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Effect of Seed Priming with Potassium Nitrate on the Performance of Tomato

Muhammad Moaaz Ali [1,†], Talha Javed [2,3,†], Rosario Paolo Mauro [4,*], Rubab Shabbir [2,3], Irfan Afzal [3] and Ahmed Fathy Yousef [1,5]

1 College of Horticulture, Fujian Agriculture and Forestry University, Fuzhou, Fujian 350002, China; muhammadmoaazali@yahoo.com (M.M.A.); ahmedfathy201161@yahoo.com (A.F.Y.)
2 College of Agriculture, Fujian Agriculture and Forestry University, Fuzhou, Fujian 350002, China; talhajaved54321@gmail.com (T.J.); rubabshabbir28@gmail.com (R.S.)
3 Seed Physiology Lab, Department of Agronomy, University of Agriculture, Faisalabad 38040, Pakistan; irfanuaf@gmail.com
4 Dipartimento di Agricoltura, Alimentazione e Ambiente (Di3A), Università degli Studi di Catania, Via Valdisavoia, 5-95123 Catania, Italy
5 Department of Horticulture, College of Agriculture, University of Al-Azhar (branch Assiut), Assiut 71524, Egypt
* Correspondence: rosario.mauro@unict.it; Tel.: +39-095-4783314
† Equally contributed authors.

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Abstract: The seed industry and farmers have challenges, which include the production of poor quality and non-certified tomato seed, which ultimately results in decreased crop production. The issue carefully demands pre-sowing treatments using exogenous chemical plant growth-promoting substances. Therefore, to mitigate the above-stated problem, a series of experiments were conducted to improve the quality of tomato seeds (two cultivars, i.e., "Sundar" and "Ahmar") and to enhance the stand establishment, vigor, physiological, and biochemical attributes under growth chamber and greenhouse conditions by using potassium nitrate (KNO_3) as a seed priming agent. Seeds were imbibed in 0.25, 0.50, 0.75, 1.0, and 1.25 KNO_3 (weight/volume) for 24 h and then dried before experiments. The results of growth chamber and greenhouse screening show that experimental units receiving tomato seeds primed with 0.75% KNO_3 in both cultivars performed better as compared to other concentrations and nonprimed control. Significant increase in final emergence (%), mean emergence time, and physiological attributes were observed with 0.75% KNO_3. Collectively, the improved performance of tomato due to seed priming with 0.75% KNO_3 was linked with higher activities of total soluble sugars and phenolics under growth chamber and greenhouse screening.

Keywords: *Solanum lycopersicum* L.; crop establishment; potassium nitrate; seed quality

1. Introduction

Tomato (*Solanum lycopersicum* L.) is a major vegetable crop on a global scale and one of the principle sources of phytonutrients [1,2], which makes it one of the preferred targets by researchers for metabolic engineering, as it is easily docile to biotechnological modifications [3]. Globally, being a vegetable of major economic importance, the tomato is a source of minerals and vitamins, as well as an anticancer agent [4]. 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 (1000 IU), ascorbic acid (22 mg), thiamin (0.09 mg), riboflavin (0.03 mg), and niacin (0.8 mg) [5]. In tomato, germination and crop establishment are the most crucial physiological stages that are affected by seed quality and genetics [6]. Rapid and uniform germination and seedling establishment is essential for increasing

tomato yield and quality [7], which is of economic importance in agriculture. Therefore, various seed enhancement approaches, such as coating, pelleting, and priming, can be responsible to a major extent for improved quality of seeds. Among these approaches, 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 [6,8].

Seed priming is a process of regulating the imbibition and active metabolism phases of germination before radical emergence followed by drying and maintenance of near to original moisture content [9]. It increases the ability of radical to protrude rapidly, as the initial stages of germination are already fulfilled even under environmental stresses [10]. Seed priming helps the plants to cope with the adverse effects of unfavorable environmental conditions [11,12]. According to Liu [13], priming improves the activities of anti-oxidative metabolites, such as superoxide dismutase and peroxidase, during seed germination. Priming helps the plants to accelerate cell division, transport stored proteins and hasten the speed of seed germination [14]. Seed priming improved germination and seedling vigor in tomato [9] by activation of antioxidants [15], reduced membrane permeability, and maintenance of tissue water contents [6].

