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RESEARCH ARTICLE

Seed priming enhances chickpea (*Cicer arietinum* L.) germination and seedling establishment under varying thermal and moisture conditions

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Abstract

Seed priming is a unique technique used to improve seed performance in the field. It can overcome the major constraint of chickpea production in areas where farmers do not have enough resources to accelerate the seedbed preparation. This experiment investigated how different priming approaches; soil moisture regimes and soaking temperature affect the germination and seedling growth of chickpea. It was a three factorial experiment laid out in Completely Randomized Design (CRD) with three replications. Experimental factors were three priming conditions (non-priming, hydro-priming and osmo-priming), two soaking temperatures (21 ˚C and 27 ˚C) and three soil moisture regimes [50 % field capacity (FC), 75 % FC and 90 % FC]. Among the three moisture regimes tested, osmo-primed chickpea seeds at 90 % FC achieved the highest germination (99.33 %), whereas non-primed seeds at 50 % FC showed the lowest germination (78.50 %). Osmo-priming at 21°C resulted in the highest germination percentage (87.89 %) and significantly increased root (12.8 cm) and shoot lengths (15.4 cm), as well as root (9.56 mg plant^{-1}) and shoot weight (9.96 mg plant^{-1}), whereas non-primed seeds at 27 °C showed the poorest performance across these parameters. The findings indicate that seed priming, especially osmo-priming at 21 °C under 90 % field capacity, is a promising strategy to improve germination efficiency and seedling establishment in chickpea.

Keywords: BARI Chola-5; chickpea; seed priming; soaking temperature; soil moisture regimes

Introduction

Chickpea (*Cicer arietinum* L.) is a widely consumed pulse crop known for its high nutritional content, including protein, vitamins, minerals and dietary fiber, which are vital for both human and animal diets (1). It also contributes to soil health by fixing atmospheric nitrogen, making it beneficial for sustainable agriculture. Globally, chickpea ranks third among legume crops, with an annual production reaching approximately 18.1 million tonnes (2). In Bangladesh, chickpea is cultivated on about 4330 hectares of land, yielding a total of 4850 metric tonnes (3). However, this level of production falls short of meeting the country's domestic demand for this nutritious legume. Enhancing chickpea production is essential to reduce reliance on imports and ensure food security. Integrating chickpea into Bangladesh's rice-based cropping systems can improve soil fertility and overall system productivity.

Seed germination and seedling emergence are the critical phases of a plant's life cycle. Inadequate seedling emergence or improper stand of seedlings is the major barrier to crop production especially during the dry periods. Uniform germination and the increased emergence rate can be achieved by the physiological amelioration of a seed lot or priming (4). It is a simple technique that hydrates seed enough to initiate metabolic activities required for germination. However, it does not allow radicle emergence to occur. Primed seeds result in a greater germination percentage than untreated seeds (5). They also promote more uniform stand establishment, even under substandard conditions (6). This method not only improves germination and stand establishment but also reduces the time of seedling emergence (7).

The effectiveness of a priming method depends on the nature and concentration of the priming agent as well as the extent of priming (8). Different priming agents such as water (hydro-priming) and solutions like PEG (osmo-priming) can be applied before germination to stimulate metabolic changes in seeds (9). Salts like $CaCl_2$, $CaSO_4$, NaCl and certain chemicals are also used as priming agents. These methods are beneficial for improving germination in both grain and legume crops.

Germination of seed can be influenced by various abiotic factors among which soil moisture is the vital one (10). Low soil moisture regimes can retard the germination process depending on the degree of its reduction (11). Whereas, the optimum soil moisture can enhance the rate of germination and seedling establishment. A high percentage of germination was recorded under sufficient soil moisture which led to high crop yields of chickpeas (12). Previous works observed that temperature influences the water absorption of maize seeds (13). A similar finding was reported in the different legume crops where the rise of temperature also increases water absorption (14). As temperature rises, the complex molecules in cold water break down into simpler forms, reducing the water's viscosity (15). This reduction accelerates chemical changes, thereby regulating the rate of water absorption through the seed coat (16). Most existing studies focus on single factors, without investigating their synergistic impacts on chickpea establishment. For optimal growth of chickpea under different moisture levels, the ideal priming soaking temperature is unknown. Addressing these research gaps can provide a more comprehensive understanding of how to optimize seed priming protocols to improve chickpea productivity, especially in water-limited and temperature-variable agroecosystems. Therefore, the present research work has been carried out to evaluate the effect of seed priming on the rate of germination and seedling establishment under variable soil moisture regimes and different soaking temperatures.

