Potassium Nitrate Priming Effect on the Germination of Tomato (Lycopersicum esculentum. Mill) cvs. “Mersa” and “Tekeze-1”

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To compare the responses of two open-pollinated tomato varieties to germination parameters and shoot growth, seeds of open-pollinated tomato varieties, Mersa and Tekeze-1 were given osmopriming treatments with potassium nitrate (KNO\textsubscript{3}) in a lab setting. A completely randomized design with four replications was used. The analysis of variance revealed that both tomato varieties responded differently to priming with potassium nitrate concentrations significantly ($P < 0.05$) for almost all measured traits. Potassium nitrate treatments also affected final germination percent ($G\%$) and mean daily germination percent significantly ($P < 0.05$) and germination index (GI) and shoot length (SL) ($P < 0.001$). However, KNO\textsubscript{3} did not have a significant effect on time for 50% germination ($T_{50}$) and mean germination time (MGT). Variety Mersa showed better performance in germination percent ($G\%$) and SL than Tekeze-1; while Tekeze-1 had shorter days for MGT and reached $T_{50}$ faster than the Mersa variety. Potassium concentrations at 0.5% and 1.5% showed better germination results than the control and at 1% KNO\textsubscript{3}. The interaction of the Mersa variety with KNO\textsubscript{3} at 1.5% and 1% resulted in the highest SL, but the Tekeze-1 variety had the highest shoot length at 0.5% KNO\textsubscript{3} concentration, indicating that the varieties have different responses to the applied KNO\textsubscript{3} rate. This study confirmed the possibility of enhancing seed germination through externally applied priming agents such as KNO\textsubscript{3}. Despite being a preliminary finding, this study demonstrated that tomato cultivars differ in how they react to KNO\textsubscript{3} priming, and more research, using other tomato varieties and priming agents, is needed.

1. Introduction

Tomato (Lycopersicum esculentum L.) is among the major vegetable crops on a global scale [1]. Mauro et al. [1] observed that being a vegetable of major economic importance worldwide, the tomato is a source of minerals and vitamins, as well as an anticancer agent [2]. Ripe tomatoes contain (average values per 100 g of edible portion) water (94.1%), energy (23 calories), calcium (1.0 g), magnesium (7.0 mg), vitamin A, ascorbic acid (22 mg), thiamin (0.09 mg), riboflavin (0.03 mg), and niacin (0.8 mg) [3].

In tomatoes, germination and crop establishment are the most crucial physiological stages that are affected by seed quality and genetics [4]. Rapid and uniform germination and seedling establishment are essential for increasing tomato yield and quality [5], which is of economic importance in agriculture. Therefore, various seed enhancement approaches, such as priming, can be responsible to a major extent for the improved quality of seeds [6].

Freshly harvested tomato seeds often fail to germinate due to the presence of dormancy and can also extend to a year [7]. Such a prolonged dormancy period can result in problems in tomato production by affecting the availability of tomato seeds at all times in the needed amount. Controlled hydration of seeds followed by drying (seed priming) is used to break dormancy and seed germination and improve the uniformity of radicle emergence [8].

Seed priming with suitable priming agents and concentrations can induce some physiological and biochemical changes in the seed, which result in improved crop performances in terms of enhanced germination potential, seedling vigor, and final yield [5, 9]. Besides, seed priming
improves the ability of radicals to protrude rapidly, as the initial stages of germination are already fulfilled even under environmental stresses [5]. It also helps plants to cope with the adverse effects of unfavorable environmental conditions [10]. Seed priming helps plants to accelerate cell division, transport stored proteins, and hasten the speed of seed germination [11]. Seed priming improved germination and seedling vigor in tomatoes [6] by reducing membrane permeability and maintenance of tissue water contents [4].

External application of priming agents to tomato seeds has a remarkable role in the presowing accomplishment of germination phases [12]. Previous studies revealed the positive role of potassium nitrate (KNO₃) as a seed priming agent on seedling establishment and vigor [6, 7, 13]. Ali et al. [6] also reported improved performance of tomato cultivars, Sundar and Ahmar, due to seed priming with 0.75% KNO₃ which was linked with higher activities of total soluble sugars and phenolics under growth chamber and greenhouse screening. Similarly, a study by Farooq et al. [7] reported the highest dormancy breakage and vigor in seeds subjected to KNO₃ priming followed by NaCl in two tomato cultivars. Another study by Haigh and Barlow [14] also indicated that tomato seeds primed in solutions that contained KNO₃ had a much shorter time spread of germination than those primed in solutions other than KNO₃.