Exogenous application of priming agents to the seeds have remarkable role for pre-sowing accomplishment of germination phases [16]. Sliwinska [17] reported that 42% of primed tomato root tip cells were arrested in the G2-phase of mitosis and did not complete cell division. Previous studies revealed the positive role of potassium nitrate (KNO_3) as a seed priming agent on seedling establishment and vigor [18]. In addition, considerable increase in germination potential and seedling vigor was observed in tomato seed treated with KNO_3 at the concentration of 50 mmol [19]. Similarly, exogenous KNO_3 treatment on rice seeds concurrently improved multiple aspects of germination and physiology. This implies that KNO_3 might play a signaling role in prompting a wide adaptation of rice seedlings [20]. Therefore, the present study was conducted to evaluate the effects of exogenously applied KNO_3 (0.25%, 0.50%, 0.75%, 1.0%, and 1.25%) as seed priming agent in two different tomato cultivars.

2. Materials and Methods

2.1. Seed Source

Six months old seeds of the pure line tomato cultivars "Sundar" and "Ahmar" (oval shaped fruit with regular leaves) were obtained from Ayyub Agricultural Research Institute, Vegetable Research Section, Faisalabad-38000, Punjab, Pakistan. The initial germination and seed moisture content before seed treatment were (86% and 10.5% in "Sundar"; 84% and 11% in "Ahmar"), respectively.

2.2. Seed Priming Treatments

Tomato seeds were primed/imbibed with 0.25%, 0.50%, 0.75%, 1.0%, and 1.25% (weight/volume) KNO_3 for 24 h at 25 °C. Pre-weighed seeds (5 g) were imbibed on two blotter papers in 9-cm diameter Petri dishes with appropriate concentration of KNO_3 solutions, followed by covering of dishes with aluminum foil. For aeration, a hole was provided in the center of each Petri dish. After each treatment, seeds were rinsed thoroughly with distilled water and dried back closer to original moisture level under shaded conditions. Nonprimed tomato seeds were maintained as control for comparison.

2.3. Experimental Site and Conditions

Growth chamber and greenhouse experiments were conducted at the research station of the University of Agriculture, Faisalabad, Punjab, Pakistan (30.37° N, 69.34° E) from 29 October 2019 to 1 December 2019. Well pulverized soil was collected from the field of the research station, and each plastic tray 35 cm × 25 cm × 15 cm in size was filled with 6 kg of soil. The textural class of soil was sandy loam having pH (6.8), electric conductivity (0.396 dS m^{-1}), available phosphorus (17.67 ppm), and potassium (353.96 ppm). After leveling the soil surface in each tray, moisture was applied up to

field capacity. In each tray, 30 seeds were sown with equal distance in the soil in both experiments and considered as one replicate. Both experiments were laid out in a completely randomized design with four replications. For growth chamber screening (optimal germination and growth conditions), all the trays were placed in the growth chamber with an optimal temperature of 25 °C and a light period of 12 h. The relative humidity during the complete execution of the growth chamber experiment was maintained at 65%. For the greenhouse experiment (suboptimal conditions), all the trays were placed in the greenhouse under natural environmental conditions. The climate data during the complete execution of greenhouse experiment is given in Figure 1.

