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Authors' Affiliation:
Better Cotton, Food and Market Programme, WWF-Pakistan

***Corresponding Author:**
Zoia Arshad Awan
Email: zaawan@wwf.org.pk

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Assessment of Seed Priming Effect on Germination and Cotton Productivity of Two Cotton Varieties in Multan

Zoia Arshad Awan*, Fawad Sufyan, Syed Azaz Mehdi, Liaqat Ali Khan, Asad-Ullah Imran

Abstract

Background: Cotton is one of the important cash crops for fiber production globally. It is highly sensitive to abiotic stresses such as temperature, drought and salinity resulting in poor seedling germination and emergence leading to a decline in cotton productivity. Seed germination can be improved through physiological techniques mainly seed priming, which is a pre-sowing treatment that enables the seed to germinate more efficiently. Therefore, to assess the effects of seed priming on growth and yield production an in vivo study was performed with two different cotton cultivars (namely, $BS^{-1}3$ and FH-Lalazar).

Methods: A field trial was conducted at Multan that comprised six treatments including T1: non-primed seeds (control) and treated seeds such as T2: hydro-priming (water), T3 & T4: hormonal priming (two different concentrations of indole acetic acid) and T5 & T6: halo-priming (two different concentrations of KNO3). The data were collected to evaluate the rate of seed germination, growth and yield of cotton under the effect of seed priming.

Results: The study revealed that halo priming treatment with KNO_3 enhanced the rate of seed germination by 83% as well as seedling emergence by ~90% in both cotton cultivars. Results showed that seed priming with KNO_3 (3 g L^{-1}) had the most promising effect on growth traits up to a variant extent as compared to the control plant. Meanwhile, yield attributes such as the number of cotton bolls and boll weight per plant significantly increased by 45% as compared to non-primed plants. Similarly, priming with KNO_3 treatment displayed a significantly high cotton yield by 17% (767 kg ha^{-1}) in both cotton cultivars as compared to their respective control treatment.

Conclusion: Current study concluded that seed priming is an efficient and cost-effective technique that plays a vital role in better crop establishment consequently increasing germination rate, plant growth attributes and productivity of the cotton crop.

Introduction

Cotton (*Gossypium hirsutum* L.) is one of the world's leading agricultural crops that plays a pivotal role in the world's economy. Being an economically important cash crop, cotton is also known globally as a strategic fiber crop [1]. The production of cotton is confined to more than 100 countries however five countries mainly China, India, USA, Brazil and Pakistan renowned due to their maximum production and consumption around the globe [2]. The fiber crop is mainly cultivated in temperate, tropical and subtropical regions of the world and its growth is broadly challenged by a variety of climate change issues [3]. Cotton is the second most important crop in Pakistan with a significant role in building the economy of the country by contributing 0.8% share in gross domestic production (GDP) and 4.5% in agriculture value addition [4]. The improvement in cotton yield has always been the objective of extensive research under local environmental conditions with the better utilization of available resources for successful crop production [5]. But crop growth, productivity and fiber quality of the cotton plant are also adversely affected by biotic and abiotic stresses. Amongst abiotic stresses i.e., heat, cold, drought and salinity pose a serious negative effect on the rate of seedlings emergence, germination, growth and crop productivity [6,7,8]. To mitigate the adverse effects of climate change and continue cotton cultivation practices, there is a need for restorative solutions such as pre-sowing, seed priming, low-input resources, better management practices, conservation agriculture, etc., which are eco-friendly and economical approaches [9]. Seed is one of the vital input resources, responsible for good germination and crop production, it may increase the possible chances of vegetative and reproductive growth of plants even under abiotic stresses [10]. Seed priming is an effective and economical pre-germination technique for early resistance, that not only prepares the plant for future environmental stress but also stimulates the homogenous seedling emergence leading to faster and more-synchronized seed germination. Moreover, primed seeds showed a high germination rate and vigor that help in effective seedling germination behavior, successful crop establishment and enhance yield potential [11]. Different seed priming methods have been used for various crops depending on the priming material seed priming is categorized into different types viz., hydro-priming (with water), osmo-priming (with organic solution i.e., sugar and polyethylene glycol, etc.), hormonal priming (soaking in different hormones i.e., indole acetic acid, kinetin, etc.,) and halo-priming (soaking in mineral salt solution i.e., NaCl, KCl, KNO_3, CaCl2, etc.) [12,13]. To mitigate the effects of biotic and abiotic stresses, this cost-effective and sustainable approach may have been adopted as a viable preventive measure that would result in better vigor of cotton plants especially during initial sowing months of high temperature by reducing seed mortality and improving uniform seed germination, [8,11,14].

