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The Impact of Hydropriming and Halopriming on Seed Vigor and Germination of Tomato (*Solanum lycopersicum*) Seeds at High Temperature

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ABSTRACT

Seed priming techniques have been widely used to enhance germination, increase germination uniformity and improve seedling establishment. This study was designed to assess the impact of hydropriming or halopriming with 10, 25, 50, or 100 mM NaCI on the seed germination of tomato (*Solanum lycopersicum*) under heat stress conditions. All treatments significantly improved the seed vigor as indicated by increased germination percentage (G%), mean germination time (MGT), germination rate index (GRI), and coefficient velocity of germination (CVG) of primed seeds compared with unprimed ones. All treatments except priming with 10 mM NaCl considerably increased the mean germination rate (MGR) and a germination value (GV) above that of the control. Overall, 100 mM NaCl was superior to the other treatments in improving the measured indices.

Keywords: Germination, Halopriming, Heat stress, Hydropriming, Seed vigor, Tomato seed

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INTRODUCTION

It is anticipated that the atmospheric temperature will rise up to 4.8°C by 2100 (1). Thus, it may further result in changes in both geographical distribution and growing seasons of crops. (2). Furthermore, temperature and light are both significant environmental factors that regulate seed germination (3). It has also been reported that temperature is crucial in influencing both the capacity and rate of germination of many crops (4) including tomatoes (5, 6). In addition, it has also been asserted that a small rise in the mean atmospheric temperature above a critical threshold may remarkably decrease crop productivity (7). The profound effects of high temperature on vegetative and reproductive phases, the quality and yield of fruit have been reported (8, 9). Heat stress has also been reported to induce a significant reduction in the germination of a number of tomato hybrids (5). Germination inhibition of tomato seeds grown at 37 and 35°C has been observed in previous studies (6, 10). Germination and early seedling establishment are decisive phases in the plant life cycle. Seed vigor is an important aspect that empowers rapid and uniform emergence and growth in a range of environmental conditions (11). Therefore, there have been many attempts to improve seed vigor, seed viability, and seedling establishment under both normal and stressed conditions such as salinity and drought. To enhance seed vigor, several pre-germination treatments, described as seed priming, have been examined and developed (3, 12). Seed priming is a pre-sowing treatment in which seeds are partially hydrated to ensure germination metabolic processes commence, sometimes accelerated by growth regulators, but seeds are held in the lag phase of germination thus preventing radical emergence. This biological technique has been widely practiced due to its desired effects on germination, seedling vigor, plant development, and yield (13). There are numerous priming media utilized; however, hydropriming and halopriming are the most commonly adopted (12).

Hydropriming is a term describing the soaking of seeds in water prior to sowing. Previous works elucidated that hydropriming effectively improved the final germination, germination index, energy of emergence and growth of *Gerbera jamesonii* (14), and tomato (*Solanum lycopersicum*) (15). Moreover, hydropriming has also proved effective in enhancing the seed vigor of mountain rye (*Secale montanum*) (16) and faba bean (*Vicia faba*) seeds (17). Similarly, beneficial effects of hydropriming on germinability of okra (*Abelmoschus esculentus*) seeds were also reported (18). Halopriming involves the soaking of seeds in an adjusted osmotic potential of an inorganic salt solution. However, specific priming agents, osmotic potential, and length of soaking time are critical factors in successful halopriming protocols (12, 19). It has been reported that NaCl as a halopriming agent resulted in the enhancement of seed germination and seedling vigor of many plants. For instance, halopriming with NaCl significantly increased the germination capacity, mean germination time, and germination index of safflower (*Carthamus tinctorius*) (20) and rice (*Oryza sativa*) (21). Raising the temperature by 10-15°C above the optimum is commonly ascribed as heat stress (22). The optimum temperature for the germination of tomato seeds is reported to be 25°C (6, 23). The objective of this investigation was to elucidate the effects of hydropriming and halopriming with different concentrations of NaCl on the germination vigor of tomato seeds under heat stress conditions (35°C).

METHODOLOGY

Source and Viability of Seeds

The tomato (Solanum Lycopersicum cv. Rio Grande) seed batch used in this experiment was obtained from a local supplier in Bani Walid, which is about 180 km southeast of Tripoli, Libya. These seeds were originally imported from La Semiorto Sementi, Italy by Jebal Atlas Company (Tripoli). According to the label the seeds were produced at the end of 2019 and expire at the end of 2022. However, a preliminary test revealed that unprimed, these seeds have a low germination percentage (35% at 25 °C). The low seed viability could be due to improper storage which is most likely due to long hours of power outage throughout the year.

