<td>6.58e</td>
<td>5.19d</td>
<td>5.76ab</td>
<td>5.20ab</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 50 mM KNO₃</td>
<td>71.36b</td>
<td>13.83b</td>
<td>6.68de</td>
<td>5.80c</td>
<td>5.33c</td>
<td>5.34ab</td>
</tr>
<tr>
<td>Nagina</td>
<td>LSD at 0.05</td>
<td>5.6531</td>
<td>2.2148</td>
<td>0.2637</td>
<td>0.2322</td>
<td>0.4255</td>
<td>0.5271</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>52.00f</td>
<td>7.46e</td>
<td>7.43a</td>
<td>6.52a</td>
<td>5.06c</td>
<td>4.93bc</td>
</tr>
<tr>
<td></td>
<td>Hydropriming</td>
<td>57.33e</td>
<td>9.43d</td>
<td>7.20ab</td>
<td>6.16b</td>
<td>5.33bc</td>
<td>5.60a</td>
</tr>
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<td></td>
<td>Halo priming in 10 mM NaCl</td>
<td>62.66cd</td>
<td>10.4c</td>
<td>6.93bc</td>
<td>6.22b</td>
<td>5.40b</td>
<td>5.23abc</td>
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<td>Halo priming in 25 mM NaCl</td>
<td>66.66bc</td>
<td>9.50d</td>
<td>6.96bc</td>
<td>6.28ab</td>
<td>5.23bc</td>
<td>4.76c</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 50 mM NaCl</td>
<td>58.66de</td>
<td>8.90d</td>
<td>7.43a</td>
<td>6.38ab</td>
<td>5.23bc</td>
<td>4.76c</td>
</tr>
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<td></td>
<td>Halo priming in 10 mM KNO₃</td>
<td>68.00b</td>
<td>11.60b</td>
<td>6.86c</td>
<td>6.23b</td>
<td>5.30bc</td>
<td>5.20abc</td>
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<tr>
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<td>Halo priming in 25 mM KNO₃</td>
<td>78.66a</td>
<td>13.80a</td>
<td>6.33d</td>
<td>5.17d</td>
<td>6.00a</td>
<td>5.20abc</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 50 mM KNO₃</td>
<td>70.66b</td>
<td>11.53b</td>
<td>6.90c</td>
<td>5.90c</td>
<td>5.16bc</td>
<td>5.33ab</td>
</tr>
<tr>
<td>Pakit</td>
<td>LSD at 0.05</td>
<td>4.4129</td>
<td>0.6906</td>
<td>0.2998</td>
<td>0.2522</td>
<td>0.3277</td>
<td>0.5631</td>
</tr>
</tbody>
</table>

Figures not sharing the same letters in a column differ significantly at p < 0.05; FGP = final germination percentage; GI = germination index; MGT = mean germination time; T50 = time taken to 50% germination.

Non-reducing sugars

While the the estimation of non-reducing sugars was done by extracting reducing sugars from the total sugars.

Statistical analysis

All experiments were repeated twice in a completely randomized design; data recorded each time were pooled for statistical analysis using software MSTATC to determine significance of variance (P<0.05). Duncan’s multiple range test was used to compare the differences among treatment means (Steel et al., 1997).

RESULTS

Germination

Halopriming treatments significantly (P < 0.05) affected germination potential of both tomato cultivars (Table 1). Most of the priming treatments resulted in lower MGT, T50 and higher FGP, GI, radicle and plumule lengths as compared to non-treated seeds of both cultivars. Maximum improvement was achieved in seeds primed with 25 mM KNO₃ as indicated by lower MGT, T50 and higher FGP, GI and radicle length than primed or non-treated seeds of both cultivars. Although all priming treatments improved final germination percentage in both cultivars and similarly increased germination index in Pakit; however, the response of priming treatments was variable in other germination attributes. It was also noted that priming with low concentration salt (10 mM NaCl and 10 mM KNO₃) also improved germination potential of tomato cultivars by decreasing MGT and increasing FGP, as well as GI. It is noteworthy that priming with higher concentration of NaCl (25 and 50 mM) failed to improve GI, MGT, T50, radicle and plumule lengths.
Table 2. Effect of halopriming on the seedling vigor of tomato cultivars.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Priming</th>
<th>FEP (days)</th>
<th>EI</th>
<th>MET (days)</th>
<th>E50 (days)</th>
<th>EM (cm)</th>
<th>FEP (mg)</th>
<th>EI (mg)</th>
<th>MET (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nagina</td>
<td>Control</td>
<td>44.66</td>
<td>14.53</td>
<td>8.26</td>
<td>7.23</td>
<td>1.6</td>
<td>4.66</td>
<td>23.10</td>
<td>6.63</td>
</tr>
<tr>
<td></td>
<td>Hydropriming for 24h</td>
<td>52.00</td>
<td>15.90</td>
<td>7.96</td>
<td>7.10</td>
<td>1.76</td>
<td>4.70</td>
<td>24.30</td>
<td>7.36</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 10 mM NaCl</td>
<td>54.00</td>
<td>15.56</td>
<td>7.23</td>
<td>7.20</td>
<td>1.83</td>
<td>4.54</td>
<td>25.20</td>
<td>7.80</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 25 mM NaCl</td>
<td>50.00</td>
<td>15.06</td>
<td>7.76</td>
<td>6.63</td>
<td>1.96</td>
<td>4.50</td>
<td>24.80</td>
<td>8.00</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 50 mM NaCl</td>
<td>45.33</td>
<td>13.24</td>
<td>7.13</td>
<td>6.33</td>
<td>1.33</td>
<td>4.12</td>
<td>22.53</td>
<td>6.70</td>
</tr>
<tr>
<td>Pakit</td>
<td>Halo priming in 10 mM KNO₃</td>
<td>50.66</td>
<td>15.13</td>
<td>8.18</td>
<td>6.90</td>
<td>2.00</td>
<td>4.73</td>
<td>25.00</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 25 mM KNO₃</td>
<td>74.00</td>
<td>19.50</td>
<td>6.36</td>
<td>6.23</td>
<td>2.30</td>
<td>4.56</td>
<td>24.06</td>
<td>7.26</td>
</tr>
<tr>
<td></td>
<td>Halo priming in 50 mM KNO₃</td>
<td>45.33</td>
<td>16.73</td>
<td>7.50</td>
<td>6.73</td>
<td>1.89</td>
<td>4.80</td>
<td>24.06</td>
<td>7.26</td>
</tr>
<tr>
<td></td>
<td>LSD at 0.05</td>
<td>3.2382</td>
<td>0.5508</td>
<td>0.2396</td>
<td>0.2714</td>
<td>0.4385</td>
<td>0.6582</td>
<td>1.3328</td>
<td>0.4908</td>
</tr>
</tbody>
</table>

