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Research Article

Effect of Different Concentrations of *Aloe vera* Gel on Seed Germination and Growth of Moringa (*Moringa oleifera*)

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ABSTRACT

Moringa (*Moringa oleifera*) cultivation is limited germination and early seedling growth challenges. *Aloe vera* gel, a natural biostimulant, shows potential, but its effects on Moringa are underexplored. The primary objective of this investigation was to identify sustainable ways to increase the germination as well as seedling vigor of Moringa. The study had taken place at the Horticulture Department of Sindh Agriculture University in Tandojam during the fall of 2024. The findings from this research investigates the impact of varying concentrations of *Aloe vera* gel on the germination and growth of Moringa (*Moringa oleifera*). The experiment was laid out in a CRD with six treatments, replicated three times. T_0 (control), T_1 priming (distilled water), T_2 (1% *Aloe vera* gel), T_3 (30% *Aloe vera* gel), T_4 (60% *Aloe vera* gel), and T_5 (100% *Aloe vera* gel). Key germination and growth parameters, including germination percentage, time to germination, germination index, seedling vigor index, number of branches per plant, shoot and root fresh biomass, seedling quality index, plant height, and sturdiness quotient were evaluated in this study. Findings showed that 100% *Aloe vera* gel (T_5) significantly improved germination percentage (82.66%), germination index (4.99), vigor index (2230), plant height (42.11 cm), and number of branches (14.66), while control treatment consistently produced the lowest values. Interestingly, shoot and root biomass, as well as seedling quality index, were maximized at lower concentrations (1% *Aloe vera* gel). These results highlight the potential of *Aloe vera* gel as a sustainable and natural biostimulant to overcome germination challenges in Moringa. Future studies should focus on field-scale validation, optimization of gel concentrations, and integration with other eco-friendly priming techniques to establish standardized protocols for large-scale Moringa cultivation.

Keywords: Moringa, *Aloe vera*, Priming, Natural Biostimulant, Seed Germination and Seedling Vigor.

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INTRODUCTION

Moringa (*Moringa oleifera*), the most widely cultivated species of the Moringa genus, is well adapted to diverse environments, ranging from arid hot zones to humid tropical regions (Pandy et al., 2012). It is distributed across South Asia, the

Arabian Peninsula, Madagascar, and Africa, with northwestern India identified as an important cultivation zone (Meireles et al., 2020). Belonging to the Moringaceae family, it is also grown in Pakistan, particularly in the western and sub-Himalayan regions, Arabia, and Africa. The moringa tree has many local names such as horseradish tree, drumstick tree and the malunggay tree (Mahato et al., 2022). *M. oleifera* is recognized for its exceptional nutritional profile, being rich in phytochemicals, proteins, vitamins (A, C, and B complex), and minerals such as calcium, iron, and potassium, which makes it valuable for addressing malnutrition and improving food security (Gopalakrishnan et al., 2016; Falowo et al., 2018). Globally, it is cultivated in more than 80 countries, with India accounting for nearly 80% of the annual production exceeding 12 million tons of fresh biomass (Leone et al., 2015; Rashid et al., 2021). In Pakistan, *M. oleifera* is naturally adapted to semi-arid and arid zones, thriving in Sindh, Punjab, and southern Khyber Pakhtunkhwa, where it holds promise for nutritional security, livestock feed, and climate-resilient agriculture (Nouman et al., 2013; Anwar et al., 2020).

M. oleifera possesses significant economic value due to its robust nutritional and bioactive properties that promote antimicrobial, anti-inflammatory, and therapeutic benefits. It also has potential in agriculture, livestock enhancement, as well as the environment (Hao et al., 2024). It is extensively used in conventional diets and medicine due to its richness in nutrient value and health properties especially on its leaves, pods and seeds. It is now turning out to be more modern as a medicine to metabolic syndrome, a method of losing weight, and a means of treating chronic conditions (Sreeja et al., 2021; Herman-lara et al., 2024; Schaffer et al., 2024). *M. oleifera* has attracted an enormous amount of scientific attention because of the occurrence of high concentrations of bioactive chemicals, which have huge biological activity. These were found to be high in antioxidants, anti-inflammatory and antibacterial properties (Rocchetti et al., 2019). These properties not only expand the potential applications of the plant within the traditional medical practice, but also render it usable in the modern medicine. All the health benefits, and drug properties of *M. oleifera* are still being studied by scientists. These findings provide new avenues to further research and application of this exotic plant in health and nutrition (Nuapia et al., 2020).

The quality of seed determines the level of agricultural production and profitability since the rate and uniform germination of the seed can positively influence the ultimate production of crop production or yield. Delayed germination of the seeds may cause weak seedlings which will be more vulnerable to diseases (Nouman et al., 2014). To regulate these factors, pre-sowing techniques like as seed priming have been developed to enhance seed performance by increasing the germination rate and subsequent establishment. This approach is successful in minimizing time to emergence and even-handed growth of seedlings in varied crops (Hemalatha et al., 2014). Basil leaf extract priming enhances okra germination and seedling growth, and similarly *Aloe vera* gel can promote germination and growth in Moringa (Chachar et al., 2025). The recent development has resulted in a variety of chemicals to be applied in seed priming including hormones, botanicals, bioagents and growth regulators. All of them have documented favorable impacts on germination and general yields (Janmohammadi et al., 2008, Chachar et al., 2025).

Aloe vera (*Aloe vera* L.), succulent perennial member of the Liliaceae family with its origin rooted in Africa is one of such agents that have become popular among consumers due to its medical and agricultural importance. Its mucilaginous gel and leaf extracts have attracted a significant interest because of highly nutrient rich content and bioactive properties which make them an excellent natural growth promoters and regulators. The gel contains vital minerals such as calcium, iron, magnesium, and so on (Dagne et al., 2000; Ramachandra & Rao, 2008), are linked to amino acids, monosaccharides, lignin, macronutrients, micronutrients, vitamins, gibberellins as well as salicylic acid (Ni et al., 2004; Surjushe et al., 2008; Hamouda et al., 2012; Chatterjee et al., 2013; Raman et al., 2013; Sahu et al., 2013). Moreover, the gel is enzyme-rich and has established anti-inflammatory and healing properties (Hernández-Cruz et al., 2002; Ni & Tizard, 2004), Lobotomizing its economic sustainability in agriculture. The potential of the *Aloe vera* as a bio stimulant has come with the prospect of its application as an alternative to artificial growth regulators especially in nutrient-endowed farming crops like Moringa (René et al., 2024). Macronutrient availability significantly influences spinach growth, and similarly *Aloe vera* gel, containing nutrients and bioactive compounds, can enhance seed germination and seedling growth in Moringa (Aamur et al., 2025). Research has revealed that the diluted *Aloe vera* gel can have an impressive impact of enhancing growth and productivity of plants as was the case in the research experiment that was done with *S. officinalis* (Abbas et al., 2016). It is a biostimulant nature that has been proved to elevate vegetative growth, enhance biomass production, and enhance the overall fitness of the plants. As compared to the gel, *Aloe vera* leaf extract (ALE) has been demonstrated to be very promising as a natural plant growth regulator. Multiple experiments have indicated that ALE has the potential in vegetative development among most plant categories. *A. esculentus*, *O. biennis*, and *M. hortensis* (Padmaja et al., 2007; El-Shayed, 2009; Nouman et al., 2014). Extracts of *Aloe vera* contain bioactive molecules such as gibberellins and phytohormones, and this gives plants a boost in growth and productivity, replacing the use of synthetic growth regulators. Being rich in nutrients, *Aloe vera* acts as a source of nutrients and biostimulant, which enhances stress tolerance and promotes environmentally friendly cultivation. Its versatility across species elicits its impending usefulness and even additional research (DongZhi et al., 2004; Nour El-Din, 2005; Mady, 2008; Hamouda et al., 2014). *Aloe vera* extracts have dual uses: they can be applied to diverse agricultural needs because they can be used to enhance crop production and regulate vegetative growth. They may be applied when priming the seeds, which may increase the germination and growth of the *Moringa oleifera*, yet the diversity of gel concentration has not been investigated. Consequently, the research proposed was carried out to check the impact of various levels of *Aloe vera* gel on the germination of the seeds and the initial growth of the seedlings of. *M. oleifera* with the aim of establishing the most appropriate conditions to enhance crop productivity and promote the use of sustainable agricultural methods.

MATERIALS AND METHODS

Experimental Material

The present investigation was carried out in the Department of Horticulture, Sindh Agriculture University, Tandojam, during the autumn of 2024. The study analyzed the effects of various concentrations of *Aloe vera* gel on the germination and growth of *Moringa oleifera*. The experiment was executed using a Completely Randomized Design (CRD) with three replications. Six treatments were applied: T_0 = Control, T_1 = Priming (distilled water), T_2 = 1% *Aloe vera* gel, T_3 = 30% *Aloe vera* gel, T_4 = 60% *Aloe vera* gel, T_5 = 100% *Aloe vera* gel.

