BERESI Journal of Environmental Research

BERESI (*Journal of Environmental Research*)
BJE 2(1): 36-51 (20 March 2026)
ISSN XXXX-XXXX

Growth Response and Mineral Content of Green Spinach (*Amaranthus sp.)* Grown in Planting Media Supplemented with Water Spinach Stem Compost

Novi Puji Lestari[1*], Chairunnisah J. Lamangantjo[1], Wirnangsih D.Uno[1], Syam S. Kumaji[1], Novri Y. Kandowangko[1], Yuliana Retnowati[1].

[1]Department of Biology, Faculty of Mathematics and Natural Science, Universitas Negeri Gorontalo, Jl. Prof. Dr. Ing. B.J. Habibie, Tilongkabila, Bone Bolango 96583 Indonesia

*Corresponding author: *novipujilestari06november@gmail.com (Novi Puji Lestari)*

ABSTRACT

Background: Green spinach (*Amaranthus sp*.) is a leafy vegetable with high nutritional value and is widely consumed by the community. The use of organic compost as a planting medium supplement is one strategy to improve plant growth while utilizing organic waste. Water spinach stems (Ipomoea aquatica) have the potential to be processed into compost; however, their effectiveness as a planting medium supplement for green spinach growth and mineral accumulation has not been widely studied. **Objective:** This study aimed to analyze the effect of planting media supplemented with water spinach stem compost on the growth and metal/mineral content of green spinach. **Methods:** This research employed an experimental method using a Completely Randomized Design (CRD) consisting of five treatments and five replications. The treatments included K0 = 100% soil, K1 = 70% soil + 30% water spinach stem compost, K2 = 50% soil + 50% compost, K3 = 25% soil + 75% compost, and K4 = 100% compost. The observed growth parameters included plant height, number of leaves, fresh weight, dry weight, and root length during 35 days after planting. Growth data were analyzed using analysis of variance (ANOVA) at a 5% significance level, while the metal/mineral content of green spinach was analyzed descriptively using X-Ray Fluorescence (XRF). **Findings**: The results showed that water spinach stem compost supplementation did not significantly affect plant height, number of leaves, and root length. However, significant differences were observed in fresh weight and dry weight. The highest fresh weight was found in the control treatment (K0) at 111.8 g, followed closely by K1 at 111.4 g, while the lowest value was recorded in K4. Similarly, the highest dry weight was obtained in K0 at 16.2 g, whereas the lowest dry weight was found in K4 at 5.4 g. XRF analysis showed that green spinach contained several dominant mineral compounds, including K_2O, Na_2O, CaO, MgO, and Fe_2O_3, with varying percentages among treatments. Trace amounts of heavy metal compounds such as CdO and Sb_2O_3 were also detected. **Conclusion:** Planting media supplemented with water spinach stem compost did not consistently improve the growth of green spinach. The use of excessive compost, particularly 100% compost, tended to reduce plant biomass. The best growth performance was generally observed in the control treatment and in the moderate compost treatment. **Novelty/Originality**: This study provides preliminary information on the use of water spinach stem compost as an organic planting medium supplement and its relationship with growth performance and mineral composition in green spinach.

KEYWORDS: Green spinach; Mineral content; Organic compost; Plant growth; X-Ray fluorescence

1. INTRODUCTION

Green spinach (*Amaranthus sp*.) is one of the leafy vegetables widely cultivated and consumed because of its nutritional value, adaptability, and relatively short growing period. Amaranthus leafy vegetables are known to contain various essential nutrients, including minerals, vitamin C, phenolic compounds,

***Cite This Article*:**
Lestari, N.P., Lamangantjo, C.J., Uno, W.D., Kumaji, S.S., Kandowangko, N.Y., and Retnowati, Y. (2026). Growth Response and Mineral Content of Green Spinach (*Amaranthus sp.)* Grown in Planting Media Supplemented with Water Spinach Stem Compost. *BERESI: Journal of Environmental Research (BJE), 2*(1): 36-51

flavo-noids, and antioxidant components that contribute to their functional value as a vegetable crop (Jiménez-Aguilar & Grusak, 2017). In addition, green spinach is commonly recognized as a potential source of essential minerals such as calcium (Ca), iron (Fe), potassium (K), and magnesium (Mg), which are important for human nutrition and plant physiological processes. The mineral composition of leafy vegetables may vary depending on genetic factors, cultivation practices, nutrient availability, and the characteristics of the growing medium (Grusak, 2017; Hasmeda et al., 2021).

Plant growth and mineral accumulation are strongly influenced by the quality of the planting medium. A suitable planting medium provides adequate nutrients, supports root development, maintains water availability, and promotes beneficial soil biological activity. Organic amendments such as compost are widely used to improve soil fertility and crop productivity because they can enhance soil physical, chemical, and biological properties. Long-term application of organic amendments has been reported to improve soil structure, nutrient availability, microbial activity, and overall soil fertility (Diacono & Montemurro, 2011). In addition, organic materials can contribute to ecosystem services by improving soil functions that support agricultural productivity and environmental sustainability (Adhikari & Hartemink, 2016).

