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RESEARCH ARTICLE

Impact of seed priming on the germination and initial seedling growth of two maize hybrids under alkaline stress

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ABSTRACT

Maize (*Zea mays* L.) is a vital crop, but its productivity is hindered by soil alkalinity, characterised by high pH levels that reduce nutrient availability. This study explores the potential of calcium carbonate ($CaCO_3$) seed priming to enhance the germination and early growth of two maize hybrids, CO-6 and VGI (H) M-2, under alkaline conditions. The experiment involved priming seeds with a $CaCO_3$ solution and testing them in various alkalinity levels (0, 2, 4, 8, and 10%). Results showed that priming significantly improved shoot growth and root length in both hybrids CO-6 and VGI H (M)-2 exhibited varying levels of tolerance to alkalinity, with primed seeds generally outperforming unprimed seeds in shoot growth and root length. This study concludes that $CaCO_3$ priming can enhance maize tolerance to alkaline soils, improving overall plant health. Further field studies and biochemical tests are recommended to validate these findings and optimise maize cultivation in alkaline environments. This study offers a workable solution to the problems caused by soil alkalinity in maize cultivation, which advances sustainable agricultural techniques.

Keywords: alkalinity, germination, seed priming, shoot length, root length, *Zea mays.*

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INTRODUCTION

Maize (*Zea mays* L.) is a globally important crop, essential for food, feed, and industrial purposes. The adaptability of maize to different climates and soils has made it a versatile crop, grown in diverse regions across the globe (Denham, 2020). It provides essential nutrients and is used in various forms, such as cornmeal, corn flour, and corn syrup. A significant portion of maize production is used as livestock feed (Erenstein et al., 2022). However, soil alkalinity often challenges its productivity, a condition where high pH levels impede nutrient availability and uptake, thereby stunting plant growth (Barrow, & Hartemink, 2014). Addressing this issue is critical for ensuring sustainable maize production, particularly in regions where alkaline soils are prevalent.

Alkaline soils, characterised by a pH greater than 7.5, often contain high levels of sodium, calcium, and magnesium carbonates, leading to nutrient deficiencies, particularly iron, manganese, and zinc (Marschner, 2011). These deficiencies manifest in poor seed germination, stunted growth, and reduced yield, posing a significant challenge to farmers (Marschner, 2011). Traditional methods to ameliorate alkaline soils include the application of organic matter and soil conditioners, but these approaches can be labour-intensive and costly (Xu et al., 2023).

Recently, seed priming approaches have surfaced as an effective method to improve seed performance under diverse stress conditions (Thakur et al., 2022; Mahara et al., 2022). Seed priming involves treating seeds with certain agents before sowing to improve their germination and vigour (Jisha et al., 2013). Calcium carbonate ($CaCO_3$) is an agent that alleviates the negative impacts of alkalinity by increasing nutrient availability and promoting soil structure.

Soil alkalinity is caused by various factors, including the presence of basic parent materials, limited leaching in arid regions, and the use of alkaline irrigation water (Naorem et al., 2023). In alkaline conditions, essential micronutrients such as iron, manganese, and zinc become less available to plants, as they tend to form insoluble compounds (Schoonover & Crim, 2015). This nutrient imbalance can severely affect plant metabolism, leading to symptoms such as chlorosis, reduced growth rates, and lower productivity. Earlier research reports indicate that maize, being sensitive to soil pH, often exhibits poor germination rates and diminished seedling vigour in alkaline soils. This sensitivity necessitates the development of adaptive strategies to maintain crop performance (Lamichhane et al., 2018). Studies have shown that calcium carbonate priming can enhance seedling emergence and growth by improving nutrient uptake and promoting better root development (Paul et al., 2022).

Therefore, the present study aims to evaluate the impact of calcium carbonate priming on the germination and early growth of maize hybrids CO-6 and VGI (H) M-2 in alkaline soil conditions, assess the potential of calcium carbonate priming to enhance overall plant health and yield in these maize hybrids and provide practical recommendations for farmers to improve maize production in alkaline soils using seed priming techniques. By addressing these objectives, the study seeks to contribute valuable knowledge towards optimising maize cultivation in challenging soil environments, ultimately supporting agricultural sustainability and food security.

MATERIALS AND METHODS

Study site and experimental design

This study was conducted in the Department of Agriculture and Animal Science, Gandhigram Rural Institute, in the summer season of 2024. We used five 500 ml beakers for the experiment. Each beaker was allotted four germination papers having 20 cm in length and 25 cm in breadth. The beakers were kept in an open environment. Ten primed and ten unprimed seeds of CO-6 and VGI H (M)-2 hybrids were sown in germination paper in the form of roll towel paper method at a spacing of 2-3 cm. The experiment was conducted with a completely randomised design method. The experiment used two variables: alkalinity level and priming. Five concentrations of alkalinity (0, 2, 4, 8, and 10% 0.1N $Na2CO_3$+$NaHCO_3$/ml) and two priming methods (CaCO3 primed and unprimed) were employed. The alkalinity level and priming combination were randomised among the beakers.