The current research is aimed to assess whether different seed priming methods such as hydro and chemical priming at different concentrations would affect the rate of seed germination and seedling emergence in high-performing cotton cultivars in Multan, Punjab. This study is related to exploring the positive effect of different seed priming treatments on germination behavior and crop performance in terms of growth and yield attributes of the cotton crop.

Methods

Study Site

The field experiment was conducted at tehsil Shujabad (29.8717° N, 71.3231° E) located in the district Multan province of Punjab, Pakistan. Shujabad is a renowned agricultural land due to its hot weather, fertile soil and irrigation system, such climate makes it favorable for the production of economic crops such as cotton, wheat, dates and mangoes. This experiment was piloted by WWF-Pakistan under the programme Food and Markets, Better Cotton project.

Seed procurement and treatment design:

The cotton seeds of two different high-performing cotton cultivars named IUB-13 (V1) and FH-Lalazar (V2) were used in the current research work and were procured from Ayub Agricultural Research Institute (AARI), Faisalabad-Pakistan for the purpose to evaluate the effect of different seed priming methods on cotton such as rate of germination, growth and production.

T1	Control (without priming)
T2	Hydro-priming (priming with water)
T3	Hormonal priming [indole acetic acid (IAA) 10 mg L^{-1}]
T4	Hormonal priming [indole acetic acid (IAA) 20 mg L^{-1}]
T5	Halo-priming [Potassium Nitrate (KNO_3) 3 g L^{-1}]
T6	Halo-priming [Potassium Nitrate (KNO_3) 6 g L^{-1}]

Table 1: Treatment design of experiment.

Seed priming treatments:

The seeds of both cotton varieties were treated for seed priming as per the experimental treatment design.

1. For treatment T2 (hydro-priming) seeds were imbibed with water for a limited period, and cottonseeds were soaked for 24 h at room temperature (24 h), drained and then used for sowing.

2. For treatments T3 and T4 (hormonal priming), two different concentrations of indole acetic acid were used (10 mg L^{-1}), and (20 mg L^{-1}). Solutions for hormonal priming were prepared by dissolving 10mg and 20mg indole acetic acid in 1 liter of distilled water. Cottonseeds of both varieties were soaked in the

solutions for a period of 24 h, seeds were drained and then used for sowing.

3. For treatments T5 and T6 (halo-priming), two different concentrations of potassium nitrate (KNO_3) 3 g L^{-1} and 6 g L^{-1} were prepared by dissolving 3 g and 6 g of KNO_3 in 1 liter of distilled water, separately. Cotton seeds of both varieties were primed for about 24 h, seeds were drained and used for sowing.

Experimental layout

The experimental area for the field trial was 0.04 hectares (4046.86 m2). The experiment was laid out under RCBD (Randomized complete block design) with three replications for each treatment and the plot size for each treatment was 25ft×25ft. To keep the homogeneity, an almost 5 feet buffer area was kept around the actual experimental area. Cottonseeds (primed and unprimed) were sown in each plot by maintaining plant-to-plant (0.2286 m) and row-to-row (0.762 m) distance. Land preparation practices included rotavator (1-time) and chisel plough (2-times); 2-times plowing and 2-times planking for seedbed preparation and ridges were formed for seed sowing. A uniform dose of urea (100 kg $acre^{-1}$) and diammonium phosphate [DAP (50 kg $acre^{-1}$)] was applied in the experimental plots. Moreover, two pesticides namely deltamethrin and lufenuron were sprayed for pest management (against white fly and pink bollworm). For irrigation purposes about 10-times, the land was uniformly irrigated. After seed sowing, the rate of seed germination (%) and seedling emergence (3-5 days intervals %) were recorded for both varieties V1 and V2. About five plants from each replication were randomly selected and tagged (90 plants from each cotton variety). Almost 180 plants were randomly selected (from V1 and V2) and tagged from all replications of the above-mentioned six treatments. To record the data from each treatment, the tagged cotton plant was observed and assessed for the attributes related to growth, agronomic traits and yield. The growth attributes included plant height (cm), shoot length (cm) and root length (cm), plant fresh weight (g) and plant dry weight (g); agronomic parameters such as the number of branches $plant^{-1}$, and the number of fruiting branches $plant^{-1}$ and number of affected fruits and bolls $plant^{-1}$; and yield parameters such as the number of bolls $plant^{-1}$, boll weight $plant^{-1}$ (g) and cotton yield (kg ha^{-1}). Plant height was measured using a measuring tape from the base to the tip of the plant, and similarly, root and shoot lengths were also measured with measuring tape. Plant fresh weight (g) was noted at the time of crop harvest by using an electric weight balance. To take the dry weight, tagged plants were sun-dried after harvest and then weighed. About 180 cotton bolls were randomly collected from the marked plants per plot to measure the number of bolls and boll weight (g) $plant^{-1}$. Similarly, the cumulative yield from each treatment plot was used to compute the maximum cotton yield (kg ha^{-1}).

