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Reviewed by
Amrit Lamichaney
Sikkim University
Gangtok,Sikkim India
Email: alamichaney@cus.ac.in

***Correspondence**
Sanjay Kumar
sanjaykumar10187@mail.com

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Affiliation
[1]ICAR- National Research Centre on Seed Spices, Ajmer – 305206
[2]ICAR-Indian Institute of Millet Research, Regional Research Station, Barmer

Impact of hydro priming on seed germination and field emergence in ajwain (*Trachyspermum ammi* L.)

Sanjay Kumar[1]*, S.N. Saxena[2], M.K. Mahatma[1] and Ravi Y[1]

Abstract

Seed priming, a pre-sowing treatment aimed at enhancing germination speed and early seedling vigor, was evaluated in Ajwain (*Trachyspermum ammi* L.). Hydropriming durations significantly influenced germination and seedling vigour parameters. Seeds primed for 65 hours exhibited the shortest germination initiation time (16 hours) compared to 66 hours in non-primed seeds and 94 hours in seeds primed for 10–15 hours, highlighting the importance of optimal hydration for metabolic activation. The shortest Mean Germination Time (66 hours) and the highest germination uniformity were observed with hydropriming durations of 50–55 hours, demonstrating enhanced synchronization and seedling vigor. Although field emergence rates remained statistically insignificant across treatments, the hydropriming for 40-50 hours significantly enhance the speed of field emergence, seedling length and biomass (fresh and dry weights) (45 DAS), as compared to the control, indicating physiological benefits under field conditions. However, non-significant impact on seed yield (g plot^{-1}) was observed, likely due to environmental variability. These findings revealed that hydropriming can be used as a potential tool for improving germination speed and early seedling vigour in Ajwain, with possible applications in other seed spice crops.

Keywords : Ajwain, field emergence, germination, hydropriming, seedling vigor, seed spices, seed yield.

Introduction

Ajwain, a small-seeded seed spice crop of the *Apiaceae* family, is highly valued in domestic and international markets for its culinary, therapeutic, and pharmaceutical applications. The seeds, rich in bioactive compounds like thymol and carvacrol, exhibit carminative, digestive, and anti-inflammatory properties, making them indispensable in traditional medicine and the food industry. India leads in global ajwain production, cultivating approximately in 35,000 hectares with production of about 28,000 tonnes (Spice Board, 2023-

24). The crop is primarily grown in Rajasthan, Gujarat, and Karnataka, with Rajasthan contributing the largest share in terms of area and production. Ajwain is typically cultivated as a *rabi* crop under semi-arid tropical conditions, thriving in well-drained loamy or alluvial soils.

Despite its economic significance, ajwain cultivation faces challenges such as limited availability of quality seeds, slow germination rates, and inadequate marketing infrastructure, particularly in Rajasthan. The crop's tiny seed size (1000-seed weight: 0.95 g) increases its vulnerability to environmental stress, resulting in delayed seedling emergence (13–15 days) under field conditions. This delay emergence necessitates multiple irrigations (usually 2-3 before the field emergence), increasing production costs and impacting farmer profitability. Enhancing germination speed and uniformity is, therefore, critical to reducing emergence time and resource use.

Seed priming, a pre-sowing treatment involving controlled hydration, is a proven technique for improving germination and seedling vigor. It activates metabolic processes essential for germination without visible radicle emergence, thereby accelerating germination and enhancing uniformity and stress resilience. Previous studies in seed spices such as fennel (Tahaei, *et al.,* 2016), coriander (Aymen and Cherif, 2013), nigella (Espanany *et al.,* 2016) cumin (Rahimi, 2013), ajwain (Mishra *et al.,* 2023; Ghawade *et al*., 2024), Carum carvi (Mirmazloum *et al.,* 2020) and dill (Mirshekari, 2012) have demonstrated the potential of priming to improve field emergence, mean germination time, T_{50}%, and yield.