Priming and Alkalinity Treatment

Two maize hybrids, CO-6 and VGI H (M)-2, were acquired from the Maize Research Station in Vagarai, Dindigul district, Tamil Nadu, India. The seeds were surface sterilised with a 2% formaldehyde solution for 3 minutes and subsequently rinsed completely with distilled water. The seeds were subsequently primed by soaking in a 5g/L $CaCO_3$ solution for 24 hours at ambient temperature. The seed weight to $CaCO_3$ solution ratio was 1:5 (g/mL). After priming, seeds were extracted and cleansed with tap water, followed by three rinses with distilled water. Study the effect of Various concentrations of alkalinity levels (0,2,4,8,10 %) prepared by using 0.1N $Na2CO_3$+$NaHCO_3$ (pH- 9.4 and EC-29.6 ds/m) were poured into for about 100ml twice (1^{st} and 4^{th} day) containing 2 primed and 2 unprimed hybrids as seen in Figure 1.

The experiment was conducted for 7 days, and each observation was carried out 7 days after sown (DAS). The number of seeds germinated was counted and converted into percentages. Mean comparisons were made using a web agri stat package (WASP), and mean significance was detected when p-values were less than 0.

.05.

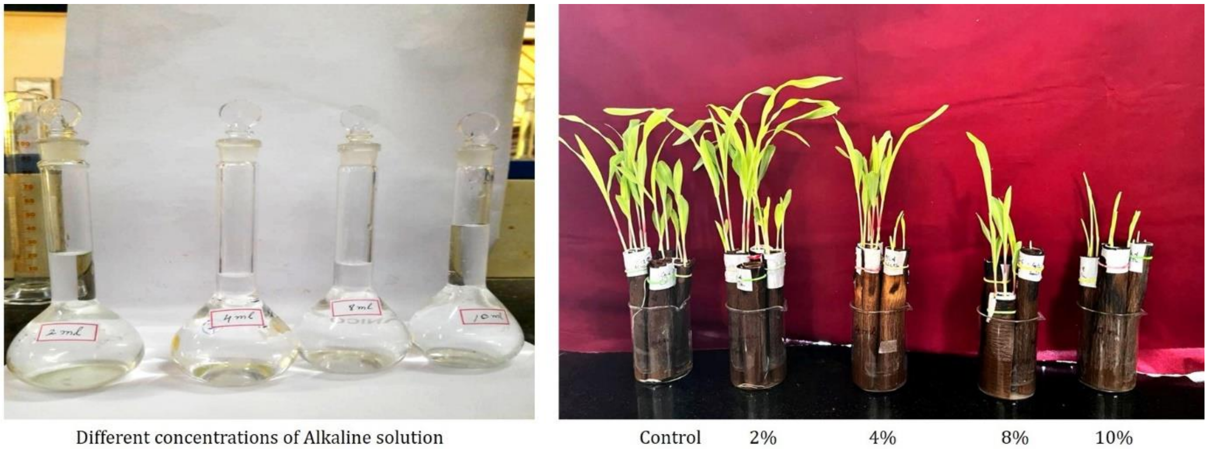

Figure 1. Study the effect of Various concentrations of alkalinity levels (0, 2, 4, 8, 10 %) in two maize hybrids at 7 DAS.

RESULTS

The impacts of seed priming and alkalinity concentration on seed germination, shoot development, and root length are assessed at 7 days after sowing (DAS). Seed priming significantly increased growth parameters for both maize genotypes (Figure 2 & 3).

Effect of seed priming and alkalinity level on seed germination

The significant difference between the germination percentage of the primed seeds from the unprimed seeds and the percent germination among alkalinity levels of both hybrids, CO-6 and VGI H (M)-2. The peak germination of CO-6 is 0, 2, and 4% alkalinity levels in primed and unprimed seeds. The peak germination of VGI H(M)-2 is 0, 2, 4% alkalinity level in primed seed and 0% alkalinity level in unprimed seed (Figure 4). Significant differences were observed between the two genotypes of primed and unprimed seeds, CO-6 and VGI H(M)-2 (Figure 5).