Data Analysis

The data of both cotton varieties were statistically analyzed by subjecting to the analysis of variance (ANOVA) and means were compared by the LSD (least significant difference test) at a level of $p \leqslant 0.05$ using statistix 8.1 software.

Results

Seed germination and emergence percentage

Cottonseeds were primed from T2 to T6 according to the treatment design to check the seed priming effect on both cotton varieties (V1 and V2). Results about the rate of seed germination (%) of both cotton varieties (variety-1 and variety-2) showed that treatment T5 (halo-priming) had a high percentage of seed germination by 83% followed by the rest of the priming treatments (~75%) as compared to the non-primed plants in T1 (Fig. 1). When seedling emergence (%) was observed at three different intervals of time, the highest seedling emergence of variety IUB-13 (V1) was shown in T5 and T6 by 92% and 89%, respectively after five days of sowing (5DAS) as compared to the plants in the control treatment (T1). Likewise, for the variety FH-Lalazar (V2), the highest seedling emergence was also observed in T5 and T6 after five days of sowing by 94% and 86%, respectively as compared to the control (Fig. 2). It was noticed that seed priming treatment improved seedling emergence and seed germination percentage.

Growth attributes

Results related to growth attributes showed that plant height in treatment T5 (KNO_3 3 g L^{-1}) significantly improved by 35% in variety-1 and by 28% in variety-2 followed by T4 (21%) as compared to their respective control plant (T1). The results of shoot length and root length showed significant improvement with KNO_3 6 g L^{-1} (T6) priming treatment in both varieties (Fig. 3). Shoot length of both varieties improved by 19% and root length also significantly increased by 40-45% as compared to the control plant (T1). While the trend of plant fresh and dry weight is similar in both varieties (V1 and V2), plant fresh and dry weight is significantly high by ~78% in treatment T5 (KNO_3 3 g L^{-1}) followed by T4 (indole acetic acid 20 mg L^{-1}) (60%) as compared to their respective control plant in T1 (Fig. 4).

Agronomic attributes

The results of the agronomic attributes of the cotton crop significantly amplified as compared to the non-primed cotton plants (Fig. 5).