Priming Protocols

For halopriming, 60 seeds were soaked in 100 ml of 10, 25, 50, or 100 mM NaCl solutions. For hydropriming, 60 seeds were immersed in distilled water. Priming treatments were carried out at room temperature for 24 h. After priming, NaCl primed seeds were rinsed thoroughly with distilled water to eliminate traces of salt. Then, treated seeds were surface dried and left to dry back approximately to their original weight under ambient conditions. Unprimed seeds (UP) served as control.

Germination Test

Primed and unprimed seeds were placed in 9 cm Petri dishes on two sheets of Whatman No. 1 filter paper and watered with 10 ml distilled water. Three replicates with twenty seeds of each treatment were put in an incubator at 35 °C and kept under a 16:8 h day/night regime. The Petri dishes were arranged in a completely randomized design. Seeds were deemed germinated when the radical was at least 2 mm long. Germination was recorded each 24 h for 14 days.

Indices

Germination percentage (GP), mean germination time (MGT), mean germination rate (MGR), coefficient of the velocity of germination (CVG), germination rate index (GRI), germination value (GV), and germination index (GI) were estimated to assess the impact of priming treatments on the germination vigor. The MGR and GV were evaluated utilizing the equations of Ranal and Santana (24). The other germination parameters were computed according to Kader (25).

Statistical Analysis

The data were subjected to one-way analysis of variance using Minitab software (version 16), and comparisons of means made by Tukey's Honestly Significant Difference Test (HSD) at $P < 0.05$ level of confidence.

RESULTS

Variations in germination percentage (GP), mean germination rate (MGR) and germination index (GI), mean germination time (MGT), germination rate index (GRI), germination value (GV) and coefficient velocity of germination (CVG) of tomato seeds, across different priming treatments are presented in Figures 1-7, respectively. Generally, the analysis of variance revealed that there were significant effects of priming treatments on the examined germination indices at $P \leq 0.05$.

GP of unprimed control seeds at 35 °C was 15%, considerably lower than the 35% recorded at 25 °C, confirming the adverse effect of heat stress. All of the priming treatments increased the GP compared with unprimed seeds (Figure 1). However, it is evident that significantly the greatest enhancement of GP was induced by treating seeds with 100 mM NaCl. The GP of these treatments was 95% compared with 15% of untreated seeds.

With regard to MGR (Figure 3), the results revealed that all pre-sowing treatments, except 10 mM NaCl, significantly improved the MGR compared with unprimed seeds. In fact, the MGR of 10 mM NaCl primed seeds did not differ significantly from all pre-sowing seed treatments. It is also evident from Figure 2 that all pre-sowing treatments significantly decreased the MGT compared with the control. However, there was no significant difference between priming treatments.

Germination index was also influenced by priming treatments (Figure 4). Compared with unprimed seeds, all treatments significantly improved the GI. Priming seeds with 100 mM NaCl gave a higher GI than the other three halopriming techniques but was not significantly more effective than hydropriming.

The GI of 100 mM NaCl and hydroprimed seeds was 378.3 and 295, respectively, compared with 25 recorded in untreated seeds. With regard to the GRI of tomato seeds, analysis of variance revealed that both hydropriming and halopriming treatments increased it significantly above that of untreated seeds (Figure 5). The highest GRI was observed in seeds primed with 100 mM NaCl. However, the GRI value of this regime did not differ significantly from those obtained with 50 mM NaCl and hydroprimed seeds.

