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Enhancing Germination and Early Seedling Growth of Eggplant (*Solanum melongena* L.) Through Aeration Priming with Potassium Nitrate (KNO_3)

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Abstract. *Eggplant (Solanum melongena L.) is an important horticultural crop in tropical and subtropical regions. However, suboptimal seed germination and poor early seedling growth often impede successful crop establishment. Seed priming with potassium nitrate (KNO_3) is widely recognized for enhancing seed performance, but prolonged soaking in priming solutions can limit oxygen availability during imbibition, potentially inhibiting metabolic activity and reducing priming efficiency. This study aimed to evaluate the effectiveness of aerated KNO_3 priming in improving germination and seedling vigor of eggplant. A completely randomized design with seven treatments, including control, KNO_3 concentrations (0%, 1%, 2%), and priming conditions (with and without aeration), was applied. Results showed that seed priming significantly improved germination parameters, stem diameter, and dry mass. The best germination performance was observed in seeds primed with 2% KNO_3 under aeration with 88.50% germination, the highest germination rate index (23.08), and the shortest mean germination time (3.38 days). While priming did not significantly affect plant height at 35 days after planting, and the concentration of KNO_3 did not significantly affect the seedling performances, aeration significantly increased stem diameter and seedling dry mass. These findings suggest that aerated priming with 2% KNO_3 can be recommended as an effective technique to enhance germination performance and seedling vigor in eggplant.*
Keywords: *aeration; eggplant; potassium nitrate; seed priming; germination performance.*

1. Introduction

Eggplant (*Solanum melongena* L.) is an important horticultural crop widely grown in tropical and subtropical areas, including Indonesia. Eggplant production in Indonesia reached 699,896 tons in 2023, accounting for 4.7% of the country's total vegetable production (Badan Pusat Statistik, 2025). Eggplant (*Solanum melongena L.*) is a nutritionally valuable vegetable with high moisture content, containing crude fiber, ash, protein, fat, and carbohydrates that contribute to its low caloric value, while also serving as a rich source of antioxidants such as ascorbic acid, anthocyanins, and nasunin, and essential minerals including potassium, sodium, calcium, phosphorus, magnesium, iron, zinc, manganese, and copper (Alighadri *et al*., 2024; Quamruzzaman *et al*., 2020). However, issues including inadequate seed germination and inconsistent seedling emergence, particularly in

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suboptimal environmental circumstances, may impede optimal crop establishment and yield (Hannachi & Van Labeke, 2018; Zhang *et al*., 2011).

Seed priming has become an efficacious pre-sowing method to improve seed performance. This technique entails regulated hydration of seeds to activate metabolic processes without actual germination, resulting in enhanced germination rates and seedling vitality (Devika *et al*., 2021). Seed priming activates crucial metabolic processes during the lag period (phase II) of germination, without causing radicle emergence (MacDonald & Mohan, 2025). It enhances the activity of antioxidant enzymes (e.g., SOD and peroxidase), promotes cellular division and the mobilization of stored proteins, and boosts the rate of germination (Farooq *et al*., 2019). Priming additionally aids in regulating membrane permeability and tissue hydration while activating DNA repair mechanisms and reactive oxygen species scavenging systems that maintain genomic integrity (Paparella *et al*., 2015). The synergistic effects enhance germination rates, uniformity, and overall seed vigor, rendering seed priming an essential method for superior crop establishment in both ideal and stressful environments.

Numerous priming agents have been investigated, with nitrate-based priming agents demonstrating significant efficacy. Nitrate facilitates the formation of nitric oxide (NO) (Hendricks & Taylorson, 1974), which then helps facilitate germination by disrupting seed dormancy via interactions with ethylene synthesis, phytochrome signaling pathways, and reactive oxygen species (ROS) (Šírová *et al*., 2011). Recent research has emphasized the advantages of nitrate-based priming agents in eggplant. Zhang *et al*. (2011) discovered that the addition of salicylic acid to KNO_3 priming solutions enhanced germination and seedling emergence at low temperatures, demonstrating the adaptability of KNO_3-based priming under diverse stress conditions. Salles *et al*. (2019) found that priming eggplant seeds with calcium nitrate improved germination rates, especially under temperature stress, indicating the efficacy of nitrate-based priming agents in enhancing seed performance.