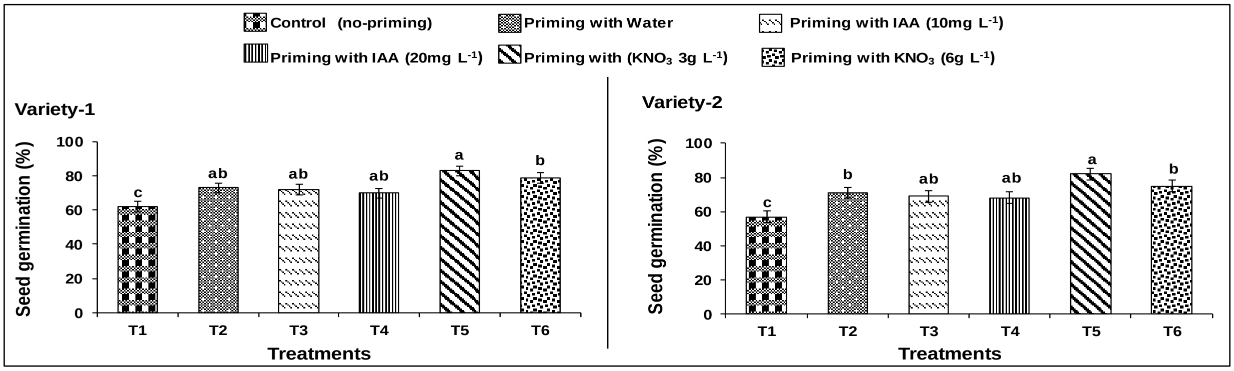

Figure 1: Effect of seed priming on seed germination (%) of two different cotton varieties (variety-1 and variety-2).

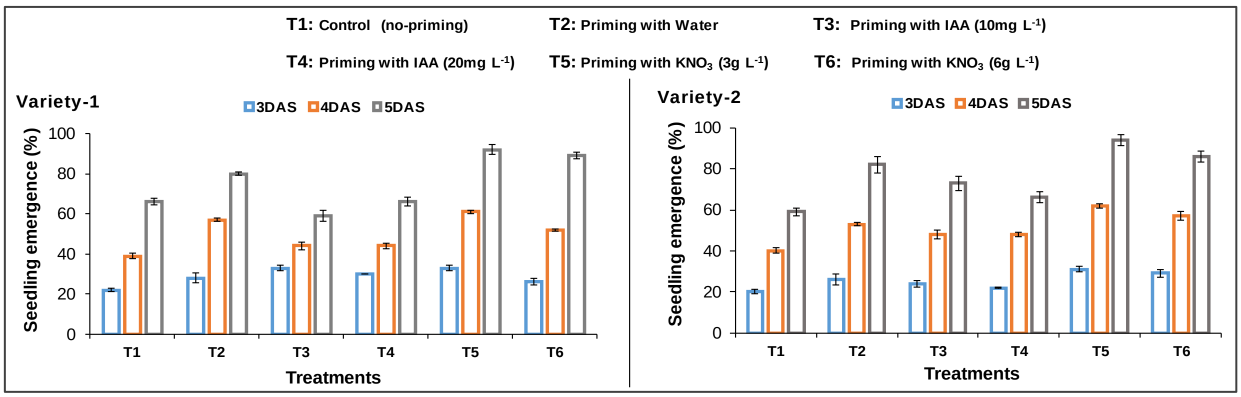

Figure 2: Effect of seed priming on seedling emergence (%) of two different cotton varieties (variety-1 and variety-2) at three intervals of day after sowing (DAS).