For seed priming, moringa seeds were soaked in the respective solutions for 24 hours at ambient laboratory temperature (25–28 °C). Immediately after priming, seeds were sown into earthen pots filled with a planting medium consisting of sand, silt, and farmyard manure (FYM) in a ratio of 2:2:1. Pots were maintained under open field conditions without the use of any controlled environment facilities. Regular irrigation was applied to ensure uniform seedling emergence and survival. Data were collected on germination and seedling growth parameters until the completion of the establishment phase.

Data procurement and methodological approach

Data on seed germination and subsequent growth characteristics were carefully recorded and analyzed statistically. The evaluated parameters encompassed germination %, mean germination time, germination index, seedling vigor index, number of branches per plant, fresh shoot biomass (g), fresh root biomass (g), seedling quality index, plant height (cm), and sturdiness quotient.

Seed germination (%)

The percent of germination has been determined by dividing the number of seeds that germinated by the total number of seeds planted and representing it as a percentage.

Days to germination

The duration from planting seeds to the first visible germination was recorded for each seed, and the mean was computed across all replications.

Germination index (GI)

The germination index was determined following the procedure outlined by the Association of Official Seed Analysts (AOSA, 1983). It was computed using the formula.

$$GI = \sum \frac{Gt}{Dt}$$

Where:

Gt = Number of seeds germinated on day t

Dt= Number of days after sowing (day t)

Seedling Vigor Index

The seedling vigor index was calculated according to the method described by Abdul-Baki and Anderson (1973). It was derived using the formula:

$$Seedling\ Vigor\ Index\ (SVI) = seedling\ length\ (cm)\ \times seed\ germination\ percentage$$

The mean seedling height (cm) was recorded at a predetermined interval following germination.

Number of branches per plant

The number of branches per plant was recorded at defined growth intervals and the mean values were calculated across all plants within each pot.

Fresh shoot biomass (g)

Fresh shoot biomass was determined by randomly sampling plants and measuring their fresh weight using an electronic balance. The results were expressed in grams

Fresh root biomass (g)

Fresh root biomass was determined by randomly sampling plants and measuring their fresh weight using an electronic balance. The results were expressed in grams.

Seedlings Quality Index

The seedling quality index was calculated using the standard formula proposed by Dickson et al. (1960).

$$DQI=\frac{TSDW}{\frac{H}{D}+\frac{SDW}{RDW}}$$

Where,

DQI = Dickson Quality index

TSDW = Total seedling dry weight (shoot + root dry weight) in grams

H = Seedling height (cm)

D = Collar diameter (mm)

SDW = Shoot dry weight (g)

RDW = Root dry weight (g)

Plant height (cm)

Plant height (cm) was measured at maturity from the base to the tip of the plant using a measuring tape, and the average values were computed across all plants in each pot.

Sturdiness Quotient (SQ)

Sturdiness quotient indicates the robust or selender nature of seedlings (Thompson, 1985). The sturdiness quotient that is measured by dividing seedling length (cm) by collar diameter (mm) as per the (Roller 1977; Luna & Chamoli, 2006).

$$Sturdiness\ Quotient\ =\ \frac{seedling\ height\ (cm)}{collar\ diameter\ (mm)}$$

Statistical analysis

The data underwent statistical analysis with Statistics 8.1 software (Statistix, 2006). An analysis of variance (ANOVA) was used to assess significant differences among treatments, and when applicable, the Least Significant Difference (LSD) test at the 0.05 probability level was performed for mean separation.

RESULTS

The experiment of the current study was conducted in the fall of 2024 at the Horticulture Department, Sindh Agriculture University, Tandojam. The data on the studied parameters are presented in (Figure 1 to 10).

Seed germination (%)

The influence of varying concentrations of *Aloe vera* gel on the seed germination percentage of Moringa was examined. The data pertaining to this parameter are provided in (Figure 1). The results of the analysis of variance revealed that different concentrations of *Aloe vera* gel had a statistically significant effect on seed germination ($P<0.05$). The results showed varying seed germination percentages across treatments. The lowest seed germination (57.00%) was observed in the control group (T_0). Seed germination increases to 60.33% in priming with distilled water (T_1). A further increase was noted by applying of 1% *Aloe vera* gel (T_2), which resulted in a germination percentage of 70.66%, considerably higher than T_0 and T_1. Seed germination continued to increase with 30% *Aloe vera* gel (T_3), achieving a percentage of 66.33%, although this was not significantly different from T_2. The 60% *Aloe vera* gel treatment (T_4) resulted in a higher germination (75.33%), significantly different from the lower treatments. Finally, the maximum seed germination (82.66%) was recorded with the 100% *Aloe vera* gel treatment (T_5), indicating its optimal effectiveness in enhancing germination.

Days to germination

The effect of different concentrations of *Aloe vera* gel on the period of time necessary for Moringa seeds to germinate was evaluated. The data for this parameter are presented in (Figure 2). The analysis of variance indicated that the days to germination were significantly affected ($P<0.05$) by various concentrations of *Aloe vera* gel. The results indicated that the control group (T_0) exhibited the longest germination time, averaging 3.00 days, indicating slower germination without priming treatment. Priming with distilled water (T_1) reduced the germination time to 2.66 days, improving over the control. Seeds treated with 1% *Aloe vera* gel (T_2) germinated in 2.33 days, further germination efficiency improvement. The germination time continued to decrease with higher concentrations of *Aloe vera* gel, with 40% *Aloe vera* gel (T_3) resulting in 2.00 days of germination, followed by 60% *Aloe vera* gel (T_4) with 1.66 days. The most significant improvement was observed with 100% *Aloe vera* gel (T_5), which recorded the shortest germination time of 1.33 days.

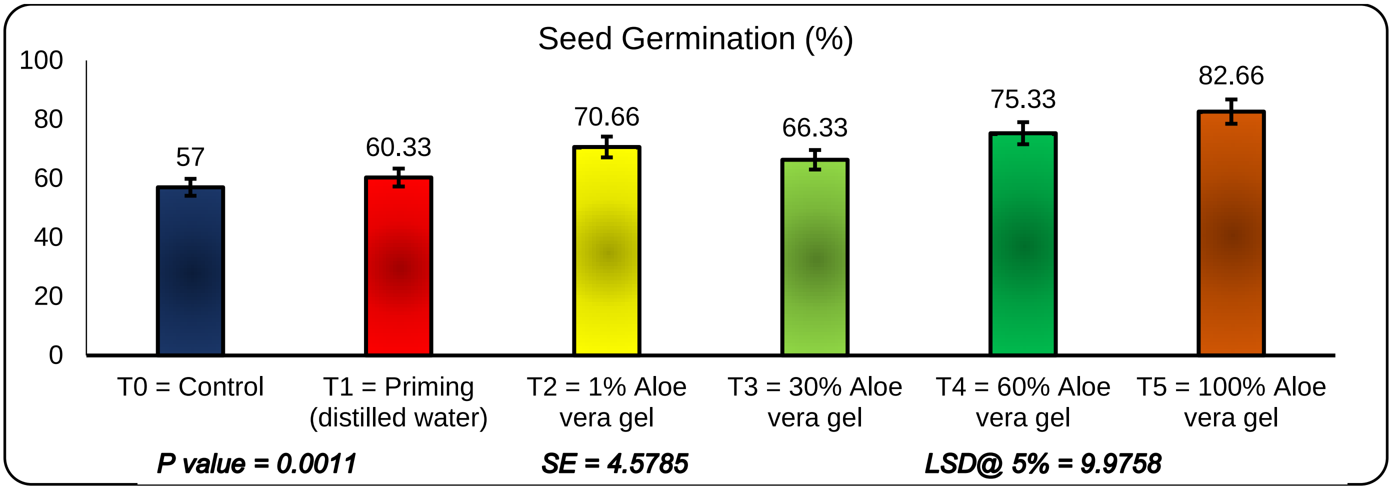

Figure 1. Seed germination (%) of Moringa as affected by varying concentrations of *Aloe vera* gel.

