

Research Article

Tomato (*Lycopersicum esculentum* L.) Seed Hydrotime Analysis on Physiological and Seedling Growth Parameters in Ethiopia

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Seed companies and farmers prioritize seeds that exhibit strong crop performances. Among the major challenges in tomato seed production are poor germinability and disease-related issues. Caution measures considered in hydropriming, a widely used seed priming method, effectively enhance seed vigor and germination. This study aimed to optimize and determine optimal soaking duration for the germination, growth, and development of tomato seedlings under greenhouse conditions during the 2020/2021 cropping season in Ethiopia. Accordingly, we utilized a completely randomized design experiment for two tomato varieties (Melka Salsa and Melka Shola), optimizing five priming durations (12, 24, 36, and 48 h). Experimental data showed that hydropriming significantly improved seedling performances, mainly with a soaking duration of 48 h for the Melka Shola variety, whereas Melka Salsa showed a high germination percentage at 36 and 48 h. Hydroprimed seeds exhibited increased seedling lengths and vigor indices compared to nonprimed ones. Hydroprimed seeds exhibited increased seedling lengths and vigor indices compared to nonprimed controls, which displayed inferior growth. Notably, the number of leaves and roots improved significantly, indicating enhanced vegetative growth. Therefore, a 48 h hydropriming treatment is recommended for optimal seedling establishment in tomato cultivation, which could enhance crop yield and performance.

Keywords: crop yield; germination; hydropriming; Melka Salsa; Melka Shola; seed vigor; seedling growth; soaking duration; tomato seedlings

1. Introduction

Tomato ranks among the major vegetable crops cultivated globally [1]. The economic significance of tomatoes is attributed to their nutritional value, essential minerals, and vitamins as well as their potential health benefits, including being anticancer agents [2]. On the contrary, the production of poor-quality and noncertified tomato seeds poses significant challenges in the tomato seed industry, leading to decreased crop yields [3, 4]. High crop yield depends on the use of high-vigor seeds on top of optimal agrometeorological factors. Thus,

seed growth stages such as the initial stage of plant development and seed germination are widely employed to stimulate germination and enhance fertilization [5, 6]. Again, reports have shown that the quality of seeds and their genetic makeup significantly influence the critical physiological stages of germination and seedling establishment in tomatoes [7]. Rapid and uniform germination, along with effective seedling establishment, is essential for improving the quality and yield of tomatoes [3]. Consequently, various seed enhancement strategies, including seed priming that alters vigor or physiological status,

are more often utilized to improve the physiological quality of crop seeds [3].

Seed priming can be categorized into several types: hydropriming (soaking seeds in water), halopriming (using salt solutions), osmopriming (using osmotic solutions), and hormone priming [8]. Among these, hydropriming is the simplest and most commonly employed method in crop production. It is a low-cost and eco-friendly technique that involves soaking seeds in either hot or cold water, without the use of chemicals, for a specified duration prior to sowing [4, 9]. It has been shown that hydropriming tomato and other vegetable seeds can trigger germination, seedling vigor, uniform seedling emergence, and growth parameters [3, 4, 10–12]. This method is simple, inexpensive, and effective for improving crop performance [13]. Garcia et al. [14] also demonstrated that seed priming technology is a viable strategy for effectively enhancing morphophysiological characteristics, optimizing enzyme metabolism, and regulating phytohormones. Freshly harvested tomato seeds often exhibit dormancy, which can last up to a year [15]. Such prolonged dormancy can adversely impact tomato production globally by affecting seed availability in required quantities. The introduction of seed priming is supposed to solve such challenges, overcoming photo- and thermodormancy, a broader germination temperature range, improved nutrient uptake, and enhanced water use efficiency [16, 17]. Coherently, a study by Cheng and Bradford [18] demonstrated that tomato seed hydropriming is used to break dormancy, speed up germination, and improve uniformity of radicle emergence. As a result, seed enhancement technology of hydropriming could be proposed as a viable option both to enhance low-vigor seeds and for dormancy breaking. Sushma et al. [19] found that optimum duration of seed hydropriming and seed to water ratio enhanced seed vigor of tomato. However, there is limited research in the study area regarding the optimal priming duration for enhancing the germination and vigor characteristics of tomatoes. Therefore, this study aims to analyze hydropriming duration and assess the response of improved tomato varieties to hydropriming for physiological and initial growth parameters in Fogera district, Northwestern Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area. This experiment was conducted at the Fogera National Rice Research and Training Center in Fogera District, Northwestern Ethiopia, during the year 2021 cropping season under greenhouse conditions. The experimental site is located at a latitude of 11°49'55" N and a longitude of 37°37'39" E, with an altitude of 1815 m above sea level. A mean annual rainfall of 1230.20 mm and average minimum and maximum temperatures of 12 and 28°C were recorded, respectively. A recent report has indicated that the soil in the study area was predominantly clayey, with 0.21% total nitrogen (N) and 9.85 mg/kg available phosphorus (P). The soil also has exhibited a high cation exchange capacity of 57 meq/100 g [20].