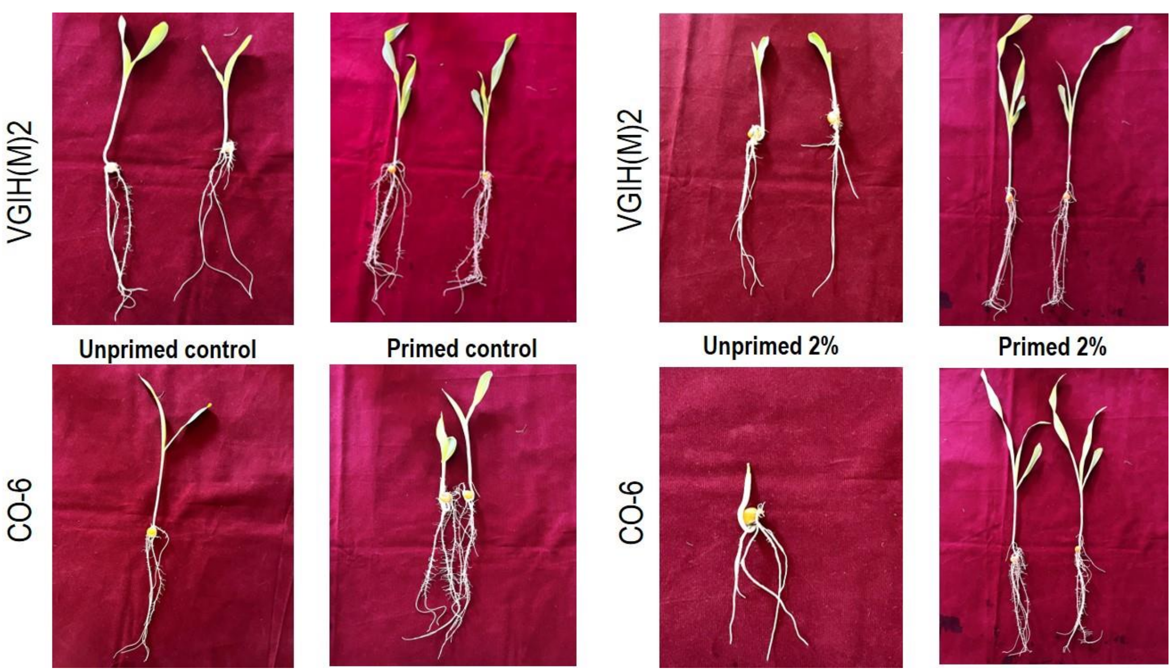

Figure 2. Effect of seed priming and alkalinity level at 0 % and 2%) for two maize hybrids.

Figure 3. Effect of seed priming and alkalinity level at 4 % and 8 %) for two maize hybrids.