This study investigates the impact of seed priming on key parameters in ajwain, including germination percentage, speed, field emergence, mean germination time, uniformity, seedling length, and yield. By addressing critical cultivation challenges, the research aims to establish seed priming as a practical tool to enhance ajwain productivity and sustainability, benefiting farmers and the seed spice industry.

Materials and methodology

Fresh truthfully labeled seeds of Ajwain variety 'Ajmer Ajwain-93' were used in this study. The seeds were cleaned and sorted to ensure uniformity in size and weight, a factor important in priming experiments to ensure consistency in water uptake and physiological response. In the imbibition three sets of 1gm intact seeds were taken for water imbibition in distilled water at 25^{0}C. Water imbibition % was recorded at 1, 2, 3, 4, 6, 8, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70 and 75 hrs interval by using following formulas Ajwain seeds were hydroprimed for 20 different durations (1, 2, 3, 4, 6, 8, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, and 75 hours) by soaking of ajwain seed in distilled water along with a control (non-primed seeds). After hydropriming, the seeds were air-dried to their original moisture content before being subjected to laboratory germination tests conducted as per ISTA guidelines (ISTA, 2022). Germination-related parameters, including germination percentage, initiation of germination, mean germination time (MGT), area under the curve (AUC), and the uniformity index (U9010), were calculated through recording of daily seed germination data to assess the effect of hydropriming (Kumar *et al.,* 2021). Following the laboratory evaluation, seeds hydroprimed for seven selected durations (10, 20,30,40,50,60 & 70 hrs) were further tested under field conditions during the Rabi season of 2022–23 at the ICAR-NRCSS farm, Ajmer. The field experiment was laid out in a randomized complete block design (RCBD) with a 2m x 2m plot size and 1g of seed per plot, with three replications, to evaluate field performance. Observations were recorded on field emergence percentage, mean germination time (MGT), uniformity index (U9010), seedling length, seedling fresh weight, and seedling dry weight at 45 days after sowing (DAS), along with seed yield per plot.

$$\frac{\text{Weight after water imbibition} - \text{Weight before water imbibtion}}{\text{Weight before water imbibition}} \times 100$$

Statistical analysis

All the treatments and control of experiment were replicated three times. The recorded data were subjected to statistical analysis with ANOVA to test the TUKEY,s Honest Significant Difference of treatment means at 5% probability level ($p \leq 0.05$) by using the statistical software 'R' version 4.2. The percentage data were transformed into arcsine value before the analysis.

Result and discussion

Water imbibition pattern

The water imbibition pattern in Ajwain seeds demonstrated that the Phase II of the three-phase water uptake model, associated with germination initiation, concluded within 40–50 hours (Fig. 1). Defining this timeline is critical for optimization of seed priming protocols, as it ensures metabolic activation of seed including mitochondrial development, ATP synthesis, and DNA repair, essential for germination while minimizing the risk of overhydration and associated seed damage (Marthandan *et al.*, 2020; Corbineau *et al.*, 2023).