Pakit

|          | Control                  | 48.00      | 15.33| 9.26      | 7.43       | 1.63     | 4.66     | 22.30   | 6.33     |
|          | Hydropriming for 24h     | 53.66      | 16.40| 8.62      | 7.17       | 1.83     | 4.70     | 23.30   | 7.25     |
|          | Halo priming in 10 mM NaCl | 56.23     | 15.89| 8.53      | 7.10       | 2.00     | 4.53     | 24.20   | 7.75     |
|          | Halo priming in 25 mM NaCl | 49.23     | 15.00| 9.23      | 6.53       | 1.96     | 4.16     | 25.80   | 8.10     |
|          | Halo priming in 50 mM NaCl | 47.45     | 13.97| 9.56      | 7.24       | 1.40     | 3.60     | 23.53   | 6.50     |
|          | Halo priming in 10 mM KNO₃ | 52.65     | 15.74| 9.13      | 6.85       | 1.90     | 4.73     | 26.00   | 7.02     |
|          | Halo priming in 25 mM KNO₃ | 66.00     | 22.26| 6.13      | 6.35       | 2.33     | 4.90     | 27.56   | 8.66     |
|          | Halo priming in 50 mM KNO₃ | 56.00     | 17.54| 8.23      | 6.52       | 2.43     | 4.46     | 23.04   | 7.21     |
|          | LSD at 0.05              | 3.6718     | 0.7040| 0.2290   | 0.2620     | 0.4135  | 0.4959   | 1.2315  | 0.5013   |

Figures not sharing the same letters in a column differ significantly at p 0.05; FEP = final emergence percentage, EI = emergence index, MET = mean emergence time, T50 = time taken to 50% emergence.

in Nagina and similarly Pakit seeds primed with 50 mM NaCl produced weaker radicle, plumule lengths and took maximum time to emerge.

Seedling vigour

There was a significant (P<0.05) effect of halopriming treatments on FEP, EI, MET, root and shoot length of both tomato cultivars (Table 2). The response of both cultivars to priming was found similar. Overall, priming with various concentrations of KNO₃ was better than NaCl. Seed priming with 25 mM KNO₃ gave lower values of E₅₀, MET and higher values of FEP, root and shoot length and seedling fresh and dry weights as compared with other primed or nonprimed seeds of both cultivars. Although priming with various concentrations of NaCl salt failed to improve seedling vigour of both cultivars; however, highest MET, E₅₀ and lowest FEP, EI, root, shoot lengths and biomass was recorded in seeds primed with 50 mM NaCl for Pakit.

All of the priming treatments were effective in lowering electrolyte leakage of tomato seeds (Figure 1). The electrolyte leakage increased with increasing imbibition period including all treatments and control. After a longer period of imbibition from 1 to 24 h, all the priming treatments lowered down the electrolyte leakage in the seeds of both tomato cultivars. However, significantly lower electrolyte leakage was observed in seeds exposed to 25 mM KNO₃ on all measuring periods.

α-Amylase and sugar contents analysis

There was a significant increase in α-amylase activity in all haloprimed seeds of both cultivars.
but maximum response was recorded in seeds primed with 25 mM KNO$_3$ (Figure 1a). All the halopriming seed treatments resulted in significantly higher contents of total soluble sugars than in the control, however reducing sugars were found highest in seeds which were exposed to halopriming with 25 mM KNO$_3$ followed by 10 mM KNO$_3$ (Figure 2).

