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Effect of Seed Priming on Seed Germination and Seedling Growth of Wheat

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Abstract: Zinc (Zn) is essential for various enzymatic, ionic, and metabolic processes, particularly during seed germination. This study is aimed to evaluate the impact of different zinc soaking solutions on the germination and early growth of wheat seeds. A field experiment was laid out at the Soil Fertility Research Institute Tandojam. Randomized complete block design was used with plot sizes of 4 × 5 meters (20 m²), and included four treatments: T_1 - distilled water (control), T_2 - 2% zinc sulfate, T_3 - 2% zinc nitrate and T_4 - 2% zinc chelate, each treatment was replicated three times. The seed germination percentage, root length, number of seeds germinated plot^{-1}, speed of emergence, seed vigor index, and number of leaves plant^{-1} were observed. Results indicated that zinc treatments significantly enhanced seed germination and seedling growth compared to the control. Seeds treated with zinc sulfate (T_2) exhibited the highest germination rate at 89%, the longest root length averaging 2.0 cm, the highest seed vigor index, emergence and maximum 5 number of leaves plant^{-1}. Zinc chelate (T_4) followed closely with an 87% germination rate, root length of 1.9 cm and 5 number of leaves plant^{-1}. Zinc nitrate (T_3) showed a germination rate of 85% with an average root length of 1.7 cm and 4 number of leaves plant^{-1} whereas the control (T_1) had the lowest values in all parameters as compared to zinc soaking treatments. These findings underscore the significant benefits of zinc supplementation, particularly with zinc sulfate and zinc chelate, in improving wheat seed germination, root development, and overall seedling vigor, thereby potentially enhancing crop productivity.

Key words: Zinc seed soaking, wheat germination, seed priming, early seedling growth, zinc biofortification.

Introduction

Seed priming, a pre-sowing technique has been introduced in crops involving soaking seeds in water or nutrient solutions, has gained prominence for enhancing germination, seedling vigor, and stress resistance which is a prerequisite for better stand establishment affecting crop production even under adverse environment (Rai-Kalal & Jajoo, 2021). This method has consistently improved crop performance across various species, underlining its potential to increase yields (Farooq *et al.*, 2019). Zinc, a vital micronutrient, plays a pivotal role during germination and early growth (Cakmak & Kutman, 2018; Broadley *et al*., 2011). This micronutrient is required for a wide range of physiological and biochemical processes such as photosynthesis, protein synthesis and antioxidant functions (Rai-Kaala & Jajoo, 2021). Zinc deficiency, prevalent in alkaline and calcareous soils leads to chlorosis, reduced leaf size, stunted growth, and poor root development, compromising yield potential (Akhtar *et al*., 2019; Cabot *et al*., 2019). Zinc enhances antioxidant enzyme activity, safeguarding cellular integrity and supporting seedling survival under stress conditions such as drought or salinity (Cakmak, 2000; Andresen *et al*., 2018). In germination, insufficient zinc impairs seedling establishment and stress tolerance (Caroli *et al*., 2020). Zinc-enriched seed priming offers a practical solution to this deficiency, enhancing seed germination, seedling vigor, and zinc bioavailability in regions where traditional fertilization is less effective (Cakmak & Kutman, 2018; Caroli *et al*., 2020). A critical function of zinc during germination is mitigating oxidative stress, a byproduct of heightened metabolic activity that generates reactive oxygen species (ROS). Zinc also influences nutrient interactions, particularly with phosphorus, which can exacerbate zinc deficiency in high-phosphorus soils. Managing such interactions through zinc-enriched priming optimizes nutrient uptake and growth, crucial for productivity in challenging soils (Akhtar *et al*., 2019; Atar *et al*., 2020). Moreover, researchers have observed that the zinc biofortification with chemo-priming significantly improves the physiology of Mungbean plant (Awal *et al*., 2024). Similarly, Bukhari et al. (2021) observed that seed priming with zinc sulfate did not cause any nutritive loss on *Momordica charanita* crop. Zinc also improves the grain quality and zinc content in wheat grain (Choukri *et al*., 2022). Keeping all above facts in mind this study was focused to evaluate the impact of zinc-based (zinc sulfate, nitrate and zinc chelate) soaking solutions on the germination and early growth of wheat seeds (Variety: Benazir). By systematically analyzing the effects of these treatments on seed germination rates, seedling vigor, and overall plant health, we hypothesized, that seed priming significantly increased the seed germination, seed vigor and different physiological characteristics of crops. This research was focused to introduce different seed-soaked methods to provide valuable insights into the optimal use of zinc in seed priming protocols. The findings from this study have the potential to contribute to more effective agricultural practices, particularly in zinc-deficient regions, thereby enhancing crop yield and supporting global food security.

