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Effects of Vermicompost Application and Moringa Extract on Growth Responses, Yield and Bioactive Compounds in Cabbage (*Brassica oleracea* var. capitata)

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Abstract

Soil fertility management plays a crucial role in agricultural production. Vermicompost and moringa extract are organic compounds that can enhance soil conditions and improve the productivity and efficiency of crops. This study aimed to examine the impact of vermicomposting and foliar application of moringa extract on the quantitative and qualitative characteristics of red and white cabbage under field conditions. Before transplanting, vermicompost was added to the soil at rates of 0, 0.5, and 1 kg/m^2. Moringa extract was sprayed on the plants every 14 days at concentrations of 0, 10, and 20 g/l. The growth characteristics and bioactive compound content of cabbage were evaluated at the commercial maturity stage. The results showed that applying 1 kg/m^2 of vermicompost resulted in an 8% increase in head diameter, a 28% increase in cabbage weight, and a 39% increase in crop yield. Additionally, using 20 g/l of moringa extract led to a 2% increase in head diameter and a 12% increase in weight and yield of cabbage. The use of vermicompost and moringa extract also increased the flavonoid content in red cabbage. The highest levels of bioactive compounds were achieved with the application of 1 kg/m^2 of vermicompost and 20 g/l of moringa extract. These treatments are recommended as effective strategies for promoting cabbage growth and enhancing bioactive compound content, particularly in hot and dry conditions.

***Keywords**:* Flavonoids, Phenolic compound, Soluble carbohydrates, Vitamin C, Yield.

Introduction

Soil is a crucial and natural resource, and maintaining and enhancing its quality is a fundamental principle in soil management. The quality of soil not only influences crop production but also plays a vital role in environmental quality, which directly impacts the well-being of plants, animals, and humans. In regions with hot and dry climates, it becomes even more critical to focus on soil management and fertility for agricultural production. These areas often have low levels of soil organic matter, resulting in reduced microbial activity and limited access to certain elements. The presence and abundance of organic matter in the soil significantly affect its biological characteristics, making it essential to prioritize organic matter for improved soil fertility (Schnitzer and Menorreal, 2011). This emphasis on organic matter can reduce the reliance on chemical fertilizers, thereby minimizing issues like nitrate accumulation and other chemical-related problems in agricultural products while preserving their quality (Herik and Vander, 2018). Consequently, the utilization of organic fertilizers enhances soil fertility by supplying essential elements and promoting overall soil health in arid regions (Lavallee *et al.*, 2020).

Vermicompost is a valuable organic compound that is utilized to enhance the physical and chemical properties of soil. These compounds have very fine particles similar to peat and possessing fine particles, high aeration, as well as a high capacity for water storage. Additionally, vermicompost has a low carbon to nitrogen ratio (Dominguez and Edward, 2004). The presence of various nutrients in vermicompost, particularly in forms readily available to plants such as nitrates, calcium, phosphorus, and potassium, stimulates plant growth (Edwardes and Bruce, 1988). Furthermore, vermicompost contain plant growth regulating substances like auxin, gibberellin, cytokinin, and humic acid. These substances contribute to the effectiveness of vermicompost in promoting plant growth and development (Atiyeh *et al.*, 2002; Jack *et al.*, 2011). The application of vermicompost stimulates root growth and increases root biomass, which will increase the growth and development of plants (Lim *et al.*, 2015).

According to Song *et al.* (2022), the application of vermicompost results in an increase in plant growth rate and biomass. Additionally, Shahbazi *et al.* (2015) and Koozehgar Kaleji *et al*. (2018) found that vermicompost application leads to increased yield in both monocot and dicot plants. Zaler (2007) and Hosseinzadeh *et al.* (2017) observed that vermicompost application enhances the growth and concentration of elements in peas and tomatoes. Furthermore, Nemati and Azizi (2013) discovered that vermicompost increases the biological yield and oil content of evening primrose medicinal plant. Najjar *et al.* (2015) demonstrated that using vermicompost prepared from aquatic plants improves the germination percentage, growth, and yield of eggplant. Moreover, Hosseinzadeh *et al.* (2017) noted that vermicompost can mitigate the negative effects of environmental stress. Rekha *et al.* (2018) and Admipour *et al.* (2019) found that by enhancing soil conditions and increasing mineral element availability, vermicompost effectively improves plant yield under environmental stress conditions.