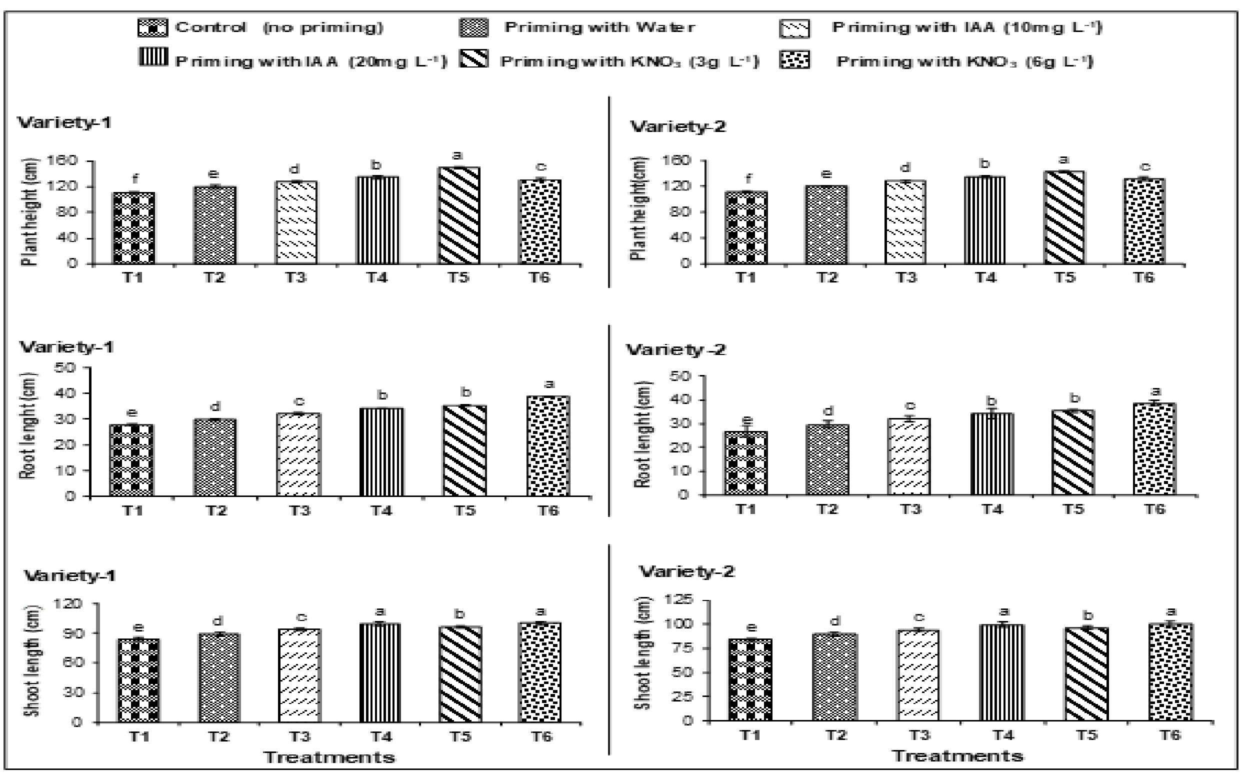

Figure 3: Effect of seed priming on plant height (cm), shoot length (cm) and root length (cm) of two different cotton varieties (variety-1 and variety-2).

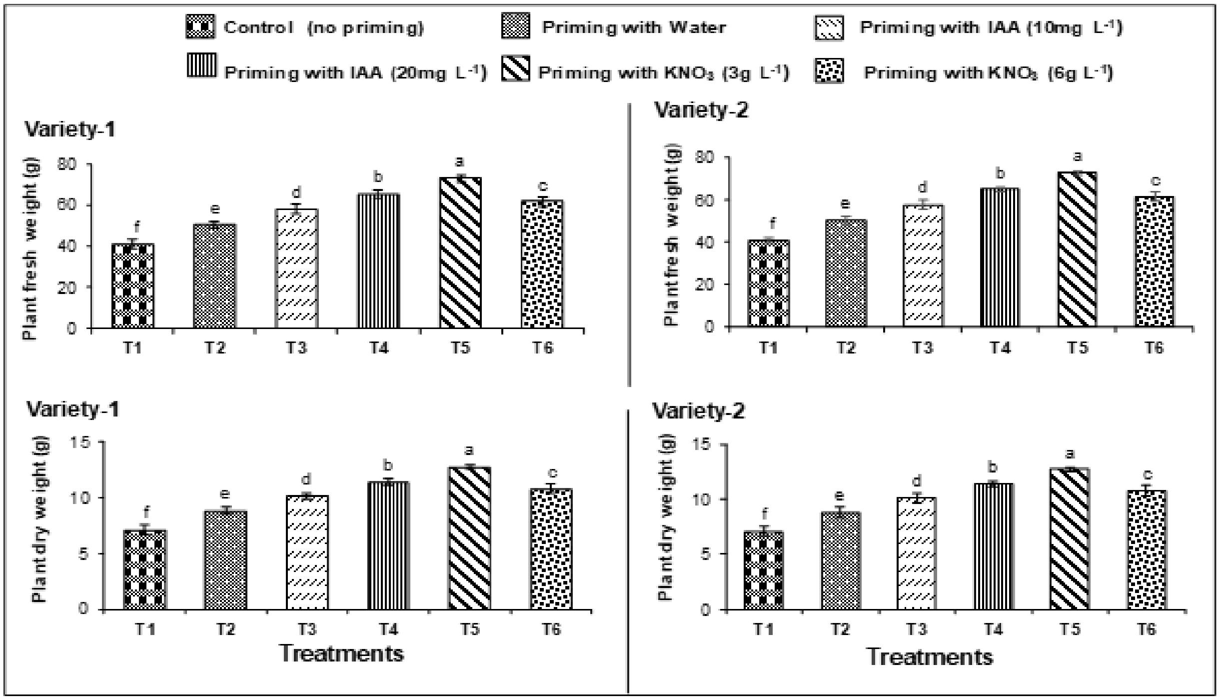

Figure 4: Effect of seed priming on plant fresh and dry weight (g) of two different cotton varieties (variety-1 and variety-2).