Nevertheless, seeds submerged in a solution for an extended duration may experience oxygen deprivation during essential stages of imbibition. Aeration during priming presents a viable answer to this issue. Raj and Raj (2019) implied that aeration is one of the elements influencing seed priming, albeit its impact differs by species. Santika *et al*. (2022) revealed that KNO_3 priming, particularly when paired with aeration, markedly enhanced germination metrics in tomato seeds, encompassing ultimate germination percentage, mean germination time, and germination rate index. The research highlighted that aeration during priming increases oxygen availability, essential for seed metabolic processes during imbibition. Muhklisin *et al*. (2024) revealed that in sweet maize, aerated priming with KNO_3 and reverse osmosis water improved germination and early seedling development, surpassing soaking or spraying approaches in essential germination parameters. Thongtip *et al*. (2022) indicated that aerating papaya seeds in a KNO_3 solution for 24 hours during seed priming yielded superior results in mean germination time (MGT) compared to non-aerated seeds.

Despite these gains, it remains necessary to refine priming techniques tailored to eggplant, considering variables such as KNO_3 concentration and the influence of aeration. The purpose of this study was to assess the impact of varying KNO_3 concentrations and aeration conditions during seed priming on the germination efficacy and initial growth of eggplant seedlings. This study aimed to evaluate the effectiveness of aerated KNO_3 priming in improving germination and seedling vigor of eggplant.

2. Materials and Methods

This study was performed in the Seed Processing Laboratory, Department of Agricultural Production, Politeknik Negeri Jember. The eggplant (*Solanum melongena* L.) seeds were sourced from a certified local vendor. The package indicates an initial seed germination rate of 80%.

The experimental design employed was a Completely Randomized Design (CRD) featuring two treatment components and four replications. The initial factor was the concentration of potassium nitrate (KNO_3), comprising three levels: 0%, 1%, and 2%. The second component was the priming technique: with and without aeration. An extra control (unprimed seeds) was incorporated as well. Consequently, seven treatments were established: (1) control, (2) 0% KNO_3 with aeration, (3) 0% KNO_3 without aeration, (4) 1% KNO_3 without aeration, (5) 1% KNO_3 with aeration, (6) 2% KNO_3 without aeration, and (7) 2% KNO_3 with aeration. The priming was done by immersing the seeds for 24 hours in 50 ml of the respective solutions contained in plastic bottles, maintained at room temperature (25 °C) under natural lighting. For the aerated treatments, a home-built aerator setup was used to maintain a continuous oxygen supply, which was made by connecting an electric air pump to the plastic bottles with rubber tubes, based on Santika *et al.* (2022). After priming, the seeds were rinsed and surface-dried under an air conditioner set at 20 ˚C for 24 hours to restore their initial moisture content before germination and growth experiments.

The observation parameters encompassed germination and first seedling growth measures. Germination was evaluated utilizing the top-of-paper technique, with 100 seeds in each replicate. The observed parameters included germination percentage, mean germination time (MGT), and germination rate index (GRI). Seedling growth observations involved placing prepared seeds in 20 x 20 cm polybags filled with a topsoil-to-manure mixture (2:1). Measurements were recorded at 35 days after planting (DAP), encompassing plant height, stem diameter, and dry weight.

The collected data were evaluated utilizing Analysis of Variance (ANOVA) within a completely randomized design. Upon detecting significant changes, mean comparisons among treatments were performed utilizing the Least Significant Difference (LSD) test at the 5% significance threshold. All statistical analyses were conducted with Microsoft Excel.

3. Results and Discussion

Table 1 presents the effects of different seed priming treatments, including aeration, potassium nitrate (KNO_3) concentrations, and their combination on the germination percentage, germination rate index (GRI), and mean germination time (MGT) of eggplant seeds.