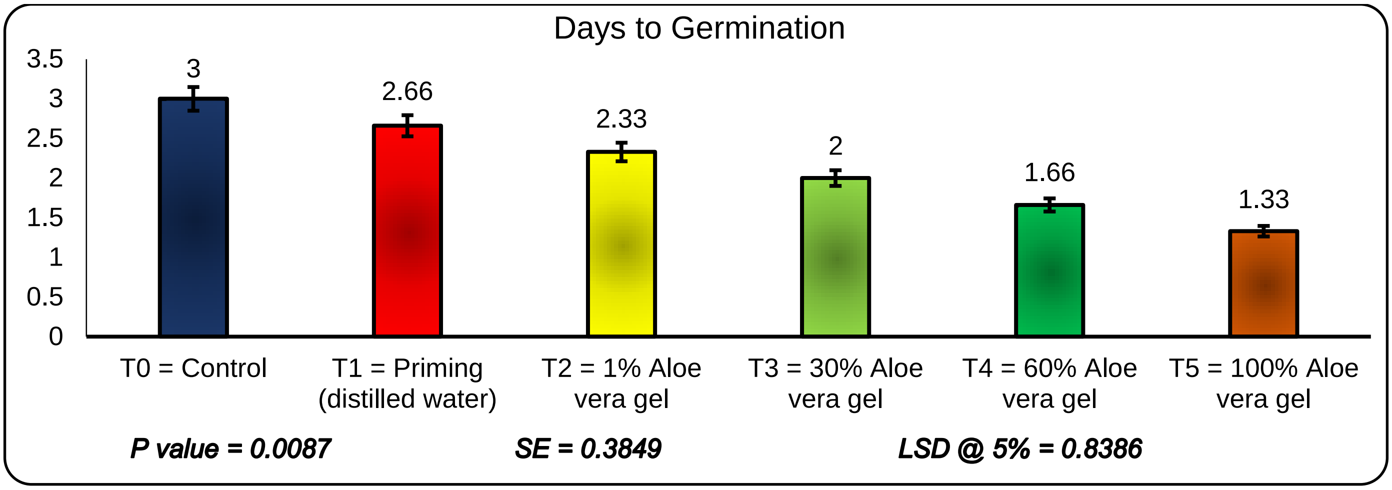

Figure 2. Days to germination of Moringa as affected by varying concentrations of *Aloe vera* gel.

Germination index (GI)

The effect of varying concentrations of *Aloe vera* gel on the germination index of Moringa was studied. The data for this parameter are presented in (Figure 3). The analysis of variance revealed that the germination index was significantly influenced ($P<0.05$) by the different concentrations of *Aloe vera* gel. The results indicated that the control group (T_0) had the lowest germination index, recording a value of 2.58, indicating poor germination performance without any priming treatment. Priming with distilled water (T_1) improved the germination index to 3.53, significantly increase. Applying of 1% *Aloe vera* gel (T_2) further enhanced the germination index to 3.81, highlighting its positive impact on germination. Applying 30% *Aloe vera* gel (T_3) resulted in a germination index of 3.66, comparable to 1% *Aloe vera* gel but slightly lower. A more significant improvement was observed with 60% *Aloe vera* gel (T_4), which achieved a germination index 3.98, indicating its higher efficacy in promoting seed germination. The highest germination index was recorded with 100% *Aloe vera* gel (T_5), with 4.99, representing the most effective treatment.

Seedling vigor index (SVI)

The impact of varying doses of *Aloe vera* gel on the vigor index of Moringa seedlings was investigated. The data related to this trait are presented in (Figure 4). The analysis of variance revealed that the seedling vigor index was significantly influenced ($P<0.05$) by varying concentrations of *Aloe vera* gel. The results indicated that the control group (T_0) exhibited the lowest seedling vigor index, recording 797, indicating poor seedling growth in the absence of any priming treatment. Priming with distilled water (T_1) improved the seedling vigor index to 1039, significant enhancement over the control. Applying 1% *Aloe vera* gel (T_2) further increased the seedling vigor index to 1230, showing the positive impact of *Aloe vera* gel on seedling vigor. A notable improvement was observed with 30% *Aloe vera* gel (T_3), resulting in a seedling vigor index of 1476. The application of 60% *Aloe vera* gel (T_4) achieved a substantial increase, with a seedling vigor index of 2045. The maximum seedling vigor index was recorded with 100% *Aloe vera* gel (T_5), which achieved a value of 2230, demonstrating the highest effectiveness in enhancing seedling vigor.

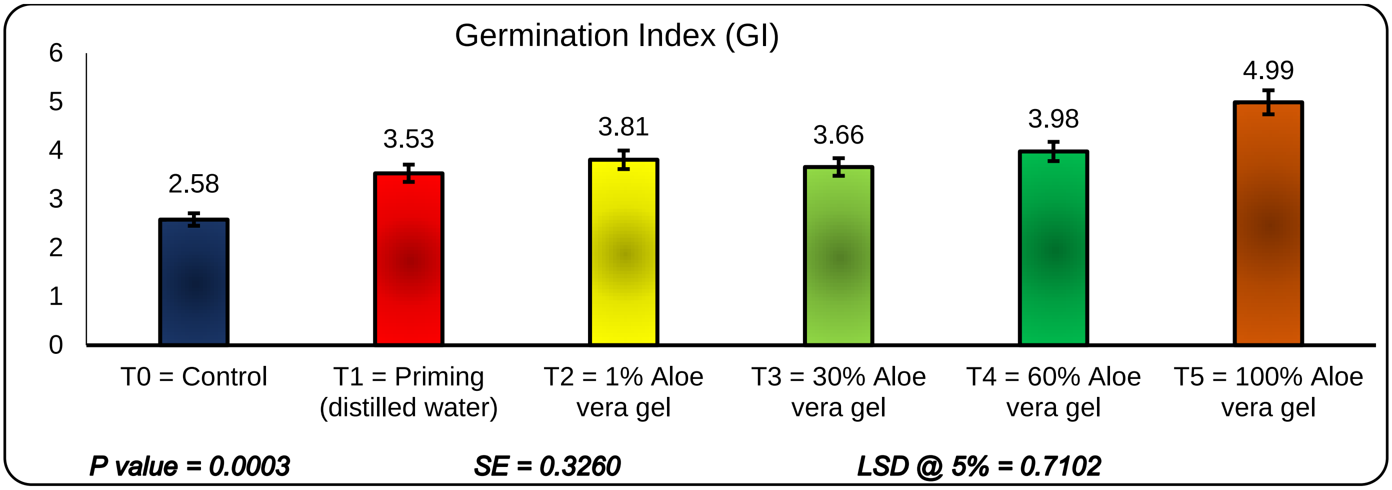

Figure 3. Germination index of Moringa as affected by varying concentrations of *Aloe vera* gel.

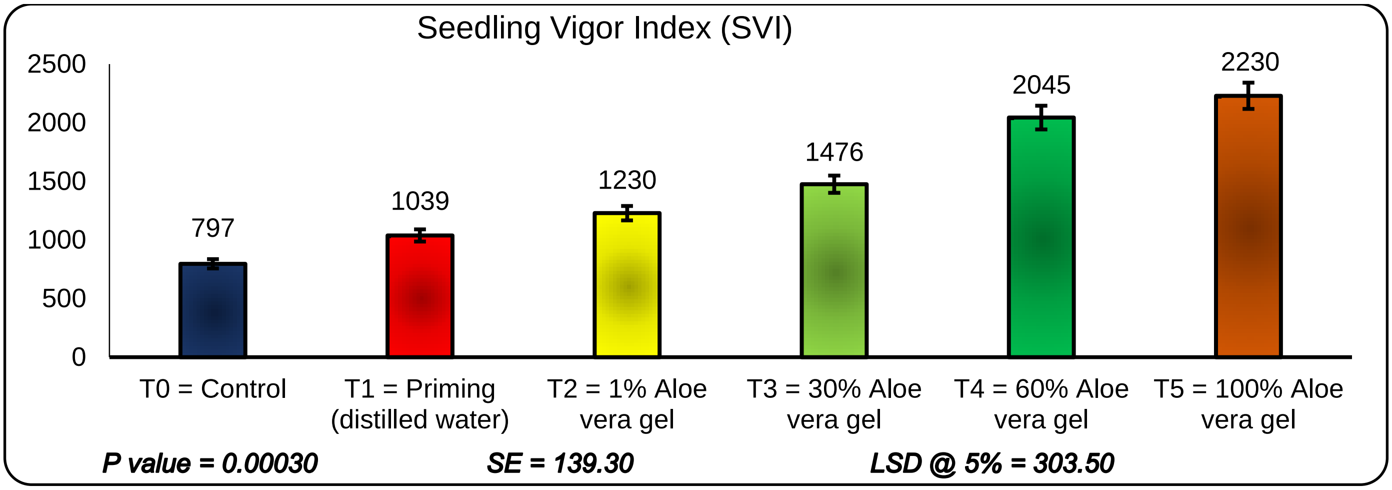

Figure 4. Seedling vigor index of Moringa as affected by varying concentrations of *Aloe vera* gel.