Materials and Methods

Experimental site and study material

The expeiment was conducted at the Seed Science & Technology Laboratory, Bangladesh Agricultural University (BAU), Mymensingh. The soil used for the experiment was silty loam in texture, more or less neutral (pH value 6.8), low in organic matter and fertility level. One high yielding chickpea variety BARI chhola-5 was used as the test crop.

Treatments and designs

The experiment consisted of three factors; factor A: priming methods (non-priming, hydro-priming and osmo-priming), factor B: soaking temperature (21 ˚C and 27 ˚C) and factor C: soil moisture regimes (50 % FC, 75 % FC and 90 % FC). It was laid out in CRD with three replications.

Experimentation

Seed priming was done at three different glass bowls with equal number of seeds for 12 hrs in normal distilled water and 20 % PEG (Polyethylene glycol) solution for hydro-priming and osmo-priming, respectively. Besides, this same number of seeds were kept for non-priming treatment. Each experimental pot was filled with 250 g of soil. To establish different soil moisture levels, the soil in each pot was moistened with specific amounts of water corresponding to the desired field capacities. Seeds were sown on 8^{th} November when soaking temperature was 27 °C and on the 19^{th} December when the temperature was 21 °C. After sowing some extra water was added in these pots and the necessary measures were taken to raise the seedlings during the test period.

Data collection

Electrical conductivity (EC) of primed and non-primed seed was recorded before the sowing of seed and germination percentage was obtained from each replicate. Germination test of chickpea seed was done in germination box filled with sterilized moist sand at a temperature of 25 °C. After 8 days, germination percentage was recorded. For standard germination percentage, 400 chickpea seeds in three replications for each treatment were tested and the normal seedlings including hard seeds were counted as per ISTA rules (17).

For shoot and root length, 10 normal seedlings were selected randomly and the root and shoot length of them were measured. Then the average root or shoot length were computed by dividing the total shoot or root length by total number of normal seedlings measured and expressed in centimeters (18) .

Statistical analysis

Data were compiled and tabulated in the proper form for statistical analysis. The mean differences among the treatments were evaluated with Duncan's Multiple Range Test (DMRT) (19).

Results

Germination percentage

Priming methods, soil moisture regimes and soaking temperatures significantly affected chickpea seed germination (Table 1). Osmo-priming produced the highest germination (87.78 %), while lowest (59.61 %) from non-priming. Among moisture regimes, 90 % FC led to the highest germination (87.06 %) and 50 % FC showed the lowest (65.61 %). Lower soaking temperature (21 °C) resulted in better germination (80 %) compared to 27 °C (73 %) (Table 1).

The highest germination (99.33 %) occurred under osmo-priming with 90 % FC, whereas non-primed seeds showed the lowest germination across all moisture levels (Fig. 1).

Similarly, soaking seeds at 21 °C with 90 % FC gave the highest germination (88.67 %), while 27 °C with 50 % FC recorded the lowest (62.11 %) (Fig. 2) and some intermediate treatments were statistically similar.

Electrical conductivity

EC was significantly influenced by different priming methods and soaking temperature (Fig. 3). The highest value of EC was 143.15 µS $cm^{-1}g^{-1}$ at non-priming condition. The lowest value (26.89 µS $cm^{-1}g^{-1}$) was recorded at hydro-priming method. EC was increased with the increasing temperature. The higher EC (80.22 µS $cm^{-1}g^{-1}$) was found at 27 °C and the lower (58.19 µS $cm^{-1}g^{-1}$) was at 21 °C (Fig. 4).