Table 1. Average of Germination Percentage, GRI, and MGT of primed eggplant seeds

Treatments	Germination (%)	GRI	MGT (day)
Combination			
Non-primed	75.50 ± 0.65 a	17.58 ± 0.27 a	5.39 ± 0.11 d
0% KNO_3 with aeration	86.50 ± 0.87 d	21.73 ± 0.44 c	4.48 ± 0.05 bc
0% KNO_3 without aeration	79.00 ± 0.71 b	19.88 ± 0.55 b	4.75 ± 0.22 c
1% KNO_3 with aeration	83.50 ± 0.65 c	23.07 ± 0.61 cd	4.17 ± 0.12 b
1% KNO_3 without aeration	85.25 ± 0.75 cd	22.44 ± 0.57 cd	4.27 ± 0.07 b
2% KNO_3 with aeration	88.50 ± 0.87 d	23.64 ± 0.52 d	3.38 ± 0.03 a
2% KNO_3 without aeration	86.75 ± 0.75 d	22.53 ± 0.26 cd	4.12 ± 0.06 b
LSD	2.21	1.41	0.33
Priming methods			
With aeration	86.17 ± 0.75 a	22.81 ± 0.91 b	4.17 ± 0.07 a
Without aeration	83.67 ± 0.79 b	21.61 ± 1.15 a	4.42 ± 0.08 b
LSD	2.26	0.88	0.22
KNO_3 concentrations			
0%	82.75 ± 0.31 a	20.81 ± 0.22 a	4.62 ± 0.08 b
1%	84.38 ± 0.32 b	22.75 ± 0.28 b	4.22 ± 0.07 a
2%	87.63 ± 0.32 c	23.08 ± 0.29 b	4.04 ± 0.08 a
LSD	1.33	0.78	0.22

Note: Means inside each cell denoted by different letters are substantially different based on Fisher's Least Significant Difference test at $P < 0.05$.

Seed priming significantly ($p < 0.05$) enhanced the germination percentage, Germination Rate Index (GRI), and reduced the Mean Germination Time (MGT) compared to non-primed seeds. The best results were obtained with 2% KNO_3 under aeration, which produced the highest germination percentage and GRI and the lowest MGT. In general, higher KNO_3 concentrations and the presence of aeration during priming promoted faster and more uniform germination.

The concentration of KNO_3 in priming affected germination performance in eggplant seeds. These findings align with previous research indicating that osmopriming with nitrate salts, such as KNO_3, enhances seed germination by facilitating water uptake and activating metabolic processes essential for germination. For instance, Ranil *et al*. (2015) reported that the use of KNO_3 as a moistening agent significantly improved the germination parameters of *Solanum torvum*, a rootstock species for eggplant. Similarly, a patent study demonstrated that soaking eggplant seeds in a 2% KNO_3 solution for 24 hours increased the germination rate to 88.3%, underscoring the efficacy of this concentration in promoting seed germination (Lu *et al*., 2015). Nitrate serves as a precursor for nitric oxide (NO) production (Hendricks & Taylorson, 1974), which promotes seed germination by breaking dormancy through its interactions with ethylene biosynthesis, phytochrome-mediated signaling, and reactive oxygen species (ROS) pathways (Šírová *et al*., 2011). KNO_3 also contributes to protoplasm and cell formation, as well as to maintaining membrane permeability, which subsequently activates enzymes involved in protein synthesis and carbohydrate metabolism (Preece & Read, 2005). In addition, KNO_3 helps protect cells against oxidative damage (Waqas *et al*., 2019).

The role of aeration during priming is also crucial, as it enhances oxygen availability, which is vital for aerobic respiration and energy production during germination. Prolonged immersion of seeds in solution can restrict oxygen availability during critical stages of imbibition, leading to the buildup of toxic by-products generated through anaerobic metabolic activity during priming (Nakorn & Kaewsorn, 2021). Although specific studies on aeration in eggplant seed priming are limited, the positive impact of oxygen availability on seed germination has been well-documented in other species, for example, in papaya (Thongtip *et al*., 2022), tomato (Santika *et al*., 2022) and maize (Muhklisin *et al*., 2024). However, Salles *et al*. (2019) found that nitrate-based priming agents, in conjunction with adequate oxygen supply, can enhance the germination performance of eggplant seeds.

The comprehensive evaluation of germination percentage, Germination Rate Index (GRI), and Mean Germination Time (MGT) indicates that seed priming with KNO_3, particularly at a 2% concentration and with aeration, is the most efficacious method for enhancing the germination performance of eggplant seeds.

Table 2 summarizes the effects of seed priming on early seedling growth at 35 days after planting (DAP). While differences in plant height among treatments were not statistically significant ($p > 0.05$), seeds primed with 2% KNO_3 under aeration produced slightly taller seedlings. In contrast, stem diameter and plant dry mass were significantly affected ($p < 0.05$) by the presence of aeration during priming. Aerated priming resulted in thicker stems and greater dry mass accumulation compared to non-aerated treatments, indicating improved seedling vigor and structural development.