2.2. Experimental Materials and Design

2.2.1. Seed Source. Seeds from two tomato varieties, Melka Shola and Melka Salsa, were utilized for this study. These seeds were

obtained from the Horticulture Research Division at the Fogera National Rice Research and Training Center in Fogera, Ethiopia.

2.2.2. Treatment Design and Setting. A greenhouse experiment was conducted at Fogera National Rice Research and Training Center, Woreta, Ethiopia. Tomato seed physiological parameters were determined. Tomato seed samples of all primed seeds with durations of 12, 24, 36, and 48 h, along with the control, were kept in a refrigerator at 4°C immediately before use. Subsequently, a pot experiment was conducted under greenhouse conditions, employing a factorial combination of two tomato varieties. A completely randomized experimental design was utilized with four replications during the experiment.

2.2.3. Seed Sorting and Experimental Screening. Poor tomato seeds, including red-colored seeds and seeds that are floating over water, were separated. The remaining pure seeds were dried at room temperature until the moisture content was reduced to 10%. A standard germination test was performed prior to soaking. Then, pure seeds were primed with distilled water for the duration of 12, 24, 36, and 48 h. Priming was done at an average temperature of 20.44°C and relative humidity of 62.19%.

For germination, a total of 200 seeds from each variety (50 seeds with four replications), were completely immersed in petri dishes containing wet blotter paper. After 14 days of soaking, we generated data on initial germination percentage and final germination percentage, seedling length, seedling fresh weight, seedling dry weight, seedling vigor index-I, and seedling vigor index-II.

2.2.4. Pot Experimental Details. Primed tomato seeds were transferred into growth pots filled with wet soil. Each pot has a width of 35 cm by 27 cm and a depth of 33 cm, containing 3.12 kilograms of sieved soil. Each experimental pot was irrigated with 1 L of water every morning for 14 days, according to literature [21]. A total of 3 g of urea and 7 g of NPS were applied to each pot. After 14 days, we generated data on seedling length, shoot and root length, stem diameter, and the number of leaves and roots.

2.3. Data Collection. For standard germination percentage analysis, data recording was started after 5 days of sowing and continued for 14 days as entailed in Sushma et al. [19]. For other parameters, data were collected after 14 days as described later.

2.3.1. Standard Germination Percentage. A germination test was conducted to assess the standard germination rates for each priming duration across the two tomato varieties. The standard germination percentage was calculated using the formula as in Equation (1) [22].

$$\text{Standard germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds sown}} \times 100. \quad (1)$$

2.3.2. Seedling Length, Root Length, and Shoot Length (cm). Ten germinated seedlings were randomly selected from each replicate at the end of the germination test, and then root length, shoot length, and total seedling length were measured

TABLE 1: Effect of soaking duration on physiological and growth parameters (mean $\pm$ SEM) of tomato varieties.