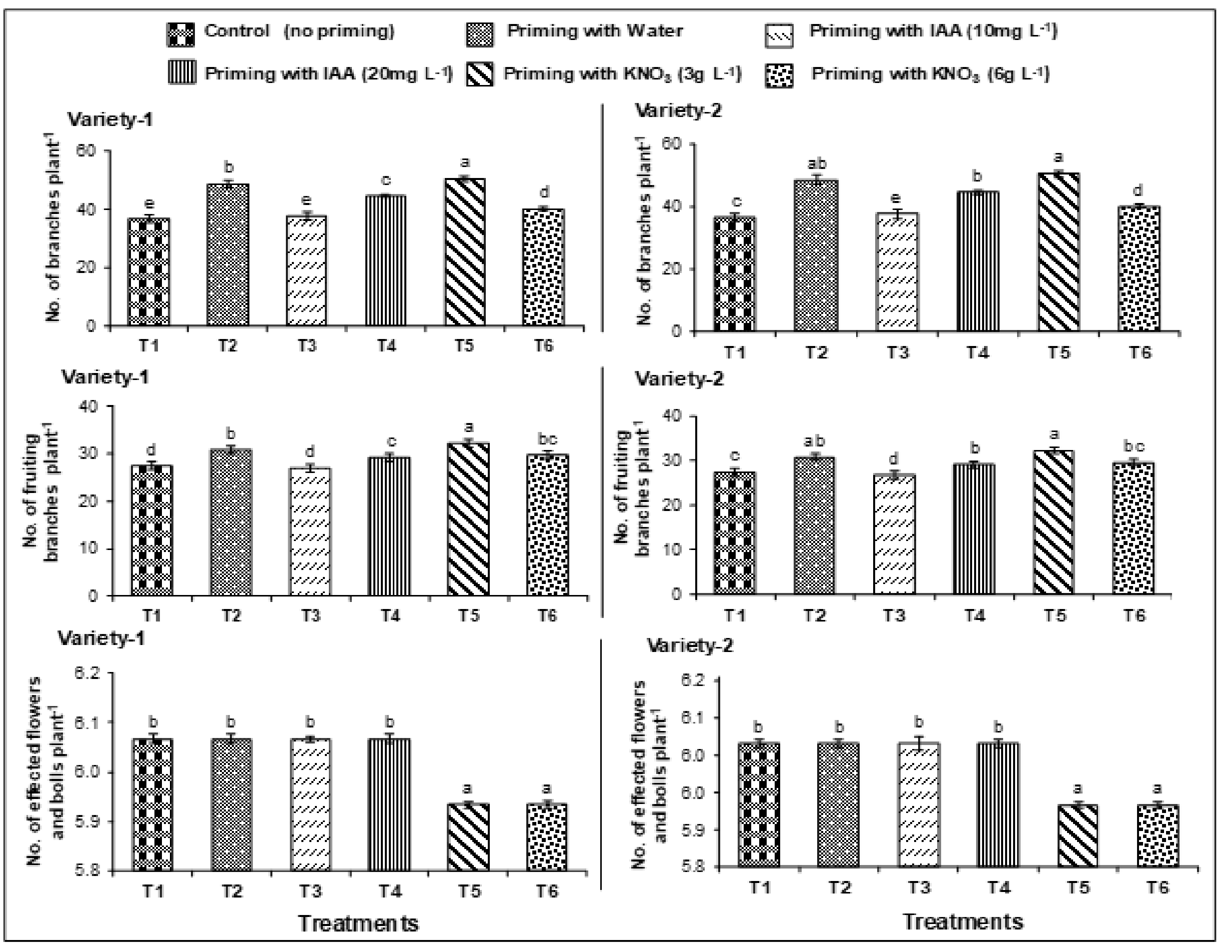

Figure 5: Effect of seed priming on the number of branches, number of fruiting branches and number of affected flowers & bolls per plant of two different cotton varieties (variety-1 and variety-2).

