Bioscientist: Jurnal Ilmiah Biologi
https://e-journal.undikma.ac.id/index.php/bioscientist

March 2026 Vol. 14, No. 1
e-ISSN: 2654-4571
pp. 422-428

Enhancing the Growth of Water Spinach (*Ipomoea reptans* L.) through the Application of Chicken Bone Waste-Based Fertilizer in Ultisol Soil

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Received: February 2026; Revised: February 2026; Accepted: March 2026; Published: March 2026

Abstract: This study aimed to evaluate the effects of the dosage and application frequency of chicken bone meal on the growth of water spinach (*Ipomoea reptans* L.). The experiment employed a factorial design within a completely randomized design (CRD) consisting of two factors, namely chicken bone meal dosage and application frequency. The observed parameters included plant height, number of leaves, and plant dry weight. The results showed that both the dosage and application frequency of chicken bone meal significantly affected the growth of water spinach. A dosage of 60 g produced the highest dry weight, reaching 20.76 g, compared with 6.10 g in the control treatment, while an application frequency of once per week resulted in better plant growth. The interaction effect indicated that the A3B1 combination produced the best growth performance, with dry weight reaching 24.97 g. Therefore, the application of chicken bone meal at an appropriate dosage and frequency can optimize the growth of water spinach.
Keywords: *Ipomoea reptans*; chicken bone meal; application frequency; plant growth; Ultisol

How to Cite: Taher, R., Suwirmen, & Noli, Z. A. (2026). Enhancing the Growth of Water Spinach (Ipomoea reptans L.) through the Application of Chicken Bone Waste-Based Fertilizer in Ultisol Soil. *Bioscientist: Jurnal Ilmiah Biologi*, *14*(1), 422–428. https://doi.org/10.33394/bioscientist.v14i1.20025

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INTRODUCTION

Soil is the primary growth medium for plants and plays a crucial role in supporting plant growth and productivity. Soil quality is determined by physical, chemical, and biological properties that interact to provide nutrients and an optimal environment for plant development (Brady & Weil, 2016). However, not all soil types possess characteristics that adequately support optimal plant growth. One such soil type is Ultisol, which is generally characterized by high acidity, low nutrient content, and low cation exchange capacity; consequently, it requires interventions to improve soil fertility (Sparks, 2003).

One approach to improving soil quality is the use of ameliorants, which are materials added to soil to enhance its physical and chemical properties. The application of ameliorants has been shown to increase soil pH, reduce toxic aluminum saturation, and improve nutrient availability for plants (Sianipar et al., 2024; Telaumbanua et al., 2023). In the context of soil fertility, improving chemical properties such as phosphorus and calcium availability is particularly important, as both elements play essential roles in root development and plant metabolism (Marschner, 2012).

In general, ameliorants can be classified into inorganic and organic types. Inorganic ameliorants include dolomite, calcitic lime, and rock phosphate, whereas organic ameliorants include compost, manure, biochar, and agricultural waste. The use of organic materials as ameliorants not only improves soil fertility but also contributes to environmental sustainability through waste recycling (Lehmann &

Joseph, 2015). One organic waste material with considerable potential is chicken bone waste. When processed into bone meal, chicken bones are known to contain high levels of phosphorus (P) and calcium (Ca), making them a potential nutrient source as well as a soil acidity neutralizer (Li et al., 2015). In addition, the utilization of chicken bone waste may help reduce environmental pollution caused by the accumulation of poorly managed organic waste (Lestari, 2015).

In West Sumatra, particularly in Padang City, the amount of chicken bone waste is relatively high. Its use as an ameliorant therefore represents a relevant alternative for addressing waste management problems while simultaneously improving the fertility of Ultisols, which are widely distributed in the region. Previous studies have shown that the application of chicken bone meal to Ultisol significantly increases available phosphorus content (Li et al., 2015). Moreover, the application of chicken bone meal at specific rates has also been reported to enhance plant growth, as observed in sorghum and cabbage (Lestari, 2015; Abdillah, 2020).