Parameters	Varieties	Soaking hours				
		0	12	24	36	48
SG (%)	Melka Salsa	67.25 $\pm$ 4.92 ^d	70.25 $\pm$ 4.47 ^{cd}	77.5 $\pm$ 2.78 ^{bc}	79.75 $\pm$ 3.47 ^{ab}	86.50 $\pm$ 1.84 ^a
	Melka Shola	63.25 $\pm$ 2.49 ^d	69 $\pm$ 4.12 ^{cd}	70 $\pm$ 1.82 ^{cd}	77 $\pm$ 2.73 ^c	80.25 $\pm$ 1.10 ^{ab}
SL (cm)	Melka Salsa	6.33 $\pm$ 0.17 ^c	6.66 $\pm$ 0.12 ^{bc}	6.57 $\pm$ 0.14 ^{bc}	6.97 $\pm$ 0.11 ^{ab}	7.41 $\pm$ 0.09 ^a
	Melka Shola	6.55 $\pm$ 0.10 ^{bc}	6.57 $\pm$ 0.14 ^{bc}	6.78 $\pm$ 0.27 ^{bc}	6.69 $\pm$ 0.21 ^{bc}	7.33 $\pm$ 0.17 ^a
SSL (cm)	Melka Salsa	4.44 $\pm$ 0.09 ^b	4.59 $\pm$ 0.11 ^b	4.49 $\pm$ 0.18 ^b	4.86 $\pm$ 0.16 ^{ab}	5.16 $\pm$ 0.08 ^a
	Melka Shola	4.62 $\pm$ 0.08 ^b	4.68 $\pm$ 0.08 ^b	4.72 $\pm$ 0.23 ^b	4.70 $\pm$ 0.13 ^b	5.19 $\pm$ 0.24 ^a
SRL (cm)	Melka Salsa	1.84 $\pm$ 0.05 ^d	2.07 $\pm$ 0.02 ^{abc}	2.12 $\pm$ 0.05 ^{ab}	2.11 $\pm$ 0.05 ^{ab}	2.25 $\pm$ 0.03 ^a
	Melka Shola	0.89 $\pm$ 0.13 ^{cd}	1.94 $\pm$ 0.00 ^{bcd}	1.99 $\pm$ 0.08 ^{bcd}	2.07 $\pm$ 0.03 ^{abc}	2.14 $\pm$ 0.08 ^{ab}

Note: Means followed by the same superscript letters for the same parameters are not significantly different from each other at 5% level of significance. Abbreviations: SG, standard germination; SL, seedling length; SRL, seedling root length; SSL, seedling shoot length.

in centimeters. The shoot length was measured from the point of attachment of the cotyledon to the tip of the seedling. The average seedling length was calculated as described in Equation (2) [19].

$$\text{Seedling length (cm)} = \text{Shoot length (cm)} + \text{root length (cm)}. \quad (2)$$

Total root area counts and measurements were reported based as per Jo and Shin [23] with minor modifications.

2.3.3. Fresh Seedling and Dry Weight (g). Seedlings were harvested 14 days after germination, and both fresh and dry weights of the shoots and roots were measured. Initially, the fresh weight of the randomly selected seedlings was recorded, and the mean weight was calculated. Accordingly, seedlings were subjected to a drying process in a hot air oven at 72°C for 24 h. After this treatment, the dry weight of the seedlings was measured, and the mean dry weight was computed [19].

2.3.4. Stem Diameter. Randomly selected plants were cut perpendicularly, and the stem diameter was measured manually using a graduated measuring tape, with slight modifications to the diameter sensors as described by Wang et al. [24].

2.3.5. Leaf and Root Number. The number of leaves was determined by counting them, and the same method was used to count the roots from 10 representative seedlings. A photograph of each of the 10 normal seedlings was taken. The numbers of leaves and roots were counted manually, which are visible in the photograph as per Jo and Shin [23] with slight modifications.

2.3.6. Seedling Vigor Index. The seedling vigor index was determined using the formula from Abdul-Baki and Anderson [25], as in Equation (3).

$$\text{Seedling vigor index I} = \text{Standard germination} \times \text{average seedling length}. \quad (3)$$

Seedling vigor index II was calculated by multiplying the standard germination percentage by the mean seedling dry weight.

TABLE 2: Mean separation of standard germination the improved tomato varieties.

