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Effect of Different Concentrations of Moringa (*Moringa oleifera*) Leaf Extract on the Growth of Pomelo (*Citrus maxima* (Burm.) Merr.) Seedlings

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Abstract

One of the major constraints in pomelo cultivation is the limited availability of high-quality seedlings. An effective approach to improve seedling quality is the application of natural plant growth stimulants such as moringa (Moringa oleifera) leaf extract. This study aimed to evaluate the effect of different concentrations of moringa leaf extract on the germination and growth of pomelo seedlings and to determine the optimal concentration. The experiment was arranged in a Randomized Block Design consisting of four treatments: control (0%), 25%, 50%, and 75% moringa leaf extract, each replicated four times. The results demonstrated that the 25% concentration produced the best performance across all observed parameters, including germination rate (17.13 days), plant height (13.39 cm), number of leaves (6.25 strands), and root length (11.50 cm). These findings indicate that moringa leaf extract at an appropriate concentration can significantly enhance pomelo seedling growth.

Keywords: *Pomelo; Moringa Leaf Extract; Concentration*

1. Introduction

Pomelo (*Citrus maxima* (Burm.) Merr.) is a citrus species of high economic and nutritional value, widely cultivated in tropical and subtropical regions, including Indonesia. In South Sulawesi, particularly in Pangkep Regency, pomelo represents a leading horticultural commodity adaptable to both lowland and highland agroecosystems (Syamsinar, 2009). Beyond its economic importance, pomelo is rich in essential nutrients such as vitamin C, provitamin A, and minerals, contributing to its increasing demand as both a fresh and functional fruit.

Despite its potential, pomelo production remains unstable due to various biotic and abiotic constraints, including pests, diseases, climatic variability, and seedling quality. These factors introduce significant production risks and income uncertainty for farmers (Offayana et al., 2016). Among these constraints, the availability of high-quality seedlings is a critical limiting factor in pomelo cultivation.

The application of plant-based biostimulants offers a promising approach to improving seedling quality. *Moringa oleifera* leaf extract has gained attention due to its rich composition of growth-promoting substances, particularly cytokinins such as zeatin, along with vitamins, minerals, and phenolic compounds (Krisnadi, 2015). These

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bioactive compounds play a crucial role in stimulating cell division, differentiation, and overall plant growth. Previous studies have demonstrated that moringa leaf extract can enhance vegetative growth, including plant height and leaf number, with optimal effects observed at specific concentrations (Rahmah et al., 2019).

Therefore, the utilization of moringa leaf extract represents a potential strategy to improve the growth and quality of pomelo seedlings, thereby supporting sustainable pomelo production.

2. Methods And Materials

Materials

The materials used in this study were pomelo seeds, soil, compost, moringa leaves, polybags (17 × 25 cm), and water.

Methods

A. Preparation of Pomelo Seeds

Generative propagation (from seeds) was carried out by first drying the seeds in the sun for approximately 2 to 3 days. Once dried, the seeds were allowed to air dry for 5 minutes before use.

B. Moringa Leaf Extract Preparation and Application

Five hundred grams of fresh moringa leaves were blended in 1,000 mL of water. The extract was then diluted to obtain concentrations of 25%, 50%, and 75%. Seeds were soaked in each solution for one hour prior to planting.

This research was conducted using a Randomized Block Design (RBD) consisting of four treatments:

P0 = Control (no soaking) P1 = 25% moringa leaf extract P2 = 50% moringa leaf extract P3 = 75% moringa leaf extract

Each treatment was replicated four times, with four experimental units per replication, resulting in a total of 64 plants.

C. Preparation of Planting Media

The planting medium was prepared using a 1:1 mixture of compost and soil (one bucket each). The mixture was placed into 17 × 25 cm polybags.

D. Planting

Planting was carried out by making a 3 cm planting hole using a wooden stake, placing the seeds into the hole, covering it, and then watering.

E. Maintenance

Plant maintenance consisted of watering and weed control. Watering was performed daily in the morning and evening. Weed control was carried out by manually removing weeds growing around the pomelo seedlings.

F. Data Analysis

The collected data were analyzed using analysis of variance (ANOVA). Observations showing significantly different results at the 5% level were further analyzed using the Least Significant Difference (LSD) test.