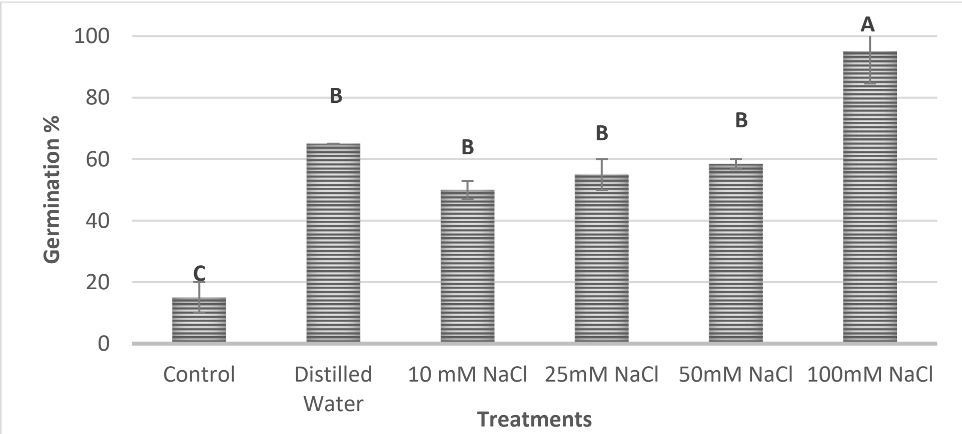

Figure. 1: The Effect of Priming Treatments on the Germination Percentage of Tomato Seeds. Means not followed by the same letter differ significantly at P ≤ 0.05.

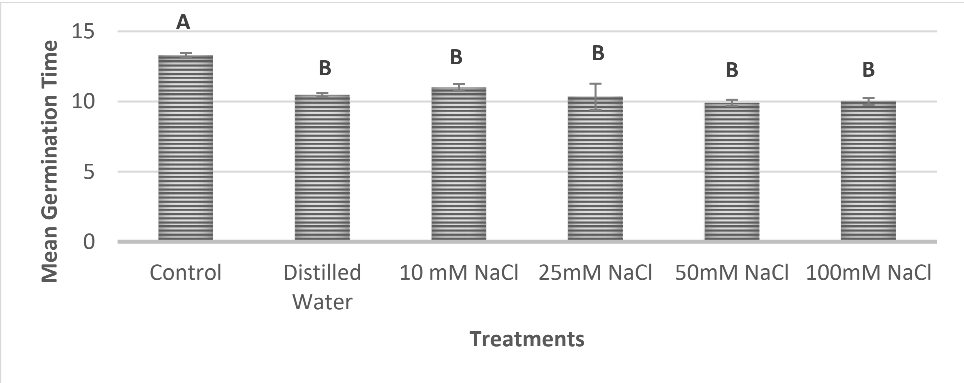

Figure 2: The Effect of Priming Treatments on the Mean Germination Time of Tomato Seeds. Means not followed by the same letter differ significantly at P ≤ 0.05.

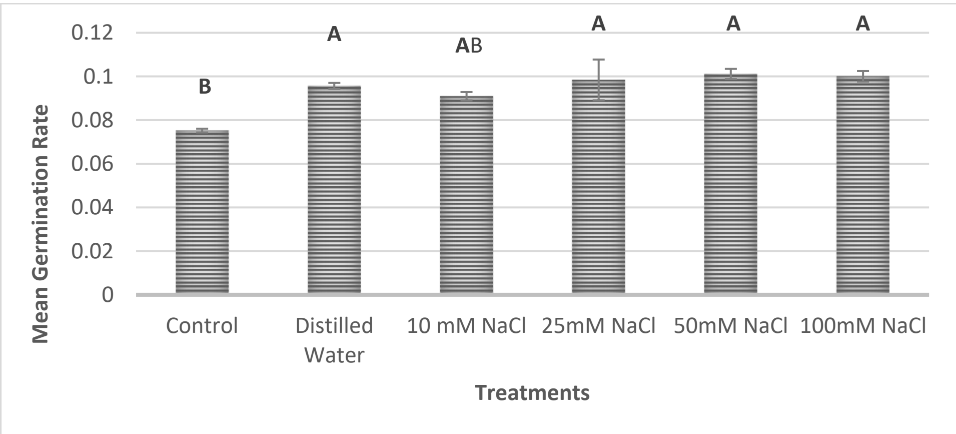

Figure 3: The Effect of Priming Treatments on the Mean Germination Rate of Tomato Seeds. Means not followed by the same letter differ significantly at P ≤ 0.05.

In addition, the GRI of the hydroprimed seeds was statistically similar to all four halopriming protocols. With regard to GV (Figure 6), the results revealed that all pre-sowing treatments, except 10 mM NaCl, significantly improved the GV compared with unprimed seeds. The highest GVs were recorded in 100 mM NaCl and hydroprimed seeds and these two treatments did not differ significantly. In fact, the germination value of hydroprimed seeds did not differ significantly from any of the halopriming protocols. The GV of 100 mM NaCl primed seeds was 6.6 compared with 0.011 observed in the control. Pre-sowing seed treatments also considerably enhanced the CVG of tomato seeds compared with untreated ones (Figure 7). Among all treatments, halopriming with 100 and 50 mM NaCl induced a greater CVG than priming with 10 or 25 mM NaCl but did not differ significantly from hydropriming. Furthermore, the CVG of hydroprimed seeds was also statistically similar to that recorded with 10 and 25 mM haloprimed seeds.