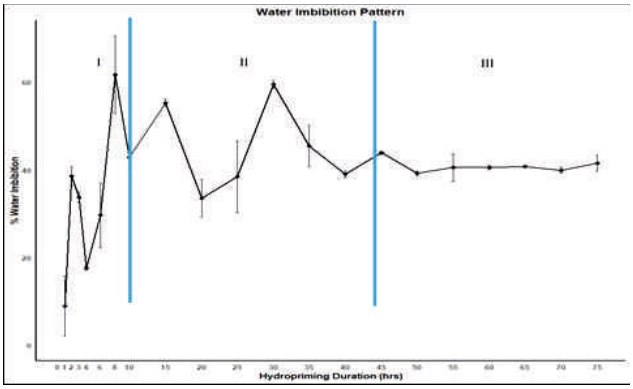

Fig. 1: Water imbibition pattern of ajwain

Seed germination attributes

Hydropriming significantly influenced the germination initiation time (t0.01) in ajwain seeds, with a duration of 65 hours resulting in the fastest germination initiation (16 hours), compared to 66 hours in non-primed seeds and 94 hours in seeds primed for 10 or 15 hours (Fig. 2a). The enhanced germination at 65 hours can be attributed to optimal water uptake, which activates enzymatic pathways and metabolic processes critical for seed vigor (Farooq *et al.*, 2006). Shorter priming durations may have caused insufficient hydration, while excessive priming may lead to imbibitional stress or metabolic imbalances (McDonald, 2000). These results emphasize the significance of tailored hydropriming durations to optimize physiological readiness and minimize germination delays, consistent with findings in other crops (Basra *et al.*, 2006). The Mean Germination Time (MGT) in ajwain seeds was significantly influenced by hydropriming duration, with seeds hydroprimed for 50 hours exhibiting the least MGT (66 hours), followed by seeds primed for 55 hours (68 hours). In contrast, non-primed seeds recorded maximum (128 hours) MGT (Fig. 2b). The faster germination in hydroprimed seeds can be attributed to the improved water absorption and metabolic activation during the priming process, which facilitates quicker seedling emergence (Corbineau *et al.*, 2023; Lamichaney *et al.*, 2018). Longer hydropriming durations may have resulted in seed stress or overhydration, reducing the benefit of priming, as noted by McDonald (2000). These findings are consistent with the general trend that moderate priming enhances seed performance, a phenomenon well-documented in various crops (Patra *et al.*, 2016).

The analysis of the area under the curve (AUC) and uniformity of germination (u9010) demonstrated superior performance in seeds hydroprimed for an optimal duration compared to non-primed and short-duration primed seeds. The highest AUC value (32) was recorded for seeds primed for 50 hours, indicating greater seed vigor and uniformity (Fig. 3a). In contrast, seeds primed for shorter durations exhibited lower AUC, suggesting delayed or uneven germination. Furthermore, the time taken for 10% to 90% germination (u9010) was shortest in seeds primed for 40 to 60 hours, which also displayed higher uniformity of germination (Fig. 3b). The improved AUC and uniformity in seeds primed for 50 hours support the hypothesis that priming duration directly influences seedling emergence and vigor (Basra *et al.,* 2006). Hydro priming had a positive impact on the seed germination percentage in ajwain, with all priming treatments showing germination rates ranging from 83% to 94%. However, statistical analysis revealed no significant differences between the treatments (Fig. 4a). Furthermore, studies have shown that while hydropriming can enhance germination rates, the magnitude of the improvement often depends on the crop species and the specific conditions under which the treatment is applied (Salehzad *et al.,* 2009).