SG (mean)	TV
76.2 ^a	MSA
71.9 ^b	MSH

Note: Means with the same letter are not significantly different. Abbreviations: MSA, Melka Salsa; MSH, Melka Shola; SG, standard germination; TV, tomato variety.

$$\text{Seedling vigor index II} = \text{Standard germination} \times \text{average seedling dry weight}. \quad (4)$$

2.4. Data Analysis. Analysis of variance (ANOVA) was employed during data analysis. The least significant difference (LSD) test was applied for the mean separation at a significance level of $p < 0.05$ [26].

3. Results and Discussion

3.1. Standard Germination Percentage (%). Both vegetative growth and seed germination are crucial phases of plant development that are susceptible to both biological and physical stresses [27]. Tomato seed viability and germination are initial steps in seedling performance. Standard germination percentage showed a significant difference for each priming duration and for tomato varieties ($p \leq 0.0004$). The result was found in agreement with the report by Akram et al. [28], showing priming treatment and genotype affecting seedling growth. Our study demonstrated that the standard germination percentage was significantly greater at 48 h of hydropriming for the Melka Shola variety compared to the control, as depicted in Table 1. Similar study by Nafees et al. [29] indicated that longer soaking hours at room temperature significantly enhanced tomato seed germination compared to unprimed seeds. The Melka Salsa variety also exhibited a significant increase in standard germination as compared to Melka Shola ($p \leq 0.05$; Table 2). It was noted, however, that standard germination was significantly enhanced at relatively shorter hydropriming durations for Melka Salsa variety. The highest germination percentage was

recorded as high as 86.50 ± 1.84 , followed by 79.75 ± 3.47 for the hydropriming duration of 48 and 36 h, respectively, for the Melka Salsa variety. In contrast, the control treatments had a germination percentage of 67.25 ± 4.92 (Table 1). A study by Venkatasubramaniam and Umarani [30] showed similar results on tomato seeds for a 48 h duration. Similarly, studies by Adhikar et al. [31] and Patel and Pa [32] demonstrated that hydro priming brought about positive enhancement in germination percentages compared to control. Furthermore, a study by Sushma et al. [19] explained a maximum germination percentage of 8.2% obtained within 24 h of priming duration compared to unprimed seeds. With their respective optimal hydropriming treatments, the Melka Salsa variety showed superior standard germination over the Melka Shola counterparts (Table 2). A study by Yang et al. [33] demonstrated that tomato seed germination is fundamentally manipulated by phytohormones, conditioning the physiological mechanisms of tomato seeds for faster germination during hydropriming.

These findings indicated germination in tomatoes has been affected by different hydropriming durations and tomato varieties. The marked increase in germination percentage at 48 h, according to our results, might be attributed to the initiation of metabolic processes and an increase in alpha-amylase activity. These findings aligned with a study by Hamdollah and Kamyar [34], who noted that soaking seeds in water led to a rapid increase in germination rates, likely due to enhanced water uptake and earlier initiation of metabolic processes [35, 36]. Hydropriming could also facilitate the softening of the seed coat, promoting the biological processes necessary for germination, thus resulting in earlier germination [37]. Additionally, it reduced initial imbibition variations among plants, leading to more uniform germination [38].

Results demonstrated that there was a significant difference in standard germination percentages between the two tomato varieties, indicating genetic variations could be among the main acting factors (Tables 2 and 3). A similar study by Thakur et al. [39] demonstrated that hydroelectrostatic hybrid priming found to enhance germination indices and vigor of tomato seeds. The potential synergism among several priming procedures conferred fast germination of tomato seeds via hormone regulation and the reprogramming of gene expression.

3.2. Seedling Length (cm). Seedling length can be considered as indicator of field performance as it is associated with vigor index-I. Hydropriming for 48 h significantly increased the seedling length of the Melka Salsa tomato variety (Table 3; $p \leq 0.05$). Seedlings treated with this duration measured 7.41 ± 0.09 cm seedling length, which is significantly greater than the control treatment (averaged 6.33 ± 0.17 cm). Unprimed tomato seeds did not show a statistically significant difference in seedling length compared to seeds hydro-primed for 12 h (6.66 ± 0.12 cm) and 24 h (6.57 ± 0.14 cm; Table 3). For the Melka Shola variety, the seedling length after 48 h of hydropriming (7.33 ± 0.17 cm) was significantly longer than the control treatment (6.55 ± 0.10 cm). In contrast, the 12, 24, and 36-h priming durations did not show significant differences compared to the control (Table 2). Both varieties exhibited significantly reduced seedling lengths in the unprimed dry seed control.

