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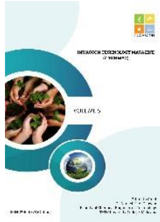

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RESEARCH ARTICLE

EFFECT OF MICRONUTRIENT SEED PRIMING ON MAIZE (ZEA MAYS L.) GERMINATION AND SEEDLING GROWTH

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ABSTRACT

Deficiency of micronutrient is a major limitation to crop productivity. Agronomic practices such as nutrient seed priming could significantly improve crop establishment in poor infertile soil. However, effectiveness of this practice depends on the efficacy of priming procedures. To address the issue of low maize yield, an experiment to highlight the effects of nutrient seed priming concentration of copper sulphate and ferrous sulphate on maize germination, seedling emergence and early growth was carried out at College of Natural Resources Management Bardibas, Mahottari during October 2023. Khumal seto variety of maize was used. Three concentrations 1%,0.1% and 0.5% were used for the experiment. Seed priming concentration levels have significant effect on the speed of germination, vigor index, and root shoot length. These parameters were improved by priming at low concentrations of micronutrients. Priming with 0.5% $FeSO_4$ resulted in earlier seedling emergence and faster seedling growth over control. The earlier seedling emergence could have contributed to superior fresh and dry seedling mass as well as both higher root and shoot ratio over control. Furthermore, NSP enhances the total germination percent, which could ultimately lead to better crop yield. This research suggests that with the optimum micronutrient concentration level, we can improve germination and seedling growth and thus maximization of yield parameters.

KEYWORDS

Nutrient seed priming, Germination, Vigor index, and Maize.

1. INTRODUCTION

Maize is known as "Queen of cereal crops" and is the second most important crop of Nepal in terms of area (940,256 ha) and production (2,969,222 mt) (AITC, 2023). Maize (Zea mays L.) is a crucial cereal crop worldwide, playing a vital role in global food security and agricultural economics (FAO, 2021). As the demand for maize continues to rise due to population growth and its diverse applications in food, feed, and industrial sectors, there is an increasing need to enhance its productivity and resilience (Shiferaw et al., 2011). One of the critical stages in maize production is seed germination and early seedling growth, which significantly influence crop establishment and subsequent yield potential (Lutts, 2016).

Micronutrient deficiencies in soils are becoming increasingly prevalent, affecting crop growth and productivity in many regions (Alloway, 2007). These deficiencies can be particularly detrimental during the early stages of plant development. Seed priming, a pre-sowing treatment that partially hydrates seeds without inducing radicle emergence, has emerged as a promising technique to enhance seed performance and early seedling vigor (Paparella et al., 2015). Micronutrient seed priming, which involves incorporating essential micronutrients during the priming process, offers a targeted approach to address nutrient deficiencies and improve early plant growth (Farooq et al., 2012). Micronutrients, though required in small quantities, play crucial roles in plant metabolism, growth, and development. Elements such as zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), and boron (B) are essential for various physiological processes, including enzyme activation, photosynthesis, and hormone synthesis (Marschner, 2011). In maize, micronutrient deficiencies can lead to reduced growth, poor grain quality, and decreased yield (Cakmak, 2008). Similarly, some researcher reported that iron fortification in maize enhanced not only plant growth but also the nutritional quality of the grains (Kaur and Nelson, 2014).

Seed priming has gained considerable attention as a method to improve seed performance and seedling establishment. Various priming techniques have been developed, including hydropriming, osmopriming, and nutrient priming (Jisha et al., 2012). These methods aim to initiate metabolic processes associated with germination without allowing radicle protrusion, thereby enhancing seed vigor and synchronizing germination (Paparella et al., 2015). A group researcher reported that priming maize seeds with calcium chloride improved germination rate, seedling vigor, and field emergence (Farooq et al., 2009). In another study, osmo-priming with polyethylene glycol (PEG) was found to enhance maize seed germination and seedling growth under salt stress conditions (Ashraf and Foolad, 2005).