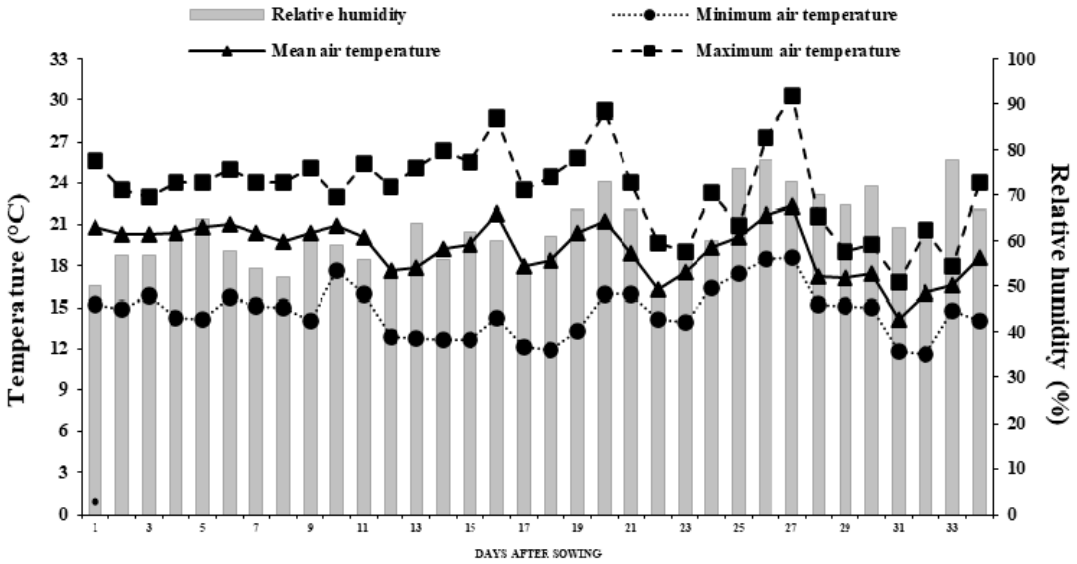

Figure 1. Microclimate conditions inside the greenhouse during the experiment at research station of University of Agriculture, Faisalabad, Punjab, Pakistan.

2.4. Seedling Establishment

Seedling emergence was recorded daily and recorded when the hypocotyl came above the soil surface. Final emergence, expressed on a percentage basis, was calculated as the ratio among number of emerged seedlings and total number of seeds sown at the end of the experiment [21]. Mean emergence time (days) was recorded as per the equation earlier reported by International Seed Testing Association (ISTA) [22]:

$$\text{Mean Emergence Time (MET)} = \frac{\sum \text{Dn}}{\sum \text{n}},$$

where n is the number of seeds which emerged on day D, and D is the number of days counted from the beginning of emergence.

2.5. Seedling Vigor

Thirty days after sowing (DAS) plant height was determined on 5 randomly selected seedlings. On the same date, both fresh and dry weight of tomato plants were recorded. For dry weight, plants were dried at 70 °C till constant weight in an oven.

2.6. Physiological Variables

At 30 DAS, i.e., with the plants at the stage of 6 true leaves, measurements of CO_2 index (μmol mol^{-1}), net photosynthetic rate (μmol CO_2 m^{-2} s^{-1}), and transpiration rate (μmol H_2O m^{-2} s^{-1}) were made on a fully expanded leaf from the top of the plant canopy by using an open system LCA-4 (ADC BioScientific Ltd., Hoddesdon, UK) portable infrared gas analyzer. Measurements were made between 6:00 a.m. and 7:00 a.m., with the following specifications: ambient pressure (P)

99.95 kPa, leaf chamber molar gas flow rate (U) 251 μmol s^{-1}, molar flow of air per unit leaf area (Us) 221.06 mol m^{-2} s^{-1}, temperature of leaf chamber (Tch) varied from 39 to 44 °C, Photosynthetically active radiation (PAR) at leaf surface was maximum up to 918 μmol m^{-2}, and leaf chamber molar gas flow rate (U) 251 μmol s^{-1}.

2.7. Biochemical Variables

To determine total phenolics, leaves were ground in liquid nitrogen by using pestle and mortar and a 20 μL sample was mixed with 1.60 mL distilled water, 100 μL Folin-Ciocalteu reagent ($_2$N), and 300 μL sodium carbonate solution in a test tube [23]. After 30 min at 40 °C in water bath, test tubes were immediately moved to an ice box and absorbance recorded at 765 nm with a spectrophotometer (UV 4000). The total soluble sugars (TSS) in leaf samples were determined by the anthrone method [24]. Ground leaf sample (25 mg) was mixed with 5 mL of $_{2.5}$NHCl in a test tube. Tubes were placed in water bath 100 °C for 3 h, followed by cooling of tubes at room temperature. By using distilled water, the volume of tube was made to 100 mL and centrifuged at 4000 rpm for 10 min. After that, 0.5 mL supernatant, 0.5 mL distilled water, and 4 mL anthrone (0.2% v/v anthrone on 95% sulfuric acid) was taken in another tube. The tube was heated again in boiling water bath for 8 min. The tube was cooled rapidly and reading was taken at 630 nm by using spectrophotometer (UV 4000).