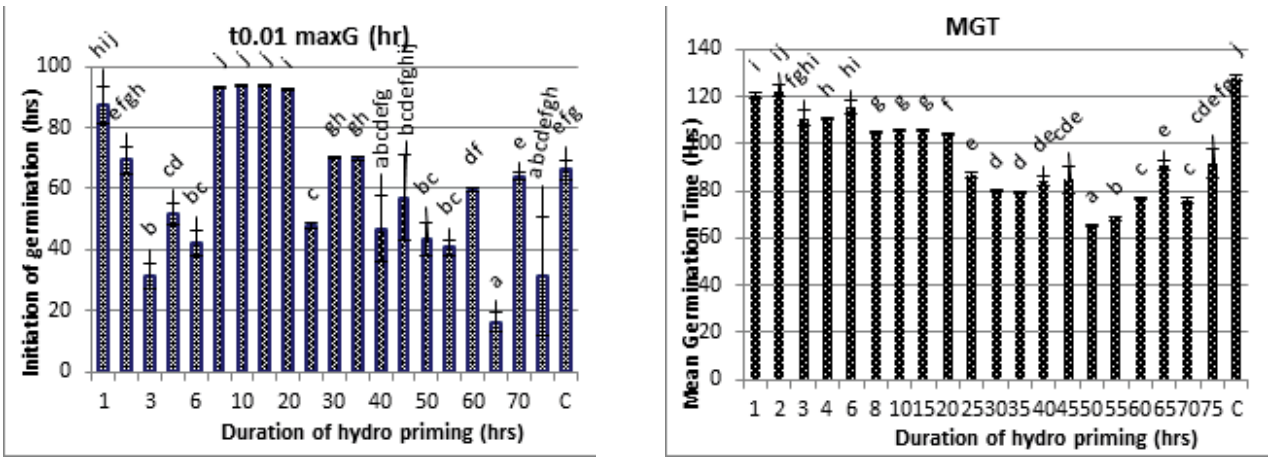

Fig. 2a & 2b: Effect of hydro priming on initiation of seed germination (t0.01 max) and MGT

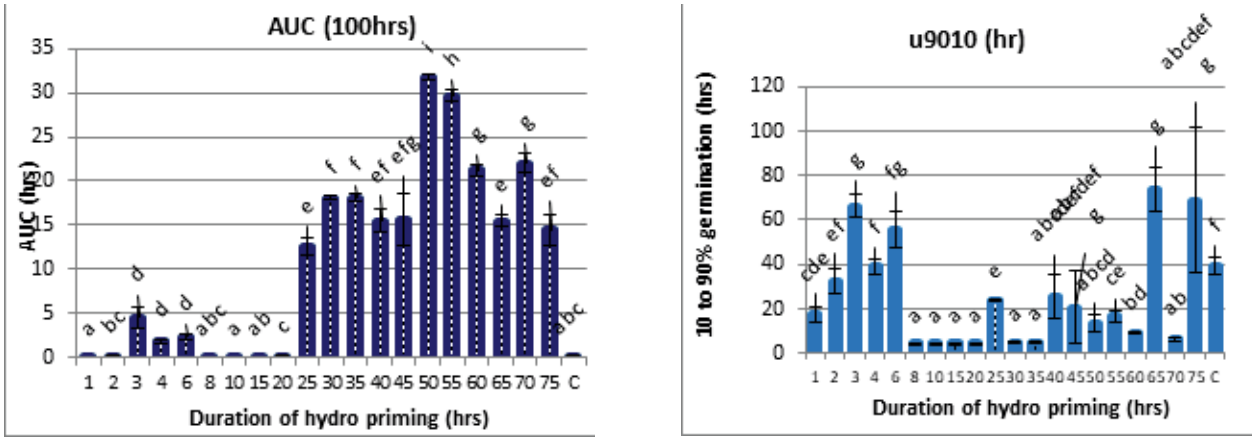

Fig. 3a & 3b : Effect of hydro priming on initiation of seed germination (t0.01 max) and MGT