Micronutrient seed priming combines the benefits of seed priming with targeted nutrient delivery. This approach has shown promising results in various crops, including cereals. A group researcher demonstrated that priming wheat seeds with zinc improved germination, seedling vigor, and grain yield in zinc-deficient soils (Harris et al., 2007). Similarly, a group researcher reported that iron-fortified rice seeds through priming resulted in higher iron concentration in the grains and improved seedling establishment (Prom-u-thai et al., 2010). In maize, several studies have explored the effects of micronutrient seed priming. A group researcher found that priming maize seeds with zinc sulfate solution significantly improved germination parameters and seedling growth under both optimal and stress conditions (Imran et al., 2013). In recent study, researchers reported that boron priming enhanced maize seedling growth and increased chlorophyll content (Mohsin et al., 2014).

The positive effects of micronutrient seed priming can be attributed to several mechanisms. Firstly, priming allows for the partial hydration of seeds, activating metabolic processes and repair mechanisms that enhance seed vigor (Jisha et al., 2012). Secondly, the incorporation of micronutrients during priming ensures their availability to the developing seedling immediately upon germination, supporting crucial early growth processes (Farooq et al., 2012). At the molecular level, micronutrient priming has been shown to influence gene expression related to stress tolerance and nutrient uptake. For instance, demonstrated that zinc priming in rice upregulated genes involved in zinc transport and antioxidant defense systems (Xu et al., 2011). In maize, reported that iron priming enhanced the expression of iron acquisition genes and improved iron homeostasis in seedlings (Chen et al., 2016).

Several studies have demonstrated the positive effects of micronutrient seed priming on maize performance. A group researcher reported that priming maize seeds with zinc sulfate solution significantly improved germination and early seedling growth in zinc-deficient soils (Harris et al., 2007). Similarly, in other study found that iron priming enhanced chlorophyll content, root and shoot growth, and nutrient uptake in maize seedlings (Imran et al., 2013).

2. Materials and Method

The experiment was carried out at the College of Natural Resource Management Bardibas Mahottari, Agriculture and Forestry University laboratory from October 11 to 15 of 2023. The site is located at latitude: 26^{0}54′6.84″ to 27^{0}08′46.90″ and longitude: 85^{0}47′42.67″ to 85^{0}56′42.97″.

2.1 Experimental Design

Petri dishes were arranged in Completely Randomized Design (CRD) with seven treatments which is replicated three times. Khumal Seto variety of maize was used. The treatments include three different priming solutions (Copper sulphate and Iron sulphate) at different concentrations i.e. 0.1%, 0.5%, 1 %, and water (control) primed for 6 hours. Seeds used for the control treatment were immersed in distilled water for same duration. Forty-five seeds were soaked in 100 ml solution at room temperature. Chemicals from the seed coats were removed by rinsing the seed three times with deionized water. Afterward, the seeds were dried at room temperature for a minimum period of 30 minutes. Germination paper was placed in 21 petri dishes, then the primed seeds were set in the petri dish for 6 days. 15 seeds were placed in each petri dish. Germination paper was irrigated with 10 ml of distilled water using a wash bottle every other day. Seed germination was recorded daily. The seeds were considered to have germinated when at least a 2mm long radicle protruded through the seed coat. Days to germination were recorded. The shoot and root lengths of five randomly selected seedlings were measured using a transparent ruler from each petri dish.

2.2 Data Collection

Data were recorded on Total germination percentage (TG%), Root Shoot Ratio (R: S), Speed of germination (SG), Root Length (RL), Shoot Length (SL), and vigor index (VI). Following formula is used to calculate the above parameters for data collection.