The impact of priming agents on tomato seed germination and growth has been the subject of numerous studies that have been conducted and reported in the past. Studies on priming agents like KNO₃ on vegetables like tomato, however, are lacking in Ethiopia. The present study examined the relationships between seed priming with KNO₃ and tomato cultivars on seed germination characteristics.

2. Materials and Methods

2.1. Tomato Varieties and Seed Source. Two open-pollinated tomato varieties, Tekeze-1 (CLN-5915-93-D4) and Mersa (Carman), were used for the study. Tekeze-1 is released in 2015 by Humera Agricultural Research Center (HARC) and Mersa in 2006 by Sirinka Regional Agricultural Research Center (SRARC) [15].

2.2. Experimental Setup and Design Layout. A tomato seed priming experiment was conducted in the horticulture laboratory of Wolkite University, College of Agriculture and Natural Resource, Ethiopia from 15 December 2020 to 5 January 2021.

A 2 × 4 factorial experiment with two tomato varieties (Mersa and Tekeze-1) and three levels, 5%, 1%, and 1.5% (weight/volume) of KNO₃ alongside a control (nonprimed), comprising a total of 8 treatment combinations. The laboratory experiment was laid out in a completely randomized design with four replications.

2.3. Seed Priming Treatments. Prior to priming, the seeds of both cultivars were sterilized by dipping them in a 0.1% HgCl₂ solution for 15 min. One hundred tomato seeds from each cultivar were counted using a seed counter and then primed with 0.5%, 1%, and 1.5% (weight/volume) KNO₃ for 24 hours in an aerated blotter papers at room temperature (25°C). Following the priming with KNO₃, concentrations, the petridishes were covered with aluminum foil and provided an aeration hole at the center.

2.4. Postpriming Operations. After priming for the prescribed duration, seeds were given three surface piles of washing with distilled water [16] and dried back to a moisture level of 11% under shaded conditions for 12 hours under room temperature [17] and the seeds were made ready for further use. For each KNO₃ treatment combination, the 100 seeds were divided into four groups (25 each) and used as replication for each treatment. Nonprimed tomato seeds were maintained as the control for comparison making the total of 32 experimental units. Each of the 25 seeds was placed in petridishes on moist Whatman 45 paper (10 ml distilled water for each treatment combination) at room temperature.

2.5. Data Collected

2.5.1. Germination Test. Germination was observed daily following the Association of Official Seed Analysts (AOSA) [18] method. Germination percentage/first germination percentage/germinability (GP) (%) measures germination capacity [19] and was computed as shown below.

\[
GP(\%) = \frac{N_g}{N_t} 
\]

where, \(N_g\) is the number of germinated seeds and \(N_t\) is the total number of seeds.

Mean germination time (MGT) (day): Mean germination time was calculated according to the equation suggested by Ellis and Roberts [20] as

\[
MGT (day) = \frac{n \times \sum D_n}{\sum D_n} 
\]

where, \(n\) is the number of seeds, which were germinated on day \(D\), and \(D\) is the number of days counted from the beginning of germination.

Mean germination rate (MGR) (day⁻¹): measures the germination rate and was computed according to the following formula as suggested by Labouriau and Valadares [21]:

\[
MGR \ (day^{-1}) = \frac{\sum_{i=1}^{k} N_i}{\sum_{i=1}^{k} N_i/T_i} 
\]

where, \(T_i\) is the time from the start of the experiment to the \(i^{th}\) interval, \(N_i\) is the number of seeds germinated in the \(i^{th}\) interval (not the accumulated number, but the number corresponding to the \(i^{th}\) interval), and \(k\) is the total number of time intervals. It is the inverse of mean germination time (MGT).

Peak germination value for germination (PV) (% day⁻¹): it is the accumulated number of seeds germinated at the point on the germination curve at which the rate of
germination starts to decrease and was determined as suggested by Czabator [22].

\[ PV = \max \left( \frac{G_1}{T_1}, \frac{G_2}{T_2}, \ldots, \frac{G_k}{T_k} \right), \]

where, \( T_i \) is the time from the start of the experiment to the \( i \)th interval, \( G_i \) is the cumulative germination percentage in the \( i \)th time interval, and \( k \) is the total number of time intervals.