Materials and Methods

The experiment was conducted at experimental farm of Soil Fertility Research Institute Tandojam, Sindh, Pakistan (25º419 N 68º546 E) during the Rabi season of 2023-24 (Fig. 1). The experimental design was randomized complete block with plot of 4 x5 m^2 in size. Wheat seed soaked with different zinc treatments were sown separately in the homogenized soil. The experiment field was located in arid and semi-arid climate zone, with average high temperature 38.1° C, humidity 36.53% and annual precipitation of 16.51 mm. The soil used in this experiment was analyzed before conducting experiment (Table 1). The soil was high in electrical conductivity, alkaline in pH with low organic matter content (0.49%), nitrogen (0.025%), low in phosphorus (2.54ppm), medium in potassium content (67.13ppm) and silty clay loam in texture.

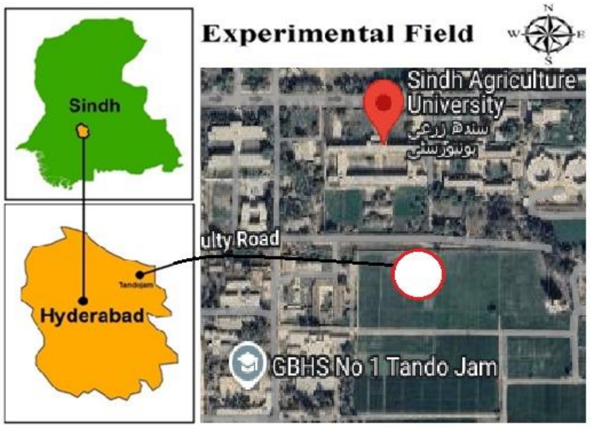

Fig.1 Geographical view of experiment field Soil Fertility Research Institute, Tando Jam.

Experimental Design and Crop Maintenance

The present study included four different sources of zinc (sulfate, nitrate and chelate), purchased from local market and applied on wheat seed with four different treatments to evaluate the effects of zinc fortification, seed priming on seed germination and seedling development. The treatments included: T_1, water soaked, T_2, zinc sulfate2% solution soaked, T_3 zinc nitrate, 2% solution soaked, and T_4 zinc chelate 2% solution soaked. Wheat seeds were soaked in solutions for 4 hours and then air-dried before sowing. The parameters including Seed Germination Percentage (germinated seeds/ total number of seeds} x100, Root length (cm), Number of seeds germinated plot^{-1}, Speed of emergence (number of germinated seeds at the starting day of germination/ number of germinated seeds at the final day of measurement) x 100, Seed vigor index (SVI) (mean seedling length x germination percentage) / 100 and Number of leaves plant^{-1} were measured.

Table 1. Physiochemical properties of soil used in this experiment.

Item	Value
Electrical Conductivity (EC) dS/m	2.41
pH	8.08
Organic Matter (%)	0.49
Nitrogen (%)	0.025
Phosphorus (ppm)	2.54
Potassium (ppm)	67.13
Soil Texture Class	Silty Clay Loam

Statistics Analysis

The data were analyzed using Analysis of Variance (ANOVA) SPSS software 27.0 version using Tukey's Honestly Significant Difference (HSD) test at a 5% significance level.

Results and Discussion

Seed Germination Percentage

The seed germination percentage varied significantly among different treatments (Fig. 2). Seeds soaked in zinc sulfate (T_2) exhibited the highest germination rate at 89%, followed closely by those soaked in zinc chelate (T_4) at 87%, and zinc nitrate (T_3) at 85%. Seeds soaked in water (T_1) had the lowest germination percentage at 75%. This indicates that zinc treatments, particularly with zinc sulfate, substantially enhance the germination process compared to water soaking. Recent research supported above findings and emphasized the positive impact of zinc on seed germination rates and seedling vigor. Haider et al. (2020) demonstrated that zinc seed priming significantly improves seed germination and growth in Mungbean, leading to better yield and biofortification. Similarly, Gupta et al. (2020) reviewed the prevalence of zinc deficiency and discussed effective zinc management strategies, which enhance seed germination and overall plant health. Umair et al. (2024) also concluded that Zinc Seed Priming significantly improved germination, resulting in earlier germination compared to non-priming.