Compost is one of the organic amendments that can be used as a supplement in planting media. Its effectiveness depends on several factors, including raw material composition, compost maturity, nutrient content, C/N ratio, decomposition process, and application dose. Compost that is properly processed may support plant growth by supplying nutrients and improving media structure. However, immature compost or excessive compost application may cause nutrient imbalance, nitrogen immobilization, changes in pH, salinity problems, or unfavorable physical conditions for plant growth (Amlinger et al., 2003; Bernal et al., 2009). Therefore, determining the appropriate proportion of compost in planting media is essential to optimize plant growth and avoid negative effects on crop performance.

Water spinach (*Ipomoea aquatica*) stems are organic materials that have the potential to be utilized as compost. Water spinach grows rapidly and produces abundant biomass, while its stems are often underutilized and may become organic waste. Processing water spinach stems into compost can be an alternative strategy for organic waste management and sustainable agriculture. The use of plant-based organic waste as compost is consistent with efforts to improve resource efficiency and reduce dependence on inorganic inputs. However, the effect of water spinach stem compost on the growth of green spinach and its relationship with mineral accumulation still requires further investigation.

Previous studies have shown that organic compost may influence the growth of spinach and other crops, although plant responses can vary depending on compost type, application rate, and environmental conditions. For example, the application of compost has been reported to affect nitrogen availability and the growth of spinach (*Amaranthus tricolor* L.) (Amir et al., 2012). Nevertheless, excessive organic amendment may not always improve plant growth, as nutrient use efficiency and plant response are determined by the balance and availability of nutrients in the growing medium (Baligar et al., 2001). This indicates that compost application should be carefully evaluated, especially when used as a major component of planting media.

In addition to growth performance, the mineral and metal content of green spinach is also an important aspect to evaluate. Leafy vegetables can absorb essential minerals from the growing medium, but they may also accumulate potentially harmful heavy metals when grown in contaminated or imbalanced media. Heavy metal contamination in vegetables is a concern because it may affect food safety and human health (Kumar et al., 2019). Therefore, the analysis of mineral and metal composition in spinach grown with organic compost supplementation is important to assess both its nutritional potential and possible safety concerns. X-Ray Fluorescence (XRF) analysis can provide information on the elemental composition of plant samples, particularly in identifying the presence of mineral compounds and trace elements.

Based on this background, this study aimed to analyze the effect of planting media supplemented with water spinach stem compost on the growth and metal/mineral content of green spinach (Amaranthus sp.). The growth parameters observed included plant height, number of leaves, fresh weight, dry weight, and root length, while the metal/mineral composition was analyzed using X-Ray Fluorescence (XRF). The findings of this study are expected to provide preliminary information on the potential use of water spinach stem compost as an organic planting medium supplement and its implications for green spinach growth and mineral composition.

2. MATERIALS AND METHODS

2.1 Research Design

This study employed an experimental quantitative method using a Completely Randomized Design (CRD). The experiment consisted of five planting media treatments with five replications for each treatment, resulting in 25 experimental units. The study was designed to evaluate the effect of planting media supplemented with water spinach stem compost on the growth and metal/mineral content of green spinach (*Amaranthus sp.).*

2.2 Time and Location of the Study

The study was conducted in July 2024 at the Agricultural Standardization and Instrumentation Agency. Plant growth observations were carried out for 35 days after planting (DAP). The observed growth parameters included plant height, number of leaves, fresh weight, dry weight, and root length. Metal/mineral content analysis was conducted using X-Ray Fluorescence (XRF).

2.3 Materials

The materials used in this study included green spinach (Amaranthus sp.) plants, soil, and compost made from water spinach (Ipomoea aquatica) stems. The planting media were prepared by mixing soil and water spinach stem compost according to the treatment composition. The tools used included planting containers or polybags, measuring instruments for plant height and root length, analytical scales for fresh and dry weight measurement, an oven or drying equipment for dry weight determination, and an X-Ray Fluorescence (XRF) instrument for metal/mineral analysis.

2.4 Treatment Composition

The treatments consisted of different proportions of soil and water spinach stem compost. The treatment composition was arranged as follows:

Treatment Code	Composition of Planting Medium
K0	100% soil without water spinach stem compost
K1	70% soil + 30% water spinach stem compost
K2	50% soil + 50% water spinach stem compost
K3	25% soil + 75% water spinach stem compost
K4	100% water spinach stem compost

Each treatment was repeated five times. The use of these treatment codes follows the data presentation in the results section, where plant growth and metal/mineral content were reported based on K0, K1, K2, K3, and K4.

2.5 Plant Growth Observation

Plant growth was observed from 7 to 35 days after planting. The parameters observed in this study were plant height, number of leaves, fresh weight, dry weight, and root length. Plant height was measured periodically at 7, 14, 21, 28, and 35 days after planting. The number of leaves was also recorded at the same observation intervals. Fresh weight was measured at harvest, namely 35 days after planting, by weighing the total plant biomass. Root length was measured after harvesting by measuring the length of the root from the base to the root tip. Dry weight was obtained by drying the plant samples until a constant weight was reached and then weighing the dried biomass.