2.8. Statistical Analysis

Collected data were subjected to a two-way analysis of variance (ANOVA) (2 genotypes × 6 KNO_3 level) and Tukey's honest significance difference (HSD) test for means comparison at 5% significance level, using the analytical software package 'Statistix 8.1'.

2.9. Greenhouse Microclimate Conditions During the Trial

During the experiment, the average mean temperature was 19.2 °C, with a sharp decrease from 22 to 14 °C (on 27 and 31 DAS, respectively), whereas average minimum and maximum temperatures oscillated between 12–19 °C and 17–30 °C, respectively (Figure 1). The average relative humidity varied between 49% and 78%, with the lowest value recorded at 22 DAS and highest one at 33 DAS (Figure 1).

3. Results

3.1. Growth Chamber Screening

3.1.1. Seedling Establishment

Seedling establishment of tomato includes seedling emergence (%) and the number of days required by seeds to germinate (mean emergence time—MET). The results of the present study indicated that the seed priming with KNO_3 improved the stand establishment of tomato (cv. "Sundar" and "Ahmar") grown in growth chamber. Tomato seeds primed with 0.75% KNO_3 had maximum emergence rate in both cultivars (98% "Sundar"; 99% "Ahmar"), so they were showing better performances when compared to the other treatments. Minimum germination (82% "Sundar"; 84% "Ahmar") was observed in nontreated seeds of tomato, while, in the case of MET, the maximum number of days (4–5) was observed in nontreated seeds of tomato. The seeds treated with 0.75% KNO_3 germinated earlier than all other treatments (Table 1).

Table 1. Final emergence (%) and mean emergence time (days) of tomato seedlings as affected by the cultivar and seed priming with potassium nitrate (KNO_3), under two different growth conditions.

	Treatments	Final Emergence (%)			Mean Emergence Time (Days)		
		"Sundar"	"Ahmar"	KNO_3 Mean	"Sundar"	"Ahmar"	KNO_3 Mean
Growth chamber	Control	82	84	83 ^{d}	5.3	4.7	5.0 ^{a}
	0.25% KNO_3	84	90	87 ^{c}	4.2	3.7	4.0 ^{b}
	0.50% KNO_3	89	93	91 ^{b,c}	3.3	3.5	3.4 ^{b,d}
	0.75% KNO_3	97	99	98 ^{a}	3.0	3.0	3.0 ^{d}
	1% KNO_3	89	93	91 ^{b,c}	3.3	3.1	3.2 ^{c,d}
	1.25% KNO_3	84	90	87 ^{c}	3.8	3.5	3.7 ^{b,c}
	Cultivar mean	88 ^{b}	92 ^{a}		3.8 ^{a}	3.6 ^{b}	
	$HSD_{interaction\ (p \leq 0.05)}$	7			0.7		
Greenhouse	Control	79	82	81 ^{e}	7.2	6.6	6.9 ^{a}
	0.25% KNO_3	81	85	83 ^{d}	6.3	5.8	6.0 ^{b}
	0.50% KNO_3	84	88	86 ^{c}	5.3	4.9	5.1 ^{c}
	0.75% KNO_3	93	97	95 ^{a}	3.9	3.6	3.7 ^{e}
	1% KNO_3	89	90	89 ^{b}	4.7	4.1	4.4 ^{d}
	1.25% KNO_3	82	85	84 ^{d}	5.2	5.3	5.3 ^{c}
	Cultivar mean	85 ^{b}	88 ^{a}		5.4 ^{a}	5.0 ^{b}	
	$HSD_{interaction\ (p \leq 0.05)}$	4			0.9		

Values sharing the same letters are non-significantly different ($p \leq 0.05$).