Number of branches per plant

The effect of different concentrations of *Aloe vera* gel on the number of branches per Moringa plant is presented in (Figure 5). The analysis of variance demonstrated that number of branches per plant was significantly ($P<0.05$) affected by the different concentrations of *Aloe vera* gel. The results indicated that the control group (T_0) exhibited the lowest number of branches per plant, with an average of 9.33, indicating the lowest branching performance without any priming treatment. Priming with distilled water (T_1) slightly improved the number of branches to 10.10, demonstrating a moderate increase over the control. Applying 1% *Aloe vera* gel (T_2) increased the number of branches to 10.55, demonstrating its positive effects at lower concentrations. A more pronounced improvement was observed with 30% *Aloe vera* gel (T_3), which resulted in 12.33 branches per plant, highlighting its superior effectiveness compared to lower concentrations. Applying 60% *Aloe vera* gel (T_4) led to 12.99 branches per plant, marking a significant branching improvement. The highest number of branches per plant was observed with 100% *Aloe vera* gel (T_5), which recorded 14.66 branches per plant, demonstrating the most effective treatment for enhancing branching.

Fresh biomass of shoot (g)

The effect of varying concentrations of *Aloe vera* gel on the fresh biomass of Moringa shoot was investigated. The data related to this trait are presented in (Figure 6). The analysis of variance revealed that the shoot's fresh biomass was not substantially influenced (P>0.05) by the varying concentrations of *Aloe vera* gel. The findings indicated that highest fresh shoot biomass (9.96 g) was observed in the treatment with 1% *Aloe vera* gel (T_2), indicating a slight improvement over other treatment. This was followed by 60% *Aloe vera* gel (T_4), which recorded a fresh biomass of 9.71 g, and 100% *Aloe vera* gel (T_5), with a value of 9.52 g. The application of 30% *Aloe vera* gel (T_3) resulted in a fresh biomass of 9.07 g, while the control group (T_0) produced a fresh biomass of 8.55 g, showing intermediate performance. The lowest fresh shoot biomass (6.93 g) was recorded in the (T_1) priming with distilled water, indicating that distilled water had the least effect on improving shoot biomass.

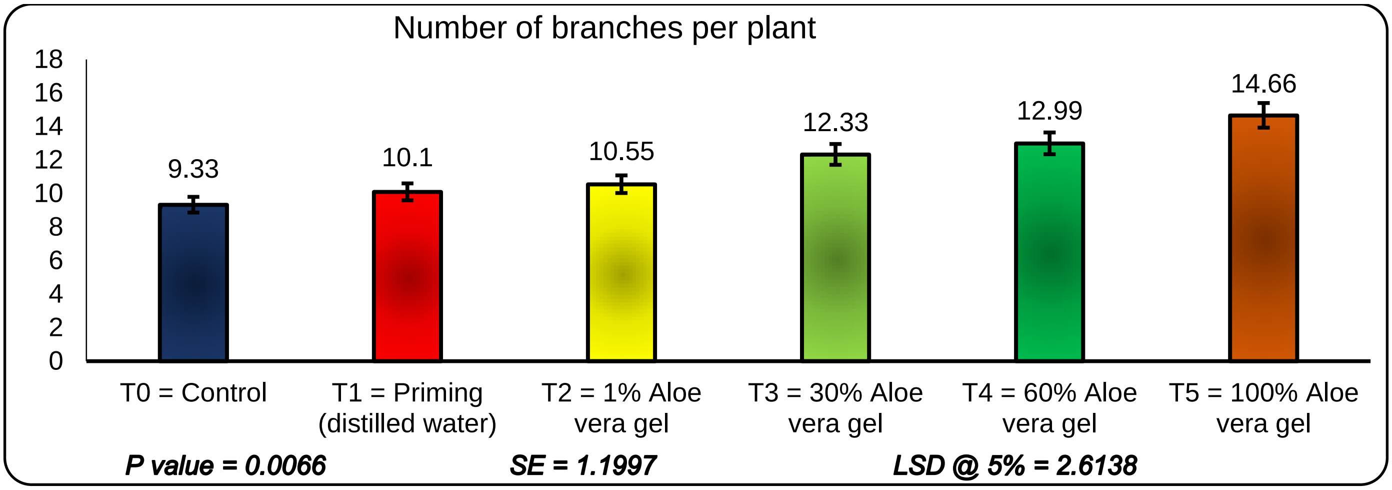

Figure 5. Number of branches per plant of Moringa as affected by varying concentrations of *Aloe vera* gel.

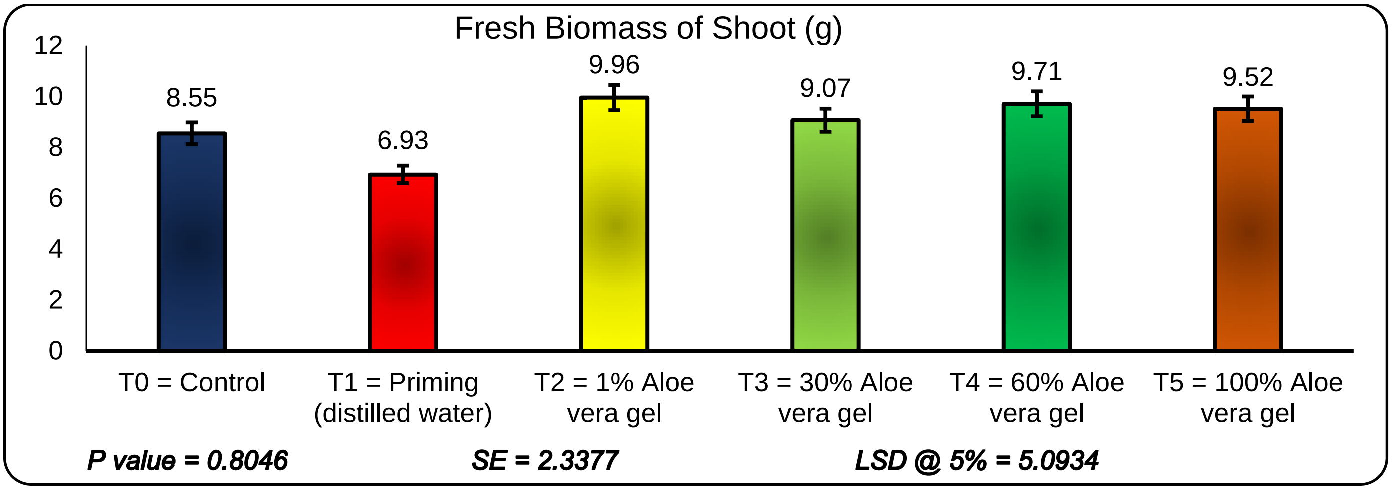

Figure 6. Fresh shoot biomass (g) of Moringa as affected by varying concentrations of *Aloe vera* gel.

Fresh biomass of root (g)

The impact of various concentrations of *Aloe vera* gel on Moringa root fresh biomass was investigated. The data related to this trait are presented in (Figure 7). The analysis of variance suggested that fresh root biomass was not significantly (P>0.05) affected by the different concentrations of *Aloe vera* gel. The findings suggested that among the treatments, the maximum fresh root biomass (18.71 g) was observed in plants treated with 1% *Aloe vera* gel (T_2), suggesting a numerical improvement over other treatment. This was followed by the treatment with 100% *Aloe vera* gel (T_5), which produced a fresh root biomass of 17.50 g. The application of 30% *Aloe vera* gel (T_3) resulted in a fresh root biomass of 16.22 g, while 60% *Aloe vera* gel (T_4) recorded a similar value of 15.81 g. Priming with distilled water (T_1) produced a slightly lower fresh root biomass of 14.13 g. The minimum fresh root biomass (13.27 g) was recorded in the control group (T_0), indicating minimal improvement without *Aloe vera* gel application.

Seedling quality index

The impact of various concentrations of *Aloe vera* gel on the Moringa seedling quality index was investigated. The data related to this trait are presented in (Figure 8). The analysis of variance revealed that the seedling quality index of Moringa was not substantially influenced (P>0.05) by the varying concentrations of *Aloe vera* gel. The results indicated that among the treatments, the highest seedlings quality index of Moringa (2.17) was observed in plants treated with 1% *Aloe vera* gel (T_2), suggesting a numerical improvement over other treatment. This was followed by the treatment with 100% *Aloe vera* gel (T_5), which recorded a seedlings quality index of Moringa 1.63. The application of 30% *Aloe vera* gel (T_3) resulted in a seedlings quality index of Moringa 1.56, while 60% *Aloe vera* gel (T_4) recorded a slightly lower value of 1.51. Priming with distilled water (T_1) showed the lowest seedlings quality index of Moringa (1.40) among the treatments, even lower than the control group (T_0), which had a value of 1.49.