2.6 Metal/Mineral Content Analysis

The metal/mineral content of green spinach was analyzed using X-Ray Fluorescence (XRF). XRF analysis was used to identify and quantify the chemical elements or mineral oxide compounds contained in the green spinach samples. The samples selected for XRF analysis were taken from representative samples of each treatment, namely K05, K13, K24, K31, and K42, as presented in the results section. The detected compounds included several mineral oxides such as K_2O, Na_2O, CaO, MgO, Fe_2O_3, ZnO, MnO, and other trace compounds.

The results of XRF analysis were presented descriptively in the form of percentage composition for each detected compound. This analysis was used to describe the variation in metal/mineral content of green spinach grown in different planting media treatments.

2.7 Data Analysis

Growth data were analyzed using analysis of variance (ANOVA) at a 95% confidence level or 5% significance level. The ANOVA was used to determine whether the different proportions of water spinach stem compost in the planting media significantly affected plant height, number of leaves, fresh weight, dry weight, and root length. The statistical decision was based on the significance value. If the significance value was less than 0.05, the treatment was considered to have a significant effect. If the significance value was greater than 0.05, the treatment was considered not to have a significant effect. When a significant effect was found, a post hoc test could be conducted to determine differences among treatments. The metal/mineral content data obtained from XRF analysis were analyzed descriptively by comparing the percentage composition of each detected compound among treatments.

3. RESULTS AND DISCUSSION

3.1 Growth Response of Green Spinach

The growth response of green spinach (*Amaranthus sp.*) grown in planting media supplemented with water spinach stem compost was evaluated based on five parameters: plant height, number of leaves, fresh weight, root length, and dry weight. The observations were conducted up to 35 days after planting (DAP), and the results are presented in Figures 1–5 and Tables 1-5.

3.1.1 *Plant Height*

Plant height is one of the main indicators used to evaluate vegetative growth. As shown in Figure 1, plant height increased from 7 to 35 DAP in all treatments. However, the growth pattern indicated that higher proportions of water spinach stem compost did not necessarily improve plant height. The control treatment (K0) and the moderate compost treatment (K1: 70% soil + 30% compost) showed better plant height performance than treatments with higher compost proportions. In contrast, the 100% compost treatment (K4) showed the lowest plant height at the end of the observation period.

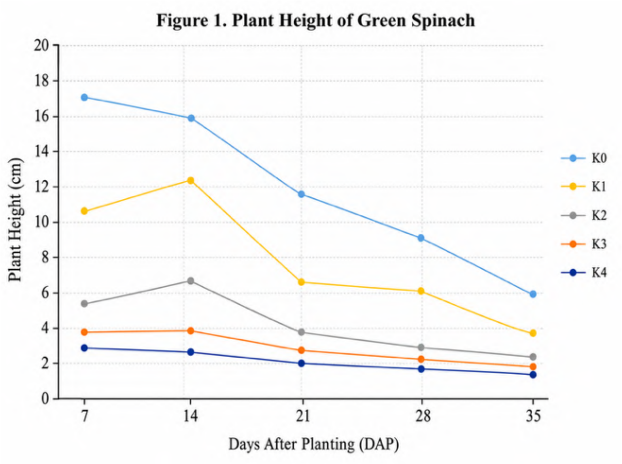

Figure 1. Plant height of green spinach

The ANOVA results in **Table 1** showed that the compost treatment did not significantly affect plant height, as indicated by the significance value of 0.307, which was greater than 0.05. This means that differences in planting media composition did not produce a statistically significant effect on plant height. The R-squared value of 0.205 indicated that only 20.5% of the variation in plant height could be explained by the treatment, while the remaining variation was likely influenced by other factors, such as seedling variation, media heterogeneity, environmental conditions, or nutrient availability.

Table 1. ANOVA Results for Plant Height

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	962.471[a]	4	240.618	1.290	0.307
Intercept	8515.968	1	8515.968	45.646	0.000
Treatment	962.471	4	240.618	1.290	0.307
Error	3731.350	20	186.568		
Total	13209.789	25			
Corrected Total	4693.821	24			

Note. Dependent variable: Plant height (TT). [a] R^2 = 0.205; Adjusted R^2 = 0.046.

Although organic amendments can improve soil fertility and support plant growth, their effects depend strongly on compost quality, maturity, nutrient balance, and application rate. Diacono and Montemurro (2011) explained that organic amendments can improve soil fertility, but their effect on crop growth is influenced by the characteristics of the organic material and the growing conditions. In this study, the decreasing trend in plant height at higher compost proportions suggests that excessive compost may have created less favorable growing conditions, such as nutrient imbalance, poor aeration, or changes in media structure.

3.1.2 *Number of Leaves*

The number of leaves reflects vegetative development and photosynthetic capacity. Based on Figure 2, the number of leaves increased during the observation period from 7 to 35 DAP. The K1 treatment showed the best leaf production trend compared with the other compost treatments. Meanwhile, the highest compost proportion, particularly K4, showed lower leaf development than the control and moderate compost treatments.