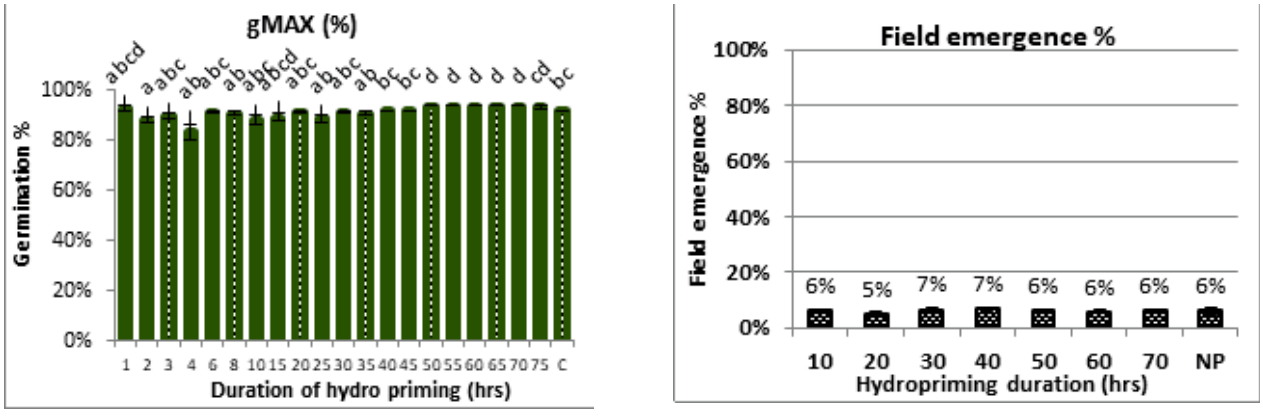

Fig. 4a & 4b : Effect of hydro priming on germination % and field emergence

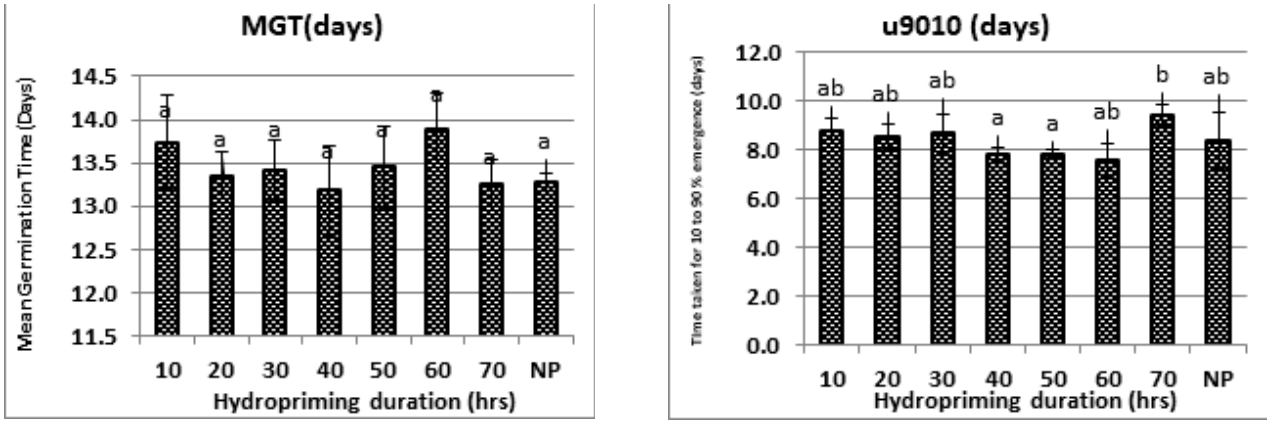

Fig. 5a & 5b : Effect of hydro priming on MGT