DISCUSSION

Exposure of plants to temporary or continuous heat stress may cause a severe decline in productivity through the induction of morphological, molecular, physiological, and biochemical alterations. It influences crops at different stages of development (22, 26), including germination (22). However, the threshold for heat stress-induced symptoms varies among species. Heat stress may induce a significant reduction in the germination speed, and germination capacity may be entirely inhibited (22).

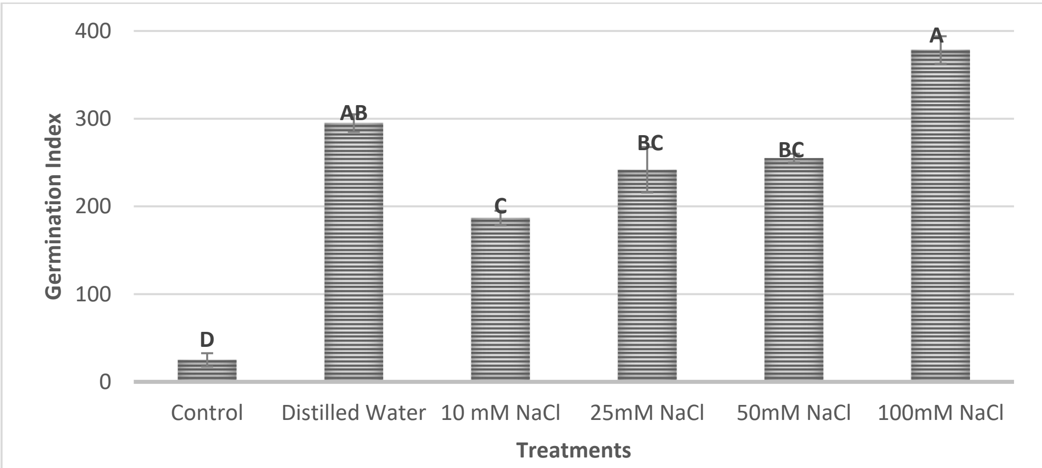

Figure 4: The Effect of Priming Treatments on the Germination Index of Tomato Seeds. Means not followed by the same letter differ significantly at P ≤ 0.05.

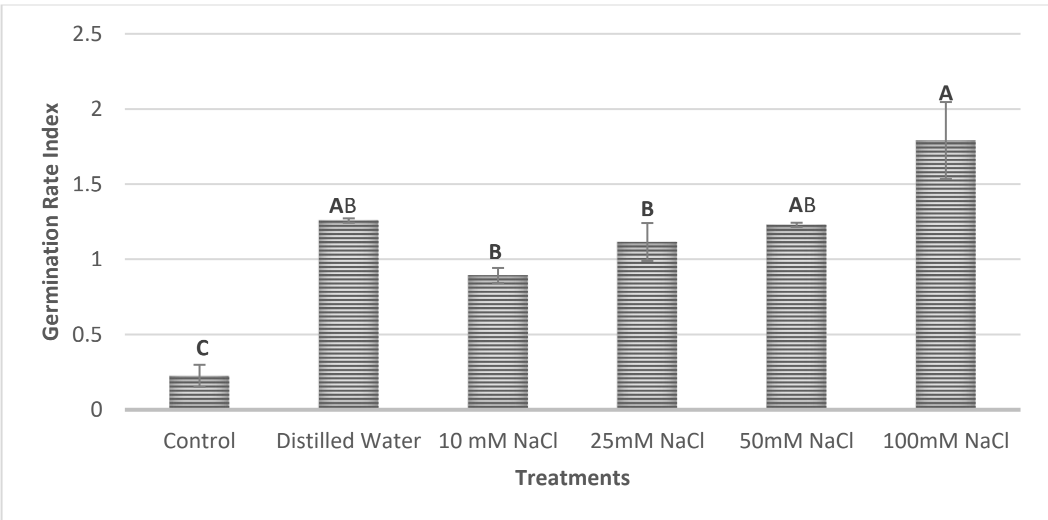

Figure 5: The Effect of Priming Treatments on the Germination Rate Index of Tomato Seeds. Means not followed by the same letter differ significantly at P ≤ 0.05.