The time to get 50% germination (\( T_{50} \)) was calculated according to the following formula [7]:

\[ T_{50} (\text{day}) = t_i + \frac{(N/2) - n_i)(t_j - t_i)}{n_j - n_i}, \]

where, \( N \) is the final number of germination and \( n_i \) and \( n_j \) are the cumulative number of seeds germinated by adjacent counts at times \( t_i \) and \( t_j \), when \( n_i < (N/2) < n_j \).

Germination index (GI): it is the rate of germination in terms of the total number of seeds that germinate in a time interval [19] and estimated as follows:

\[ GI (\text{day}) = \sum_{i=1}^{k} \frac{N_i}{T_i}, \]

where, \( T_i \) is the time from the start of the experiment to the \( i \)th time interval, \( N_i \) is the number of seeds germinated in the \( i \)th time interval (not the accumulated number, but the number corresponding to the \( i \)th interval), and \( k \) is the total number of time intervals.

Shoot length (SL) (mm): shoot length was measured for each experimental unit from five randomly selected emerged seedlings. The mean of the five plants was used for statistical analysis.

2.6. Data Analysis. Data on germination parameters and measured attributes were subjected to a two-way analysis of variance (ANOVA) (2 varieties × 4 KNO₃ levels) using SAS software v. 9.3 [23]. Treatment mean comparison was carried out using the procedure of least significant difference (LSD) test at a 5% level of probability.

3. Results and Discussion

Analysis of variance revealed that tomato varieties respond differently (\( P \leq 0.05 \)) for germination parameters and shoot length, with the exception of the germination index (GI) and peak value for germination (PV) (Table 1). Potassium nitrate levels significantly (\( P \leq 0.05 \)) affected germination percent (G%), germination index (GI), mean daily germination percent (MGR), and shoot length (SL) (Table 1). Improved performance of tomatoes due to seed priming with KNO₃ was also reported by previous studies in different tomato genotypes with different KNO₃ levels [6, 7]. However, only shoot length was significantly (\( P < 0.01 \)) impacted by the variety × KNO₃ interaction (Table 1).

Tomato variety Mersa showed better performance in G%, MGR, and SL than Tekeze-1. However, the Tekeze-1 variety had a shorter MGT (3.26 days) and a shorter time to reach \( T_{50} \) (2.59 days) than Mersa (\( T_{50} \), 2.7 days) (Table 2). A higher SL was observed in Mersa (5.03 mm) than Tekeze-1 (4.29 mm) variety which was also significantly different. Previous studies by Ali et al. [6] and Farooq et al. [7] also documented differences in tomato cultivars’ germination parameters in response to priming with KNO₃.

Tomato seeds primed with 0.5% and 1.5% KNO₃ (weight/volume) had the highest G% mean values than other treatments followed by the control and 1% KNO₃ concentration with similar G% results. Similarly, potassium nitrate concentrations both at 0.5% and 1.5% resulted in the highest mean values for GI (Table 2). The nonprimed control treatment showed GI mean value, which is not significantly different than KNO₃ concentration at 1% (Table 2). Potassium nitrate concentrations at 0.5% and 1.5% also showed similar higher means for MGR values (6.57 days each) than the rest of the treatments. An increase in germination and growth parameters as a result of seed priming with KNO₃ has been reported in different varieties of tomato by Ali et al. [6], where seed priming at 0.75% resulted in improved germination and growth parameters compared to other KNO₃ levels. In general, higher activities of total soluble sugars and phenolics were linked to improved performance of tomato seeds as a result of seed priming with KNO₃ compared to the nonprimed control [6]. Previous studies also revealed that various priming agents including halo priming improved the germination of tomato seeds [24, 25].