Furthermore, the application of plant extracts through foliar spraying has been shown to enhance crop growth and yield, in addition to the use of organic materials for soil improvement. Moringa leaf extract, derived from the *Moringa oleifera* Lam. plant, has significant pay attention in recent years due to its beneficial properties. This extract is rich in essential nutrients, carbohydrates, fats, proteins, fibers, mineral elements, and vitamins, which have been found to enhance the growth and efficiency of certain plants (Hala and Nabila, 2017; Zulfiqar *et al.*, 2020). Moreover, water extracts of this plant contain a substantial amount of amino acids such as arginine, lysine, phenylalanine, histidine, tryptophan, valine, methionine, leucine, isoleucine, and threonine (Yasman *et al.*, 2013). Additionally, moringa extract contains phytohormones like gibberellins and cytokinin that improve various physiological and biochemical processes in plants (Arif *et al.*, 2018), leading to enhanced seed germination, growth rate, and overall plant yield (Hala *et al.*, 2017). The application of moringa extract has been found to increase the yield of crops such as corn and rice (Phiei, 2010), beans (Radi and Mohammad, 2015), tomatoes (Bashir *et al.*, 2014; Alshahat *et al.*, 2022), and roselle plants (*Hibiscus sabdariffa* L.) (Hasan and Abdulsami, 2015). Furthermore, the extract from this plant contains various antioxidants (Batooll *et al.*, 2019; Zulfiqar *et al.*, 2020), calcium (Lalarukh *et al.*, 2022), and osmotic factors (Abd El-Mageed, 2017), which play a crucial role in enhancing plant tolerance to environmental stress.

Due to the cabbage (*Brassica oleracea* var. capitata) significance as a crucial winter leafy vegetable in Iraq and its notable nutritional value, this research aimed to examine the impact of vermicompost application and moringa extract foliar application on the quantitative and qualitative characteristics of cabbage in field conditions.

MATERIAL AND METHODS

The study was conducted during the 2022 growing season on a private farm in Basra, Iraq. To accomplish this, white and red cabbage varieties were obtained from the Dutch company Parasid. The seeds were sown in a seedling tray containing cocopeat substrate, and after 40 days of germination and initial growth, when the seedlings reached the 3-4 leaf stage, they were transplanted to the field.

The cultivation method used in the field involved furrow and basin techniques, with a width of 75 cm and a length of 4 meters. The seedlings were transplanted on to the basins, maintaining a distance of 40 cm between each plant. The rows were spaced 75 cm apart from each other. Prior to transplanting the seedlings, vermicompost was added to the soil at rates of 0, 0.5, and 1 kg/m^2, which was thoroughly mixed with the soil. Moringa extract was applied every two weeks for a total of four times during the experiment. The extract was sprayed onto the plants using a manual pump sprayer, with concentrations of either 0 (using distilled water), 10, or 20 grams per liter. To prevent any overspray onto adjacent rows, plastic buffers were utilized during spraying. The foliar spraying took place in the morning. At the end of the experiment, when the heads were firm, they were harvested and transported to the laboratory for qualitative and quantitative analysis.

Growth Characteristics

A caliper was used to measure the diameter of the cabbage heads. By calculating the weight of cabbage heads per square meter, the yield of the plant was calculated and then reported in unit area.

Determination of ascorbic acid (Vitamin C)

In order to measure the amount of ascorbic acid (Vitamin C), the classic method of titration with 2, 6 dichlorophenol indophenol (DCPIP) was used. This reaction is specific and quantitative for ascorbic acid at pH=1-3.5, and as a result of the reaction, the blue color of DCPIP solution becomes colorless (Nielsen, 2010).

Determination of flavonoids and total phenolic compounds

Total flavonoid content was measured using aluminum chloride reagent. to 0.5 ml of each extract (10 mg/ml), 1.5 ml of methanol, 0.1 ml of 10% aluminum chloride solution in ethanol, 0.1 ml of 1 M potassium acetate and 2.8 ml of distilled water was added. The absorbance of the mixture was read at 415 nm against a blank after 30 minutes of storage at room temperature. Quercetin was reported as a standard for drawing a flavonoid curve based on the amount equivalent to milligrams of quercetin per gram of extract (Chang *et al.*, 2002).