Nevertheless, most previous studies have primarily focused on the effects of fertilizer rates, whereas studies evaluating the influence of application frequency on plant growth remain limited. In fact, regulating fertilizer application frequency is an important factor in maintaining continuous nutrient availability in the soil (Van Straaten, 2007). Therefore, the combination of application rate and frequency of chicken bone meal requires further investigation to optimize its effectiveness as an ameliorant.

Water spinach (*Ipomoea reptans* L.) is a widely consumed leafy vegetable because of its rapid growth and high nutritional value, including vitamin A, vitamin C, and beta-carotene. However, the growth and nutritional quality of water spinach are strongly influenced by soil fertility conditions (Suryaningsih et al., 2018). Therefore, this study aimed to analyze the effects of chicken bone meal application, considering both rate and frequency, on the growth of water spinach cultivated in Ultisol soil. The findings of this study are expected to provide a scientific contribution to the utilization of organic waste as a sustainable ameliorant for improving soil fertility and crop productivity.

METHOD

This study employed an experimental design using a completely randomized design (CRD) with a two-factor factorial arrangement. The first factor was the dose of chicken bone meal (A), consisting of five levels: A1 (0 g), A2 (15 g), A3 (30 g), A4 (45 g), and A5 (60 g). The second factor was the application frequency (B), consisting of two levels: B1 (once per week) and B2 (once every two weeks). Each treatment combination was replicated three times, resulting in a total of 30 experimental units.

The research subjects were water spinach plants (*Ipomoea reptans* L.) grown in Ultisol soil medium. Each experimental unit consisted of one plant cultivated in a planting container. All plants were maintained under relatively uniform environmental conditions, including watering, light exposure, and other routine cultural practices. Water spinach was selected because of its rapid growth as a leafy vegetable crop, allowing treatment responses to be observed within a relatively short period.

Observations were conducted on plant growth parameters, including plant height, number of leaves, and plant dry weight. Plant height was measured using a ruler, the number of leaves was counted directly, and dry weight was determined by drying the plants to a constant weight. Chicken bone meal was applied according to the prescribed doses and frequencies. Throughout the experiment, all plants were maintained under uniform treatment conditions until harvest to minimize the influence of external factors.

The collected data were analyzed quantitatively using analysis of variance (ANOVA) to determine the effects of the treatments on the observed parameters. When the analysis indicated significant effects, Duncan's Multiple Range Test (DMRT) was performed at a 95% confidence level to identify differences among treatments. Data analysis was conducted using statistical software (SPSS).

RESULTS AND DISCUSSION

Plant Height Response to Treatment

The results of plant height observations in water spinach (*Ipomoea reptans* L.) are presented in Table 1.

Table 1. Mean plant height after treatment

Dose Treatment (A)	Frequency (B1) (once per week) Mean ± SD	Frequency (B2) (once every two weeks) Mean ± SD	Mean of Factor A
A1 (Control)	40.33 ± 1.53a	32.50 ± 5.77a	36.42 ± 3.65A
A2 (15 g)	43.67 ± 5.13a	49.17 ± 12.71a	46.42 ± 8.92AB
A3 (30 g)	64.33 ± 10.02a	54.33 ± 15.31a	59.33 ± 12.66C
A4 (45 g)	62.50 ± 17.67a	51.67 ± 8.22a	57.08 ± 12.94BC
A5 (60 g)	41.83 ± 5.39a	41.83 ± 5.84a	41.83 ± 5.61A
Mean of Factor B	**50.53 ± 7.94A**	**45.90 ± 9.57A**	

Based on Table 1, neither the dose of chicken bone meal (factor A) nor the application frequency (factor B) had a significant effect on the height of water spinach (*Ipomoea reptans* L.). Nevertheless, descriptively, treatment A3 at a dose of 30 g produced the greatest plant height, reaching 59.33 cm compared with the other treatments. This finding suggests that this dose may have provided nutrients at a relatively optimal level during the vegetative growth phase, although the effect was not statistically significant.