The highest SL was observed from the interaction of the Mersa variety with KNO₃ at 1.5% and was statistically at par with the interaction of the Mersa variety at 1% and variety Tekeze-1 at 0.5% KNO₃ concentrations (Table 3). In contrast, the lowest SL was observed from the interaction of both varieties at the control KNO₃ concentration and was statistically at par with the interaction of Mersa at 0.5% KNO₃, Tekeze-1 at 1%, and 1.5% KNO₃ concentrations. This study is
in line with the findings of Ali et al. [6] and Abnavi and Ghabadi [26] in which it showed improved shoot length as a result of priming with KNO₃. Oliveira et al. [27] reported seed priming with 0.5% and 1% KNO₃ enhanced vegetative growth in watermelon and Vaktabhai et al. [28] reported seed priming in tomatoes using halo-propriming in different varieties.

Table 2: Effect of priming with KNO₃ on the germination parameters and shoot length of tomato varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>G (%)</th>
<th>MGT (day)</th>
<th>GI (day)</th>
<th>T₅₀ (day)</th>
<th>PV (day %)</th>
<th>MGR (%)</th>
<th>SL (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>85.5a</td>
<td>3.52</td>
<td>6.41a</td>
<td>2.7</td>
<td>20.67</td>
<td>6.11a</td>
<td>3.75a</td>
</tr>
<tr>
<td>0.5</td>
<td>92.0b</td>
<td>3.3</td>
<td>7.49b</td>
<td>2.58</td>
<td>23.83</td>
<td>6.57b</td>
<td>4.72b</td>
</tr>
<tr>
<td>1.00</td>
<td>86.5a</td>
<td>3.43</td>
<td>6.81a</td>
<td>2.62</td>
<td>21.83</td>
<td>6.18a</td>
<td>5.02b</td>
</tr>
<tr>
<td>1.5</td>
<td>92.0b</td>
<td>3.44</td>
<td>7.23b</td>
<td>2.67</td>
<td>21.83</td>
<td>6.57b</td>
<td>5.15b</td>
</tr>
<tr>
<td>LSD(5%)</td>
<td>5.49</td>
<td>0.22</td>
<td>0.51</td>
<td>0.09</td>
<td>2.92</td>
<td>0.39</td>
<td>0.7</td>
</tr>
<tr>
<td>CV (%)</td>
<td>6</td>
<td>6.4</td>
<td>7.1</td>
<td>3.5</td>
<td>12.8</td>
<td>6</td>
<td>14.5</td>
</tr>
<tr>
<td>Mean</td>
<td>89</td>
<td>3.42</td>
<td>6.99</td>
<td>2.64</td>
<td>22.04</td>
<td>6.36</td>
<td>4.66</td>
</tr>
<tr>
<td>SE (m)</td>
<td>5.32</td>
<td>0.22</td>
<td>0.5</td>
<td>0.09</td>
<td>2.83</td>
<td>0.38</td>
<td>0.68</td>
</tr>
</tbody>
</table>

Means followed by the same letter (s) for the same parameters are not significantly different from each other at 5% level of significance. G, germination percent; MGT, mean germination time; GI, germination index; T₅₀, time to 50% germination; PV, peak value for germination; MGR, mean daily germination percent; SL, shoot length; LSD, least significant difference; KNO₃, potassium nitrate; CV, coefficient of variation; SE, standard error of the mean.

Table 3: Interaction effect of KNO₃ priming rate and variety on shoot length of tomato varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>KNO₃ rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.50 1 1.5</td>
</tr>
<tr>
<td>Mersa</td>
<td>3.75a 4.36a 5.97b 6.05c</td>
</tr>
<tr>
<td>Tekeze-1</td>
<td>3.75a 5.08b 4.07a 4.25b</td>
</tr>
<tr>
<td>LSD(5%)</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Means followed by the same letter are not significantly different from each other at a 5% level of significance and LSD, least significant difference.

4. Conclusions

The purpose of the present study was to evaluate two open-pollinated tomato varieties seeds in response to KNO₃ priming for germination parameters and shoot growth. The varieties differed significantly in the germination parameters and shoot length measured. The results also revealed that tomato seeds of both varieties (Mersa and Tekeze-1) primed with 0.5% and 1.5% showed better performance for G%, GI, and MGR parameters than other KNO₃ levels. The interaction effect was only observed for shoot length, where tomato varieties responded differently for shoot length under different rates of KNO₃. This study provides the existence of variation for tomato varieties in response to priming agents and indicated the possibility of enhancing seed germination in tomatoes for better productivity. However, more research is required, taking a range of priming techniques, other tomato genotypes, and environmental conditions into consideration.

Data Availability

The data used for this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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References