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Research Article

Examining the Optimal Amount of Moringa Leaf Extract to Improve the Morphological and Inner Quality of Cabbage (*Brassica oleracea* var. *capitata*)

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Moringa leaves contain a proper amount of antioxidants, amino acids, vitamins, hormones, macronutrients, and micronutrients. Therefore, it is applied as a natural, inexpensive, and simple-to-make biostimulant to boost nutritional value and growth parameters in a variety of plants. The main purpose of this study is to determine the optimal concentration of *Moringa oleifera* L. leaf extract (MLE) as an effective biostimulant to improve nutritional and physical quality in cabbage (*Brassica oleracea* var. *capitata*). To do this, three concentrations of MLE (6, 8, and 10%) were foliar sprayed to the plant leaves at a rate of 25 mL plant^{-1} for every two weeks from transplantation till harvest, while control plants (Ø) were sprayed with distilled water only. Our results show that MLE greatly increased cabbage growth, nutrient content, pigment content, and nutrient absorption, while a high concentration of 10% MLE could also significantly reduce nitrate content in cabbage leaves. In comparison to the control plants, sprays of 6%, 8%, and 10% MLE reduced nitrate content by 23%, 14%, and 12%, respectively. However, the lowest nitrate content was found for the plants sprayed with 6% MLE. Except for the dry matter, all the growth parameters, mineral content, and pigment content were significantly higher after spraying with 10% MLE, while better vitamin C and lower nitrate were found in the plants treated with 6% MLE. A Pearson correlation reveals that head weight has a positive correlation with head diameter, head height, chlorophyll a, and carotenoids at p levels of 0.01 and a positive correlation with chlorophyll b and vitamin C at p levels of 0.05. Vitamin C and dry matter, on the other hand, had a negative connection with nitrate content.

1. Introduction

Cabbage (*Brassica oleracea* L. var. *capitata*) is a member of the *Brassicaceae family*, the biggest plant family. It is a cool-season vegetable with short roots that is cultivated for its enormous leafy head. It was initially cultivated in Western Europe [1]. According to the Food and Agriculture Organization of the United Nations (FAO), worldwide cabbage production in 2021 was 71.7 million tons, making it one of the world's most widely grown vegetables, with Asia accounting for 78.2%, Europe 13%, Africa 5.7%, America 2.9%, and Oceania 0.2% [2]. In 2021, Hungary's total production of white cabbage was about 37 thousand tons [3]. The plant is grown for its large leaves. The physical properties of the cabbage cultivars, such as head size, shape, and colour, as well as the texture of the leaves, vary greatly amongst cultivars. Cabbage has been classified into three categories: white cabbage, red cabbage, and savoy cabbage [4].

The cabbage leaves are well-known for their high nutritional value as antioxidant phytochemicals [1, 5], macro- and micronutrient content [6], and richness in vitamins C, E, and K [7]. Cabbage is one of the most important vegetables for healthy diets and can be cooked or consumed raw.

Approximately, 100 g of leaf sample contains 93 mL water, 15 g protein, 0.2 g fat, 4.0 g carbohydrate, 4 g calcium, and 0.5 g iron [8]. Cabbage also contains plenty of essential micronutrients which are crucial for human health and plant biological, chemical, and physiological functions such as copper (Cu), zinc (Zn), and iron (Fe) [9].

Leafy vegetables (particularly cabbage) require a high amount of N, P, and K, especially nitrogen fertilizer [10]. However, this may lead to various issues, like the excessive and careless use of chemical fertilizers, which raises the cost of planting and increases the risk of environmental degradation. Therefore, it is critical to enhance fertilization practices and fertilizer use efficiency to support agriculture's sustainable development.

Many research studies have recommended a variety of natural extracts to minimize fertilizer usage without reducing the quality and total yield of the products. Biostimulants, especially moringa leaf extract from the moringa tree (*Moringa oleifera* Lam.), are among the suggestions that have been practiced not only to reduce the amount of fertilizer used but also to improve the quality of many vegetables [11], such as lettuce (*Lactuca sativa* L.) [12–14], tomatoes (*Solanum lycopersicum*) [15], peppers (*Capsicum annuum*) [16], cabbage (*Brassica oleracea* var. *capitata*) [17], onions (*Allium cepa* L.) [18, 19], and squash (*Cucurbita pepo* L.) [20].

Moringa leaf extract is a currently introduced plant extract in Hungary as an active and helpful plant biostimulant to improve vegetable plant quality characteristics and reduce nitrate content in some leafy vegetables [14]. However, because it grows well in tropical and subtropical climates, the plant is most known in African and Asian countries [21, 22] rather than in Europe. Much scientific research in recent years has demonstrated that the plant contains significant nutritional value, antioxidants, minerals, and growth hormones. However, the content or nutritional value varies depending on the age of the leaf and the technique of extraction [23]. There is very limited research on the influence of moringa concentration on cabbage quality and yield. The purpose of this study was to see if moringa (*Moringa oleifera* Lam) leaf extract could alleviate nutritional value and physical parameters of cabbage (*Brassica oleracea* var. *capitata*) cultivated in an unheated plastic housing in Hungary and which concentration of extract may lead to an improvement in the quality of cabbage. Additionally, we aimed to increase the quality of fresh vegetables by using natural plant biostimulants while reducing the amount of artificial fertilizers used in vegetable cultivation. By doing this, consumers receive fresher, healthier food while also reducing environmental pollution, and farmers save money on fertilizer purchases.