and uniformity of field emergence

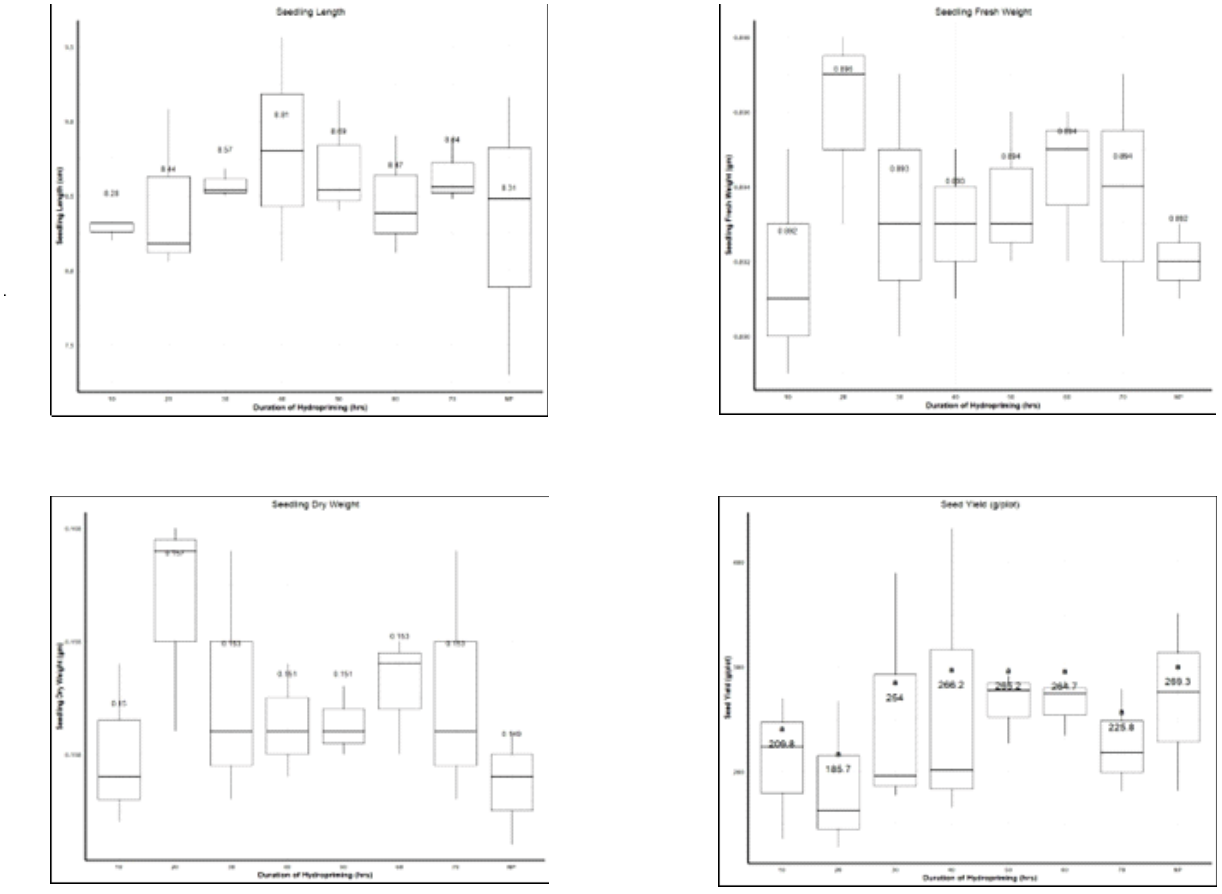

Fig. 6 :Effect of hydro priming on seedling length (a), seedling fresh weight (b), seedling dry weight (c) and seed yield (d)