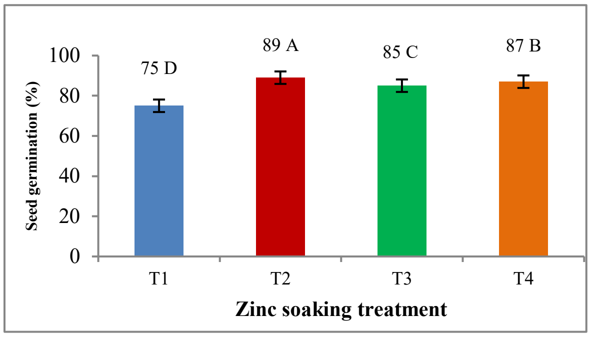

Fig. 2 Effect of different zinc seed priming compounds on wheat seed germination (%). Different letters show significant difference between the treatment (N=4).

Root Length (cm

Root length measurements showed notable differences among the treatments (Fig. 3). The longest roots were observed in seeds treated with zinc sulfate (T_2) and zinc chelate (T_4), both averaging around 2 cm. Zinc nitrate (T_3) treatments resulted in an average root length of 1.7 cm, while the water-soaked seeds (T_1) had the shortest roots at 1.4 cm. The increased root length in zinc-treated seeds suggests improved nutrient uptake and early root development, which are crucial for plant establishment.

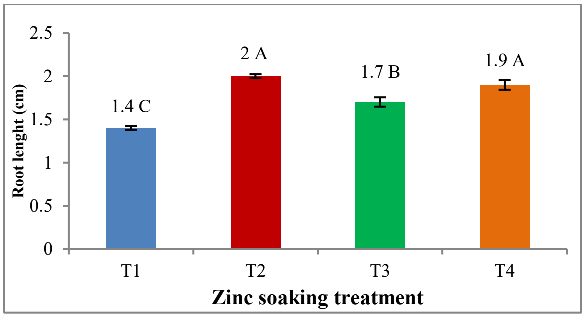

Fig. 3 Effect of different zinc compounds wheat seed priming on root length (cm). Different letters show significant difference between the treatment (N=4).

Root length is a critical indicator of seedling development and nutrient uptake. Root length increased after treated with zinc-sulfate and the similar findings were by Lee et al. (2020) that zinc application improves root development and nutrient absorption in plants. Additionally, Long et al. (2010) highlighted the role of zinc in promoting root elongation through transcription factors and metal efflux proteins, which enhance nutrient acquisition.

Number of Seeds Germinated /Plot

In terms of the number of seeds germinated plot^{-1}, zinc treatments again outperformed the water-soaked control (Fig. 4). All three zinc treatments (T_2, T_3, and T_4) had a mean germination of 93.33 seeds plot^{-1}, significantly higher than the 68.33 seeds plot^{-1} observed in the water-soaked seeds (T_1). This consistency across the zinc treatments highlights their effectiveness in promoting higher germination rates. The results of this study showed that zinc priming treatments had a significant increase in germination. Similar improvements in germination, yield, and biofortification have been observed by Rameshraddy et al. (2017) with zinc oxide nanoparticles (ZnO-NP) in ragi (Finger Millet) and with $ZnSO_4 \cdot 7H_2O$ in wheat by (Hassan *et al*., 2019).

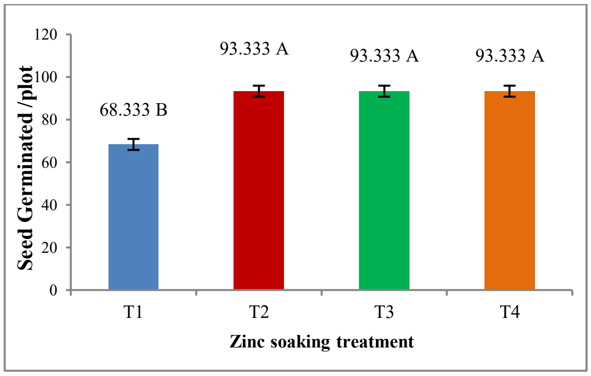

Fig. 4 Effect of different zinc compounds wheat seed priming on number of seed germination plot^{-1}. Different letters show significant difference between the treatment (N=4).