Total Germination Percentage (TG%) = (Number of germinated seeds/total number of seeds set for germination) ×100

Speed of Germination (SG)= N1/D1 +N2/D2+N3/D3+………+Nn/ Dn

Where, N= Number of germinated seed

D= Number of Days

Vigor Index (VI) = Germination % × Seedling Length

2.3 Data Analysis

Analysis of variance (ANOVA) was carried out for the test to find out the effects of treatments on maize development and yield parameters using Gen Stat Version 2015 Software. Mean comparison was performed using the Least Significance Difference Test (LSD) at α= 0.05.

3. Result and Discussion

3.1 Effect of seed priming with copper sulphate on germination

All three concentrations of Copper Sulphate ($CuSO_4$) significantly($p<0.05$) increased the total germination percentage, and speed of germination and reduced the vigor index and average length of root and shoot whereas reduced the total germination and speed of germination, vigor index, shoot, and root averages with respect to the control. The lowest vigor index was observed in 0.5% $CuSO_4$ (Table 1). A significant difference was observed in the vigor index from 1% to 0.5%. Priming seeds with $CuSO_4$ for 6 hours significantly slowed down the overall vigor index compared to seeds primed with water (Table 3). Hence, the seed primed with $CuSO_4$ at 1% increased vigor index but significantly differed from those primed with 0.1% and 0.5% $CuSO_4$ (Table 1).

The seed primed with CuSO4 at 0.1% obtained a faster SG while the slowest was achieved for 1% $CuSO_4$ (Table 1). Priming seeds with $CuSO_4$ for 6 hours significantly slowed down the overall SG as compared to seeds primed with water (Table 3). Total germination percentages observed for the seed primed with $CuSO_4$ at 1%, 0.1%, and 0.5% were not significantly different from the rest of the treatment (Table 1). Priming seeds with $CuSO_4$ for 6 hours has no significant difference in overall TG % compared to seeds primed with water (Table 3).

3.2 Effect of Ferrous Sulphate on seed germination

Ferrous Sulphate seed priming concentration has significant ($p<0.05$) effects on VI and non-significant effects on SG and TG % (Table 2). Seed priming with $FeSO_4$ at 0.5% for 6 hours significantly increased the overall vigor index as compared to 1 and 0.1%. The lowest vigor index was observed on 0.1% $FeSO_4$ (Table 2). Priming seeds with $FeSO_4$ for 6 hours significantly slowed down the overall SG compared to seeds primed with water (Table 3). Priming seed with $FeSO_4$ at 0.5% does not reduce the vigor index significantly as compared to water (Table 3). Primed seed with $FeSO_4$ at 1%, 0.1%, and 0.5% does not show a significant difference as compared to seed primed with water (Table 3).

3.3 Effect of priming on seedling growth

Priming with 0.5% $FeSO_4$ resulted in earlier seedling emergence and faster seedling growth over control (Table 4). Priming with 1% $FeSO_4$ resulted in faster root growth over control (Table 4). Faster root growth helps in better crop stand in micronutrient-deficient soils which leads to higher productivity. The lowest root growth was observed in the seed treated with 0.5% $CuSO_4$. Similarly, the highest and lowest shoot growth was observed in Water, 0.5% Fes04 and 0.1%FeSO4 (Table 4).

Table 1: Effect of seed priming with various concentrations of copper sulphate on germination percentage, vigor index, and speed of germination

Treatment	TG %	VI	SG%
1% $CuSO_4$	91.11a	273.4abc	9.39b
0.1% $CuSO_4$	93.33a	208.4bc	10.39ab
0.5% $CuSO_4$	93.33a	200.8bc	10.06ab

[Note: Means followed by the same letter(s) within each column are not significantly different at 5% level of significance by DMRT]

Table 2: Effect of seed priming with various concentrations of Ferrous Sulphate on germination percentage, vigor index and speed of germination

Treatment	TG %	VI	SG%
1% $FeSO_4$	95.56a	348.6ab	12.94ab
0.1% $FeSO_4$	95.56a	157.7c	12.78ab
0.5% $FeSO_4$	97.78a	421.9a	13ab

[Note: Means followed by the same letter(s) within each column are not significantly different at 5% level of significance by DMRT]

Table 3: Effect of seed priming with water on germination percentage, vigor index and speed of germination

Treatment	TG %	VI	SG%
Water	95.56a	422.6a	13.50ab

[Note: Means followed by the same letter(s) within each column are not significantly different at 5% level of significance by DMRT]

Table 4: Effect of seed priming with different micronutrient concentrations on Root length and shoot length.