3.1.2. Seedling Vigor

Statistical analysis of data about seedling vigor revealed that the effect of seed priming treatments was significant in both "Sundar" and "Ahmar". All priming treatments significantly improved the seedling length in both cultivars, whereas the cultivar did not exert any significant effect. Maximum seedling length was achieved in tomato seed primed with 0.75% (8.36 and 8.35 cm in "Sundar" and "Ahmar", respectively), followed by 1% KNO_3 solution (7.5 and 7.8 cm), whereas the lowest values for seedling length in both cultivars was observed in control (5.2 and 5.3 cm). In both cultivars, plants raised from seeds treated with 0.75% KNO_3 showed higher values for seedling fresh weight (35.1 and 37.6 mg in "Sundar" and "Ahmar", respectively) and dry weight (17.9 and 19.1 mg) as compared to other treatments (Table 2).

Table 2. Seedling length, shoot fresh weight, and shoot dry weight of tomato as affected by seed priming with KNO_3 under two different growth conditions.

	Treatments	Seedling Length (cm)			Shoot Fresh Weight (mg)			Shoot Dry Weight (mg)		
		"Sundar"	"Ahmar"	KNO_3 Mean	"Sundar"	"Ahmar"	KNO_3 Mean	"Sundar"	"Ahmar"	KNO_3 Mean
Growth chamber	Control	5.2	5.3	5.2 ^{d}	25.7	24.4	25.1 ^{d}	10.9	12.9	11.9 ^{d}
	0.25% KNO_3	6.2	6.1	6.2 ^{c}	29.2	28.6	28.9 ^{c}	13.8	15.7	14.7 ^{c}
	0.50% KNO_3	7.2	7.4	7.3 ^{b}	32.5	34.7	33.6 ^{b}	16.0	16.6	16.3 ^{b}
	0.75% KNO_3	8.4	8.4	8.4 ^{a}	35.1	37.6	36.3 ^{a}	17.9	19.1	18.5 ^{a}
	1% KNO_3	7.5	7.8	7.7 ^{b}	31.9	32.4	32.2 ^{b}	15.4	16.9	16.2 ^{b}
	1.25% KNO_3	7.3	7.7	7.5 ^{b}	28.9	28.6	28.8 ^{c}	13.0	12.4	12.7 ^{d}
	Cultivar mean	7.0 ^{b}	7.1 ^{a}		30.5 ^{a}	31.1 ^{a}		14.5 ^{b}	15.6 ^{a}	
	$HSD_{interaction\ (p \leq 0.05)}$	0.7			2.5			1.9		
Greenhouse	Control	3.8	3.9	3.8 ^{d}	21.8	25.1	23.4 ^{c}	9.3	10.1	9.7 ^{c}
	0.25% KNO_3	4.5	4.9	4.7 ^{c}	24.3	24.1	24.2 ^{c}	10.1	11.2	10.6 ^{c}
	0.50% KNO_3	6.0	6.1	6.0 ^{b}	27.6	26.5	27.1 ^{b}	11.9	13.1	12.5 ^{b}
	0.75% KNO_3	7.0	7.1	7.0 ^{a}	30.3	32.1	31.2 ^{a}	14.6	14.4	14.5 ^{a}
	1% KNO_3	6.0	5.7	5.9 ^{b}	26.9	27.7	27.3 ^{b}	12.9	14.1	13.5 ^{a,b}
	1.25% KNO_3	6.1	6.2	6.1 ^{b}	23.9	24.9	24.4 ^{c}	10.4	11.6	11.0 ^{c}
	Cultivar mean	5.6 ^{a}	5.7 ^{a}		25.8 ^{b}	26.7 ^{a}		11.5 ^{b,c}	12.4 ^{a}	
	$HSD_{interaction\ (p \leq 0.05)}$	0.9			3.3			2.2		

Values sharing the same letters are non-significantly different ($p \leq 0.05$).

3.1.3. Physiological and Biochemical Attributes

The results shown in Tables 3 and 4 indicate that seed priming treatments significantly improved the physiological and biochemical attributes of both tomato cultivars, while the genotype effect was also found significant. The highest photosynthesis rate, transpiration rate, and CO_2 index were linked to tomato seeds treated with 0.75% KNO_3, whereas the lowest values were found in the nonprimed

seeds (Table 3). A statistical evaluation of data demonstrated that total soluble sugars and phenolic contents were significantly influenced by seed priming treatments. Though all the seed priming treatments proved successful to improving these biochemical attributes, highest values were observed in plants deriving from seeds primed with 0.75% KNO_3 under growth chamber screening (Table 4).