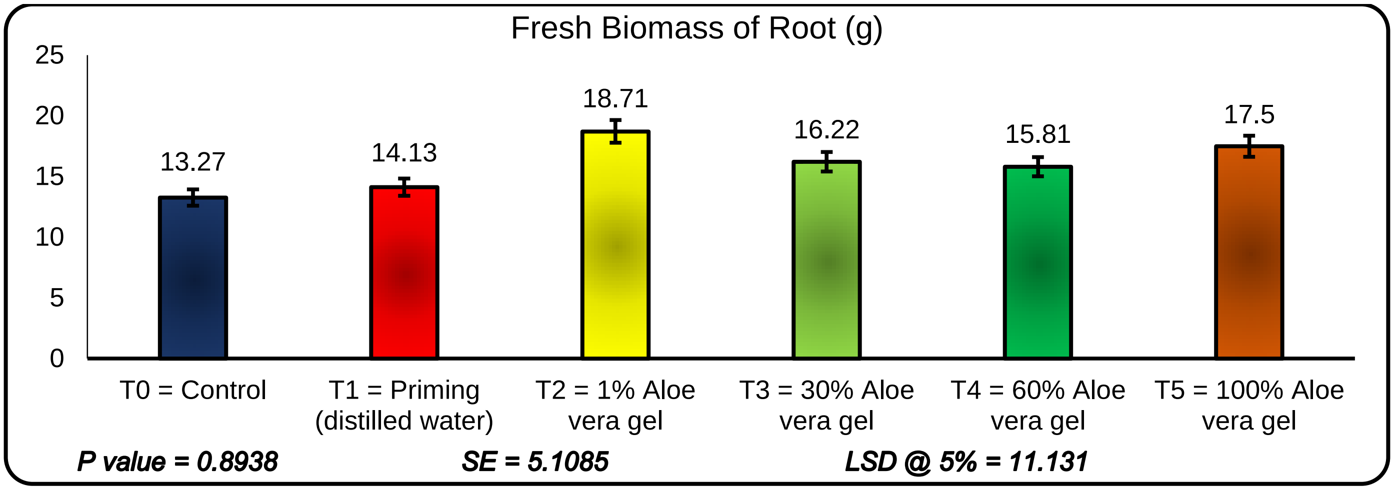

Figure 7. Fresh biomass of root (g) of Moringa as affected by varying concentrations of *Aloe vera* gel.

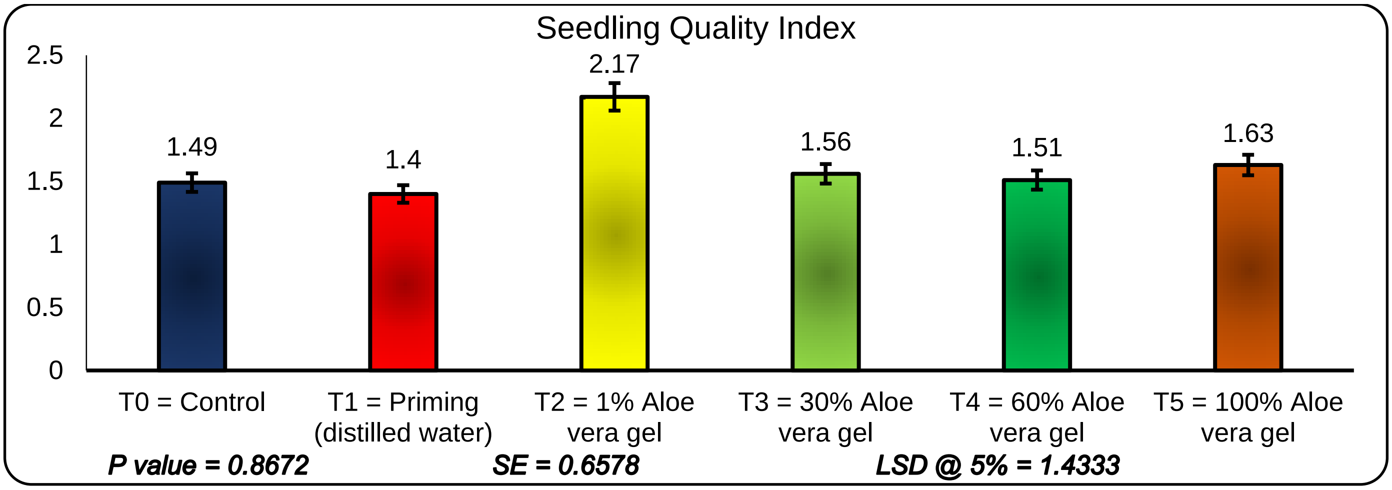

Figure 8. Seedling quality index of Moringa as affected by varying concentrations of *Aloe vera* gel.

Plant height (cm)

The impact of various *Aloe vera* gel concentrations on Moringa's plant height was investigated. The data related to this trait are presented in (Figure 9). The analysis of variance revealed that plant height was significantly influenced ($P<0.05$) by various concentrations of *Aloe vera* gel. The results indicated that among the treatments, the Moringa's maximum plant height (42.11 cm) was recorded with 100% *Aloe vera* gel (T_5), followed closely by the treatment with 60% *Aloe vera* gel (T_4), which resulted in a plant height of 40.33 cm. The application of 30% *Aloe vera* gel (T_3) produced a plant height of 38.88 cm, while the treatment with 1% *Aloe vera* gel (T_2) showed a plant height of 36.21 cm. The control group (T_0) and priming with distilled water (T_1) resulted in the lowest plant heights, measuring 31.66 cm and 31.55 cm, respectively.

Sturdiness quotient (SQ):

The impact of various *Aloe vera* gel concentrations on Moringa's sturdiness quotient was investigated. The data related to this trait are presented in (Figure 10). The analysis of variance indicated that Moringa's sturdiness quotient was significantly ($P<0.05$) affected by different concentrations of *Aloe vera* gel. The results indicated that Moringa's highest sturdiness quotient (7.84) was observed in seedlings treated with 60% *Aloe vera* gel (T_4). This was followed by applying of 100% *Aloe vera* gel (T_5), which produced a sturdiness quotient of 6.90. Seedlings treated with 30%

Aloe vera gel (T_3) exhibited a sturdiness quotient 6.82, statistically similar to that of 100% *Aloe vera* gel. Treatments with distilled water priming (T_1) and 1% *Aloe vera* gel (T_2) resulted in sturdiness quotients of 6.31 and 5.92, respectively. The lowest sturdiness quotient (5.74) was recorded in the control group (T_0).

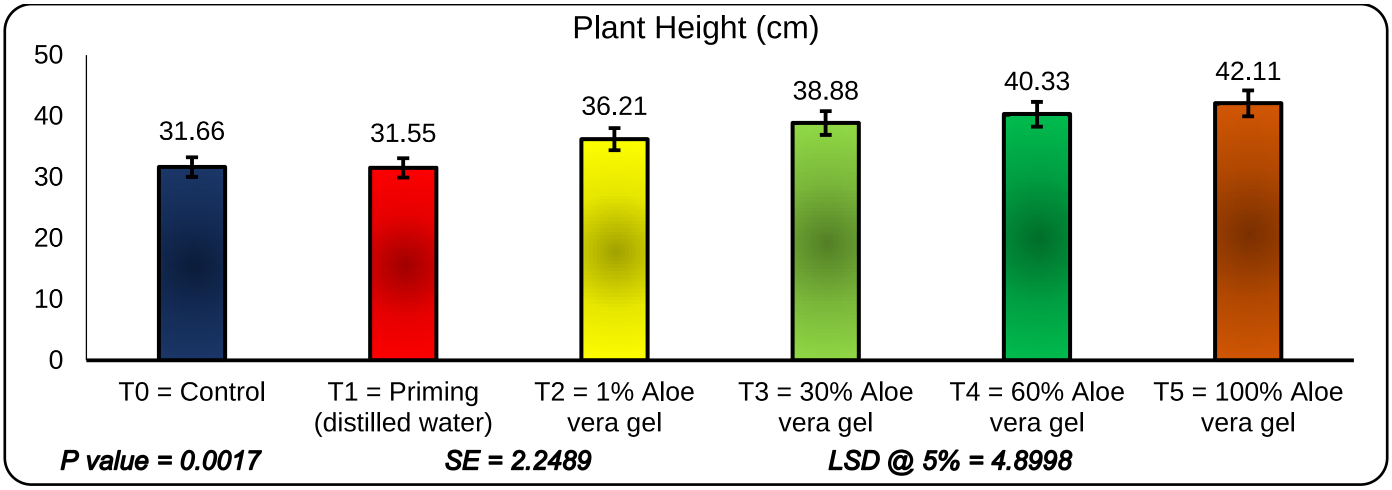

Figure 9. Plant height (cm) of Moringa as affected by different concentrations of *Aloe vera* gel.