Root and shoot length

Seedling length of chickpea was significantly influenced by seed priming methods, soil moisture regimes and soaking temperatures (Table 1). Among the priming treatments, osmo-priming resulted in the longest root (12.37 cm) and shoot (14.53 cm), followed by hydro-priming, which also performed better than the non-priming condition. The shortest root (9.05 cm) and shoot (11.45 cm) lengths were observed in non-priming seeds (Table 1). Regarding soil moisture, the highest root (11.51 cm)

Table 1. Effect of priming, moisture regime and soaking temperature on germination percentage, shoot and root length and shoot and root weight of chickpea seed

	Germination percentage	Shoot length (cm)	Root length (cm)	Shoot weight (mg plant^{-1})	Root weight (mg plant^{-1})
Priming methods					
Hydro-priming	82.11b	13.34b	11.50b	8.50b	8.30b
Osmo-priming	87.78a	14.53a	12.37a	8.90a	8.70a
Non-priming	59.61c	11.45c	9.05c	6.80c	6.30c
Level of sig.	1.00	1.00	1.00	1.00	1.00
Moisture regimes (Field capacity)					
90 %	87.06a	15.08a	11.51a	9.56a	8.56a
75 %	78.17b	13.77b	10.61b	8.28b	7.52b
50 %	65.61c	11.40c	9.44c	7.00c	6.54c
Level of sig.	1.00	1.00	1.00	1.00	1.00
Soaking temperature					
21 °C	80a	14.48a	11.97a	9.03a	8.53a
27 °C	73b	12.45b	9.74b	7.29b	6.96b
Level of sig.	1.00	1.00	1.00	1.00	1.00

In a column, same letter does not differ significantly whereas with dissimilar letter differ significantly (as per DMRT)

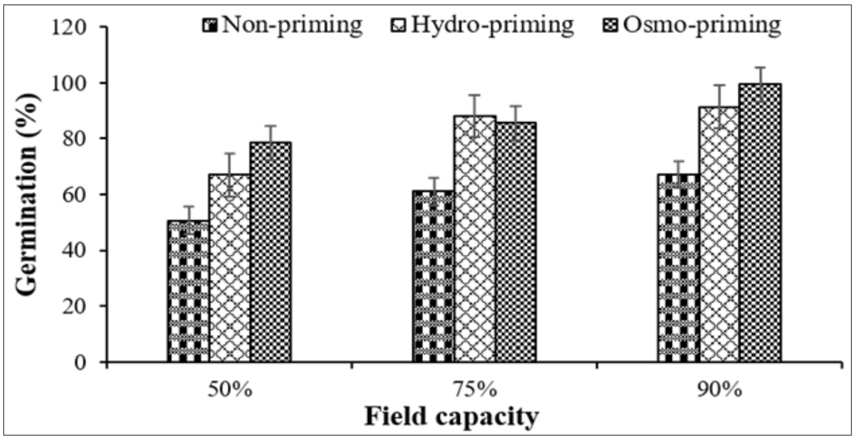

Fig. 1. Interaction effect of priming methods and soil moisture regimes on percent germination of chickpea seed.