Chicken bone meal contains essential nutrients such as phosphorus (P) and calcium (Ca), which play important roles in cell division, new tissue formation, and stem elongation. Phosphorus is involved in energy metabolism through the formation of ATP, which is required for cell division and cell elongation, whereas calcium functions in cell wall formation and stabilization and in maintaining membrane integrity, thereby supporting plant tissue development. However, the absence of a significant treatment effect on plant height may indicate that plant height was more strongly influenced by genetic factors, environmental conditions, and the relatively uniform nutrient availability among treatments.

These results are consistent with previous studies showing that phosphorus and calcium play important roles in supporting vegetative plant growth. Phosphorus is a major component of plant energy metabolism because it is involved in the formation of energy molecules such as ATP and ADP, which are required for various physiological processes in plants (Satheesh et al., 2022; Lambers, 2022). In addition, calcium contributes to maintaining cell structural stability and supports cell division and expansion (Jin et al., 2025). Regarding application frequency, plant responses to organic materials are more strongly influenced by total nutrient availability and mineralization processes than by short-term application intervals (Cesarano et al., 2017). Thus, the 30 g dose of chicken bone meal showed a tendency to produce greater plant height than the other treatments.

Number of Leaves

The results of leaf number measurements in water spinach after chicken bone meal treatment are presented in Table 2.

Table 2. Number of leaves of water spinach

Dose Treatment (A)	Frequency (B1) (once per week) Mean ± SD	Frequency (B2) (once every two weeks) Mean ± SD	Mean of Factor A
A1 (Control)	39.67 ± 24.58a	59.00 ± 20.42a	49.33 ± 22.81A
A2 (15 g)	79.67 ± 6.03a	46.33 ± 22.05a	63.00 ± 23.28AB
A3 (30 g)	100.33 ± 11.15a	77.00 ± 20.30a	88.67 ± 19.43B
A4 (45 g)	85.67 ± 32.88a	84.00 ± 26.67a	84.83 ± 26.79B
A5 (60 g)	87.33 ± 31.53a	69.67 ± 22.86a	78.50 ± 26.46AB
Mean of Factor B	**78.53 ± 21.23A**	**67.20 ± 22.46A**	

Based on Table 2, the dose treatment and its interaction significantly affected the number of leaves of water spinach (*Ipomoea reptans* L.). Treatment A3B1 (30 g chicken bone meal with an application frequency of once per week) produced the highest number of leaves, namely 100.33 leaves, indicating that phosphorus (P) supplied at an optimal dose was able to enhance vegetative plant growth.

Physiologically, phosphorus plays an important role in photosynthesis, cell division, and energy transfer (ATP); therefore, its optimal availability can promote leaf formation (Fathi, 2023). In addition, bone meal, as a source of organic phosphorus, has slow and sustained nutrient-release characteristics, thereby supporting nutrient availability throughout the vegetative growth phase of the plant (Mackay et al., 2017). The dose response indicates that a moderate dose produced more optimal results than either lower or higher doses. Low doses may lead to nutrient limitation, whereas high doses do not necessarily increase leaf number significantly, possibly due to nutrient imbalance (Fathi, 2023). This is consistent with Liebig's Law of the Minimum, which states that plant growth is constrained by the nutrient in shortest supply.

The interaction between dose and application frequency indicates that application once per week was able to maintain more stable nutrient availability in the root zone, thereby supporting sustained vegetative growth. This is in line with reports showing that the frequency of organic material application affects soil nutrient dynamics and the efficiency of nutrient uptake by plants (Cesarano et al., 2017). Moreover, plant responses to nutrient availability also reflect resource allocation strategies, in which plants regulate nutrient distribution among organs to optimize growth under prevailing environmental conditions (Cheng & Yu, 2025; Jiang et al., 2024). In contrast, less frequent application intervals may cause fluctuations in nutrient availability that can inhibit leaf formation (Siedliska et al., 2021).