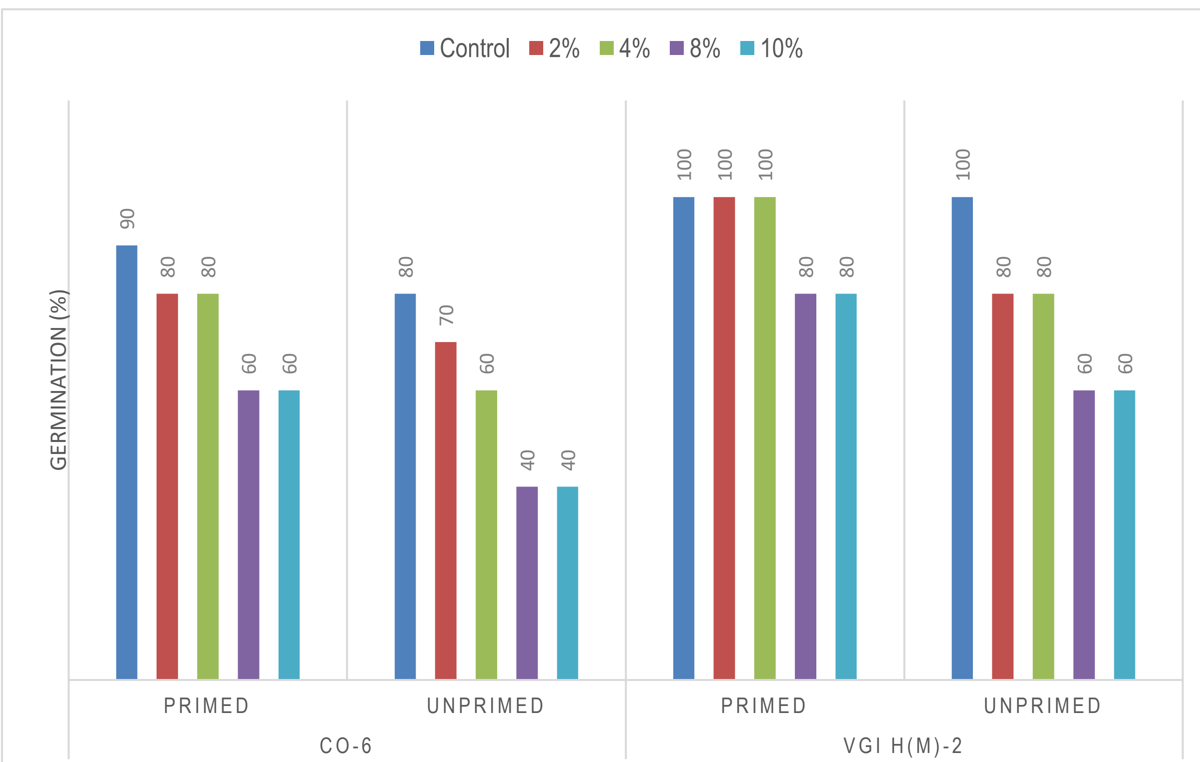

Figure 4. Effect of seed priming and alkalinity level on seed germination

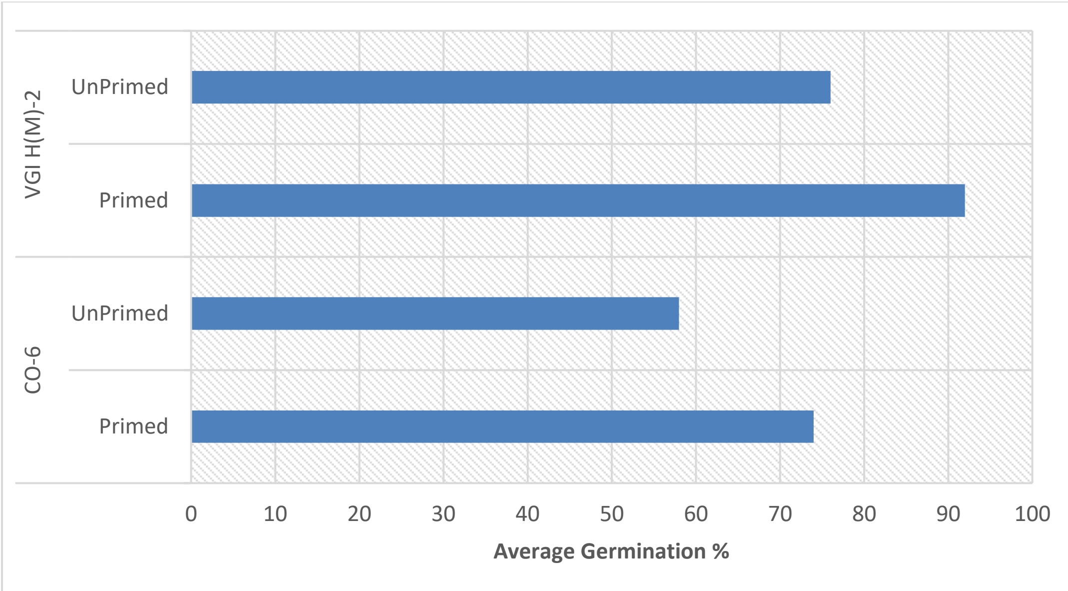

Figure 5. Comparison of average germination percentage of primed and unprimed two maize hybrids

Effect of seed priming and alkalinity level on shoot growth

At varying alkalinity levels, primed seed significantly outperformed normal seed in shoot growth. The maximum shoot growth in the CO-6 hybrid was observed at a 2% alkalinity level for primed seed (30 cm) and a 0% alkalinity level for unprimed seed (18.3 cm). The VGI H(M)-2 genotype showed the maximum shoot growth at a 2% alkalinity level for primed seed (26.6 cm) and a 0% alkalinity level for unprimed seed (9.2 cm) (Figure 6). The two maize genotypes showed significant differences in average shoot length (cm). However, there is no significant difference between the two hybrids unprimed seed shoot growth separate comparisons (Figure 7).