Total phenolic content was measured using Folin-Ciocaltiu reagent. 0.5 ml of each extract (10 mg/ml), 2.5 ml of Folin-Ciocaltio reagent 0.2 normal was added, after 5 minutes, 2 ml of 75 g/l sodium carbonate solution was added to it. added. After 2 hours, the absorbance of the mixture at a wavelength of 760 nm was read by a spectrophotometer (model JENWAY 6305, JENWAY, UK) against a blank. Gallic acid was used as a standard to draw the calibration curve. The amount of total phenolic acid was reported based on the amount equivalent to mg of gallic acid per gram of extract (Slincard and Singleton, 1977).

Measurement of soluble carbohydrates

To measure soluble carbohydrates, first, 0.5 grams of plant tissue was ground in a Chinese mortar and 5 ml of 95% ethanol was added to it. Put the supernatant in the test tube and add 5 ml of 70% ethanol to remove the impurities and add it to the contents of the test tube. Then its impurities were accurately separated in a centrifuge for 15 minutes at 1500 rpm. In this case, this extract was used as a base extract for sugar measurement. Take 100 microliters of the prepared extract or standards and add 3 ml of anthrone reagent to it and then put it in a boiling water bath for 10 minutes and after cooling the samples, absorb them at a wavelength of 625 nm with a spectrophotometer. was read Pure glucose was used to draw the standard curve. Concentrations of 0, 20, 40, 60, 80, 100 and 120 mg/liter were prepared and possible operations were performed on them like the original samples (Mc Cready et *al.*, 1950).

Statistical Analysis

Experimental treatments in this research include two cultivars of cabbage (white and red), three levels of vermicompost (0, 0.5 and 1 kg/m^2) and three levels of moringa extract foliar application (0, foliar application with distilled water, 10 and 20 grams per liter). The experiment was conducted in factorial split plot design based on randomized complete block design in three replications, cultivar was considered as the main factor and vermicompost and moringa extract foliar application as secondary factors. Statistical analyzes of this experiment were performed using SAS software. After analysis of variance, means were compared using Duncan's multiple range test at the 5% probability level.

RESULTS

Growth and yield characteristics

The effect of vermicompost and foliar application of moringa extract on cabbage diameter was statistically significant at 1%. In such a way that the application of 1 kg/m^2 of vermicompost led to an 8% increase in the diameter of cabbage compared to the control treatment On the other hand, with the increase in the concentration of moringa extract, the diameter of cabbage also increased. In such a way that the maximum and minimum diameter of cabbage was observed in the 20 g/l and control treatments, respectively, but there was no significant difference between the 10 g/l treatment and the control treatment (Table 1).

Table 1- Comparison of the average main factors of cultivar, vermicompost and moringa extract foliar application on the growth and yield of cabbage cultivars

Factor	Yield (t/ha)	Cabbage weight (kg)	Cabbage diameter (cm)
Cultivar			
White cabbage	59.61[a]	2.50[a]	57.37[a]
Red cabbage	58.77[a]	2.47[a]	57.81[a]
Vermicompost (kg/m^2)			
0	50.20[c]	2.11[c]	55.11[c]
0.5	57.47[b]	2.41[b]	57.22[b]
1	69.91[a]	2.94[a]	60.44[a]
Moringa extract (g/l)			
0	55.03[b]	2.31[b]	56.78[b]
10	60.85[a]	2.56[a]	57.50[b]
20	61.71a	2.59[a]	58.50[a]

Averages with different letters are significantly different at the 5% level of Duncan's test.

The effect of foliar application of moringa extract and vermicompost on the weight of cabbage was significant and significant at the probability level of 1%. Application of vermicompost at the rate of 1 kg/m^2 led to a 28% increase in the weight of cabbage compared to its non-application. Also, application of moringa extract treatment resulted in 12 and 9% increase in cabbage weight in 20 and 10 g/l treatments, respectively. Also, moringa extract and vermicompost had a significant effect on cabbage yield per unit area. In terms of yield, the highest and lowest amount was in the 1 kg/m^2 treatment and the control treatment, respectively. On the other hand, application of moringa extract foliar application at two levels of 10 and 20 g/l led to an increase in cabbage yield per unit area (Table 1).