Differences in leaf number response to variation in application frequency further indicate the operation of plant resource allocation strategies. More frequent application tended to enhance the formation of new leaves, suggesting that stable nutrient availability supports meristematic activity. Conversely, under more limited nutrient availability, plants tend to allocate resources toward maintaining the growth of already formed organs. This reflects a vegetative growth resource allocation mechanism in response to changing nutrient availability (Yong et al., 2025).

Dry Weight of Water Spinach after Treatment

The results of dry weight measurements of water spinach after chicken bone meal treatment are presented in Table 3.

Table 3. Dry weight of water spinach

Dose Treatment (A)	Frequency (B1) (once per week) Mean ± SD	Frequency (B2) (once every two weeks) Mean ± SD	Mean of Factor A
A1 (Control)	6.73 ± 0.54a	5.48 ± 3.05a	6.10 ± 1.79A
A2 (15 g)	21.14 ± 3.42bc	13.91 ± 6.74ab	17.53 ± 5.08B
A3 (30 g)	24.97 ± 7.97c	14.19 ± 1.06ab	19.58 ± 4.51B
A4 (45 g)	20.77 ± 4.98bc	17.96 ± 4.82bc	19.36 ± 4.90B
A5 (60 g)	18.46 ± 6.09bc	23.06 ± 3.28bc	20.76 ± 4.68B
Mean of Factor B	**18.41 ± 4.60A**	**14.92 ± 3.80B**	

Based on Table 3, the dose and frequency of chicken bone meal application, as well as their interaction, significantly affected the dry weight of water spinach (*Ipomoea reptans* L.). Treatment A5 (60 g) produced the highest dry weight (20.76 g), whereas the control (A1) showed the lowest value (6.10 g), indicating that increasing fertilizer dose enhanced plant biomass accumulation. This increase was associated with nutrient availability, particularly phosphorus (P) and calcium (Ca), which play important roles in photosynthesis and plant tissue formation. Optimal nutrient availability supports efficient biomass accumulation, in agreement with studies showing that bone meal application increases plant dry weight through improved soil nutrient availability (Atemni et al., 2023).

An application frequency of once per week (B1) resulted in a higher dry weight (18.41 g) than the less frequent application (B2, 14.92 g), indicating that continuity of nutrient supply plays an important role in supporting growth. The treatment interaction showed that the A3B1 combination produced the highest dry weight (24.97 g), suggesting that the effectiveness of organic fertilizer is determined not only by dose but also by application frequency. This is supported by studies reporting that the frequency of organic fertilizer application affects nutrient availability and nutrient uptake efficiency by plants (Cesarano et al., 2017).

CONCLUSION

Based on the results of this study, the application of chicken bone meal at different doses and frequencies significantly affected the growth of water spinach (*Ipomoea reptans* L.). The 60 g dose produced the best overall growth performance, particularly in terms of plant dry weight, whereas an application frequency of once per week resulted in more optimal growth than less frequent application. The interaction between dose and frequency indicated that the A3B1 combination was the best treatment for enhancing plant growth. Therefore, the use of chicken bone meal at an appropriate dose and application frequency can optimize the growth of water spinach under Ultisol soil conditions.

RECOMMENDATION

Future studies are recommended to examine the long-term effects of chicken bone meal application on the chemical and biological properties of Ultisol soils, as well as to evaluate plant growth responses and yield in order to determine the most effective dose and application frequency. In addition, studies combining chicken bone meal with other organic materials or phosphate-solubilizing microbes are needed to optimize and sustain its use as an ameliorant.

ACKNOWLEDGMENT

The authors would like to express their gratitude to the Institute for Research and Community Service (LPPM), Universitas Andalas, for financial support through the 2025 student research grant scheme under contract number 325/UN16.19/PT.01.03/PSS/2025, and to the Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Andalas, for providing the facilities and infrastructure that supported the implementation of this research. The authors also sincerely thank the first and second supervisors for their guidance, direction, and valuable suggestions from the planning stage through to the completion of the article. Appreciation is also extended to the laboratory analysts for their assistance in providing facilities that enabled the research to proceed smoothly. Finally, the authors acknowledge all parties who provided technical and academic support throughout the research process. Their support and contributions were invaluable to the successful completion of this study.

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