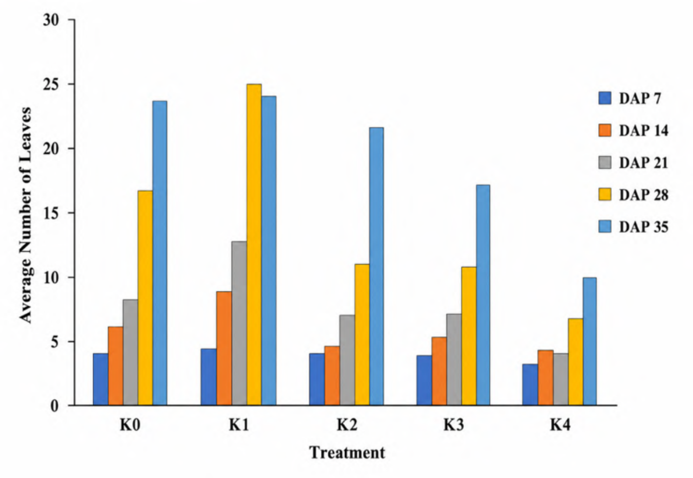

Figure 2. Number of leaves of green spinach

The ANOVA results in Table 2 indicated that the treatment did not significantly affect the number of leaves, with a significance value of 0.326, which was greater than 0.05. This result shows that different proportions of water spinach stem compost did not produce statistically significant differences in leaf number. The R-squared value of 0.199 indicates that only 19.9% of the variation in leaf number was explained by the treatment.

Table 2. ANOVA Results for Number of Leaves

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	240.791[a]	4	60.198	1.241	0.326
Intercept	2617.550	1	2617.550	53.956	0.000
Treatment	240.791	4	60.198	1.241	0.326
Error	970.262	20	48.513		
Total	3828.604	25			
Corrected Total	1211.054	24			

Note. Dependent variable: Number of leaves (JD).
[a] R^2 = 0.199; Adjusted R^2 = 0.039.

This finding suggests that moderate compost addition may support leaf formation descriptively, but the effect was not strong enough to be statistically significant. Plant responses to organic amendments are often variable because nutrient release from compost depends on decomposition rate, microbial activity, and the balance between available and immobilized nutrients. Amlinger et al. (2003) reported that nitrogen availability from compost depends on the dynamics of mineralization and immobilization. Therefore, if the compost is not fully mature or if the nutrient release does not match plant demand, leaf development may not increase significantly.

3.1.3 Fresh Weight

Fresh weight represents the total biomass of the plant at harvest, including the water content in plant tissues. As shown in Figure 3, the highest fresh weight was recorded in the control treatment (K0) at 111.8 g, followed closely by K1 at 111.4 g. The fresh weight decreased in K2 at 79 g, K3 at 44.8 g, and reached the lowest value in K4 at 10.2 g. This pattern indicates that increasing the proportion of compost did not improve fresh biomass; instead, excessive compost reduced plant fresh weight substantially.

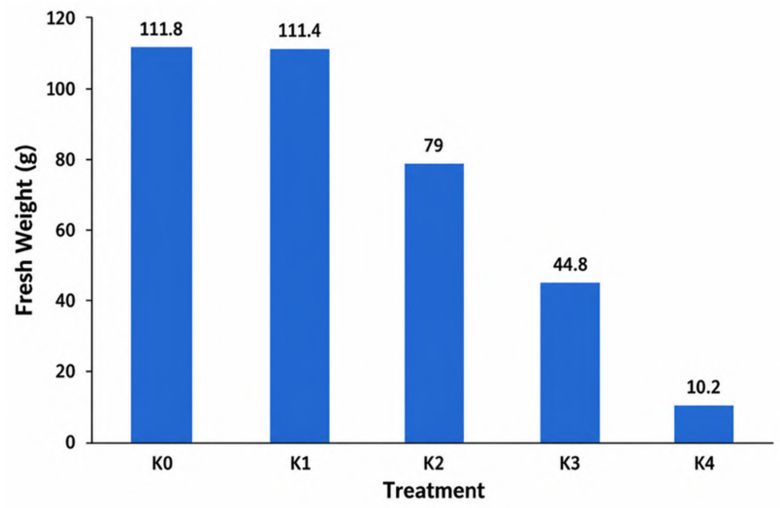

Figure 3. Fresh weight of green spinach at 35 DAP

The ANOVA results in Table 3 showed a significant effect of treatment on fresh weight, as indicated by the significance value of 0.001, which was lower than 0.05. Therefore, the different proportions of water spinach stem compost significantly affected the fresh weight of green spinach. The R-squared value of 0.589 indicates that 58.9% of the variation in fresh weight could be explained by the treatment.

Table 3. Anova results for fresh weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	38714.560[a]	4	9678.640	7.179	0.001
Intercept	127591.840	1	127591.840	94.633	0.000
Treatment	38714.560	4	9678.640	7.179	0.001
Error	26965.600	20	1348.280		
Total	193272.000	25			
Corrected Total	65680.160	24			

Note. Dependent variable: Fresh weight (BS).
[a] R^2 = 0.589; Adjusted R^2 = 0.507.