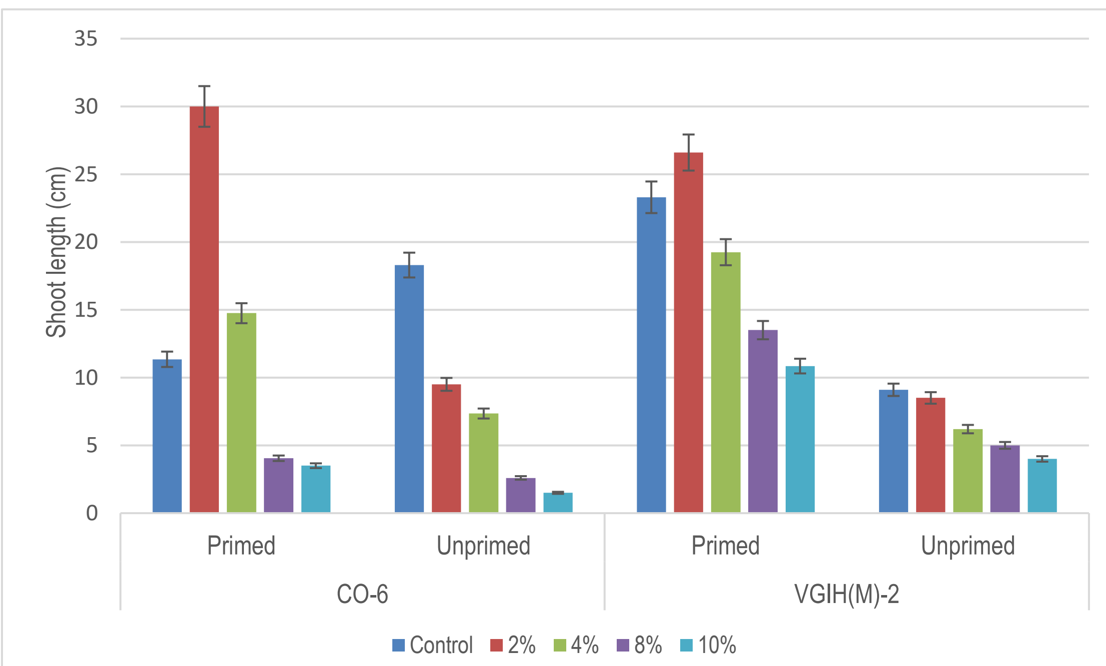

Figure 6. Effect of seed priming and alkalinity level on shoot growth.

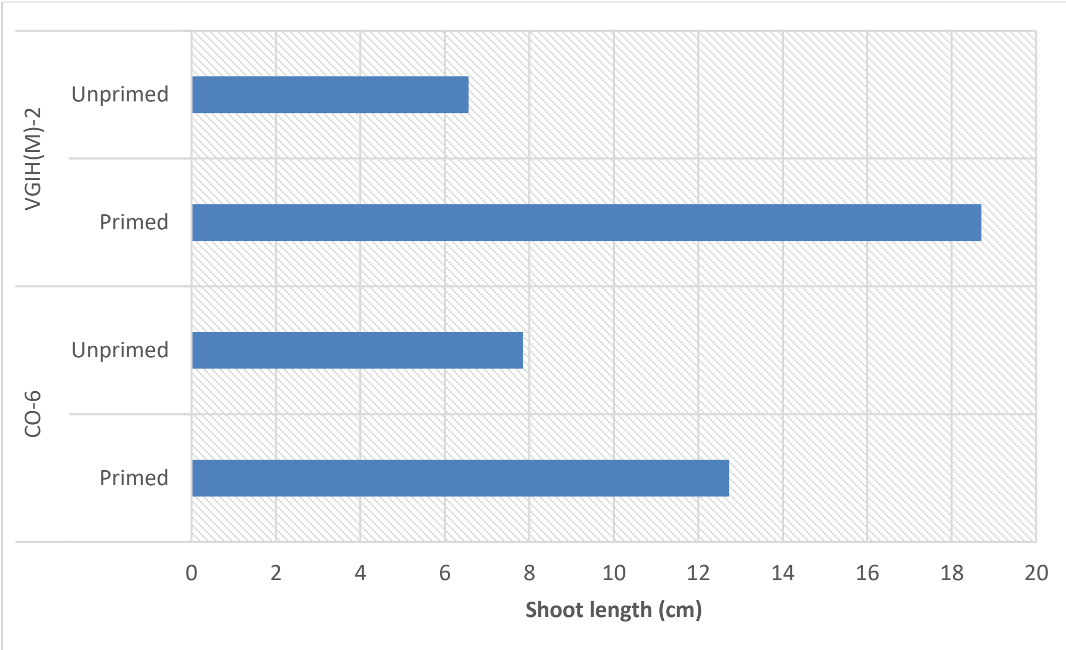

Figure 7. Comparison of average shoot length of primed and unprimed two maize hybrids

Effect of seed priming and alkalinity level on root length:

Significant improvement in root length of both hybrids was observed in primed seed than normal seed at different alkalinity levels. The maximum root length in the CO-6 hybrid for primed seed was observed in 0% and 2% alkalinity levels (20 cm & 17 cm), and for unprimed seed, it was observed in 0% and 4% alkalinity levels (16.4 cm & 7.6 cm) (Figure 8). The maximum root length in the VGI H(M)-2 hybrid for primed seed was observed at 0% and 2% alkalinity levels (21.7 cm and 18.3 cm), and for unprimed seed it was also observed at 0% and 2% alkalinity levels (17.25 cm and 16.9 cm). There is no significant difference between the two hybrids primed and unprimed average root length (Figure 9). The total number of roots and total biomass for both hybrids primed and unprimed seed was also observed, but there was no significant difference (data were not shown).