TABLE 3: ANOVA table for priming duration of different physiological and seedling growth parameters under seeds of improved tomato varieties.

Parameters	Source of variation				
	Trt DF	Error DF	F-value	p-Value	CV
SG	9	30	5.03	$p \leq 0.01$	8.65
SD	9	30	1.87	0.090	4.68
RN	9	30	6.99	$p \leq 0.01$	11.14
VI-I	9	30	7.1	$p \leq 0.01$	10.26
VI-II	9	30	7.12	$p \leq 0.01$	15.66
SL	9	30	4.57	$p \leq 0.01$	6.55
SSL	9	30	2.74	$p \leq 0.01$	4.83
SRL	9	30	3.36	$p \leq 0.01$	6.68
SFW	9	30	3.67	$p \leq 0.01$	15.98
SDW	9	30	4.96	$p \leq 0.01$	10.67
NL	9	30	2.65	$p \leq 0.01$	4.7

Abbreviations: Error DF, error degree of freedom; NL, number of leaves; RN, root number; SD, stem diameter; SDW, seedling dry weight; SFW, seedling fresh weight; SG, standard germination; SL, seedling length; SRL, seedling root length; SSL, seedling shoot length; SV, source of variation; Trt DF, treatment degree of freedom; VI-I, vigor index-I; VI-II, vigor index-II.

The increased growth of seedlings from primed seeds could be attributed from the direct effects of pretreatment on cell cycle regulation and mechanisms of cell elongation [40, 41]. This finding is supported by Adhikar et al. [31], who reported that hydropriming improved seedling height. Early germination and emergence lead to rapid seedling growth, contributing to increased height. Similar results were observed by Ogbuehi et al. [42], Mehta et al. [43], and Shakuntala et al. [44], who reported improved shoot lengths in groundnut, bitter melon, and cucurbits, respectively, when seeds were sown after priming compared to those that were not primed.

3.3. Seedling Fresh and Dry Weight (g). Seedling fresh and dry weights are assumed indicators of growth quality because they are associated with vigor index-II. Maximum seedling fresh and dry weights were observed after 36 and 48 h of priming for the Melka Shola and Melka Salsa varieties, respectively (Table 1). Umair et al. [45] reported that hydropriming increased seedling dry weight under laboratory conditions. Hamdollah and Kamyar [34] also reported that hydropriming significantly improved seedling dry weight. It was noted that better root establishment was indirectly linked to hydropriming treatments that had led to quicker plant growth and enhanced nutrient absorption [46].

3.4. Seedling Shoot and Root Length (cm). Root and shoot lengths are critical parameters in fruit growth for plants [47]. Seedling shoot and root length in our experiments were measured on a centimeter scale. The longest shoot and root lengths were observed after 48 h of hydro-priming for both Melka Salsa and Melka Shola varieties, significantly surpassing other treatment combinations ($p \leq 0.05$). The data generally indicated an increasing trend in seedling shoot and root lengths with longer soaking durations, showing statistical differences after 48 h durations (Table 1). These findings aligned with the results of

TABLE 4: Effect of soaking duration on seedling fresh weight, dry weight and vigor indices.