Bioactive compounds and leaf carbohydrates

Evaluation of the effect of vermicompost and foliar application of moringa extract on bioactive compounds and carbohydrates showed that the main effect of cultivar was statistically significant at 1%. In addition to the main effects, the interaction effects of vermicompost and moringa extract foliar spray, the interaction effect of variety and moringa extract foliar spray, as well as the interaction effect of variety, vermicompost and moringa extract foliar spray on the mentioned indicators were significant at the probable level of 1%. The highest content of flavonoids was observed in red cultivar, which was 47% more than white cabbage (Table 2).

Table 2- Comparison of the average of the main factors of the cultivar, vermicompost and moringa extract foliar application on the content of bioactive compounds and soluble carbohydrates in the leaves of cabbage cultivars

Factor	Phenolic content	Soluble carbohydrates	Vitamin C	Flavonoids
		mg/100g		
Cultivar				
White cabbage	115.7^{b}	24.53^{a}	25.35^{a}	542.5^{b}
Red cabbage	211.2^{a}	24.91^{a}	24.83^{a}	1030^{a}
Vermicompost(kg/m^2)				
0	151.0^{b}	23.14^{b}	21.53^{c}	754.1^{b}
0.5	153.3^{b}	24.86a^{b}	25.26^{b}	779.4^{b}
1	184.9^{a}	26.15^{a}	28.48^{a}	826.1^{a}
Moringa extract (g/l)				
0	151.1^{b}	24.04^{b}	23.71^{b}	760.4^{b}
10	163.9^{ab}	23.73^{b}	24.86^{ab}	807.9^{a}
20	175.2^{a}	26.38^{a}	26.70^{a}	791.2^{a}

Averages with different letters are significantly different at the 5% level of Duncan's test.

The application of vermicompost led to an increase in the amount of flavonoids in cabbage. The highest amount was observed in the treatment of 1 kg/m^2, so that the application of vermicompost led to an increase of 8% of flavonoids compared to the control treatment. Also, the amount of flavonoids increased with the increase in the concentration of moringa extract. In fact, this increase was about 5.87% and 4.05% respectively in the 20 and 10 g/l treatments compared to the control treatment. The interaction effect of three factors of vermicompost, foliar application of moringa extract and cultivar on the content of soluble carbohydrates in cabbage was statistically significant at the level of 1% (Figure 1). The highest amount of flavonoids was in the treatment of 1 kg/m^2 of vermicompost with concentrations of 10 and 20 g/l of moringa extract foliar spray and also the concentration of 0.5 kg/m^2 with 10 g/l of moringa extract foliar spray (Table 2)