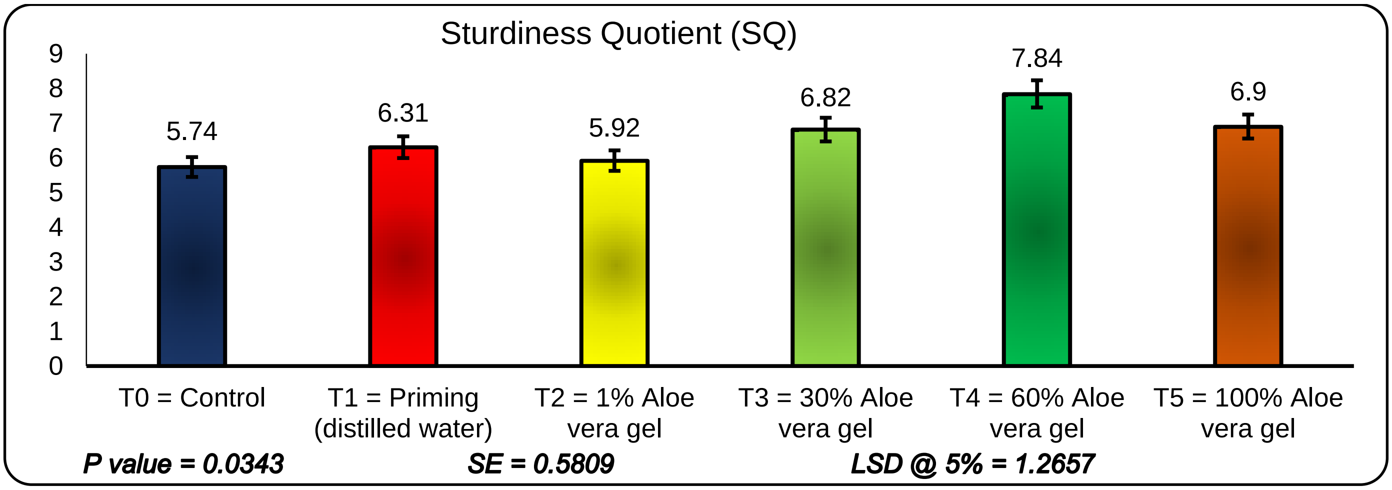

Figure 10. Sturdiness quotient of Moringa as affected by different concentrations of *Aloe vera* gel.

DISCUSSION

The present investigation aimed to determine how various concentrations of *Aloe vera* gel affected the germination and growth of *Moringa oleifera*. Moringa is recognized as a highly nutritious and multipurpose crop valued for both its medicinal and agricultural applications. Its leaves, pods, and seeds are rich in proteins, vitamins, minerals, and bioactive compounds that provide food security and medicinal benefits to vulnerable populations (Jayanthi et al., 2015; Alegbeleye, 2018; Moremane et al., 2023). As a crop, moringa holds substantial promise for addressing malnutrition, serving as livestock fodder, and contributing to sustainable agriculture. However, its wider adoption is constrained by germination and establishment challenges, which makes the search for natural, cost-effective seed priming agents such as *Aloe vera* crucial. *Aloe vera*, known for its richness in bioactive compounds, functions as a natural growth promoter capable of enhancing seed germination, seedling vigor, and overall plant development (René et al., 2024). *Aloe vera* gel has been documented to increase germination rates and accelerate emergence across diverse species (Abbas et al., 2016; Tamuk & Singh, 2022). The present findings, therefore, provide evidence of its application to moringa as a target crop of global nutritional importance.

Seed germination is a fundamental determinant of crop establishment in *Moringa oleifera*. In this study, *Aloe vera* gel treatments significantly improved moringa germination, with the 100% gel concentration (T_5) achieving 82.66% germination compared to 57% in the control (T_0). This shows that *Aloe vera* is a potential tool for improving seed viability in moringa cultivation. These results are consistent with Zeljković et al. (2020), who observed improved germination in *Salvia splendens*, and Imran et al. (2014), who reported similar effects in lentil under stress. Bioactive compounds in *Aloe vera* gel such as gibberellins, polysaccharides, salicylic acid (Çavuşoğlu et al., 2016), and hydrogen peroxide (Kaur et al., 2020) aid in dormancy breaking, enzymatic activation, and oxygen release, thereby enhancing germination performance. In moringa, faster and more uniform germination provides a competitive advantage for seedling establishment in marginal and stress-prone environments where the crop is commonly grown. *Aloe vera* gel also reduced the days to germination in moringa seeds, with the 100% gel treatment (T_5) inducing germination in 1.33 days compared to 3.00 days in the control (T_0). This rapid establishment is particularly significant for moringa cultivation under arid and semi-arid conditions. Comparable findings were reported by Rene et al. (2024) in tomato, where *Aloe vera* accelerated germination. The gibberellic acid in *Aloe vera* gel activates seed enzymes, thereby initiating metabolic activity and increasing viability (Suleiman et al., 2008). Increased oxygen availability and ion transfer (DongZhi et al., 2004) further explain the high germination rate observed. Sumantra and Widnyana (2011) similarly highlighted the wide biostimulant potential of *Aloe vera* gel in *Dendrobium* orchids. The higher germination index of 4.99 observed in T_5 relative to 2.58 in T_0 demonstrates that *Aloe vera* gel improves both speed and uniformity of germination in moringa, which is consistent with the quality improvements reported in tomato (Dzib-Ek et al., 2021) and attributed to salicylic acid-mediated hormonal regulation (Rodriguez-Larramendi et al., 2017). The enhanced enzymatic and metabolic activity resulting from *Aloe vera* bioactives (Reynolds & Dweck, 1999) supports its applicability for achieving rapid and even germination in moringa seeds.

Seedling vigor is a crucial factor for moringa establishment and long-term productivity. In the present study, the seedling vigor index was highest in the 100% *Aloe vera* gel treatment (T_5: 2230) compared to the control (T_0: 797). Improved vigor in moringa seedlings directly correlates with better field performance and stress resilience. These findings are in agreement with Imran et al. (2014) in lentil, as well as Hanafy et al. (2012) and Suleiman et al. (2008), who linked *Aloe vera*'s polysaccharides and salicylic acid with root elongation and enhanced tolerance. In moringa, strong vigor translates into improved survival in marginal soils, rapid canopy development, and higher photosynthetic efficiency, thereby increasing its utility as a climate-resilient crop.

Branching is a vital morphological trait in moringa as it influences leaf yield and biomass, which are the primary harvested products. In this study, 100% *Aloe vera* gel (T_5) produced the highest number of branches (14.66), whereas the control (T_0) had only 9.33. These results align with Ahmed et al. (2014), who reported that *Aloe vera* extracts enhance lateral growth through nutrient uptake and hormonal activity. Auxins, cytokinins, and salicylic acid in *Aloe vera* suppress apical dominance and stimulate lateral bud outgrowth (Sumantra & Widnyana, 2011; Dzib-Ek et al., 2021), thereby increasing branch numbers. For moringa, improved branching directly enhances biomass production and leaf availability, both critical for nutritional and medicinal use. Thus, *Aloe vera* gel application not only improves growth but also enhances the functional yield of moringa.

Shoot and root biomass are critical indicators of plant establishment. The 1% *Aloe vera* gel treatment (T_2) significantly increased moringa shoot (9.96 g) and root biomass (18.71 g). This is consistent with El-Shayeb (2009), who showed *Aloe vera* enhances water retention, cell elongation, and biomass accumulation. The presence of calcium, magnesium, potassium, and polysaccharides in *Aloe vera* (Dagne et al., 2000) enhances photosynthesis, nutrient transport, and stress tolerance, thereby boosting moringa's vegetative development. Aloe bioactives also mitigate oxidative stress and regulate growth hormones (Ahmed et al., 2014), which are essential for moringa seedlings that often face abiotic stresses during establishment in semi-arid regions.

Plant height in moringa was maximized under 100% *Aloe vera* gel (T_5: 42.11 cm), compared to 31.66 cm in the control (T_0). Increased plant height contributes to faster canopy closure, reduced weed pressure, and improved competitive ability in moringa plantations. Similar elongation effects of *Aloe vera* have been reported in *Allium cepa* (Çavuşoğlu et al., 2016). This elongation is associated with gibberellic acid–induced cell division and internodal elongation (Suleiman et al., 2008). Comparable findings in *Salvia splendens* (Zeljkovic et al., 2020), tomato (Padmaja et al., 2007), and other crops (DongZhi et al., 2004) confirm *Aloe vera*'s broad-spectrum role as an eco-friendly growth enhancer, now validated in moringa.