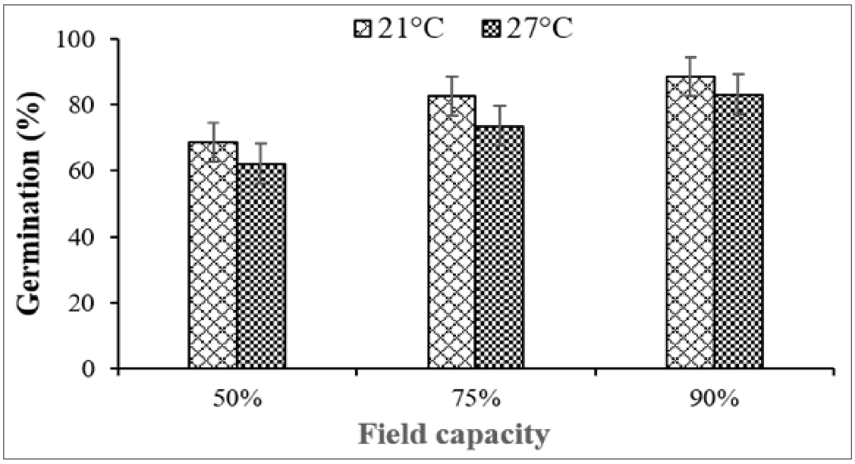

Fig. 2. Interaction effect of soaking temperatures and soil moisture regimes on percent germination of chickpea seed.

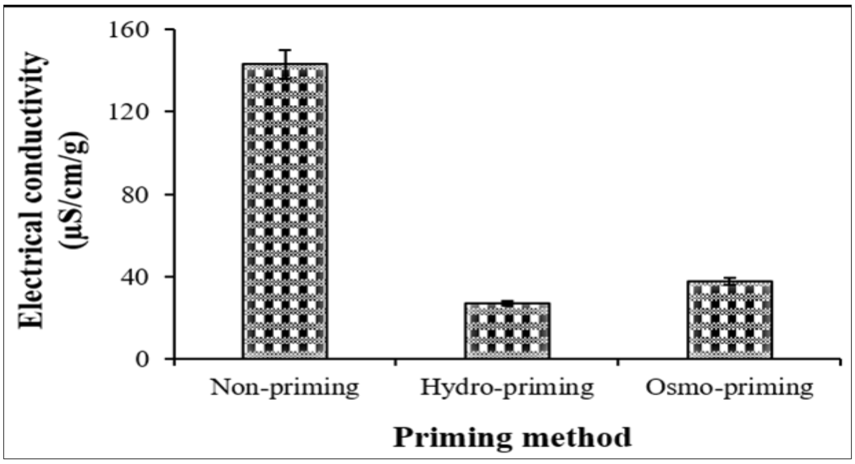

Fig. 3. Effect of priming method on electrical conductivity of chickpea seed.

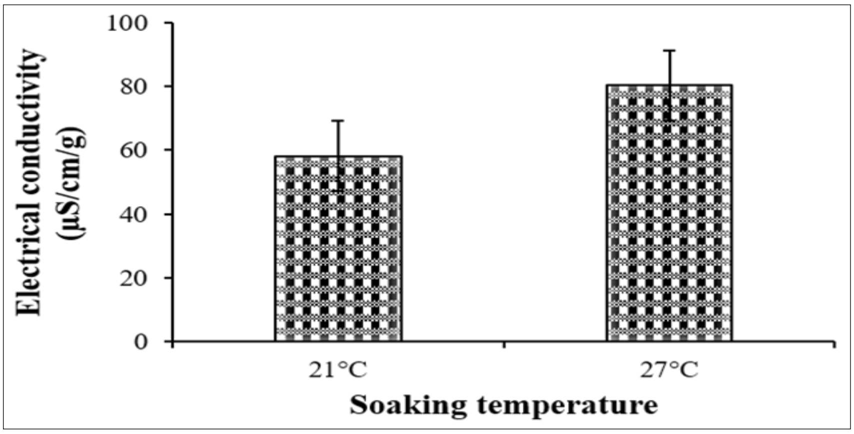

Fig. 4. Effect of soaking temperature on electrical conductivity of chickpea seed.

and shoot (15.08 cm) lengths were recorded at 90 % FC, while the lowest (root: 9.44 cm; shoot: 11.40 cm) occurred at 50 % FC. Soaking temperature also had a significant effect, with lower temperature (21 °C) producing longer roots (11.97 cm) and shoots (14.48 cm) than higher temperature (27 °C) (Table 1).

Interaction between soaking temperature and soil moisture regimes also showed statistical significance (Table 2). The largest root (12.67 cm) and shoot (15.83 cm) lengths were found at 90 % FC and 21 °C, while the smallest (root: 9.05 cm; shoot: 10.81 cm) were noted at 50 % FC and 27 °C. At every moisture level, 21 °C soaking temperature consistently produced longer seedlings than 27 °C (Table 2).