Parameters	Varieties	Soaking hours				
		0	12	24	36	48
SFW	M. Shola	0.06 ± 0.00^{bc}	0.06 ± 0.00^b	0.06 ± 0.00^{bc}	0.07 ± 0.00^a	0.07 ± 0.00^a
	M. Salsa	0.05 ± 0.00^c	0.06 ± 0.00^{bc}	0.05 ± 0.01^{bc}	0.06 ± 0.01^{bc}	0.07 ± 0.01^a
SDW	M. Shola	0.01 ± 0.00^{bc}	0.05 ± 0.00^{bc}	0.01 ± 0.00^{bc}	0.01 ± 0.00^b	0.01 ± 0.00^a
	M. Salsa	0.01 ± 0.00^c	0.01 ± 0.00^{bc}	0.01 ± 0.00^{bc}	0.01 ± 0.00^{bc}	0.01 ± 0.00^a
VI-I	M. Shola	4.16 ± 0.20^c	4.58 ± 0.10^{bc}	4.67 ± 0.29^{bc}	5.08 ± 0.13^b	5.16 ± 0.27^a
	M. Salsa	4.28 ± 0.42^c	4.70 ± 0.37^{bc}	5.08 ± 0.08^{bc}	5.92 ± 0.30^{ab}	6.03 ± 0.12^a
VI-II	M. Shola	0.01 ± 0.00^d	0.01 ± 0.00^{cd}	$0.01 \pm 0.00^{b-d}$	0.01 ± 0.00^{bc}	0.01 ± 0.00^a
	M. Salsa	0.01 ± 0.00^d	$0.01 \pm 0.00^{b-d}$	$0.01 \pm 0.00^{b-d}$	0.01 ± 0.00^b	0.01 ± 0.00^a

Note: Means followed by the same letters for the same parameters are not significantly different from each other at 5% level of significance.

Abbreviations: M. Salsa, Melka Salsa; M. Shola, Melka Shola; SDW, seedling dry weight; SFW, seedling fresh weight; VI-I, vigor index-I; VI-II, vigor index-II.

Umair et al. [48], who reported that priming mung bean seeds with water enhanced shoot and root growth under laboratory conditions.

3.5. Seedling Vigor Index-I. Seedling Vigor Index-I is a multiplication result of seedling length and standard germination percentage. The results revealed that increased water soaking duration significantly increased the seedling vigor index-I ($p \leq 0.05$) (Tables 2 and 4). For the Melka Salsa variety, seedlings that were hydroprimed for 48 h exhibited a significantly higher vigor index-I (6.03 ± 0.12) compared to those from shorter hydropriming durations except it was statistically comparable to the results of 36 h hydropriming treatment (5.92 ± 0.3). Similarly, for the Melka Shola variety, the maximum seedling vigor index-I was observed at 48 h (5.16 ± 0.27), while the minimum was recorded in the control (4.16 ± 0.20). Both tomato seed varieties showed statistically similar vigor index-I results for priming durations of 0, 12, and 24 h (Table 4). This finding aligned with Thakare et al. [47], who noted that oxygenated peptone treatments enhanced vigor index-I in chick-pea seeds. Similarly, Umair et al. [48] reported improvements in vigor index-I for mung beans due to hydro-priming.

3.6. Seedling Vigor Index-II. Seedling Vigor Index-II is a direct measure of seedling dry weight and standard germination percentage, which is actually expressed without units. A 48 h hydropriming treatment significantly enhanced the seedling vigor index-II ($p \leq 0.05$) in both the Melka Salsa and Melka Shola varieties, compared to the control (Table 1). These results suggested that a 48-h hydropriming duration is optimal for achieving better seedling vigor index-II compared to the control. Both improved tomato varieties exhibited statistically similar results for vigor index-II across studied durations, while the 36 h duration significantly differed from the control. This outcome aligns with Adhikari et al. [31], who found that the most vigorous seedlings, in terms of both vigor index-I and II, were recorded after 48 h of hydropriming.

3.7. Number of Leaves and Root Number. The number of leaves and roots for both tomato varieties differed significantly ($p \leq 0.05$) from the control after 48 h of hydropriming. The highest number of leaves recorded was 3.65 ± 0.06 for Melka Shola and 3.85 ± 0.08 for Melka Salsa. For Melka Salsa, the

priming durations of 12, 24, and 36 h were comparable to the control. In contrast, for Melka Shola, the 12 h hydropriming was comparable with the control, while the 12, 24, 36, and 48 h treatments were statistically similar regarding the number of leaves (Table 4).