Furthermore, Broadley et al. (2011) also observed that zinc enhance seedling growth by mobilizing to the coleoptile and radicals, where it supports key processes such as enzyme activation and carbohydrate metabolism, which are crucial for improved germination and growth (Ozturk *et al*., 2006). Additionally, Bukhari et al. (2021) concluded same results that plants treated with zinc sulfate exhibited a higher germination percentage compared to the control plants.

Speed of Emergence

The speed of emergence was also enhanced by zinc treatments (Fig. 5). Seeds soaked in zinc sulfate (T_2) and zinc chelate (T_4) showed the fastest emergence rates, both averaging around 80%, while zinc nitrate (T_3) had an emergence rate of approximately 79%. In contrast, the water-soaked seeds (T_1) exhibited the slowest emergence rate at about 68%. Faster emergence rates indicate more vigorous and uniformly growing seedlings. Zinc availability enhances seed emergence speed by playing a crucial role in several physiological and biochemical processes essential for germination and early growth. Zinc acts as a cofactor for numerous enzymes involved in energy production, protein synthesis, and hormonal regulation, particularly auxin biosynthesis, which promotes cell elongation and division during germination. The same result was found by Ullah et al.(2020) that zinc-based seed treatments, such as priming with $ZnSO_4$, have been shown to enhance the speed of emergence, seedling vigor (Farooq *et al.*, 2018), crop yield, and grain zinc content in crops like chickpea, rice, Mungbean, and wheat (Haider *et al.*, 2020; and Harris *et al.*, 2007). These findings highlighted zinc priming as an effective strategy to boost agricultural productivity and nutritional quality. Additionally, Majda et al. (2019) observed that Nutri priming is cost-effective, environmentally beneficial, and enhances seedling emergence, stress tolerance, and yield quality and quantity. Furthermore, Bukhari et al. (2021) also concluded that the final emergence rate of *M. charantia* seeds treated with a 0.3% zinc sulfate solution was found to be significantly higher.

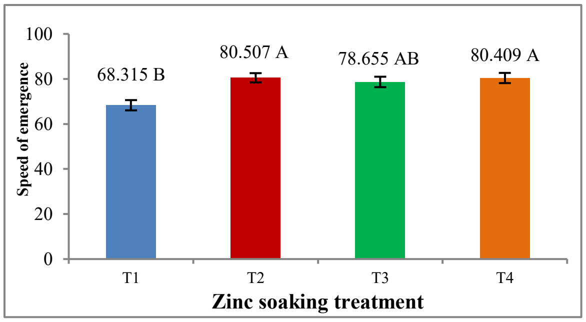

Fig. 5 Effect of different zinc compounds wheat seed priming on speed of emergence. Different letters show significant difference between the treatment (N=4).

Seed Vigor Index

The seed vigor index, which combines seedling length and germination percentage, was highest for seeds treated with zinc sulfate (T_2) and zinc chelate (T_4), with indices of 2.27 and 2.24, respectively (Fig. 6). Zinc nitrate (T_3) had a vigor index of 1.98, while water-soaked seeds (T_1) had the lowest index at 1.12. Higher seed vigor indices in zinc-treated seeds suggest more robust and resilient seedlings. Seedling vigor, which reflects seedling growth and stress resilience, is enhanced by zinc priming. The same finding was observed by Jisha et al. (2013), who noted that seed priming with zinc enhances seedling vigor. Similarly, Ma et al. (2017) concluded that Zn-containing superoxide dismutase (SOD) and catalase enzymes appear to help the seed to increase its vigor by controlling the Reactive oxygen species (ROS) levels. Moreover, H aider et al. (2020) also concluded that Zinc treatment improves germination, seedling emergence, stand establishment, yield, and micronutrient content, while boosting resistance to abiotic and biotic stresses, supporting the improved vigor (Imran *et al*., 2015; Cabot *et al*., 2019; Rehman et al., 2012). Additionally Rai and Jajoo (2024) demonstrated that nanopriming wheat seeds with ZnO nanoparticles significantly improved seed quality by increasing germination percentage and vigor index. However, ZnSO4 treatment resulted in an even greater enhancement of the seedling vigor index compared to untreated seedlings.