Table 3. Variations in physiological attributes of two tomato cultivars under the influence of seed priming with KNO_3 in two different growth conditions.

	Treatments	Photosynthetic Rate (μmol CO_2 m^{-2} s^{-1})			Transpiration Rate (μmol H_2O m^{-2} s^{-1})			CO_2 Index (μmol mol^{-1})		
		"Sundar"	"Ahmar"	KNO_3 Mean	"Sundar"	"Ahmar"	KNO_3 Mean	"Sundar"	"Ahmar"	KNO_3 Mean
Growth chamber	Control	9.7	10.7	10.2 ^{e}	0.81	0.92	0.86 ^{e}	110	113	111 e
	0.25% KNO_3	11.7	12.3	12.0 ^{d}	0.99	1.09	1.04 ^{d}	121	123	122 ^{d}
	0.50% KNO_3	13.8	14.8	14.3 ^{b,c}	1.21	1.29	1.25 ^{c}	138	141	139 ^{b}
	0.75% KNO_3	16.7	17.3	17.0 ^{a}	1.61	1.70	1.65 ^{a}	162	164	163 ^{a}
	1% KNO_3	14.9	16.3	15.6 ^{a,b}	1.30	1.40	1.35 ^{b}	144	145	145 ^{b}
	1.25% KNO_3	13.0	13.7	13.3 ^{c,d}	1.24	1.30	1.27 ^{c}	133	134	134 ^{c}
	Cultivar mean	13.3 ^{b}	14.2 ^{a}		1.19 ^{b}	1.28 ^{a}		135 ^{a}	137 ^{a}	
	$HSD_{interaction\ (p \le 0.05)}$	3.0			0.19			11		
Greenhouse	Control	11.0	12.7	11.8 ^{e}	1.01	1.12	1.06 ^{e}	121	123	122 ^{e}
	0.25% KNO_3	12.7	14.3	13.5 ^{d,e}	1.19	1.28	1.23 ^{d}	131	133	132 ^{d}
	0.50% KNO_3	15.1	17.0	16.1 ^{b,c}	1.41	1.49	1.45 ^{c}	148	152	150 ^{b}
	0.75% KNO_3	18.3	19.3	18.8 ^{a}	1.81	1.88	1.84 ^{a}	172	177	174 ^{a}
	1% KNO_3	16.3	18.3	17.3 ^{a,b}	1.51	1.60	1.55 ^{b}	154	155	155 ^{b}
	1.25% KNO_3	14.7	15.7	15.2 ^{c,d}	1.44	1.50	1.47 ^{c}	144	144	144 ^{c}
	Cultivar mean	14.7 ^{b}	16.2 ^{a}		1.39 ^{b}	1.47 ^{a}		145 ^{a}	147 ^{a}	
	$HSD_{interaction\ (p \le 0.05)}$	3.1			0.20			13		

Values sharing the same letters are non-significantly different ($p \le 0.05$).

Table 4. Variations in biochemical attributes of two tomato cultivars under the influence of seed priming with KNO_3 in two different growth conditions.