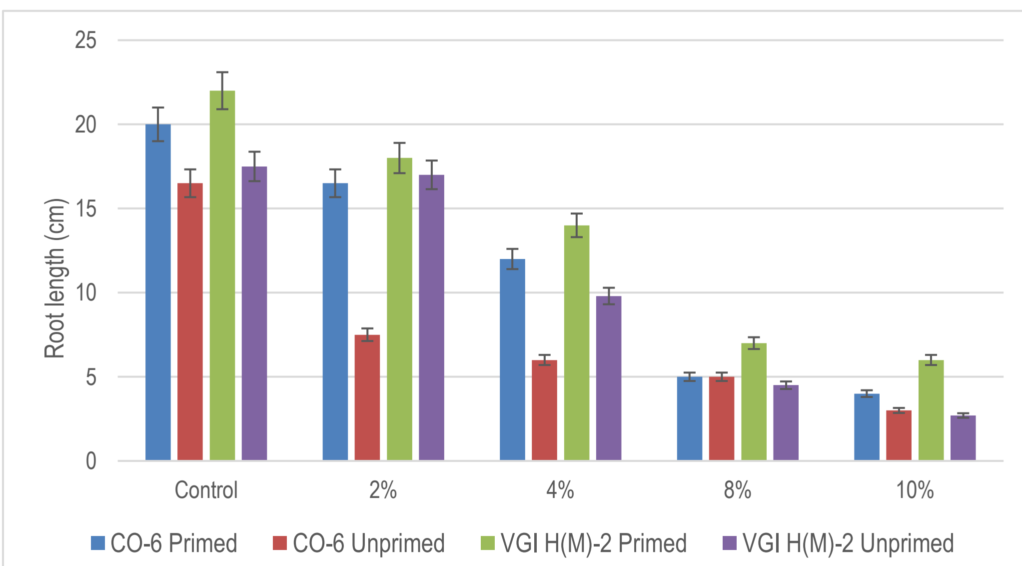

Figure 8. Effect of seed priming and alkalinity level on root length of two maize hybrids.

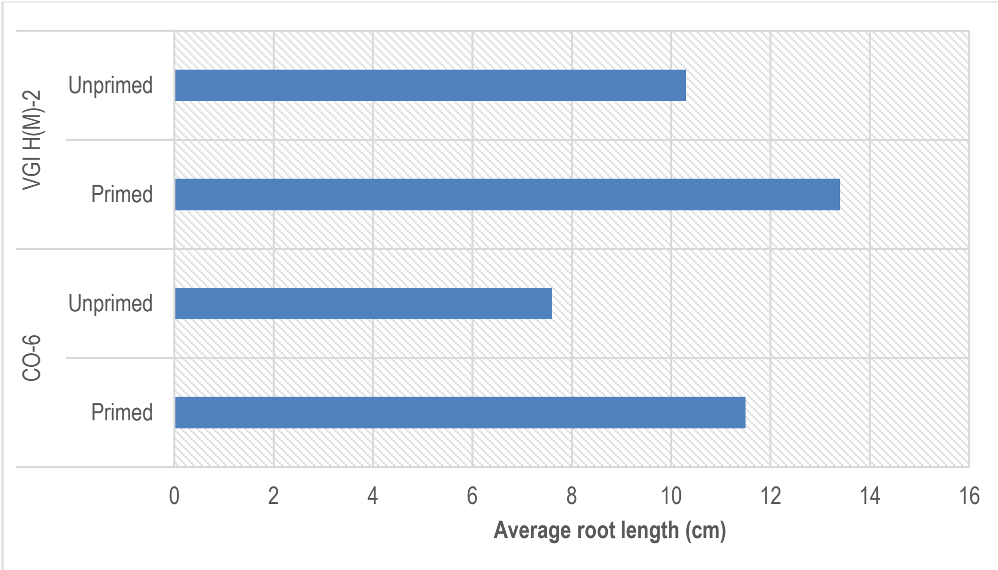

Figure 9. Comparison of average root length of primed and unprimed two maize hybrids.

DISCUSSION

Seed priming is a widely employed technique for enhancing plant tolerance to salinity, drought, and alkalinity stressors (Kumar et al., 2013; Ashokkumar et al., 2013). It is the process of regulated hydration of seeds to a degree that allows pre-germinative metabolic activity to occur while inhibiting the actual development of the radicle. Researchers have suggested several priming approaches, including hydropriming, halopriming, and osmopriming, among others (Farooq et al., 2009; Venothini et al., 2024). Osmopriming is the translocation of solvent molecules from a dilute solution to a concentrated solution via a semipermeable membrane (Zhang et al., 2006; Kubala et al., 2015). Osmosis is classified into two types: endosmosis and exosmosis. An exosmotic mechanism occurs, utilising a hypertonic fluid to prime the seed. Seed priming employs several substances, such as polyethylene glycol (PEG), water, and chloride salts of sodium, potassium, and calcium (Mahara et al., 2022; Khodarahmpour & Choukan, 2011). Seed priming enhances multiple metabolic and physiological processes in plants during germination and initial growth (Farooq et al., 2006; Abraha and Yohannes, 2013).