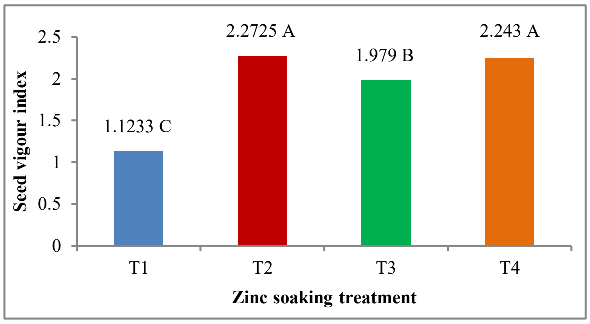

Fig. 6 Effect of different zinc compounds wheat seed priming on seed vigor index. Different letters show significant difference between the treatment (N=4).

Number of Leaves Plant^{-1}

The number of leaves plant^{-1} was another parameter that benefited from zinc treatments (Fig. 7). Zinc sulfate (T_2) and zinc chelates (T_4) treatments resulted in an average of 5 leaves plant^{-1}, while zinc nitrate (T_3) showed an average of 4 leaves plant^{-1}. The water-soaked control (T_1) had the fewest leaves, averaging 3 plant^{-1}. More leaves plant^{-1}indicates better vegetative growth, contributing to overall plant vigor and productivity. The study by Haider et al. (2020) also supported these findings, showing that zinc priming enhances seedling vigor and growth in Mungbean. Zinc treatments have been shown to improve various growth parameters and overall seedling performance.

Gupta et al. (2020) discussed the importance of zinc in enhancing crop yields and plant health, supporting the observed benefits of zinc treatments in seedling growth. Additionally, Salama et al. (2019) also found that seed priming with Zn-NP increases amino acids like glutamate and glycine, boosting metabolism, chlorophyll synthesis, and plant growth.

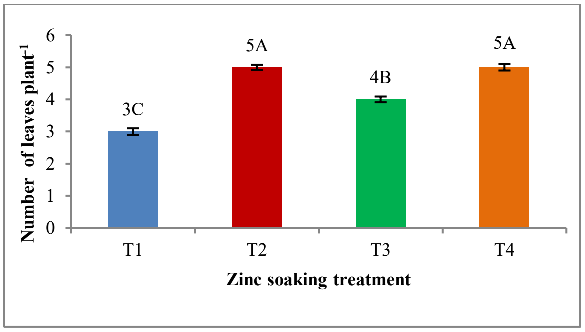

Fig. 7 Effect of different zinc compounds wheat seed priming on number of leaves plant-1. Different letters show significant difference between the treatment (N=4).

Table 2. Pearson correlation of different parameters after the soaked seeds

Correlations (Pearson)						
Correlation	**SG %**	**RL (cm)**	**SGP**	**NL**	**SE**	**p- values**
RT (cm)	0.8539*					
SGP	0.9320*	0.9550*				
NL	0.7812*	0.9195*	0.8860*			**<0.005**
SE	0.6505*	0.6884*	0.7840*	0.7721*		
SVI	0.9313*	0.9391*	0.9809*	0.8928*	0.8315*	

All pairwise correlation: effect of zinc seed priming compounds on SG%=Seed germination%, RL=Root length, SGP=Seed germinated plot-1, NL=Number of leaves, SE=Speed of emergence, SVI= Seed Vigour Index, the Pearson correlation* indicate significant p-value<0.005.

Conclusion

This study highlights the importance of zinc application to zinc biofortified wheat to mitigate the adverse effect of treatment with different zinc sources. Wheat seeds were cultivated and germination percentage, seed vigor, seed emergence, number of leaves/plants were observed in a trail in response to seed priming treatments with zinc. It is concluded that seed priming with 2% of zinc sulphate and zinc chelate solutions significantly enhances the wheat germination percentage, and germination rate compares with nitrate and unsoaked seed. Thus, seed priming with low concentration of zinc chelate and sulfate solution might be an efficient option to enhance the seed vigor and seedling growth and grain size. It is concluded that, seed priming and socked seed for four hours with sulfate or chelate improve the seed germination as well seed health.

Conflict of Interest: There is no conflict of Interest of authors

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