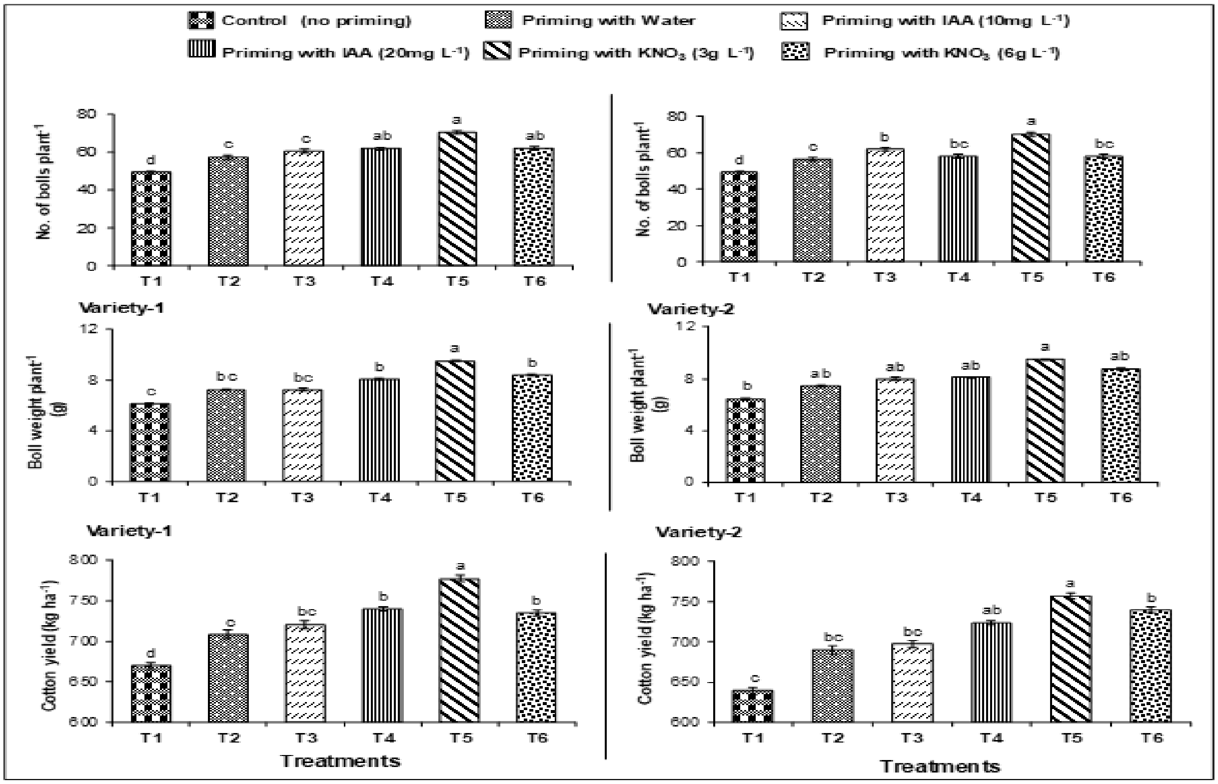

Figure 6: Effect of seed priming on the number of bolls per plant, boll weight and cotton yield of two different cotton varieties (variety-1 and variety-2).

Cotton plants of seed priming treatment (T5) with 3 g/L of KNO_3 showed a significant rise in the number of branches per plant by 37% as well as the number of fruiting branches per plant by 17% in both varieties (V1 and V2) as compared to their respective control plant (T1). There is a significant deviation in the results of pest-affected flowers and bolls per plant by 2% in T5 and T6 of both varieties as compared to the other treatments and control plants.

Yield attributes

Likewise, regarding the growth and agronomic traits of the cotton crop, the results of yield attributes showed almost the same trend of yield improvement. The number of cotton bolls per plant has significantly augmented by 43% in treatment T5 which is almost 70 cotton bolls per plant as compared to the non-primed plant with almost 50 cotton bolls per plant. Similarly, our assessment regarding halo-priming revealed that T5 showed a significant improvement in boll weight by 47% as compared to the respective control plant in both varieties. Lastly, the cotton yield was assessed in all treatments of seed priming and found a positive impact on the improvement of cotton yield, as T5 showed a significant increase by 16% (777 kg ha^{-1}) in variety^{-1} and improved by 18% (754 kg ha^{-1}) in variety-2 (T5) as compared to their respective control cotton crop (650 kg ha^{-1}) in T1 (Fig. 6).