The seedling quality index, an important indicator of transplant survival and field performance, was highest in moringa seedlings primed with 1% *Aloe vera* gel (T_2: 2.17). This aligns with El-Sherif (2017), who noted *Aloe vera* significantly improved shoot-to-root ratios and biomass stability. In moringa, this means greater transplant ability and improved survival in field conditions. Vitamins (C and β-carotene), minerals (potassium and calcium), and amino acids (alanine and proline) in *Aloe vera* (Reynolds & Dweck, 1999; Dagne et al., 2000) fortify physiological functions such as photosynthesis, nutrient translocation, and stress resistance, ultimately enhancing moringa seedling vigor and quality.

The sturdiness quotient, which evaluates the structural stability of seedlings, was highest in the 60% *Aloe vera* gel treatment (T_4: 7.84). In moringa, sturdiness is critical because it determines the ability of seedlings to withstand environmental stress such as wind and drought. Moderate *Aloe vera* concentrations improved moringa's structural integrity by enhancing the root-to-shoot ratio and mechanical strength, consistent with Zeljković et al. (2020). Auxins and gibberellins in *Aloe vera* promote balanced root and shoot elongation (Suleiman et al., 2008), while salicylic acid and minerals such as potassium and calcium contribute to cell wall strengthening (Reynolds & Dweck, 1999; Dagne et al., 2000). These results highlight *Aloe vera* gel's role in producing sturdy moringa seedlings capable of thriving in harsh environments.

CONCLUSION

The findings of this research reveal that varying concentrations of *Aloe vera* gel significantly (P < 0.05) influenced the seed germination and growth characteristics of *Moringa oleifera*. Among the evaluated treatments, seed priming with 100% *Aloe vera* gel produced the best germination percentage (82.66%), germination index (4.99), seedling vigor index (2230), and plant height (42.11 cm). The findings indicate that 100% *Aloe vera* gel is the most efficacious concentration for promoting the germination and initial growth of *M. oleifera*.

AUTHOR CONTRIBUTIONS

Muzafaruddin Chachar conducted the experiment, collected and analyzed the data, and prepared the initial draft of the manuscript. Saba Ambreen Memon and Tanveer Fatima Miano supervised the research, guided the experimental design, and critically reviewed and revised the manuscript. Sadaruddin Chachar and Memoona Islam Majeedano assisted in data interpretation and literature compilation. Zaheer Ahmed Chachar, and Saeed Ahmed Chachar contributed to data curation and visualization. Raheem Ullah, Sana Shazia Jiskani and Tahir Mahmood supported in manuscript editing and formatting.

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COMPETING OF INTEREST

The authors declare no competing interests.

REFERENCES

Aamur, G. R., T. F. Miano, M. Chachar, M. I. Majeedano, M. R. Tunio, S. S. Jiskani, R. Ullah and Z. A. Chachar. 2025. Effect of macronutrient levels on growth and development of spinach (*Spinacia oleracea* L.). Integrative Plant Biotechnology, 3 (3), 231–239.

Abbas, S., M. Zaglool, E. El-Ghadban, A. El-Kareem and A. Waly. 2016. Effect of foliar application with aloe leaf extract (ALE) on vegetative growth, oil percentage and anatomical leaf structure of sage (*Salvia officinalis* L.) plant under sand soil conditions. HortScience Journal of Suez Canal University, 5(1), 9–14.

Abdul Baki, A. A. and J. D. Anderson. 1973. Vigor determination in soybean seed by multiple criteria. Crop Science, 13(6), 630–633.

Ahmad, S. K., K. A. Hammam and A. A. Amer. 2014. Effect of bio-fertilization and some plant extracts on the growth, yield, and chemical constituents of basil plant. Journal of Plant Production, 5(2), 193–210.

Alegbeleye, O. O. 2018. How functional is *Moringa oleifera*? A review of its nutritive, medicinal, and socioeconomic potential. Food and Nutrition Bulletin, 39(1), 149–170.

AOSA. 1983. *Seed vigor testing handbook* (Contribution No. 32 to Handbook on Seed Testing). Association of Official Seed Analysts.

Çavuşoğlu, D., S. Tabur and K. Çavuşoğlu. 2016. The effects of *Aloe vera* L. leaf extract on some physiological and cytogenetical parameters in *Allium cepa* L. seeds germinated under salt stress. Cytologia, 81(1), 103–110.

Chachar, S. A., N. A. Wahocho, M. Chachar, M. I. Majeedano, Z. A. Chachar, S. S. Jiskani, M. A. Wagan and R. Ullah. 2025. Effects of Basil Leaf Extract Priming on Seed Germination and Seedling Growth of Okra (*Abelmoschus esculentus*). Integrative Plant Biotechnology, 3(3), 193-204.

Chatterjee, P., C. Bodhisattwa and N. Subhangkar. 2013. Significant pharmacological activities of *Aloe vera* plant. Mintage Journal of Pharmaceutical and Medical Sciences, 3(1), 21–24.

Dagne, E., D. Bisrat, A. Viljoen and B.-E. Van Wyk. 2000. Chemistry of *Aloe* species. Current Organic Chemistry, 4(10), 1055–1078.

Dickson, A., A. L. Leaf and J. F. Hosner. 1960. Quality appraisal of white spruce and white pine seedling stock in nurseries. The Forestry Chronicle, 36(1), 10–13.

DongZhi, L., E. Tsuzuki, Y. Sugimoto, D. YanJun, M. Matsuo and H. Terao. 2004. Allelopathic effects of aqueous *Aloe vera* leaf extracts on selected crops. Allelopathy Journal, 13(1), 67–74.

Dzib-Ek, G., E. Villanueva-Couoh, R. Garruña-Hernández, S. Vergara Yoisura and A. Larqué-Saavedra. 2021. Effect of salicylic acid on germination and root growth of tomato. Mexican Journal of Agricultural Sciences, 12(4), 735–740.

El Bilali, H., I. Dan Guimbo, R. K. Nanema, H. Falalou, Z. Kiebre, V. M. Rokka, S. R. F. Tietiambou, J. Nanema, L. Dambo, F. Grazioli, A. K. Naino Jika, M. Gonnella and F. Acasto. 2024. Research on *Moringa* (*Moringa oleifera* Lam.) in Africa. Plants, 13(12), 1613.

El Sherif, F. 2017. *Aloe vera* leaf extract as a potential growth enhancer for *Populus* trees grown under in vitro conditions. American Journal of Plant Biology, 2(4), 101–105.

El-Shayeb, N. S. 2009. Physiological studies on Oenothera biennis (bio-fertilizer and plant extracts). Faculty of Agriculture, Moshtohor, Benha University.

Falowo, A. B., F. E. Mukumbo, E. M. Idamokoro, J. M. Lorenzo, A. J. Afolayan and V. Muchenje. 2018. Multi-functional application of *Moringa oleifera* Lam. in nutrition and animal food products: A review. Food Research International, 106(1), 317–334.

Gopalakrishnan, L., K. Doriya and D. S. Kumar. 2016. *Moringa oleifera*: A review on nutritive importance and its medicinal application. Food Science and Human Wellness, 5(2), 49–56.

Hamouda, A. M. A., D. M. Hendi and O. F. Abu-El-Leel. 2012. Improving basil growth, yield and oil production by *Aloe vera* extract and active dry yeast. Egyptian Journal of Horticulture, 39(1), 45–71.

Hanafy, M. S., F. M. Saadawy, S. M. N. Milad and R. M. Ali. 2012. Effect of some natural extracts on growth and chemical constituents of *Schefflera arboricola* plants. Journal of Horticultural Science and Ornamental Plants, 4(1), 26–33.

Hao, P. M., L. P. T. Quoc, P. N. M. Thu, N. T. T. Dao and L. B. Vy. 2024. A comprehensive review of *Moringa oleifera* Lam.: A valuable plant in food and medicine. International Journal of Agricultural Technology, 20(5), 1899–1916.

Hemalatha, G., K. Manoj Kumar and U. Gowthamy. 2024. Effect of seed priming studies on seed germination in groundnut (*Arachis hypogea* L.). International Journal of Advanced Biochemistry Research, 8(6), 165–170.

Herman-Lara, E., J. Rodríguez-Miranda, S. Ávila-Manrique, C. Dorado-López, M. Villalva, L. Jaime, S. Santoyo and C. E. Martínez-Sánchez. 2024. *In vitro* antioxidant, anti-inflammatory activity and bioaccessibility of ethanolic extracts from Mexican *Moringa oleifera* leaf. Foods, 13(17), 2709.