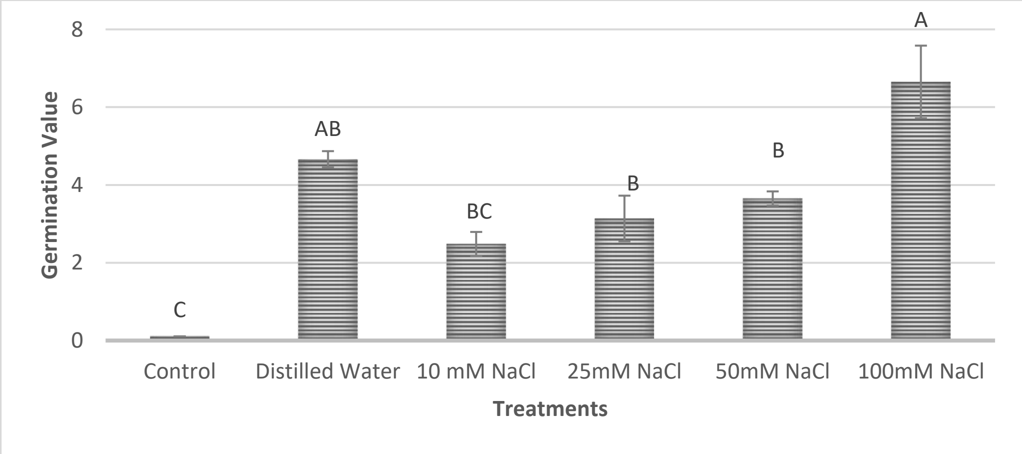

Figure 6: The Effect of Priming Treatments on the Germination Value of Tomato Seeds. Means not followed by the same letter differ significantly at P ≤ 0.05.

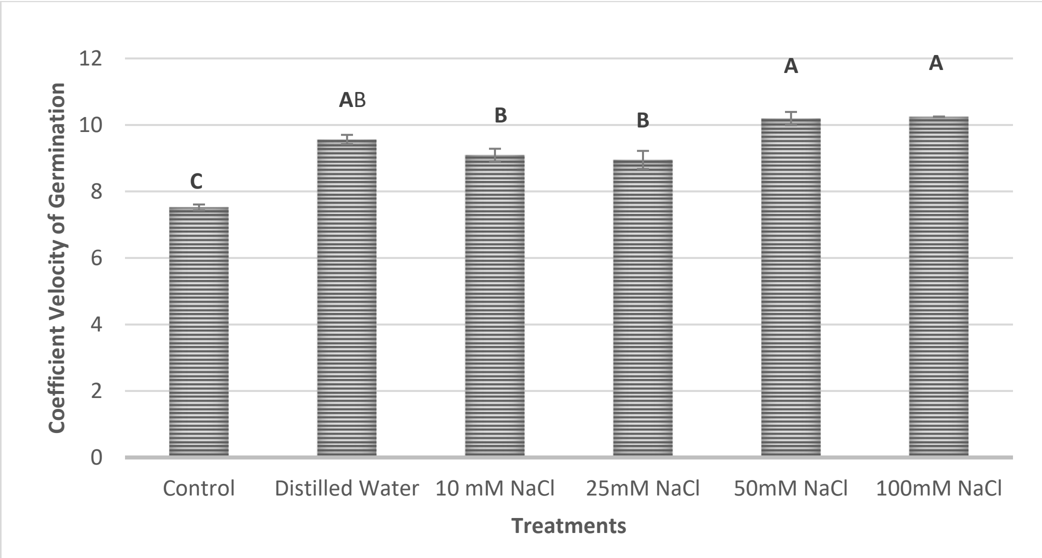

Figure 7: The Effect of Priming Treatments on the Coefficient of Velocity of Germination of Tomato Seeds. Means not followed by the same letter differ significantly at P ≤ 0.05.