The highest fresh weight in K0 and K1 suggests that green spinach performed better in soil-based media and in media containing a moderate proportion of compost. This result may indicate that 30% compost was still within a tolerable range for plant growth, whereas higher compost proportions may have caused unfavorable physical or chemical conditions in the planting medium. Bernal et al. (2009) stated that compost maturity and chemical characteristics are important factors affecting plant response. Similarly, Zhang et al. (2013) reported that the use of composted organic materials as growth media may influence plant growth depending on compost composition and maturity. In this study, the low fresh weight in K4 suggests that 100% compost was not suitable as a single planting medium for green spinach.

3.1.4 Root Length

Root length is an important indicator of the plant's ability to explore the growing medium for water and nutrients. As presented in Figure 4, the longest root length was observed in K4 at 13 cm, followed by K0 at 12.64 cm, K1 at

12.02 cm, K2 at 11.56 cm, and K3 at 11.5 cm. Although K4 produced the longest roots, the difference among treatments was relatively small.

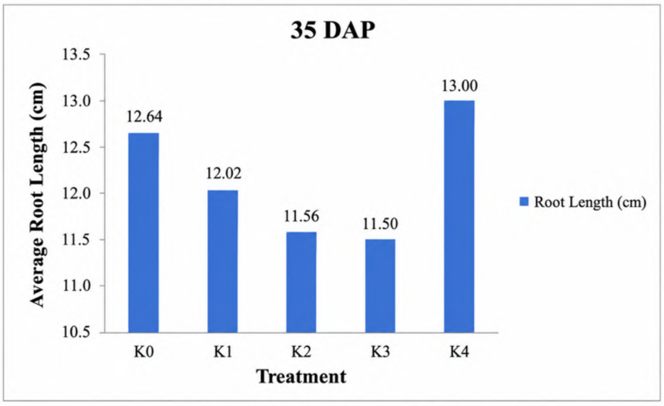

Figure 4. Root Length of Green Spinach

The ANOVA results in Table 4 showed that the treatment had no significant effect on root length, with a significance value of 0.915, which was greater than 0.05. The R-squared value of 0.045 indicates that only 4.5% of the variation in root length could be explained by the treatment.

Table 4. ANOVA results for root length

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8.750[a]	4	2.187	0.235	0.915
Intercept	3686.918	1	3686.918	396.929	0.000
Treatment	8.750	4	2.187	0.235	0.915
Error	185.772	20	9.289		
Total	3881.440	25			
Corrected Total	194.522	24			

Note. Dependent variable: Root length (PA).
[a] R^2 = 0.045; Adjusted R^2 = -0.146.

The longer root observed in K4 may reflect an adaptive response to less favorable nutrient or physical conditions in the medium. When nutrient availability is limited or imbalanced, plants may allocate more growth to roots in order to increase nutrient and water absorption. However, because the statistical analysis showed no significant difference, this trend should be interpreted cautiously. Nakagawa and Cuthill (2007) emphasized that biological trends and statistical significance should be interpreted together, especially when effect sizes and variability influence the strength of conclusions. Organic amendments may improve soil physical, chemical, and biological properties, but their effectiveness depends on compost type, crop species, and environmental conditions (Dou et al., 2012; Adhikari & Hartemink, 2016).

3.1.5 Dry Weight

Dry weight reflects the accumulation of plant biomass after water content has been removed. As shown in Figure 5, the highest dry weight was recorded in K0 at 16.2 g, followed by K1 at 15 g, K2 at 10.2 g, K3 at 8.2 g, and K4 at 5.4 g. This pattern shows a clear decline in dry biomass as the proportion of compost increased.

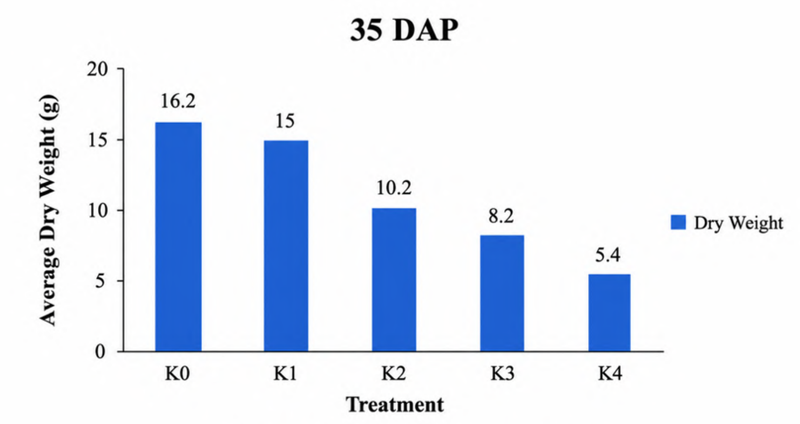

Figure 5. Dry Weight of Green Spinach

The ANOVA results in Table 5 showed that the treatment significantly affected dry weight, with a significance value of 0.001, which was lower than 0.05. Therefore, the addition of water spinach stem compost had a significant effect on dry biomass accumulation. The R-squared value of 0.597 indicated that 59.7% of the variation in dry weight was explained by the treatment.