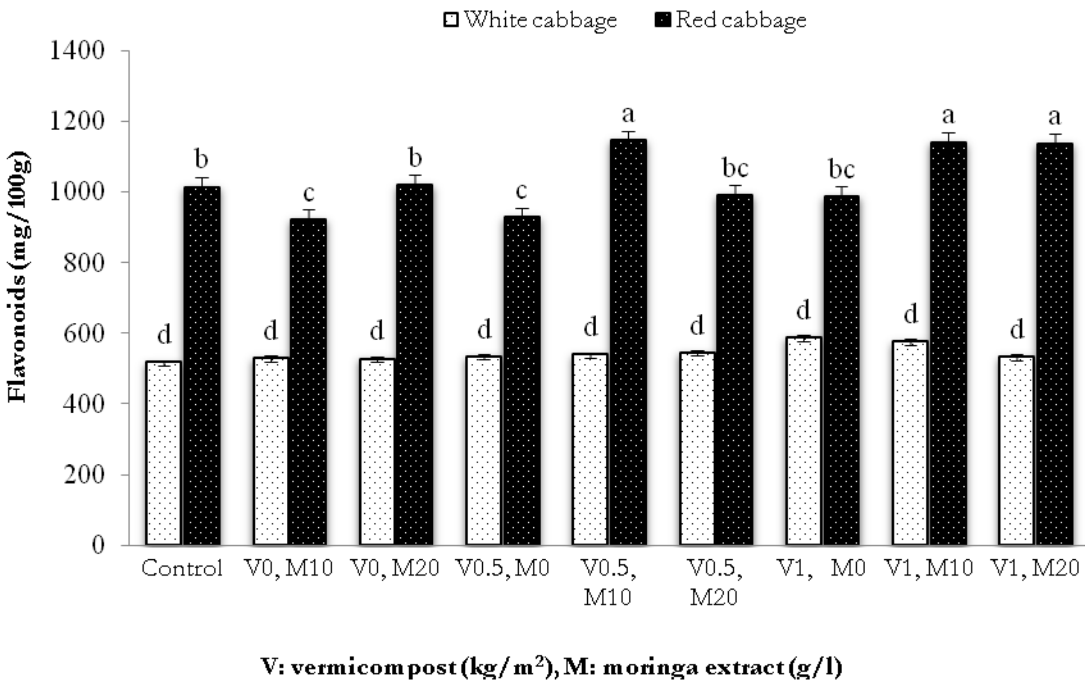

Figure 1. The effect of cultivar interaction, vermicompost application and moringa extract foliar application on the content of flavonoids in cabbage cultivars

The effect of vermicompost on the amount of vitamin C in cabbage leaves was significant at the level of 1%. The highest and lowest levels were in the 1 kg/m^2 and control treatments, respectively. The results of analysis of variance showed that the effect of moringa extract foliar application on the amount of vitamin C was significant at the level of 5%. Its highest amount was in the 20 g/l treatment (26.70 mg/100 g) and the lowest was in the control treatment (23.71 mg/100 g) (Table 2). The effect on the interaction of vermicompost, cultivar and application of moringa extract on the content of soluble carbohydrates was significant at the level of 1%. The highest amount of carbohydrates was in the vermicompost treatments of 1 kg/m^2 and 20 g/l of moringa extract foliar spraying in both cultivars, and the lowest in treatment 1 was 1 kg/m^2 and the control treatment of foliar spraying (Figure 2).

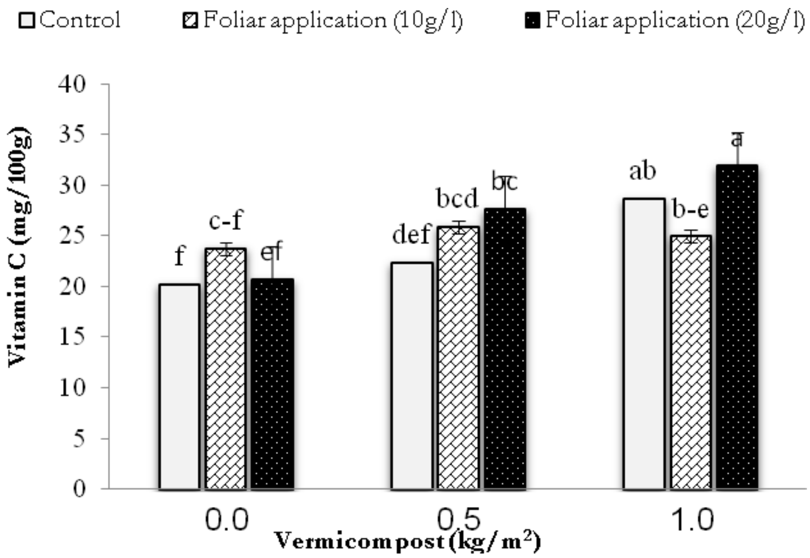

Figure 2. The interaction effect of moringa extract foliar application and vermicompost soil application on the amount of vitamin C in cabbage cultivars

The results of analysis of variance showed that the effect of vermicompost on the amount of carbohydrates in leaves was significant at the level of 1% (Table 2). The highest and lowest amount was in the treatments of 1 kg/m^2 and the control, respectively. On the other hand, foliar application of moringa plant extract was also significant on the amount of leaf carbohydrates at the level of 1%. So that, the use of 20 g/l of moringa extract foliar spray increased it by 8% compared to the control treatment (Table 2).

The effect on the interaction of vermicompost, variety and application of moringa extract was significant at the level of 1%. The highest amount of carbohydrates was in vermicompost treatments of 1 kg/m^2 and 20 g/l of moringa extract foliar spraying in both cultivars, and the lowest amount in treatment 1 was 1 kg/m^2 and the control treatment of foliar spraying (Figure 3).