Vigorous seeds and seedlings are crucial for crop establishment because of their contribution to crop growth uniformity, maturity, and productivity. Therefore, enhancing seed vigor is a principal task to ensure successful crop establishment and development (17), particularly under stress conditions including high temperature. This investigation revealed that both hydropriming and halopriming are effective in enhancing seed vigor under heat stress conditions as illustrated by improved germination percentage (GP), germination rate (GR), germination index (GI) coefficient of the velocity of germination (CVG) of tomato seeds. Much research has elucidated that hydropriming advanced germination of several crops resulting in greater germination and seedling vigor and seedling development. The results recorded in this study are in line with Ansari and Zadeh (16) who reported that the germination capacity, normal seedling, GI, MGT, CVG, and seedling vigor index (SVI) of hydroprimed mountain rye seeds were higher than those of untreated controls. Similarly, soaking faba bean seeds in distilled water for 8, 16, or 24 h considerably enhanced their GR, GI and MGT compared with unprimed seeds (17). Furthermore, hydropriming of pepper (*Capsicum annum* cv. Goliath) seeds for 18 or 24 h significantly increased the CVG, coefficient of the velocity of emergence (CVE), emergence %, and coefficient uniformity of germination (CUG), and reduced MGT and T50 of germination and emergence (27). An earlier investigation, (28) also showed that hydropriming rice seeds for 24 h resulted in remarkable enhancement of seedling vigor as indicated by improved time to reach 50% germination, MGT, GR, germination energy (GE), GV, Peak Value (PV), MDG, GI and Relative Growth Index (RGI). Hydropriming also effectively increased the GP, germination rate, GRI, and seedling length of spinach (*Spinacia oleracea*) under heat stress conditions (30 °C) (29).

The effectiveness of halopriming treatments with NaCl on the germination vigor of several plants has also been widely reported. For instance, NaCl as a priming agent significantly improved the GP, MGT, GI, and CVG of safflower seeds (20). Similarly, 1% NaCl significantly decreased MGT, T50% emergence and coefficient of variation (CV), and improved seedling vigor of two tomato rootstocks (30). Significant enhancement of seed vigor of tomato seeds as depicted by improved GP, GR, GI, germination energy (GE) and decreased MGT has also been observed (31). The beneficial effects of NaCl on germination vigor of *Acacia cyanophylla* seeds as indicated by significant improvement of GI, GRI, and GV have been reported (32). Furthermore, it has also been reported that halopriming seeds of white clover (*Trifolium repens* cv. Ladino) seeds with 0.5, 1, or 2.5 mM NaCl significantly improved the germinability, GI, and GV, and reduced MGT under water stress conditions but not under normal growth conditions (33).

It has been stated that temperature is one of the main aspects that influence the germinability and rapidity of germination. It regulates the metabolism engaged in the process of germination through direct involvement in seed imbibition and in the biochemical reactions (3). However, exposing plants to temporary or continuous heat stress may adversely affect crops at different stages of development including germination (22, 26). High temperature can cause a severe decline in productivity through the induction of morphological, molecular, physiological, and biochemical alterations (22). The poor performance of unprimed seeds observed in this study could be due to hyperaccumulation of reactive oxygen species which can cause inhibition of enzymes, harm the chromatin and encourage early senescence (34), and disturb membrane integrity and metabolic processes (26).

The reduction in MGT, and the enhancement of GI, MGR, GRI, CVG, and GP of primed seeds compared with unprimed controls is an indicator of earlier and synchronized germination and consequently improvement in seed vigor of tomato seeds. It has been claimed that seed vigor determines the capability of rapid, uniform germination and the establishment of robust seedlings in harsh environments (35). Moreover, it has also been asserted that the speedy emergence of seedlings would induce greater resource attainment and better usage consequently ensuing better yield (36). Thus, it is anticipated that halopriming with 100 mM NaCl or hydropriming tomato seeds may result in greater performance under normal and abnormal environmental conditions. In addition, although all NaCl concentrations and hydro priming improved the measured germination indices, overall, 100 mM NaCl was superior in this regard. This observation confirms the assertion that the priming media and the osmotic potential of the priming agents are among the factors affecting the efficacy of seed priming (12, 19). Furthermore, the advantageous impact of priming on germination vigor of many crops has been attributed to several biochemical and physiological changes including enhanced replication of DNA (37, 38, 39), regulation of ROS synthesis (29), repair of cellular and subcellular damage or membrane repair (40, 41), restoration of cellular integrity (42, 43), and activation of antioxidant enzymes (40, 44, 45).

CONCLUSION

It can be concluded that halopriming with 100 mM NaCl and hydro priming is effective regimes in alleviating the deleterious impact of heat stress as indicated by enhanced seed vigor of tomato seeds. It is evident from the results that priming has effectively raised the germination percentage of untreated seed six-folds. This enhancement would improve the seedling establishment of low-quality seeds which is considered as one of the prime targets of crop growers. These protocols are safe, cost-effective, and easily adopted by farmers. Additional investigation should also be conducted to assess the efficacy of these two regimes on the emergence and seedling growth under field seedlings.

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