Osmo priming combined with 90 % FC yielded the maximum root (13.60 cm) and shoot (18.06 cm) lengths, while non-priming at 50 % FC resulted in the shortest growth. Seedling length under hydro-priming was superior to that observed in the non-priming treatment (Table 2).

Root and shoot weight

Seedling weight of chickpea was significantly influenced by priming methods, soil moisture regimes and soaking temperatures (Table 1). The greatest root (8.70 mg plant^{-1}) and shoot (8.90 mg plant^{-1}) weights were recorded under the osmo-priming method, while the lowest root (6.30 mg plant^{-1}) and shoot (6.80 mg plant^{-1}) weights occurred under the non-priming condition. Among the three soil moisture regimes, 90 % FC produced the heaviest seedlings (root: 8.56 mg plant^{-1}; shoot: 9.56 mg plant^{-1}), while 50 % FC resulted in the lightest (root: 6.54 mg plant^{-1}; shoot: 7.00 mg plant^{-1}) (Table 1). Soaking temperature also affected seedling weight, with 21 °C producing greater root (8.53 mg plant^{-1}) and shoot (9.03 mg plant^{-1}) weights than 27 °C.

A significant interaction was observed between soaking temperature and soil moisture levels (Table 2), where the highest seedling weights were found at 21 °C combined with 90 % FC. At this lower temperature, root and shoot weights peaked at 8.09 mg and 8.56 mg plant^{-1}, respectively, while the lowest weights occurred at 50 % FC.

Similarly, the interaction of priming methods and moisture regimes showed that osmo-priming at 90 % FC produced the highest root (9.50 mg plant^{-1}) and shoot (10.33 mg plant^{-1}) weights, whereas non-priming at 50 % FC showed the lowest (root: 5.83 mg plant^{-1}; shoot: 6.50 mg plant^{-1}) (Table 2).

Discussion

Seed priming had a significant influence on the germination and seedling establishment of chickpeas. In this study, the primed seeds showed a higher percentage of germination and seedling growth than the non-primed seeds at each level of soil moisture regimes and soaking temperatures. This result collaborates with the finding of early workers who reported that primed seeds increased the speed of germination along with the uniform seedling establishment (20).

Table 2. Effect of soaking temperatures and priming methods on root and shoot growth of Chickpea at different moisture regimes

	Field capacity	Shoot length (cm)	Root length (cm)	Shoot weight (mg plant^{-1})	Root weight (mg plant^{-1})
Temperature (°C)					
	90 %	15.83a	12.67a	11.00a	8.22a
21	75 %	14.62b	11.71b	8.56b	8.09a
	50 %	12.27c	11.03b	7.56c	7.34b
	90 %	14.32b	10.35c	8.11b	7.42b
27	75 %	12.92c	10.17c	8.00b	7.44b
	50 %	10.81d	9.05d	6.94d	6.50c
Level of Significance		1.00	1.00	1.00	1.00
Priming conditions					
	90 %	14.33b	10.69b	10.00a	8.33b
Hydro-priming	75 %	13.49bc	10.60b	8.00b	8.33b
	50 %	12.11c	9.42c	7.50b	7.50c
	90 %	18.06a	13.60a	10.33a	9.50a
Osmo-priming	75 %	15.28b	12.06ab	8.83b	9.33a
	50 %	11.26cd	10.79b	7.67b	7.67bc
	90 %	12.18c	9.57c	7.67b	7.33c
Non-priming	75 %	11.88c	9.50c	7.50b	6.83c
	50 %	9.81d	8.40d	6.50c	5.83d
Level of significance		1.00	1.00	1.00	1.00

In a column, same letter does not differ significantly whereas with dissimilar letter differ significantly (as per DMRT)