Table 5. ANOVA results for dry weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	411.840[a]	4	102.960	7.407	0.001
Intercept	3069.160	1	3069.160	220.803	0.000
Treatment	411.840	4	102.960	7.407	0.001
Error	278.000	20	13.900		
Total	3759.000	25			
Corrected Total	689.840	24			

Note. Dependent variable: Dry weight (BK).
[a] R^2 = 0.597; Adjusted R^2 = 0.516.

The decrease in dry weight at higher compost proportions suggests that excessive compost may reduce biomass accumulation. Several factors may explain this result. First, the compost may have had an unsuitable C/N ratio, causing nitrogen immobilization and reducing nutrient availability for plant growth. Bernal et al. (2009) stated that C/N ratio and compost maturity are important indicators of compost quality. Second, the use of 100% compost may have altered the physical structure of the medium, including porosity, water retention, and aeration. Third, nutrient imbalance may have occurred because compost nutrient composition varies depending on raw materials and decomposition conditions (Diacono & Montemurro, 2011). Therefore, although compost can be beneficial as an organic amendment, its excessive use may reduce crop performance.

3.2 Metal and Mineral Content of Green Spinach

The metal and mineral content of green spinach was analyzed using X-Ray Fluorescence (XRF). The samples analyzed were K05, K13, K24, K31, and K42, representing selected samples from the treatment groups. The XRF results are presented in Tables 6-10. The detected compounds were mainly mineral oxides, including K_2O, Na_2O, CaO, MgO, Fe_2O_3, ZnO, MnO, and several trace compounds.

In Table 6, the K05 sample showed that the dominant compounds were K_2O at 40.03%, Na_2O at 26.2%, CaO at 14.98%, SO_3 at 8.82%, and Fe_2O_3 at 3.47%. This indicates that potassium, sodium, calcium, sulfur, and iron compounds were present in relatively high proportions in the control sample. However, CdO was also detected at 0.33%, indicating the presence of a trace heavy metal compound that requires attention.

Table 6. Metal content of green spinach in treatment K05

Atomic Number	Compound	Percentage (%)
11	Na_2O	26.20
15	P_2O_5	3.08
16	SO_3	8.82
17	Cl	0.25
19	K_2O	40.03
20	CaO	14.98
25	MnO	0.25
26	Fe_2O_3	3.47
29	CuO	0.19
30	ZnO	0.45
37	Rb_2O	0.47
38	SrO	0.22
48	CdO	0.33
50	SnO_2	0.37
52	TeO_2	0.78

In Table 7, the K13 sample was dominated by Na_2O at 49.1%, followed by K_2O at 16.39%, CaO at 11.98%, MgO at 7.5%, SO_3 at 4.88%, and Fe_2O_3 at 2.42%. Trace compounds such as CdO at 0.29% and Sb_2O_3 at 0.95% were also detected. The high Na_2O content in K13 indicates that the mineral composition of green spinach varied among treatments.

Table 7. Metal content of green spinach in treatment K13

Atomic Number	Compound	Percentage (%)
11	Na_2O	49.10
12	MgO	7.50
13	Al_2O_3	0.54
15	P_2O_5	0.86
16	SO_3	4.88
17	Cl	0.55
19	K_2O	16.39
20	CaO	11.98
25	MnO	0.24
26	Fe_2O_3	2.42
30	ZnO	0.17
35	Br	0.24
37	Rb_2O	0.39

38	SrO	0.64
40	ZrO_2	0.16
42	MoO_3	0.13
48	CdO	0.29
50	SnO_2	0.32
51	Sb_2O_3	0.95
52	TeO_2	1.81
56	BaO	0.15

In Table 8, the K24 sample contained CaO as the dominant compound at 32.22%, followed by Na_2O at 24.6%, K_2O at 22.95%, and Fe_2O_3 at 6.33%. This treatment also showed CdO at 0.66% and Sb_2O_3 at 1.36%. The Fe_2O_3 content in K24 was the highest among the reported samples, suggesting that the mineral composition of green spinach may be influenced by planting media composition.

Table 8. Metal content of green spinach in treatment K24

Atomic Number	Compound	Percentage (%)
11	Na_2O	24.60
16	SO_3	4.50
17	Cl	0.50
19	K_2O	22.95
20	CaO	32.22
25	MnO	0.58
26	Fe_2O_3	6.33
29	CuO	0.18
30	ZnO	0.49
37	Rb_2O	0.17
38	SrO	1.50
42	MoO_3	0.11
48	CdO	0.66
51	Sb_2O_3	1.36
52	TeO_2	2.65
56	BaO	0.50
57	La_2O_3	0.59

In Table 9, the K31 sample was dominated by Na_2O at 42.1%, followed by K_2O at 21.01%, CaO at 11.28%, MgO at 9.5%, and Fe_2O_3 at 2.79%. The table also showed the presence of trace compounds such as CdO, Sb_2O_3, SnO_2, and TeO_2. In Table 10, the K42 sample was dominated by K_2O at 38.77%, followed by Na_2O at 20.6%, CaO at 12.14%, MgO at 9.2%, SO_3 at 8.34%, and Fe_2O_3 at 2.27%. Sb_2O_3 was also detected at 1.50%.