**DISCUSSION**

During the course of study, more uniform and earlier germination and emergence was observed in seeds primed with 25 mM KNO$_3$ as shown by lesser mean germination or emergence time, higher final germination and emergence percentage, shoot length, seedling fresh
Figure 2. α-Amylase activity and sugar contents of Nagina and Pakit tomato cultivars as affected by different halopriming treatments.
and dry weight. There was a significant decrease in time taken to 50% germination which may be attributed to early reserve breakdown as well as reserve mobilization. It might also be due to possible early activation or de novo synthesis of cell wall degrading enzymes (Hisashi and Francisco, 2005). Our results are in line with Tzortzakis (2009) and Sarihan et al. (2005) as shown in (Table 1).

Furthermore, hydropriming resulted in increased normal germination. The results are in line with the findings of Thornton and Powell (1992) in Brassica and Srinivasan et al. (1999) in mustard. Fujikura et al. (1993) indicated the beneficial effects of hydropromining on aged or unaged seeds with respect to germination and percentage of normal seedlings in cauliflower. Roberts and Smith (1977) reported that presowing treatment of endives seeds with KNO$_3$ (50 and 150 mM) was significantly (P<0.05) effective, possibly through oxidized forms of nitrogen causing a shift in respiratory metabolism to the pentose phosphate pathway. Halopriming with NaCl treatments failed to improve germination as compared to KNO$_3$ seed treatment; it might be that NaCl treated seeds had taken up more Na$^+$ and/or Cl$^-$ from the salt solution, hence leading to the toxic effect as suggested by Bradford (1995). During some earlier studies, it was evident that primed seeds of different crops cause improvement in germination, seedling establishment and in some cases enhances crop yield (Harris et al., 1999).

The results regarding root and shoot fresh and dry weights are in agreement with those of Ashraf and Rauf (2001) who reported that fresh and dry weights of seedlings from haloprimed seeds were significantly higher, as compared to other unprimed seeds. Seed priming may help in dormancy breakdown may be due to embryo development or leaching of emergence inhibitors (Yamauchi and Winn, 1996), which resulted in increased FEP; these results are in agreement with Haigh and Barlow (1987) who found that KNO$_3$ was beneficial in decreasing the emergence spread of tomato, carrot, onion and sorghum seeds.

Pretreatment with NaCl could have stimulative effect related to salt acclimation, and a toxic effect due to salt stress. At the high NaCl pretreatment level (50 mM), the toxic effect would be increased and the stimulative effect would be nullified. This finding is further supported by the data in Table 2. Several studies on halopriming in germinating seeds depicted that during this stage the seeds were in particular sensitive to the NaCl concentration (Bewely and Black, 1982). Halopriming with NaCl might pose toxicity problems as ions accumulate in tissues as reported in various vegetable species (Brocklehurst and Dearman, 1984), that is why reduction in emergence percentage of seeds subjected to NaCl was due to accumulation of salts in tissue, which cause toxicity (Smith and Cobb, 1991). An increase in shoot length was recorded in KNO$_3$ treated seeds as compared to control and remaining priming treatments, which might be the result of higher embryo cell wall extensibility. Demir and Ozokat (2003) also found that root and shoot lengths increased in seeds due to salt priming as compared to non-primed seeds.

There was an increased α-amylase activity along with contents of total and reducing sugars of primed seeds in both the cultivars Nagina and Pakit (Figure 1). It confirmed the primary role of halopriming in either inducing the de novo synthesis or increasing the activities of existing enzymes (Lee and Kim, 2000), thus helped to produce germination metabolites in required amounts. Our results are in line with the findings of Afzal et al. (2009) who reported that increased α-amylase activity resulted in increased contents of total and reducing sugars subjected to priming in marigold. Seed leachates electrical conductivity is considered as an effective indicator of seed germination (Waters and Blanchette, 1983). All priming treatments were effective in decreasing electrolyte conductivity of seed leachates, which shows membrane stability. An increase in electrolyte leakage was observed by 10, 25 and 50 mM NaCl at all soaking periods which showed the toxic behaviors and/or penetration of salts in the seed tissues and was probably due to the loss of ability to reorganize cellular membranes rapidly and completely (McDonald, 1980).

Our findings are in agreement with the work done by Ashraf et al. (1999) they reported that the higher EC values were observed in seeds treated with NaCl than in the non-primed seeds. Decreased leakage of solute in KNO$_3$ treatment than control may be because of better membrane repair during hydration (Shannon and Francois, 1977; Dewir et al., 2011) as KNO$_3$ has a positive influence on membranes. However, our results are in line with the findings of Argerich and Bradford (1989) for tomato seeds. From this study, it can be concluded that germination and seedling vigor may be enhanced by halopriming treatments in both the tomato cultivars Nagina and Pakit by dormancy breakdown. However, halopriming with 25 mM KNO$_3$ was more effective than all other halopriming treatments.

ACKNOWLEDGEMENT

This work is part of a Ph.D research and was supported by financial assistance of the Directorate of Research University of Agriculture Faisalabad.

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