Hernández-Cruz, L. R., R. Rodríguez-García, L. D. Rodríguez, J. Janik and A. Whipkey. 2002. *Aloe vera* response to plastic mulch and nitrogen. Environmental Science and Pollution Research, *9*(special issue), 570–574.

Imran, S., I. Afzal, M. Amjad, A. Akram, K. M. Khawar and S. Pretorius. 2014. Seed priming with aqueous plant extracts improved seed germination and seedling growth under chilling stress in lentil (*Lens culinaris* Medik). Acta Advances in Agricultural Sciences, 2(1), 58–69.

Janmohammadi, M., P. M. Dezfuli and F. Sharifzadeh. 2008. Seed invigoration techniques to improve germination and early growth of inbred line of maize under salinity and drought stress. Journal of Applied Plant Physiology, 34(3–4), 215–226.

Jayanthi, M., S. K. Garg, P. Yadav, A. K. Bhatia and A. Goel. 2015. Some newer marker phytoconstituents in methanolic extract of *Moringa oleifera* leaves and evaluation of its immunomodulatory and splenocytes proliferation potential in rats. Indian Journal of Pharmacology, 47(5), 518–523.

Kaur, A., A. Singh and R. Monga. 2020. Seed germination enhancement through breaking seed dormancy: A review in tropical and temperate tree species. International Journal of Current Microbiology and Applied Sciences, 9(9), 1673–1688.

Luna, R. K. and N. Chamouli. 2006. Effect of root trainer size on the quality of seedling production in *Albizia proscera* (Roxb.) Benth., *Eucalyptus teriticornis* Sm., and *Acacia catechu* Wild. Annals of Forestry, 14(2), 184–193.

Mady, A. (2008). Effect of certain medicinal plant extracts on growth, yield and metabolism of some medicinal and aromatic plants (M.Sc. thesis). Faculty of Science, Al-Azhar University.

Mahato, D. K., R. Kargwal, M. Kamle, B. Sharma, S. Pandhi, S. Mishra and P. Kumar. 2022. Ethnopharmacological properties and nutraceutical potential of *Moringa oleifera*. Phytomedicine Plus, 2(1), 100162.

Meireles, D., J. Gomes, L. Lopes, M. Hinzmann and J. Machado. 2020. A review of properties, nutritional and pharmaceutical applications of *Moringa oleifera*: Integrative approach on conventional and traditional Asian medicine. Advances in Traditional Medicine, 20(4), 495–515.

Moremane, M. M., B. Abrahams and C. Tiloke. 2023. *Moringa oleifera*: A review on the antiproliferative potential in breast cancer cells. Current Issues in Molecular Biology, 45(8), 6880–6902.

Ni, Y. and I. R. Tizard. 2004. Analytical methodology: The gel-analysis of aloe pulp and its derivatives. In T. Reynolds

(Ed.), *Aloes: The genus Aloe* (pp. 129–144). CRC Press.
Ni, Y., D. Turner, K. Á. Yates and I. Tizard. 2004. Isolation and characterization of structural components of *Aloe vera* L. leaf pulp. International Immunopharmacology, 4(14), 1745–1755.
Nouman, W., S. M. A. Basra, A. Yasmeen, T. Gull, S. B. Hussain, M. Zubair and R. Gul. 2014. Seed priming improves the emergence potential, growth and antioxidant system of *Moringa oleifera* under saline conditions. Plant Growth Regulation, 73(3), 267–278.
Nour El-Din, T. 2005. Physiological studies on marjoram plants (Majorana hortensis) (M.Sc. thesis). Department of Ornamental Horticulture, Faculty of Agriculture, Zagazig University (Banha Branch).
Nuapia, Y., E. Cukrowska, H. Tutu and L. Chimuka. 2020. Statistical comparison of two modeling methods on pressurized hot water extraction of vitamin C and phenolic compounds from *Moringa oleifera* leaves. South African Journal of Botany, 129(1), 9–16.
Padmaja, C. K., B. Kowsalya and C. Seethalakshmi. 2007. Efficacy of *Aloe vera* (L.) leaf powder as a biostimulant in enhancing the growth and yield of lady's finger (*Abelmoschus esculentus* L.). Research on Crops, 8(2), 395–397.
Pandey, A., R. D. Pandey, P. Tripathi, P. P. Gupta, J. Haider, S. Bhatt and A. V. Singh. 2012. *Moringa oleifera* Lam. (Sahijan) – A plant with a plethora of diverse therapeutic benefits: An updated retrospection. Medicinal and Aromatic Plants, 1(1), 1–8.
Ramachandra, C. T. and P. S. Rao. 2008. Processing of *Aloe vera* leaf gel: A review. American Journal of Agricultural and Biological Sciences, 3(2), 502–510.
Raman, R. P. V., R. S. Rita, B. C. Mondal and S. K. Singh. 2013. Effect of *Aloe vera* and clove powder supplementation on carcass characteristics, composition and serum enzymes of Japanese quails. Veterinary World, 8(5), 664–668.
René, N. P., D. C. Tonessia, D. F. Soko, E. F. Soumahin, K. D. N'goran and D. S. Akaffou. 2024. Influence of *Aloe vera* gel on germination and early growth of tomato (*Solanum lycopersicum*) seedlings in the nursery. Journal of Experimental Agriculture International, 46(10), 91–102.
Reynolds, T. and A. C. Dweck. 1999. *Aloe vera* leaf gel: A review update. Journal of Ethnopharmacology*, 68*(1–3), 3–37.
Rocchetti, G., F. Blasi, D. Montesano, S. Ghisoni, M. C. Marcotullio, S. Sabatini, C. Lina and L. Lucini. 2019. Impact of conventional and non-conventional extraction methods on the untargeted phenolic profile of *Moringa oleifera* leaves. Food Research International, 115(1), 319–327.
Rodríguez-Larramendi, L. A., M. G. Ramírez, M. A. Gómez-Rincón, F. Guevara-Hernández, M. Á. Salas-Marina and A. Gordillo-Curiel. 2017. Effects of salicylic acid on germination and early growth of bean seedlings (*Phaseolus vulgaris* L.). Revista de la Facultad de Agronomía (LUZ), 34(3), 253–269.
Roller, K. J. 1977. Suggested minimum standards for containerized seedlings in Nova Scotia. *Canadian Forestry Service, Department of Environment, Information Report M-X-69.*
Sahu, K. P., D. D. Giri, R. Singh, P. Pandey, S. Gupta, A. K. Shrivastava and D. K. Pandey. 2013. Effect of *Aloe vera* on some annual plants. Scientific Research of Pharmacology and Pharmacy, 4(6), 599–610.
Schaffer, M., D. A. Grant, K. Berge and N. Y. D. Ankrah. 2024. Moringa reduces glucose levels and alters *Wolbachia* abundance in *Drosophila melanogaster*. Microbiology Research, 15(3), 1870–1879.
Sreeja, M., P. Jayasri, N. Keerthi, J. Yeshashwini and J. Praveen. 2021. *Moringa oleifera*: A review on nutritive importance and its potential use as nutraceutical plant. Journal of Medicinal Plants, 9(2), 15–17.
Statistix. (2006). *Statistix 8 user guide, version 1.0.* Analytical Software.
Suleiman, M. K., N. R. Bhat, M. S. Abdal, S. Zaman, R. R. Thomas and S. Jacob. 2008. Germination studies in *Nitraria retusa* (Forssk.) Asch. Middle-East Journal of Scientific Research, 3(4), 211–213.
Sumantra, I. K. and I. K. Widnyana. 2011. Effectiveness of *Aloe vera* gel and coconut water as a bioregulator on seed germination of *Dendrobium* orchid. Jurnal Agrimeta*,* 1(1), 1–9.
Surjushe, A., R. Vasani and D. Saple. 2008. *Aloe vera*: A short review. Indian Journal of Dermatology, 53(4), 163–166.
Tamuk, G. and B. Singh. 2022. Enhancing seed germination in *Altingia excelsa* Noronha pre-treated by natural plant extracts under laboratory conditions at Pasighat in Arunachal Pradesh, India. The Pharma Innovation Journal*, 11*(12), 357–362.
Thompson, B. E. 1985. Seedling morphological evaluation: What you can tell by looking. In M. L. Duryea (Ed.), *Proceedings:* Evaluating seedling quality—principles, procedures, and predictive abilities of major tests (pp. 59–71). Forest Research Laboratory, Oregon State University.
Zeljković, S., N. Parađiković, J. D. Gidas, E. Mladenović and A. Vujošević. 2020. The effect of water extract of *Aloe vera* (L.) Burm. f. on germination and growth of scarlet sage. In XI International Scientific Agricultural Symposium "Agrosym 2020" Proceedings (pp. 262–267). University of East Sarajevo.