Table 9. Metal content of green spinach in treatment K31

Atomic Number	Compound	Percentage (%)
11	Na_2O	42.10
12	MgO	9.50
13	Al_2O_3	1.72
15	P_2O_5	0.69
16	SO_3	5.66
17	Cl	0.22
19	K_2O	21.01
20	CaO	11.28

25	MnO	0.30
26	Fe_2O_3	2.79
30	ZnO	0.53
37	Rb_2O	0.51
38	SrO	0.32
40	ZrO_2	0.10
48	CdO	0.34
50	Sb_2O_3	0.31
51	SnO_2	0.67
52	TeO_2	1.33
56	BaO	0.23
57	La_2O_3	0.26

Table 10. Metal content of green spinach in treatment K42.

Atomic Number	Compound	Percentage (%)
11	Na_2O	20.60
12	MgO	9.20
13	Al_2O_3	2.86
16	SO_3	8.34
17	Cl	0.81
19	K_2O	38.77
20	CaO	12.14
25	MnO	0.47
26	Fe_2O_3	2.27
29	CuO	0.12
30	ZnO	0.37
37	Rb_2O	0.71
38	SrO	0.51
42	MoO_3	0.23
51	Sb_2O_3	1.50
56	BaO	0.41
57	La_2O_3	0.56

Overall, the XRF results indicate that the mineral oxide composition of green spinach varied among treatments. The dominant compounds across the samples were K_2O, Na_2O, CaO, MgO, SO_3, and Fe_2O_3. These results are consistent with previous reports that Amaranthus leafy vegetables contain various minerals and bioactive compounds (Jiménez-Aguilar & Grusak, 2017; Grusak, 2017). However, the interpretation of XRF data must be made carefully because the results are expressed as oxide percentages and do not directly represent nutrient concentration in edible fresh tissue, bioavailability, or food safety limits.

The detection of trace heavy metal compounds such as CdO and Sb_2O_3 should also be interpreted cautiously. Their presence indicates the need for further analysis using more specific quantitative methods, such as Atomic Absorption Spectrophotometry (AAS) or Inductively Coupled Plasma Mass Spectrometry (ICP-MS), especially if the study aims to evaluate food safety. Kumar et al. (2019) emphasized that heavy metal contamination in vegetables is an important food chain issue and requires appropriate monitoring and risk assessment. Therefore, the XRF results in this study should be considered preliminary information on elemental composition rather than definitive evidence of nutritional or toxicological safety.

3.3 Discussion

The results of this study show that water spinach stem compost did not consistently improve the growth of green spinach. Plant height, number of leaves, and root length were not significantly affected by the treatment, while fresh weight and dry weight showed significant differences among treatments. The descriptive data from Figures 3 and 5 indicate that the control treatment and the moderate compost treatment produced better biomass than the high-compost treatments. This suggests that soil-based media and moderate compost supplementation were more suitable for green spinach growth than media dominated by compost.

The reduced growth performance at higher compost proportions may be related to compost quality, nutrient imbalance, physical properties of the growing medium, or incomplete decomposition. Compost can improve nutrient availability and soil biological activity, but its benefits depend on the maturity and chemical characteristics of the material (Amlinger et al., 2003; Bernal et al., 2009). Excessive compost application may create unfavorable conditions, including high salinity, poor aeration, or imbalanced nutrient availability. This agrees with Baligar et al. (2001), who stated that nutrient use efficiency in plants depends not only on nutrient availability but also on the balance and suitability of nutrients for plant needs.

The findings also suggest that water spinach stem compost has potential as an organic planting medium supplement, but it should not be used excessively or as the sole planting medium. The K1 treatment, consisting of 70% soil and 30% compost, generally showed relatively good performance, particularly in plant height, number of leaves, fresh weight, and dry weight. Therefore, moderate application of compost may be more appropriate for green spinach cultivation than high compost proportions.

From the mineral content perspective, the XRF analysis showed that green spinach contained several essential mineral compounds, particularly potassium, sodium, calcium, magnesium, and iron oxides. However, because the data were presented as oxide percentages, further quantitative and food safety analyses are needed before making strong nutritional claims. Future studies should include analysis of compost maturity, soil nutrient status, pH, C/N ratio, electrical conductivity, and heavy metal concentration in mg/kg. In addition, post hoc tests should be conducted for fresh weight and dry weight because the ANOVA results showed significant treatment effects.

4. CONCLUSION

This study showed that the supplementation of water spinach stem compost in the planting medium did not consistently improve the growth of green spinach (*Amaranthus sp.*). Based on the ANOVA results, the treatments had no significant effect on plant height, number of leaves, and root length. However, signifi-cant effects were observed on fresh weight and dry weight, indicating that different proportions of water spinach stem compost influenced biomass accumulation in green spinach.