This study examined the effects of seed priming and alkaline stress on maize germination and growth. Restoring alkaline or basic soils necessitates neutralising the alkalinity and substituting the majority of sodium ions with calcium ions, which are more advantageous for plant growth (Debta, et al., 2023). Consequently, maize seeds were subjected to priming in a calcium carbonate solution before sown on germination paper and subsequently immersed in a beaker containing an alkaline solution. Significant variation in germination % was observed between primed and unprimed seeds of CO-6 and VGI H (M)-2 hybrids at different alkalinity levels. There was a notable variance in root length and shoot growth between primed and unprimed seed hybrids of CO-6 and VGI H (M)-2 across varying alkalinity levels. Comparable findings were noted for two maize hybrids subjected to salt stress (Zheng et al., 2016). A recent investigation indicated that maize exhibited alkaline stress resistance when seeds were primed with silicon nanoparticles (Alsamadany et al., 2024). The two preceding papers corroborated the findings of the current investigation. The distinct comparison of the primed seeds from the two hybrids, with the unprimed seeds of the same hybrids, yielded varying results. The germination %, shoot length, and root length of the primed seeds of CO-6 and VGI H (M)-2 exhibited a significant difference, but the number of roots of the primed seeds of CO-6 and VGI H (M)-2 did not demonstrate a significant difference. In all instances, the mean values of germination %, shoot growth, and root length were superior in primed seeds compared to unprimed seeds. The findings indicate that alkalinity stress in maize substantially affects radicle emergence, shoot development, and root length.

CONCLUSION

Alkalinity may impede germination and seedling development in maize. Seed priming is an efficacious technique to enhance alkalinity tolerance in maize cultivation. This experiment indicates a significant tolerance for cultivating primed seedlings in alkaline environments. Seed priming enhances germination and supports the plant's general growth and development. After practising the priming technique, the two hybrids subjected to the alkaline condition in the laboratory can be further tested in open field conditions or under pot culture, which will be more effective in determining their tolerance. Additional biochemical tests may reveal its true effectiveness.

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AUTHORS CONTRIBUTION STATEMENT

All authors made contributions to the conception, design and execution of the study as well as to the analysis of the results and drafting of the manuscript.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

REFERENCES

Abraha, T., & Yohannes, G. (2013). The role of seed priming in alleviating the impact of salinity stress on maize (*Zea mays* L.) germination and early seedling growth. *Agricultural Sciences, 4*(12), 666-673.

Alsamadany, H., Alharby, H. F., Ahmad, Z., Al-Zahrani, H. S., Alzahrani, Y. M., & Almaghamsi, A. (2024). Improving alkaline stress tolerance in maize through seed priming with silicon nanoparticles: a comprehensive investigation of growth, photosynthetic pigments, antioxidants, and ion balance. *Silicon*, *16*(5), 2233-2244. https://doi.org/10.1007/s12633-023-02833-5

Ashokkumar, K., Raveendran, M., Senthil, N., Vijayalaxmi, D., Sowmya, M., Sharma, R. P., & Robin, S. (2013). Isolation and characterization of altered root growth behavior and salinity tolerant mutants in rice. *African Journal of Biotechnology*, *12*(40), 5852-5859. https://doi.org/10.5897/AJB2013.12880

Ashraf, M., & Foolad, M. R. (2005). Pre-sowing seed treatment—a shotgun approach to improve germination, plant growth, and crop yield under saline and non-saline conditions. *Advances in Agronomy, 88,* 223-271. https://doi.org/10.1016/S0065-2113(05)88006-X

Barrow, N. J., & Hartemink, A. E. (2023). The effects of pH on nutrient availability depend on both soils and plants. *Plant and Soil*, *487*(1), 21-37. https://doi.org/10.1007/s11104-023-05960-5

Debta, H., Kunhamu, T. K., Petrík, P., Fleischer Jr, P., & Jisha, K. C. (2023). Effect of hydropriming and osmopriming on the germination and seedling vigor of the East Indian Sandalwood (*Santalum album* L.). *Forests, 14*(6), 1076. https://doi.org/10.3390/f14061076

Denham, T. (2020). Maize: Origins and Development. In Encyclopedia of Global Archaeology (pp. 6686-6688). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-30018-0_2179

Erenstein, O., Jaleta, M., Sonder, K., Mottaleb, K., & Prasanna, B. M. (2022). Global maize production, consumption and trade: trends and R&D implications. *Food security*, *14*(5), 1295-1319. https://doi.org/10.1007/s12571-022-01288-7

Esfandiari, E., & Shakiba, M.R. (2014). The effect of salinity and alkalinity on seed germination and growth of maize (*Zea mays* L.). *International Journal of Agronomy and Plant Production, 5*(12), 2014-2020.