The observation parameters in this study were:

- Germination rate (days after planting, DAP), observed each time a shoot appeared or germinated.
- Plant height (cm), measured using a ruler from the base of the stem to the tip of the longest leaf, recorded every two weeks for a total of five measurements.
- Number of leaves (blades), observed by counting the total number of leaves per plant in each polybag, recorded every two weeks for a total of five observations.
- Root length (cm), measured using a ruler from the base of the stem to the tip of the longest root, recorded at the end of the observation period.

3. Results And Discussion

Results

A. Germination Rate

Observations on the germination rate of pomelo plants showed that treatments with various concentrations of moringa leaf extract had a significant effect on the germination rate of pomelo seedlings. The LSD test results for the average germination rate per treatment are presented in Table 1.

Table 1. LSD Test Results for Germination Rate of Pomelo Seedlings at Various Concentrations of Moringa Leaf Extract

Treatment	Average (days)	LSD 0.05
MLE 75% (P3)	20.88 a	1.68
MLE 50% (P2)	20.25 a	
Control (P0)	19.00 ab	
MLE 25% (P1)	17.13 c	

Note: Numbers followed by the same letter indicate no significant difference at LSD = 0.05.

Table 1 shows that the 25% moringa leaf extract treatment (P1) produced the fastest average germination rate at 17.13 days, which was highly significantly different from the control (P0; 19.00 days), MLE 50% (P2; 20.25 days), and MLE 75% (P3; 20.88 days). The slowest germination was recorded under MLE 75% (P3) at 20.88 days, which differed significantly from P0 and P1, but was not significantly different from P2 (20.25 days).

B. Plant Height

Observations on plant height revealed that treatments with various concentrations of moringa leaf extract had a highly significant effect on the height of pomelo seedlings. The LSD test results for average plant height are presented in Table 2.

Table 2. Average Height of Pomelo Seedlings at 12 Weeks After Planting at Various Concentrations of Moringa Leaf Extract

Treatment	Average (cm)	LSD 0.05
MLE 25% (P1)	13.39 a	1.24
MLE 75% (P3)	12.50 ab	
MLE 50% (P2)	11.63 abc	
Control (P0)	11.35 c	

Note: Numbers followed by the same letter indicate no significant difference at LSD = 0.05.

Table 2 shows that MLE 25% (P1) produced the highest average plant height (13.39 cm), significantly different from the control (11.35 cm) and MLE 50% (11.63 cm), but not significantly different from MLE 75% (12.50 cm). The control treatment yielded the lowest plant height (11.35 cm), which was significantly lower than MLE 25% (P1) but did not differ significantly from MLE 50% (P2) and MLE 75% (P3).

C. Number of Leaves

Observations on the number of leaves indicated that moringa leaf extract concentrations significantly affected this parameter. The LSD test results for the average number of leaves per treatment are presented in Table 3.

Table 3. Average Number of Leaves of Pomelo Seedlings at 12 Weeks After Planting

Treatment	Average (blades)	LSD 0.05
MLE 25% (P1)	6.25 a	1.46
MLE 75% (P3)	6.13 ab	
MLE 50% (P2)	5.75 ab	
Control (P0)	4.75 b	

Note: Numbers followed by the same letter indicate no significant difference at LSD = 0.05.

Table 3 shows that the MLE 25% treatment (P1) yielded the highest average number of leaves (6.25 blades), significantly different from the control (4.75 blades), but not significantly different from MLE 50% (5.75 blades) and MLE 75% (6.13 blades). The control treatment had the fewest leaves and differed significantly only from P1.

D. Root Length

Observations on root length showed that moringa leaf extract concentrations significantly affected root development. The LSD test results for average root length are presented in Table 4.

Table 4. Average Root Length of Pomelo Seedlings at 12 Weeks After Planting at Various Concentrations of Moringa Leaf Extract

Treatment	Average (cm)	LSD 0.05
MLE 25% (P1)	11.50 a	2.95
MLE 75% (P3)	10.78 ab	
MLE 50% (P2)	9.10 ab	
Control (P0)	8.53 c	

Note: Numbers followed by the same letter indicate no significant difference at LSD = 0.05.