	Treatments	Total Soluble Sugars (mg g^{-1})			Phenolics (mg g^{-1})		
		"Sundar"	"Ahmar"	KNO_3 Mean	"Sundar"	"Ahmar"	KNO_3 Mean
Growth chamber	Control	70.2	64.5	67.4 ^{b}	1.29	1.27	1.28 ^{c}
	0.25% KNO_3	70.8	69.9	70.3 ^{b}	1.45	1.34	1.39 ^{c}
	0.50% KNO_3	83.5	82.5	83.0 ^{a}	1.70	1.65	1.67 ^{a,b}
	0.75% KNO_3	85.0	86.3	85.6 ^{a}	1.81	1.74	1.77 ^{a}
	1% KNO_3	80.8	79.0	79.9 ^{a,b}	1.75	1.53	1.64 ^{a,b}
	1.25% KNO_3	79.5	76.0	77.8 ^{a,b}	1.68	1.50	1.59 ^{b}
	Cultivar mean	78.3 ^{a}	76.4 ^{a}		1.61 ^{b}	1.50 ^{a}	
	$HSD_{interaction\ (p \le 0.05)}$	9.8			0.29		
Greenhouse	Control	71.3	65.6	68.4 ^{c}	1.33	1.26	1.29 ^{e}
	0.25% KNO_3	71.7	71.2	71.5 ^{b,c}	1.51	1.35	1.43 ^{d,e}
	0.50% KNO_3	84.5	83.0	83.7 ^{a}	1.74	1.63	1.68 ^{b,c}
	0.75% KNO_3	88.8	87.2	88.0 ^{a}	1.86	1.76	1.81 ^{a}
	1% KNO_3	83.8	80.2	82.0 ^{a,b}	1.79	1.52	1.65 ^{a,b}
	1.25% KNO_3	79.7	77.3	78.5 ^{a,c}	1.73	1.49	1.61 ^{c,d}
	Cultivar mean	79.9 ^{a}	77.4 ^{a}		1.66 ^{b}	1.50 ^{a}	
	$HSD_{interaction\ (p \le 0.05)}$	11.0			0.24		

Values sharing the same letters are non-significantly different ($p \le 0.05$).

3.2. Greenhouse Screening

3.2.1. Seedling Establishment

Seed priming treatments improved the final emergence of both tomato cultivars under greenhouse conditions. The highest emergence values were recorded in tomato seed primed with 0.75% KNO_3 (93.29% and 96.68% in "Sundar" and "Ahmar", respectively), whereas the lowest ones were found in the nonprimed seeds. Seed priming with 1% KNO_3 proved to improve the final emergence of both cultivars too (88.7% in "Sundar" and 90.1% in "Ahmar") (Table 1). In both cultivars, no variation in final emergence was observed among experimental units receiving tomato seed primed 0.50% and 1% KNO_3. However, when compared to the other treatments, the lowest MET value was recorded in tomato seeds primed with 0.75% followed by 1% KNO_3. Besides, both nontreated cultivars showed the highest values for MET (Table 1).

3.2.2. Seedling Vigor

Seedling length of both tomato cultivars is presented in Table 2, and data revealed that maximum seedling length in both cultivars was achieved in tomato seed primed with 0.75% (7.0 and 7.1 cm in "Sundar" and "Ahmar", respectively), followed by 1.25% KNO_3 solution (6.1 and 6.2 cm in "Sundar" and "Ahmar", respectively), whereas the lowest ones were recorded in the control (3.8 and 3.8 cm in "Sundar" and "Ahmar", respectively). Seed priming with KNO_3 also proved effective in improving the seedling fresh and dry weight; nonetheless, the effect of different cultivars was not pronounced. Plants in both cultivars raised from seeds treated with 0.75% KNO_3 showed higher values for seedling fresh (30.3 mg in "Sundar" and 32.1 mg in "Ahmar") and dry weight (14.6 and 14.4 mg, respectively) as compared to all other treatments. No significant difference in seedling fresh and dry weight was observed among tomato seed treated with 0.50% and 1.0% KNO_3 in both cultivars (Table 2).

3.2.3. Physiological and Biochemical Variables

Seed priming treatments improved the physiological and biochemical of both tomato cultivars under greenhouse conditions. Higher values for photosynthetic rate, transpiration rate, and CO_2 index were recorded in experimental units receiving tomato seed primed with 0.75% KNO_3 as compared to control (Table 3), while in the case of genotypes, "Ahmar" showed better photosynthetic rate and transpiration rate as compared to "Sundar". Seed priming with 1% KNO_3 improved the physiological attributes of both cultivars, too. No variation in physiological attributes was observed among experimental units receiving tomato seed primed 0.50% and 1% KNO_3 in "Ahmar". In the same way, maximum total soluble sugars were observed in tomato seeds primed with 0.75% followed by 1% KNO_3 (Table 4). The lowest values for phenolic contents were recorded in control in both cultivars (Table 4).