Discussion

In the agriculture production system, seed quality is a primary concern responsible for the germination behavior leading to better crop performance in the field. So, the quality of seed is essential which can not only contribute to high seed germination but can also help plants to grow earlier and uniformly to attain higher yields of crops [15]. Seed priming is an eco-friendly and cost-effective pre-germinative technique, that has been adopted to improve the rate of seedling emergence, germination, plant growth, nodulation and productivity for various crops even under environmental stresses [11, 16, 17]. Our results indicated a uniform and improved germination behavior under different seed priming treatments, where primed seeds might facilitate the germination by the activation of pre-germination enzymes, enhancement of metabolite production, synthesis of protein and osmotic adjustment as compared to non-primed seeds as reported by previous studies [18, 19, 20, 21]. Similarly, Sung et al. [22] reported that the positive impact of primed seeds on germination rate is triggered by cell cycle regulation and cell elongation processes. Likewise, Chatterjee et al. [23]

studied that seed priming treatment stimulates the seed with the activation of enzymes and initiates the synthesis of growth-promoting chemicals in various agronomic crops leading to uniform seed germination. Our results related to cotton seed germination behavior are aligned with the previous studies, Fahad et al. [8] Ahmadvand et al. [10], Nazir et al. [24] reported that KNO_3 primed seeds induce nitrate reductase enzyme can lead to an increase in germination and seedling growth by breaking seed dormancy.

The present study indicated that the growth and agronomic traits of the cotton crop were also enhanced significantly by seed priming. Previous studies exhibited that different priming treatment methods improve the morphological attributes of the plant and the activities of defense-related antioxidant enzymes which enable the plant to encounter environmental stresses including biotic and abiotic [15, 25]. Our results revealed the positive impact of priming on plant growth may be due to developed nutrient use efficiency allowing a higher relative growth rate. Although other priming treatments were also effective the impact of KNO_3 was marked. Results of the experiment showed that KNO_3 primed seeds exhibited a more promising effect on the morphological and yield traits of the cotton crop. Potassium (K) and nitrogen (N), both are vital macronutrients, essential for regulating plant developmental processes viz., protection of cell membrane, protein synthesis, enzyme activation, photosynthesis and stomata regulation [26]. Previously it was noticed that priming treatment/s induced stress resistance may be a consequence of improved discrimination for K+ over Na+ nutrition which enhances the uptake of mineral nutrients from the soil [14, 27]. Besides, priming stimulates the effective germination rate and high plant density resulting in high economic yield [20]. Likewise, in the current study along with the improved morphological traits of the crop, improvement in the yield traits also promising. Similar increments in the yield of various crops have been noticed, previously with the adoption of different seed priming techniques [27, 28, 29, 30]. All these results indicated that different seed priming methods had a significant impact on improved plant growth and potential yield. Thus, it can be used in cotton as an effective and economic technique under field conditions for better cotton production. The results presented in this paper revealed that seeds of both cotton cultivars primed with KNO_3 (3 g L^{-1}) proved to be more successful in improving germination behavior, growth and yield attributes in the field as compared to the non-primed seeds. The present study provides the direction toward further molecular investigation about the mechanism of plant response under the positive effect of seed priming.

This study highlights the significant impact of seed priming which is a sustainable approach to improving the rate of seed germination. Our current findings concluded that both cotton cultivars with the seed priming treatment/s showed a considerable positive effect on germination rate, growth and yield attributes. The findings suggested that intensive research services should pursue to create awareness and accelerate the adoption of this viable and cost-effective strategy in the cotton-growing areas. Besides, the regulatory pathways of seed priming that pose a positive effect on cotton seeds need to be explored with the integration of molecular approaches.

Competing Interest

The authors have declare that there is no conflict of interest.

Author Contributions

F.S: Conceptualization and design methodology; Supervise the field trial.
S.A.M: Investigation and Data Curation.
Z.A.A: Analysis and interpretation of the data; Writing-original draft or revising the manuscript critically for important intellectual content.
L.A.K: Supervisor; Review and editing the draft
A.I: Project administration

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