Treatment	Av. Root length	Av. Shoot length
1% $CuSO_4$	3.567c	2.940bc
0.1% $CuSO_4$	2.820c	2.233c
0.5% $CuSO_4$	2.720c	2.167c
1% $FeSO_4$	8.473ab	3.653ab
0.1% $FeSO_4$	6.987b	1.653c
0.5% $FeSO_4$	8.580a	4.287a
Water	7.887b	4.413a

[Note: Means followed by the same letter(s) within each column are not significantly different at 5% level of significance by DMRT]

Table 5: CV LSD and SED of different parameters			
Parameters	**CV%**	**LSD**	**SED**
VI	7.2	142.9	65.6
TG%	4.1	13.98	4.54
SG	8.4	3.501	1.136

[Note: LSD = Least Significant Difference; CV (%) = Coefficient of Variation; SED = Standard Error of Difference]

4. Discussion

This study investigated the effects of seed priming with different concentrations of copper sulfate ($CuSO_4$), iron sulfate ($FeSO_4$), and water on germination parameters and seedling growth of a cereal crop(maize). The results demonstrate the significant impacts of these treatments on various aspects of seed performance and early plant development.

4.1 Germination Parameters

While total germination percentage (TG%) was high across all treatments (91.11% - 97.78%), with no statistically significant differences, other germination parameters showed more variability. The vigor index (VI) and speed of germination (SG%) were notably influenced by the priming treatments. $FeSO_4$ at 0.5% concentration and water priming yielded the highest vigor indices (421.9 and 422.6, respectively), significantly outperforming other treatments. This suggests that these priming methods may enhance the overall seed vigor, potentially leading to improved field performance. As noted by some researcher seed priming can significantly improve seed vigor and germination speed, which aligns with the current findings (Farooq et al., 2009).

4.2 Seedling Growth

The study revealed striking differences in root and shoot growth among the treatments. $FeSO_4$ treatments, particularly at 0.5% concentration, consistently produced longer roots (8.580 cm) and shoots (4.287 cm) compared to $CuSO_4$ treatments. Water priming also showed favorable results, especially for shoot length (4.413 cm). The superior performance of $FeSO_4$ treatments in promoting seedling growth can be attributed to iron's crucial role in various physiological processes. Iron is essential for chlorophyll synthesis and enzyme activities, which are fundamental for plant growth and development. The positive effects of iron on root and shoot growth observed in this study corroborate these established physiological roles.

5. Implications and Future Directions

These findings have significant implications for agricultural practices, especially in regions with iron-deficient soils. Seed priming with FeSO4, particularly at 0.5% concentration, emerges as a promising and cost-effective method to enhance crop establishment and potentially increase yield. This aligns with the growing need for sustainable agricultural practices to ensure food security, as discussed by in the context of cereal crops (Shiferaw et al., 2011).

However, it's important to note that while these results are promising, they are based on controlled conditions. Further research is needed to validate these findings under various field conditions and to assess the long-term impacts on crop yield and quality. Additionally, investigating the physiological and molecular mechanisms underlying the observed effects could provide valuable insights for optimizing seed priming techniques.

6. Conclusion

Nutrient seed priming with Ferrous Sulphate improved the germination and early seedling growth of maize as compared to control. Priming at lower nutrient concentrations gave the best result as compared to priming at higher concentrations. Nutrient seed priming with $FeSO_4$ at 0.5% for six hours was the most effective treatment in improving seedling growth. It is however necessary to carry out further experiments on the effects of association of these micronutrients since they may interact with each other in their effects on maize growth.

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