Table 4 shows that MLE 25% (P1) produced the longest average root length (11.50 cm), significantly different from the control (8.53 cm), but not significantly different from MLE 50% (9.10 cm) and MLE 75% (10.78 cm). The shortest root length was recorded in the control treatment, which differed significantly only from P1.

Discussion

Based on the research results, treatment with 25% moringa leaf extract affected all parameters of pomelo seed germination and growth, including germination rate, plant height, leaf number, and root length. This suggests that 25% moringa leaf extract concentration is capable of stimulating germination and growth of pomelo seeds.

Soaking with moringa leaf extract tended to decrease germination rates with increasing concentrations, likely due to the seeds' specific water absorption capacity. Consistent with Srilaba et al. (2018), seed soaking accelerates germination. The best germination was observed in P1 (25% MLE; 17.13 days). Some pomelo seeds in treatment P3 (75% MLE) did not germinate due to seed rot, possibly caused by immature embryos. This was attributed to insufficient water absorption through imbibition, making it difficult for the embryo to penetrate the hard seed coat.

Kusumo (1990) argues that seed soaking constitutes a plant growth regulator (PGR) treatment that increases water content and stimulates germination. Moringa leaves contain growth hormones such as auxin, cytokinin, and gibberellin, which can stimulate seed growth.

Moringa leaf extract functions as a growth regulator (PGR) with a high zeatin content that serves as a natural cytokinin source. Moringa is also rich in ascorbic acid, phenol, potassium, and calcium, all of which promote plant growth (Marita, 2017). Amriyanti and Ajiningrum (2019) confirmed that organic PGR from moringa leaves increased plant height and number of leaves in soybean plants (*Glycine max* (L.) Merr.).

The highest average plant height (13.39 cm) at the 25% concentration suggests that this dose maximizes auxin activity. According to Howladar et al. (2014), moringa leaf extract contains phytohormones including auxin, cytokinin, and gibberellin. Auxin (IAA—indole acetic acid), produced in the apical meristem, is transported downward to stimulate stem cell elongation and increase plant height (Dewi et al., 2008). As a biostimulant, moringa leaf extract also increases nutrient absorption efficiency, maintains soil water content, enhances microbial and enzyme activity, improves soil fertility, and promotes photosynthesis (Degennaro et al., 2014), all of which translate into increased plant height.

The highest average number of leaves (6.25) at 25% MLE is supported by high cytokinin levels in the extract. Cytokinin regulates cell growth and differentiation, stimulates shoot formation, induces cell division, stimulates lateral shoot formation, and delays leaf aging (Gusti, 2020).

Moringa leaf extract provides a comprehensive combination of growth-promoting substances, including N, P, K, Ca, Fe, essential minerals, amino acids, cytokinin (zeatin), auxin, and gibberellin. Its administration is particularly influential during the growth period due to improved plant metabolism from high mineral content (Mageed et al., 2017). The N content (1.14%) in moringa leaf extract stimulates cell division and enlargement, supporting vegetative growth (Rajiman, 2019). High cytokinin content further increases new cell growth and induces division in leaf primordia cells. The zeatin concentration (0.00002–0.02 µg/g) can increase both plant height and leaf number in pomelo plants.

The longest average root length (11.50 cm) at 25% MLE is attributed to the auxin content. Auxin relaxes cell walls, allowing osmotic water entry that drives cell elongation, which subsequently stimulates cell wall resynthesis and cytoplasm formation. Furthermore, the synergistic action of auxin and gibberellin stimulates vascular tissue development and promotes cell division in the vascular cambium, supporting root elongation (Rusmin, 2011). Sufficient nutrient absorption stimulates and promotes root elongation. This is consistent with Rahman et al. (2017), who reported that moringa leaf extract at 25% concentration significantly affected root length in sugarcane (*Saccharum officinarum*) nurseries, demonstrating that this concentration is optimal for improving metabolic processes and nutrient uptake efficiency in pomelo plants.

4. Conclusion

Based on the research results, the following conclusions are drawn:

- Application of moringa leaf extract had a highly significant effect on germination rate and plant height, and a significant effect on number of leaves and root length.
- Moringa leaf extract at a concentration of 25% (P1) produced the best results across all parameters: germination rate (17.13 days), plant height (13.39 cm), number of leaves (6.25 blades), and root length (11.50 cm).

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