For the Melka Salsa variety, the greatest root count was observed at 48 h of hydropriming, followed by 36 h, while the other durations (0, 12, and 24 h) were statistically similar (Table 5). Similarly, hydropriming has been shown to increase the speed and uniformity of germination for garden cress and basil after 12 h, improving early growth [49]. The differences in the number of leaves across priming durations might be attributed to genetic factors, as environmental conditions remained uniform.

3.8. Stem Diameter. Stem diameter was measured on a millimeter scale. Stem diameter was significantly greater for the Melka Salsa variety at 48 h of hydropriming and at 36 h compared to the control ($p \leq 0.05$; Table 5). Similarly, for Melka Shola, the stem diameter at 48 h showed a significant increase, followed by 36 h, compared to the control (Table 5). This increase in stem diameter might be due to longer imbibition times, which enhance the metabolites in tomato seeds. Conversely, insufficient imbibition time may hinder seeds from breaking dormancy or absorbing adequate nutrients. This finding contrasts with Sikhondze and Ossom [50], who reported that seedlings grown from seeds primed for 24 h exhibited the greatest mean stem length and diameter compared to other durations and controls.

4. Conclusion

The study demonstrated that hydropriming significantly enhanced the growth and vigor of tomato seedlings, with optimal effects observed at a soaking duration of 36 and 48 h. Both Melka Salsa and Melka Shola varieties exhibited increased germination percentages, seedling lengths, and higher seedling vigor indices when hydroprimed for 48 h duration. Notably, the number of leaves and roots also significantly improved, indicating enhanced vegetative growth compared to control (unprimed) seeds. Unlike Melka Shola, Melka Salsa tomato variety demonstrated earlier hydro-priming durations (36 h) for standard germination and significantly greater in germination values. Thus, implementing hydropriming treatment

TABLE 5: Effect of soaking duration on growth parameters (mean $\pm$ SEM) of tomato varieties.

Parameters	Varieties	Soaking hours				
		0	12	24	36	48
NL	Melka Shola	3.4 ± 0.09^d	$3.5 \pm 0.10^{b-d}$	3.6 ± 0.13^{abc}	3.7 ± 0.08^{ab}	$3.65 \pm 0.06^{a-c}$
	Melka Salsa	3.4 ± 0.08^{cd}	$3.5 \pm 0.07^{b-d}$	3.6 ± 0.08^{abc}	3.6 ± 0.08^{abc}	3.85 ± 0.08^a
SD	Melka Shola	2.8 ± 0.04^{bc}	2.8 ± 0.06^{bc}	2.9 ± 0.00^{bc}	2.9 ± 0.07^a	2.91 ± 0.05^{ab}
	Melka Salsa	2.7 ± 0.08^c	2.8 ± 0.06^{bc}	2.9 ± 0.07^{bc}	2.9 ± 0.07^b	3.10 ± 0.07^a
RN	Melka Shola	2.2 ± 0.11^a	2.3 ± 0.14^a	2.3 ± 0.16^a	2.4 ± 0.14^a	2.50 ± 0.18^a
	Melka Salsa	2.2 ± 0.10^c	2.2 ± 0.08^c	2.6 ± 0.06^c	2.9 ± 0.19^b	3.30 ± 0.11^a

Note: Means followed by the same letters for the same parameters are not significantly different from each other at 5% level of significance.

Abbreviations: NL, number of leaves; RN, root number; SD, stem diameter.

being vital for better seedling establishment in tomato cultivation, potentially leading to improved tomato seed yield and performance. For further confirmation, researches are required in strengthening the recommendation provided and to affirm for other varieties.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement

This study was conducted in accordance with ethical standards of institutional review boards and got permission to be published.

Disclosure

All authors have agreed to be accountable for all aspects of the work. The funders has no role in design of the study, data collection, analysis, and interpretation of the results.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Yilikal Melak Assaye contributed to the study conception and design, analysis and interpretation of the data, drafting of the paper, revised the comments, and submitted the final approval version to be published. Esuyawkal Demis Tenaw conducted the greenhouse experiment and progressed the drafted paper. Karta Kaske Kalsa revised the paper critically for rational content.

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