Among the priming, osmo-priming employs solutions like PEG to limit water uptake, slowly initiating germination metabolism without causing rapid imbibition. This gradual hydration minimizes cell damage compared to hydro-priming, where rapid water entry can disrupt membranes. Osmo-primed seeds maintain better plasma membrane stability and exhibit enhanced activities of hydrolytic enzymes (e.g., amylases, phytases) that mobilize reserves, boosting germination uniformity and vigor (21). Osmo-priming enhances antioxidant enzyme activities (e.g., superoxide dismutase, catalase), providing better protection against oxidative damage during germination (22). Moreover, the highest seed dry weight was recorded from osmo priming which is statistically similar to the hydro-priming at favorable soil moisture. This might be the result of increased synthesis of gibberellin hormone which triggers the activity of a protein called α-amylase, which in turn stimulates the process of other germination specific enzymes (e.g., nuclease, protease) that are involved in the hydrolysis of the starch and its assimilation (23, 24). In the case of the priming treatments, the EC of seed leachates decreased significantly than the non-primed treatment. Slow water uptake during osmo-priming reduces reactive oxygen species (ROS) accumulation. In contrast, hydro-primed seeds often exhibit more oxidative stress and higher electrolyte leakage (25). Decreased leakage of solute from primed seed might be because of the better membrane repair during hydration (26). Greater membrane integrity and decreased electrolyte leakage in primed seed were also reported in previous works for hybrid maize (27).

In addition, the rate of germination, seedling length and seedling dry weight of chickpeas were found relatively higher at 21 °C soaking temperature compared to 27 °C under different priming conditions and water regimes. At higher germination temperatures, seed priming reduced the rate of germination of some seeds (28). Comparing the two priming methods, the osmo -priming showed higher germination and seedling emergence than the hydro-priming under laboratory conditions. This finding was slightly contradictory with some other researchers who claimed that osmo-priming had an adverse impact on germination with the decreased water potential (29). In chickpea, the enhanced germination performance observed under osmo-priming conditions might be attributed to differences in water uptake dynamics. While hydro-primed seeds absorb more water, PEG-treated seeds experience restricted imbibition due to the osmotic potential of the PEG solution. Moreover, PEG poses additional limitations; its high viscosity can reduce the dissolved oxygen availability in the priming solution. This oxygen limitation may adversely affect key physiological processes such as protein synthesis and degradation, ultimately hindering respiration and impairing the overall germination process. But in this experiment moisture regime supplied the required amount of water facilities for better germination at osmo-priming condition. Besides this, during hydro-priming condition high moisture regime provide extra water which was not required. As a result, osmo-priming showed better result compared to hydro-priming condition (29, 30). The current study also found that primed seeds gave a higher population than non-primed seeds at all soil moisture levels. This is supported by the observation of early works who reported that the decreased level of soil moisture reduced the rate of seedling emergence (12). Therefore, it can be said that priming can help to establish a better number of stands in sub-optimal moisture conditions (31).

Conclusion

Germination percentage and seedling establishment traits of chickpea were notably influenced by seed priming techniques, varying soil moisture regimes and soaking temperatures. Among all treatments, osmo-priming consistently performed better than hydro-priming and non-priming across different field capacities. Particularly, osmo-primed seeds at 90 % FC recorded the highest germination rate and superior seedling traits including shoot and root length and weight. In contrast, non-primed seeds under 50 % FC showed the lowest germination and poor seedling development. Moreover, EC reached its peak in seeds that were not primed and soaked at the higher temperature. Comparing to two different soaking temperatures, lower temperature showed better result for germination and seedling establishment. Overall, it can be concluded that optimum seedling establishment of chickpea could be possible by priming seed at lower soaking temperature with optimum soil moisture regime. It is recommended that subsequent studies examine the economic viability and scalability of osmo-priming techniques in regions experiencing variable temperatures and water scarcity.

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Authors' contributions

SJLN and AKH prepared the research plan and methodology. SJLN, SP, FZ and AKH performed the Statistical analysis and drafted the manuscript. SSI, MMR, SSI, SM and MSI participated in the reviewing and editing of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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