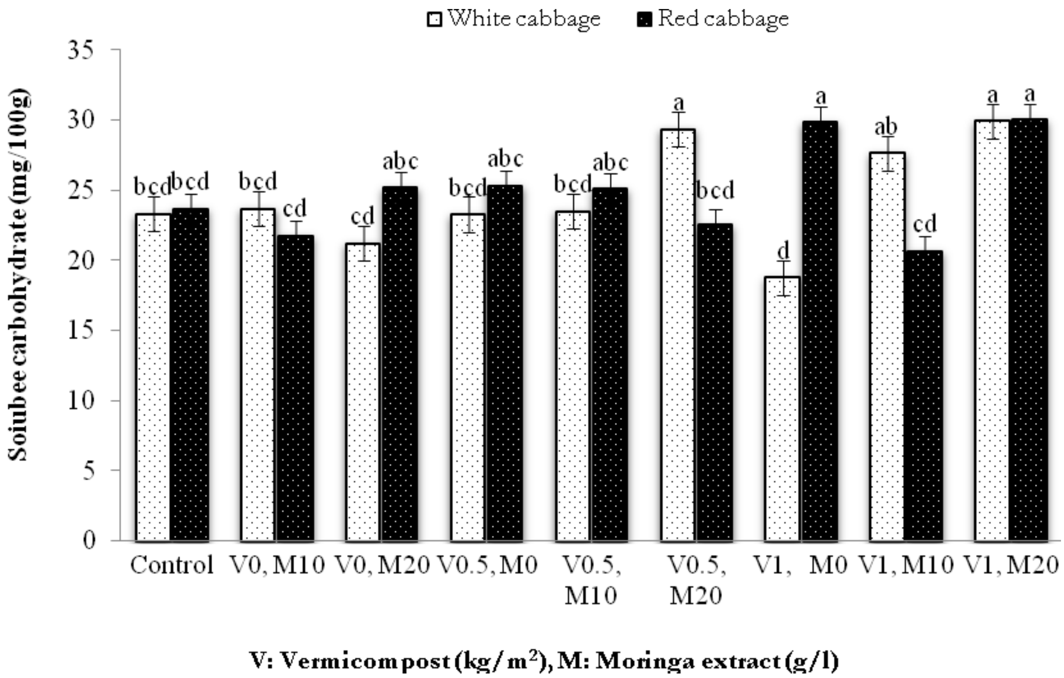

Figure 3. The interaction effect of cultivar, foliar application and vermicompost on the amount of soluble carbohydrates in cabbage cultivars

The effect of cultivar, vermicompost and foliar application of moringa extract on the amount of phenolic acid in the leaves was significant at the level of 1%. On the other hand, the interaction effect of vermicompost and foliar application, vermicompost and cultivar, cultivar and foliar application, and the interaction effect of three factors of vermicompost, foliar application and cultivar were significant at the 1% level. Compared to the two cultivars of cabbage, in terms of the amount of phenolic acid in the leaves, the highest amount was observed in the red cultivar and the lowest in the white cultivar, which was about 45% in the red cultivar compared to the white cultivar. The effect of vermicompost on the amount of phenolic acid was significant at the level of 1%, which was the highest in the treatment of 1 kg/m^2 and the lowest in the treatments of 0.5 kg/m^2 and the control, which was 18% more than the control in the highest case. Also, in terms of foliar application of moringa extract, the highest and lowest amount of phenolic acid was observed in 20 g/l and control treatments, respectively (Table 2).

The interaction effect of variety, foliar spraying of moringa extract and vermicompost showed that the highest amount of leaf phenolic acid was in the red cultivar and in the treatments of 1 kg/m^2 of vermicompost combined with the treatment of 20 g/l of moringa extract foliar spraying, and the respective treatments were able to increase the amount of phenolic acid in the leaves, increase to 255.50 mg per 100 grams. The lowest amount was in the white cultivar and in the vermicompost treatments of 0.5 kg/m^2 and in the treatments of 0 and 20 g/l of plant extract, respectively, at the rate of 0.85 and 83.5 mg/100 grams (Figure 4).