Farooq, M., Basra, S. M. A., Wahid, A., & Khaliq, A. (2006). Optimization of seed priming by osmohardening and its evaluation for water stress tolerance in rice (*Oryza sativa* L.). *Plant Growth Regulation, 49*(2-3), 121-128.

Farooq, M., Wahid, A., Kobayashi, N., Fujita, D., & Basra, S. M. A. (2009). Plant drought stress: Effects, mechanisms and management. *Agronomy for Sustainable Development*, 29(1), 185-212.

Jisha, K. C., Vijayakumari, K., & Puthur, J. T. (2013). Seed priming for abiotic stress tolerance: An overview. *Acta Physiologiae Plantarum, 35*(5), 1381-1396. https://doi.org/10.1007/s11738-012-1186-5

Khodarahmpour, Z., & Choukan, R. (2011). Effect of calcium carbonate on germination and seedling growth of maize under saline conditions. *Journal of Agricultural Science, 3*(4), 60-66.

Kubala, S., Wojtyla, L., Quinet, M., Lutts, S., & Garnczarska, M. (2015). Enhanced expression of the proline synthesis gene P5CSA in relation to seed osmopriming improvement of drought stress tolerance in *Brassica napus* L. *Journal of Plant Physiology, 183*, 1-12. https://doi.org/10.1016/j.jplph.2015.04.009

Kumar, K. A., Kumar, M. S., Sudha, M., Vijayalakshmi, D., Vellaikkumar, S., Senthil, N., & Raveendran, M. (2013). Identification of genes controlling

ABA accumulation in rice during drought stress and seed maturation. *International Journal of Advanced Biotechnology and Research*, *4*(4), 481-487.

Lamichhane, J. R., Debaeke, P., Steinberg, C., You, M. P., Barbetti, M. J., & Aubertot, J. N. (2018). Abiotic and biotic factors affecting crop seed germination and seedling emergence: a conceptual framework. *Plant and soil*, *432*, 1-28. https://doi.org/10.1007/s11104-018-3780-9

Mahara, G., Bam, R., Kandel, M., Timilsina, S., Chaudhary, D., Lamichhane, J., Bajgai, T., Pant, B., Bhattarai, U., Upadhyaya, J. (2022). Seed priming with NaCl improves germination in maize under saline soil conditions. *Eurasian journal of soil science,11*(2): 151-156. http://dx.doi.org/10.18393/ejss.1027558

Marschner, H. (2011). Marschner's mineral nutrition of higher plants. Academic Press. https://doi.org/10.1016/C2009-0-63043-9

Naorem, A., Jayaraman, S., Dang, Y. P., Dalal, R. C., Sinha, N. K., Rao, C. S., & Patra, A. K. (2023). Soil constraints in an arid environment—challenges, prospects, and implications. *Agronomy*, *13*(1), 220. https://doi.org/10.3390/agronomy13010220

Paul, S., Dey, S., & Kundu, R. (2022). Seed priming: an emerging tool towards sustainable agriculture. *Plant Growth Regulation*, *97*(2), 215-234. https://doi.org/10.1007/s10725-021-00761-1

Schoonover, J. E., & Crim, J. F. (2015). An introduction to soil concepts and the role of soils in watershed management. *Journal of Contemporary Water Research & Education*, *154*(1), 21-47. https://doi.org/10.1111/j.1936-704X.2015.03186.x

Thakur, M., Tiwari, S., Kataria, S., & Anand, A. (2022). Recent advances in seed priming strategies for enhancing planting value of vegetable seeds. *Scientia Horticulturae*, *305*, 111355. https://doi.org/10.1016/j.scienta.2022.111355

Venothini, S., Sujith, A. S., Riya, E., Soji, S. A., Vinodha, K., & Ashokkumar, K. (2024). Effect of halo priming on germination and growth parameters of finger millet, little millet, and barnyard millet under osmotic stress. *Journal of Current Opinion in Crop Science*, *5*(2), 62-69. https://doi.org/10.62773/jcocs.v5i2.246

Xu, X., Guo, L., Wang, S., Wang, X., Ren, M., Zhao, P., ... & Lin, A. (2023). Effective strategies for reclamation of saline-alkali soil and response mechanisms of the soil-plant system. *Science of The Total Environment*, *905*, 167179. https://doi.org/10.1016/j.scitotenv.2023.167179

Zhang, M., Zhang, H., Lu, S., & Li, L. (2006). Seed priming with uncouplers of oxidative phosphorylation alleviates salt stress in rice as related to the improvement of respiratory metabolism. *Plant Growth Regulation, 49*(1), 17-23.

Zheng, Y., Wu, Y., Huang, Y., Zhan, J., & Sun, W. (2016). The effects of seed priming on the germination and early seedling growth of two maize hybrids under salt stress. International *Journal of Agriculture and Biology, 18*(1), 32-38.