4. Discussion

4.1. Seedling Establishment

Tomato seed priming with KNO_3 affected the emergence of seedling and the speed of seed germination. Major events in other literature on priming includes metabolic changes, such as repair of DNA and increases in the biosynthesis of RNA [25], and enhancement in the respiration process of seed [26]. This indicates that the time of seed imbibition is very important for seed priming. For the study of seed priming of tomato with different levels of KNO_3, it is important to know about the emergence percentage and mean emergence time. The results of the present study indicate that the performance of both tomato cultivars primed with 0.75% KNO_3 was appreciable in growth chamber, as well as in greenhouse screening, meaning that this effect was still appreciable under suboptimal growth conditions. The pattern of seedling emergence and mean emergence time were almost the same in both cultivars, as well as in both growth environments (growth chamber and greenhouse). The time of water intake by the seed during priming can vary within the cultivars, which can affect the performance of the seed priming agent (KNO_3) [27]; similarly, in our study, the difference between the performance of both cultivars were seen.

The data shown in Table 1 indicated that priming of tomato seeds with 0.75% KNO_3 was better than other treatments in terms of final emergence and mean emergence time. Our study is in correspondence with another study that revealed that the emergence percentage of wheat seeds was decreased when they were primed with >1% KNO_3 [28]. This indicates that KNO_3 concentration above a certain threshold may not be appropriate to boost seed germination. Seed priming with 1% KNO_3 was found useful in terms of emergence percentage in sorghum [29] and rice [30]. Besides, soybean seed primed with 1% KNO_3 for 1 day enhanced the emergence percentage as compared to nontreated seeds, both in laboratory and field experiments [18].

4.2. Seedling Vigor

Seedling vigor is the combined result of the emerged seeds under a wide range of biotic and abiotic stresses. Seedling vigor is not a single measurable entity, but it is a sum of many growth parameters, such as seedling length, seedling fresh weight, and seedling dry weight [22]. Maximum vigor was observed when seed priming with 0.75% KNO_3 was done. Our study is in line with another study in which seedling vigor of wheat was improved by priming with KNO_3 [28]. Similar results were found in corn when the priming of seed was done with 1% KNO_3 [31]. Our findings are similar to other studies, in which the shoot length of watermelon and tomato were increased by the seed priming with KNO_3 [32,33]. Seed priming with 0.5% and 1% KNO_3 improved the vegetative growth of watermelon [34] and tomato [35], respectively, under salt stress. Seed priming with KNO_3 can cause a significant increase in seedling vigor of the wheat crop as compared to hydro-priming or dry broadcasting [36].

4.3. Physiological and Biochemical Attributes

Plant growth is based mainly upon photosynthesis, while its performance is mostly dependent on the opening/closing of stomata, which modulates photosynthetic rate, respiration rate, and CO_2 index [37–39]. The results of the present study revealed that the maximum photosynthesis rate, transpiration rate, and CO_2 index was observed in tomato plants grown by seeds primed with 0.75% KNO_3, compared to other priming treatments. Our study is in corroboration with another study in which the increased photosynthetic rate, respiration rate, and CO_2 index of cucumber seedlings as the result of seed priming with KNO_3 were reported. The photosynthesis rate of the seedlings has a positive correlation with the growth of seedling [40]. The results of the present study revealed that the biochemical attributes, e.g., total soluble sugars and phenolic content, of tomato plants were enhanced by seed priming with KNO_3. The maximum increase was observed when seeds were treated with 0.75% KNO_3, while minimum values were seen in nonprimed seedlings. Previous studies expressed that seed priming with KNO_3 significantly improved the biochemical indices of chicory [41] and rice [20].

5. Conclusions

The performance of tomato is diminished by the poor quality of seed. Therefore, the present study was conducted to improve the quality of tomato seed by priming with KNO_3. The results presented in this paper revealed that tomato seeds of both cultivars primed with 0.75% KNO_3 proved to be successful for improving seedling establishment and vigor, as well as physiological and biochemical attributes, under growth chamber and greenhouse conditions. The present study provides the direction towards further molecular investigation related to the seed priming of tomato.

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