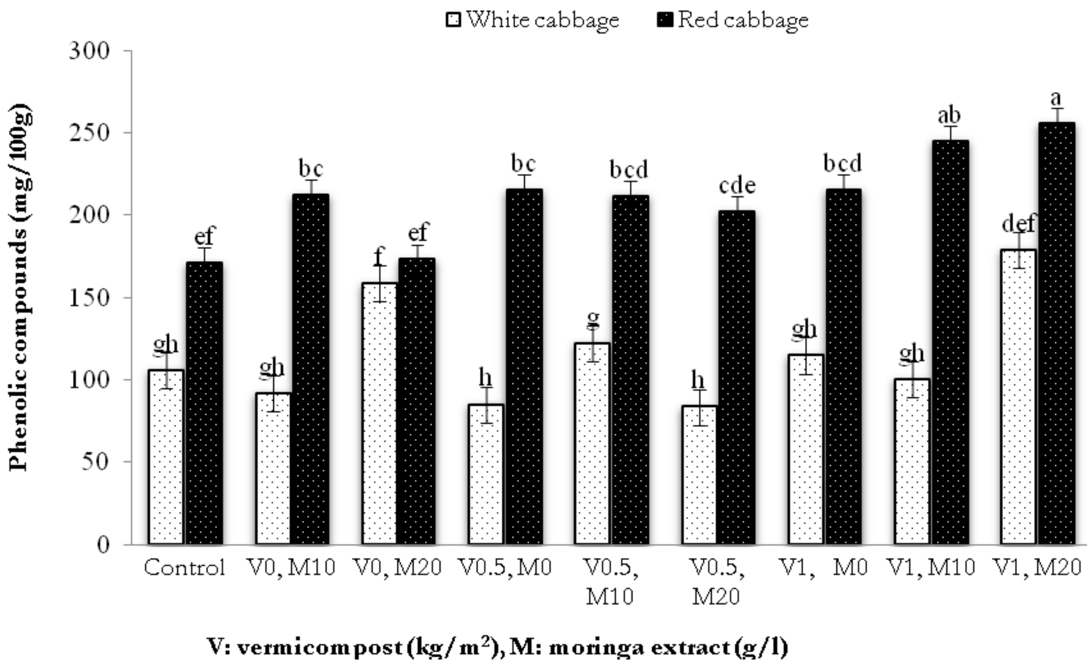

Figure 4 . The interaction effect of cultivar, foliar application and vermicompost on the amount of phenolic compound in cabbage cultivars

DISCUSSION

Growth and yield characteristic

The findings of the study demonstrated that the utilization of vermicompost and foliar application of moringa extract had a positive impact on the growth of cabbage. The use of vermicompost resulted in improvements in various vegetative growth characteristics and yield, such as cabbage diameter, weight, and overall yield. This aligns with previous research conducted on wheat, which also found that vermicompost application increased plant height, stem diameter, and yield compared to the control group (Jashi *et al.,* 2013). Similarly, another study found that vermicompost application enhanced total biomass, yield, crop diameter, and harvest index in cabbage (Norhdayti *et al.,* 2016).

The observed increase in plant growth and yield can be attributed to the enhancement of soil structure, increased moisture capacity, and nutrient supply facilitated by vermicompost (Battacharya *et al.,* 2008). The presence of abundant nutrients in vermicompost is believed to contribute to the improvement in plant growth and yield (Lim *et al.,* 2015; Rahman *et al.,* 2023). Ultimately, it appears that the chemical and physical properties of the soil are enhanced through increased microbial activity and improved food and water storage capacity, leading to greater availability of nitrogen and moisture for plant growth (Jouquet *et al.,* 2011; Pathma and Sakthivel, 2012; Lim *et al.,* 2015).

On the contrary, the application of moringa extract through foliar spraying resulted in an increase in cabbage diameter, weight, and overall yield. According to El-Awady (2003), moringa plant extract contains a significant amount of zeatin hormone, ranging from 5 micrograms to 200 micrograms per gram of substance. Additionally, Fugil (2000) confirmed the presence of cytokinin hormone in moringa extract and highlighted its ability to enhance crop yield when used as a foliar spray. Another study demonstrated that the use of moringa extract led to improved growth and yield in greenhouse tomatoes (Culver *et al.*, 2012). Consequently, the enhanced cabbage diameter and crop yield observed in vermicompost treatments can be attributed to improved nutrient absorption from the soil and increased cytokinin hormone production resulting from the application of moringa extract through foliar spraying. The presence of cytokinin in this extract plays a crucial role as it facilitates nutrient transportation within stems and serves as an effective storage for maintaining physiological and biochemical activities in plants (Redy *et al.*, 2015). Therefore, it is anticipated that the utilization of moringa extract will stimulate cell division, increase plant length, leaf number, and leaf surface area, ultimately enhancing photosynthesis and yielding positive results (Arif *et al.*, 2023).