The beneficial effects of aeration on seedling growth are likely due to enhanced energy metabolism during seed imbibition, which supports more efficient mobilization of stored carbohydrates and lipids for early seedling development. Forti *et al*. (2020) reported similar outcomes, attributing higher biomass accumulation in aerated priming to improved oxidative metabolism and reserve utilization. However, variations in KNO_3 concentration did not significantly affect plant height, stem diameter, or dry mass, suggesting that nitrate primarily enhances germination rather than post-emergence growth under these conditions.

Table 2. Average of plant height, stem diameter, and dry mass of primed eggplant

Treatments	Plant height at 35 DAP (cm)	Stem diameter at 35 DAP (mm)	Plant dry mass (g)
Combination			
Non-primed	15.75 ± 0.74 a	6.23 ± 0.25 a	4.92 ± 0.20 ab
0% KNO_3 with aeration	15.80 ± 0.68 a	6.96 ± 0.20 a	5.54 ± 0.19 b
0% KNO_3 without aeration	14.86 ± 0.82 a	6.19 ± 0.17 a	4.49 ± 0.17 a
1% KNO_3 with aeration	15.69 ± 0.59 a	6.49 ± 0.16 a	4.96 ± 0.10 ab
1% KNO_3 without aeration	14.88 ± 0.54 a	6.50 ± 0.17 a	5.15 ± 0.16 b
2% KNO_3 with aeration	16.70 ± 0.64 a	6.67 ± 0.16 a	5.32 ± 0.18 b
2% KNO_3 without aeration	15.95 ± 0.72 a	6.24 ± 0.17 a	4.65 ± 0.14 a
LSD	NS	NS	0.48
Priming methods			
with aeration	16.06 ± 0.36 a	6.71 ± 0.11 b	5.27 ± 0.38 b
without aeration	15.23 ± 0.40 a	6.31 ± 0.10 a	4.76 ± 0.40 a
LSD	NS	0.30	0.33
KNO_3 concentrations			
0%	15.33 ± 0.52 a	6.57 ± 0.19 a	5.01 ± 0.19 a
1%	15.28 ± 0.40 a	6.49 ± 0.11 a	5.06 ± 0.09 a
2%	16.33 ± 0.47 a	6.45 ± 0.14 a	4.99 ± 0.16 a
LSD	NS	NS	NS

Note: Means inside each cell denoted by different letters are substantially different based on Fisher's Least Significant Difference test at $P < 0.05$.

Although aeration priming significantly improved stem diameter and dry mass in eggplant, variations in KNO_3 concentration did not result in statistically significant differences in these parameters. This indicates that while the presence of KNO_3 may enhance germination characteristics, its concentration during priming does not strongly influence its effects on early vegetative growth.

4. Conclusion

Seed priming with potassium nitrate (KNO_3) and aeration significantly improved the germination and early growth of eggplant seedlings. The treatment enhanced seed vigor and seedling establishment, with aeration combined with 2% KNO_3 showing the most consistent benefits. This method is simple, low-cost, and has strong potential for application in seed industries as well as among smallholder farmers. Further research should explore its long-term effectiveness under diverse abiotic stresses, particularly in relation to climate change resilience.

Abbreviations

ANOVA	Analysis of Variance
CRD	Completely Randomized Design

DAP	Days After Planting
DNA	Deoxyribonucleic Acid
GRI	Germination Rate Index
KNO_3	Potassium Nitrate
LSD	Least Significant Difference
MGT	Mean Germination Time
NO	Nitric Oxide
NS	Non-significant
ROS	Reactive Oxygen Species
SA	Salicylic Acid
SOD	Superoxide Dismutase

Data availability statement

Data will be made available on request.

Credit authorship contribution statement

Putri Santika: Conceptualization, Data curation, Formal analysis, and Writing – review and editing. **Ilham Muhklisin:** Funding acquisition, Investigation, Methodology, Project administration, and Resources. **Jahrotul Laili:** Writing – original draft and Investigation. **Leli Kurniasari:** Supervision and Validation. **Donald Makama:** Writing – review and editing.

Declaration of Competing Interest

The authors of this manuscript declare that there are no conflicts of interest or competing interests.

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