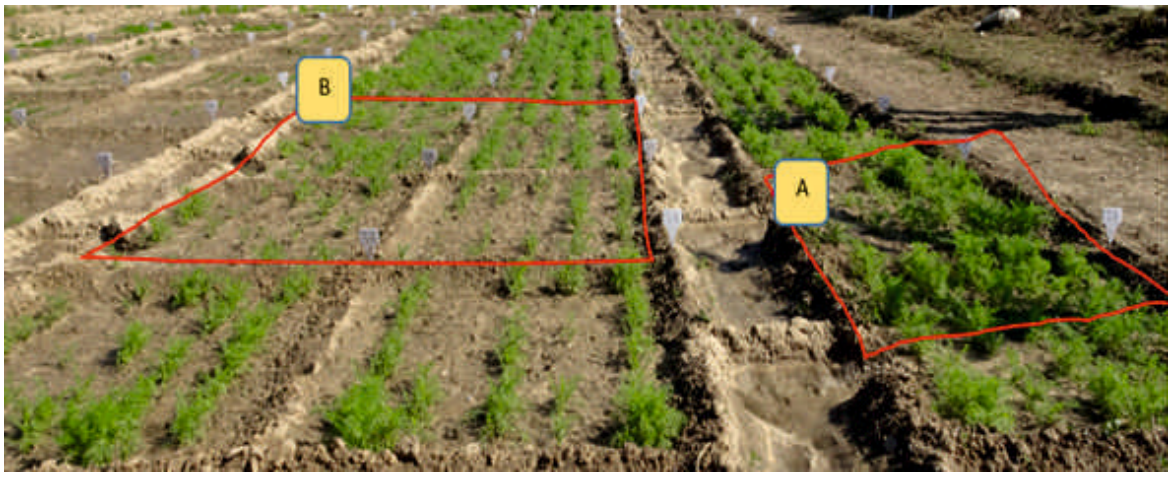

Fig. 7 : Field View: A: Vigrous plant growth in 40 & 50 hrs hydro primed seed; B: Poor plant growth in non-primed and short duration hydro primed treatments

Field emergence attributes

Field evaluation of hydroprimed ajwain seeds across eight priming durations, including a non-primed control, showed no significant differences in final field emergence percentage, which ranged between 5% and 7% (Fig. 4b). Though the laboratory germination was very high (>83%), the field emergence was extremely low (< 7%), indicating low seed vigour in ajwain. Similar reports on high laboratory germination and poor field emergence have been reported in other crops (Lamichaney *et al*., 2017; Tyagi *et al*., 2024). Despite the low emergence rates, the resulting plant population was adequate for field conditions, indicating that ajwain's compensatory growth potential can offset lower emergence. The non-significant differences in emergence could be attributed to external factors like temperature, soil condition in the field that mitigate the effects of priming observed in laboratory conditions (Lamichaney and Katiyar, 2017). These findings underscore the need to integrate laboratory optimization with field conditions for a holistic assessment of seed priming techniques. The shortest MGT (13.2 days) was observed in seeds hydroprimed for 60 hours, marginally better than the control (13.3 days), while seeds primed for 10 hours exhibited the longest MGT (13.7 days) (Fig. 5a). Seeds hydroprimed for 40, 50, and 60 hours exhibited more uniform emergence, completing 90% germination within 7.5 - 7.8 days from initiation, outperforming both non-primed seeds (8.3 days) and seeds hydroprimed for 70 hours (9.4 days) (Fig. 5b). This enhanced performance with 40–60 hours of hydropriming likely resulted from optimal hydration levels promoting metabolic synchronization and repair mechanisms, as reported by Harris *et al.* (1999). Excessive priming durations may lead to suboptimal physiological conditions or damage due to prolonged hydration (Farooq *et al*., 2019).

These findings underline the importance of selecting precise hydropriming durations to achieve improved field emergence and germination uniformity, aligning with studies in other seed spice crops (Basra *et al.,* 2006). Hydropriming significantly influenced the seedling length of ajwain (45 DAS), with the longest seedlings observed in seeds primed for 40 hours (8.81 cm) compared to the control (8.31 cm) (Fig. 6a). Additionally, hydropriming positively affected seedling fresh and dry weights across all primed treatments compared to the control (Fig. 6b & 6c), reflecting improved vigor, despite no significant enhancement in early field emergence (Fig. 7). These findings are consistent with previous reports indicating that hydropriming strengthens seedling establishment through physiological enhancements rather than emergence rate (McDonald, 2000). However, hydropriming showed no significant effect on seed yield (g plot^{-1}) (Fig. 6d), likely due to environmental and biotic factors influencing yield under field conditions, as noted by Kaya *et al.* (2006).

Conclusion

Hydropriming demonstrated a significant influence on the germination and seedling growth attributes of ajwain, particularly with durations of 40–50 hours proving optimal for enhancing seed germination initiation, mean germination time, and seedling vigor. However, no significant improvements were observed in field emergence percentage and seed yield, highlighting the influence of environmental factors under field conditions. These findings suggest that hydropriming is an effective pre-sowing treatment for early seedling establishment in controlled environments and improving seedling vigour under field conditions.

Conflicts of interest: There are no conflicts of interest.

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