Bioactive compounds

According to research, the use of vermicompost enhances nutrient availability in the soil. Consequently, this increase in nutrients leads to a rise in Rubisco enzyme activity, resulting in higher net photosynthesis in plants (Müller *et al.*, 2013). Vermicompost also promotes the absorption of potassium, which plays a crucial role in the synthesis of secondary compounds like phenolic compounds. This activation of enzymes involved in starch and protein biosynthesis is based on the relationship between primary and secondary metabolites (Ghasemzadeh*et al.*, 2011; Muller *et al.*, 2013). Additionally, studies have shown that ginger plants experience an increase in phenolic compounds, flavonoids, and antioxidant activity as a result of heightened photosynthesis and photosynthetic pigments (Ghasemzadeh *et al.*, 2011).

Based on the findings of the current study, the application of vermicompost, particularly when combined with foliar spraying, resulted in an increase in flavonoid content in the leaves. This can be attributed to the enhanced absorption of nutrients from the soil and their involvement in photosynthesis and the synthesis of secondary compounds. Wang *et al.* (2019) also reported a significant increase in vitamin C, phenols, and flavonoids following vermicompost application. Furthermore, it has been observed that the increase in phenolic compounds is directly linked to the increase in carbohydrates within the plant. As carbohydrates serve as the building blocks for phenolic compounds, an increase in their availability as substrates for phenolic compounds leads to their higher production (Nguyen *et al.*, 2010). Therefore, in this study, the use of vermicompost, particularly in combination with moringa extract as a foliar spray, resulted in an increase in both carbohydrate and phenolic compound content. These findings are consistent with previous research where an increase in soluble carbohydrates was observed in other plants such as sour tea (Heidari and Khalili, 2014), tomatoes, and carrots. Essentially, vermicompost enhances hormonal activity in plants, facilitating the absorption of mineral elements like phosphorus and potassium, which subsequently improves photosynthesis and increases sugar production within the plant.

According to Yasman *et al.* (2012), moringa plant extract contains zeatin, calcium, potassium, zinc, and iron, which are involved in the transportation of materials produced through photosynthesis and cell expansion. The presence of potassium in the leaf extract aids in the efficient transfer of carbohydrates, potentially explaining the increase in carbohydrate content observed in the Moringa extract foliar treatments (Alloway, 2004). This finding aligns with previous research that reported an increase in carbohydrates, proline, ascorbic acid, and total carotenoids in beans following the application of Moringa plant extract (Reddy and Mohammad, 2015). Additionally, the ascorbate present in Moringa plant extract promotes ascorbate production in plants when used as a foliar spray. Moreover, the extract's zinc and potassium content contribute to carbohydrate metabolism and directly participate in its conversion to vitamin C (Nguyen *et al.,* 2010).

CONCLUSION

The results of this study indicate that the use of vermicompost in the soil and foliar application of moringa extract led to increased growth and yield of cabbage. Overall, the evaluation of cabbage cultivars revealed that red cabbage has a higher nutritional value compared to white cabbage in terms of bioactive compounds. Both red and white cabbage showed a significant improvement in product quality with the use of vermicompost and moringa extract. However, these substances did not have a significant impact on the flavonoid content of white cabbage. The significant interaction effects between vermicompost application and moringa extract application demonstrated that the treatment involving the application of 1 kg/m^2 of vermicompost plus foliar application of moringa extract with a concentration of 20 g/l resulted in the highest content of soluble carbohydrates and bioactive compounds. These treatments are recommended as environmentally friendly management solutions that improve soil biological conditions in hot and dry environments. Based on the observed results, it is suggested to evaluate the profile of flavonoid and phenolic compounds in cabbage cultivars and evaluate the antioxidant activity of the cultivars in response to the application of vermicompost and foliar application of moringa extract.

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