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Research Article

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_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_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_3. The interaction of the *Mersa* variety with KNO_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_3 concentration, indicating that the varieties have different responses to the applied KNO_3 rate. This study confirmed the possibility of enhancing seed germination through externally applied priming agents such as KNO_3. Despite being a preliminary finding, this study demonstrated that tomato cultivars differ in how they react to KNO_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 (KNO_3) 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% KNO_3 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 KNO_3 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 KNO_3 had a much shorter time spread of germination than those primed in solutions other than KNO_3.

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 KNO_3 on vegetables like tomato, however, are lacking in Ethiopia. The present study examined the relationships between seed priming with KNO_3 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 KNO_3 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% $HgCl_2$ 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) KNO_3 for 24 hours in an aerated blotter papers at room temperature (25°C). Following the priming with KNO_3 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 KNO_3 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/final germination percentage/germinability (GP) (%) measures germination capacity [19] and was computed as shown below.

$$\mathrm{GP}\,(\%) = \frac{N_g}{N_t}, \tag{1}$$

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

$$\mathrm{MGT}\,(\mathrm{day}) = \frac{\sum D_n}{\sum n}, \tag{2}$$

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]:

$$\mathrm{MGR}\left(\mathrm{day}^{-1}\right) = \frac{\sum_{i=1}^{k} N_i}{\sum_{i=1}^{k} N_i T_i}, \tag{3}$$

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

Table 1: Mean squares of analysis of variance for the effects of potassium nitrate osmopriming on germination parameters in two tomato varieties.

Source of variation	d.f	G (%)	MGT (day)	GI (day)	T_{50} (day)	PV (% day^{-1})	MGR (%)	SL (mm)
Variety	1	338.0***	0.86***	0.002^{ns}	0.10***	6.72^{ns}	1.73**	4.44***
KNO_3	3	97.33*	0.07^{ns}	1.80***	0.02^{ns}	13.83^{ns}	0.50*	3.21***
Variety: KNO_3	3	0.67^{ns}	0.04^{ns}	0.11^{ns}	0.01^{ns}	5.09^{ns}	0.004^{ns}	3.44***
Error	24	28.33	0.05	0.25	0.01	8.02	0.15	0.46

df, degree of freedom. *Significant at the 0.05 probability level, **significant at the 0.01 probability level. ***significant at the 0.01 probability level, and ^{ns} not significant. G%, germination percent; MGT, mean germination time; GI, germination index; T_{50}, time to 50% germination; PV, peak value for germination; MGR, mean daily germination percent; KNO_3, potassium nitrate.

germination starts to decrease and was determined as suggested by Czabator [22].

$$\mathrm{PV} = \max\left(\frac{G_1}{T_1}, \frac{G_2}{T_2}, \ldots, \frac{G_k}{T_k}\right), \tag{4}$$

where, T_i is the time from the start of the experiment to the ith 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]:

$$T_{50}\,(\text{day}) = t_i + \frac{\left((N/2) - n_i\right)\left(t_j - t_i\right)}{n_j - n_i}, \tag{5}$$

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:

$$\mathrm{GI}\,(\text{day}) = \sum_{i=1}^{k} \frac{N_i}{T_i}, \tag{6}$$

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 KNO_3 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 KNO_3 was also reported by previous studies in different tomato genotypes with different KNO_3 levels [6, 7]. However, only shoot length was significantly ($P < 0.01$) impacted by the variety × KNO_3 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 KNO_3.

Tomato seeds primed with 0.5% and 1.5% KNO_3 (weight/volume) had the highest G% mean values than other treatments followed by the control and 1% KNO_3 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 KNO_3 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 KNO_3 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 KNO_3 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 KNO_3 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 KNO_3 at 1.5% and was statistically at par with the interaction of the *Mersa* variety at 1% and variety *Tekeze-1* at 0.5% KNO_3 concentrations (Table 3). In contrast, the lowest SL was observed from the interaction of both varieties at the control KNO_3 concentration and was statistically at par with the interaction of *Mersa* at 0.5% KNO_3, *Tekeze-1* at 1%, and 1.5% KNO_3 concentrations. This study is

Table 2: Effect of priming with KNO_3 on the germination parameters and shoot length of tomato varieties.

Main effect	G (%)	MGT (day)	GI (day)	T_{50} (day)	PV (day %)	MGR (%)	SL (mm)
Variety							
Mersa	92.25[a]	3.59[a]	6.98	2.7[a]	21.58	6.59[a]	5.03[a]
Tekeze-1	85.75[b]	3.26[b]	7	2.59[b]	22.5	6.13[b]	4.29[b]
$LSD_{(5\%)}$	3.88	0.16	0.36	0.07	2.07	0.28	0.49
$KNO_{(3\%)}$							
Control	85.5[a]	3.52	6.41[a]	2.7	20.67	6.11[a]	3.75[a]
0.5	92.0[b]	3.3	7.49[b]	2.58	23.83	6.57[b]	4.72[b]
1.00	86.5a[c]	3.43	6.81[a]	2.62	21.83	6.18[a]	5.02[b]
1.5	92.0[b]	3.44	7.23[b]	2.67	21.83	6.57[b]	5.15[b]
$LSD_{(5\%)}$	5.49	0.22	0.51	0.09	2.92	0.39	0.7
CV (%)	6	6.4	7.1	3.5	12.8	6	14.5
Mean	89	3.42	6.99	2.64	22.04	6.36	4.66
SE (m)	5.32	0.22	0.5	0.09	2.83	0.38	0.68

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 KNO_3 priming rate and variety on shoot length of tomato varieties.

Variety	KNO_3 rate (%)			
	Control	0.50	1	1.5
Mersa	3.75[a]	4.36[a]	5.97[b]	6.05[b]
Tekeze-1	3.75[a]	5.08[b]	4.07[a]	4.25[a]
$LSD_{(5\%)}$	0.99			

in line with the findings of Ali et al. [6] and Abnavi and Ghobadi [26] in which it showed improved shoot length as a result of priming with KNO_3. Oliveira et al. [27] reported seed priming with 0.5% and 1% KNO_3 enhanced vegetative growth in watermelon and Vaktabhai et al. [28]reported seed priming in tomatoes using halo-propriming in different varieties.

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 KNO_3 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 KNO_3 levels. The interaction effect was only observed for shoot length, where tomato varieties responded differently for shoot length under different rates of KNO_3. 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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