The highest fresh weight was recorded in the control treatment (K0) at 111.8 g, followed closely by K1 at 111.4 g, while the lowest fresh weight was found in K4, which used 100% compost. A similar pattern was observed in dry weight, where K0 produced the highest value at 16.2 g, followed by K1 at 15.0 g, whereas K4 produced the lowest value at 5.4 g. These findings indicate that soil-based media and moderate compost supplementation supported better growth performance than media with high compost proportions. The use of 100% water spinach stem compost as a single planting medium tended to reduce plant biomass.

The XRF analysis showed that green spinach contained several dominant mineral oxide compounds, including K_2O, Na_2O, CaO, MgO, SO_3, and Fe_2O_3, with different proportions among treatments. Trace compounds such as CdO and Sb_2O_3 were also detected in several samples. Therefore, although green spinach showed a diverse mineral composition, further quantitative analysis using more specific methods is needed to determine actual mineral concentrations and assess food safety more accurately.

Overall, water spinach stem compost has potential as an organic planting medium supplement, particularly when applied in moderate proportions. However, excessive use of compost may negatively affect green spinach growth. Future studies should evaluate compost maturity, C/N ratio, pH, electrical conductivity, nutrient availability, and heavy metal concentrations to optimize the use of water spinach stem compost for sustainable vegetable cultivation.

5. CONFLICT OF INTEREST

The authors declare that there is no conflict of interest related to the research, authorship, or publication of this article. No personal, financial, institutional, or professional relationship influenced the design, implementation, data analysis, interpretation, or reporting of this study.

6. ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the supervisors and examiners for their guidance, constructive suggestions, and academic support throughout the research and manuscript preparation process. The authors also extend their appreciation to the Head of the Agricultural Standardization and Instrumentation Agency (BSIP) for providing facilities and support during the implementation of this research. Appreciation is also addressed to all parties who contributed to the completion of this study.

REFERENCES

Adhikari, K., & Hartemink, A. E. (2016). Linking soils to ecosystem services: A global review. Geoderma, 262, 101–111.

Amir, L., Sari, A. P., Hiola, S. F., & Jumadi, O. (2012). Ketersediaan nitrogen tanah dan pertumbuhan tanaman bayam (Amaranthus tricolor L.) yang diperlakukan dengan pemberian pupuk kompos Azolla. Journal Sainsmat, 1(2), 167–180.

Amlinger, F., Götz, B., Dreher, P., Geszti, J., & Weissteiner, C. (2003). Nitrogen in biowaste and yard waste compost: Dynamics of mobilisation and availability: A review. European Journal of Soil Biology, 39(3), 107–116

Baligar, V. C., Fageria, N. K., & He, Z. L. (2001). Nutrient use efficiency in plants. Communications in Soil Science and Plant Analysis, 32(7–8), 921–950.

Bernal, M. P., Alburquerque, J. A., & Moral, R. (2009). Composting of animal manures and chemical criteria for compost maturity assessment: A review. Bioresource Technology, 100(22), 5444–5453.

Bernal, M. P., Sommer, S. G., Chadwick, D., Qing, C., Guoxue, L., & Michel, F. C., Jr. (2017). Current approaches and future trends in compost quality criteria for agronomic, environmental, and human health benefits. Advances in Agronomy, 144, 143–233.

Diacono, M., & Montemurro, F. (2011). Long-term effects of organic amendments on soil fertility. In Sustainable Agriculture Volume 2 (pp. 761–786).

Diacono, M., & Montemurro, F. (2015). Effectiveness of organic wastes as fertilizers and amendments in salt-affected soils. Agriculture, 5(2), 221–230.

Dou, L., Komatsuzaki, M., & Nakagawa, M. (2012). Effects of biochar, mokusakueki, and bokashi application on soil nutrients, yields, and qualities of sweet potato.

Grusak, M. A. (2017). Minerals, vitamin C, phenolics, flavonoids, and antioxidant activity of Amaranthus leafy vegetables. Subtropical Plant Science.

Hasmeda, M., Sari, I. Y., Munandar, M., Ammar, M., & Gustiar, F. (2021, December). Respons pertumbuhan dan hasil pada tanaman bayam (Amaranthus sp.) terhadap biofortifikasi unsur hara kalsium (Ca) dan besi (Fe) dengan sistem hidroponik DFT (Deep Flow Technique). In Seminar Nasional Lahan Suboptimal (Vol. 9, No. 2021, pp. 721–733).

Jiménez-Aguilar, D. M., & Grusak, M. A. (2017). Minerals, vitamin C, phenolics, flavonoids, and antioxidant activity of Amaranthus leafy vegetables. Journal of Food Composition and Analysis, 58, 33–39.

Kumar, S., Prasad, S., Yadav, K. K., Shrivastava, M., Gupta, N., Nagar, S., ... & Malav, L. C. (2019). Hazardous heavy metals contamination of vegetables and food chain: Role of sustainable remediation approaches—A review. Environmental Research, 179, 108792.

Nakagawa, S., & Cuthill, I. C. (2007). Effect size, confidence interval, and statistical significance: A practical guide for biologists. Biological Reviews, 82(4), 591–605.

Zhang, L., Sun, X., Tian, Y., & Gong, X. (2013). Composted green waste as a substitute for peat in growth media: Effects on growth and nutrition of Calathea insignis. PLOS ONE, 8(10), e7812.