2. Materials and Methods

2.1. Experimental Setup and Layout. The design of our study was a complete randomized block design (CRBD), with three replications and 20 plants per replication. The cabbage seeds were first grown in a glasshouse, and once the plants had grown to four true leaves, they were transplanted to direct soil in an unheated plastic house from where some metrological data are shown in Table 1.

Two weeks after transplanting, seedlings were foliar sprayed with moringa leaf extract (MLE) at the concentrations of 6, 8, and 10%, whereas control plants (Ø) received only distilled water.

The chemical components of soil samples were taken from 10 to 15 cm depth adjacent to plant roots to determine whether the plant needs to be fertilized. The experiment was carried out on lowland chernozem soil and the quality characteristics of the experimental soil are shown in Table 2.

Soil quality was affected by pH, total water-soluble salt, humus, and accessible nutrients. That is why, adding fertilizer has been recommended for leafy plants in such type of soil, as indicated by Liu et al. [24]. Based on the experimental soil testing, the inorganic fertilizer called FERTICARE 24-8-16 (NPK) was applied to our plants at the beginning of the experiment with the amount of 200 kg N ha^{-1} once.

2.2. Preparation of Moringa Leaf Extract and Spraying Treatment. Fresh green moringa leaves (approximately 40 days old) were harvested, washed, and cleaned from moringa trees grown in a glasshouse at the Agrar Campus of the University of Debrecen, Hungary. The leaves were then dried in a shaded area. According to Sowley et al. [25], the dried leaves were finely grounded with a grinder and then sieved with fine netting to create moringa leaf powder.

The extract was made from moringa leaf powder, as recommended by Makkar and Becker [26], who advocates making moringa leaf extract from powdered leaves of 20 g mixed with 225 mL of 80% ethanol every 3 hours to obtain 675 mL of extract. The extract was then maintained at 0°C until spraying began. The extract was diluted to 6, 8, and 10% before being sprayed onto the plant leaves every two weeks in the early morning with 25 mL per plant. We solely sprayed distilled water to treat the controlled plants. Some chemical contents of the extract were measured as it is shown in Table 3.

2.3. Growth and Physical Measurements. Major important physical and growth parameters (head weight, head height, stem length, and dry matter) were measured on the 5 best plants from each replication on the day of harvest. Also, the leaf samples of about 0.25 g were ground in 2 mL of 80% ethanol in combination with sand 0.1% or 0.1 $CaCO_3$ to assess the chlorophyll and carotenoid content (μg mL^{-1}). The samples were filtered using filter papers, and the final volume was reduced to (25 mL) before being transferred to a spectrophotometer to calculate absorbency at the wavelengths of (A663, A646, and A470) using equations (1)–(3)

Table 1: Temperature, humidity, and light intensity averages under a plastic house during the spring experiments.

Months		
March	April	May
Temperature (°C), mean		
11.3	15.6	21.2
Relative humidity (RH %), mean		
79.4	58.8	38.7
Light emission (W/m^2), mean		
175.6	196.2	245.5

Table 2: Soil chemical content of the experimental location.

Soil content	Value
pH (KCl)	7.58
Plasticity index of Arany K_A	45
Total water-soluble salt (m/m)	0.04
Calcium hydroxide (slaked lime) Ca $(OH)_2$ (m/m)	1.24
Organic carbon (humus content) (m/m)	2.89
Phosphorus pentoxide P_2O_5 (mg/kg)	1365
Potassium oxide (k_2O)	368
Nitrate NO_3^-	206

Source: Agricultural Laboratory Centre, University of Debrecen.

Table 3: Content of minerals in 100 g of moringa leaf extract (MLE) from powdered leaves.

Minerals	Values (mg)
Phosphorus (P)	100
Potassium (K)	350
Sulphur (S)	267
Calcium (Ca)	326
Magnesium (Mg)	86.8
Sodium (Na)	11.4
Iron (Fe)	2.24
Copper (Cu)	0.319
Zinc (Zn)	0.477
Boron (B)	0.581

Source: Yaseen and Takacs-Hajos [14].

[27–30]. In this investigation, a Japanese-made spectrophotometer named APEL PD-303 (APEL CO., LTD., Japan) was used and the measured data were assessed.

The cabbage samples were dried at 60°C for 4 days to analyse mineral contents such as Ca, K, Mg, P, and NO_3^- which were measured using the ICP-OES (iCAP™ 7400, Thermo Scientific) by European Virtual Institute for Speciation Analysis (EVISA, Germany) and approached according to Yaseen and Takacs-Hajos [31], where 0.5000 g of the properly prepared sample was measured in a high-pressure teflon bomb. 5 mL of deionized water with cc. HNO_3 and 3 mL of 30% H_2O_2 were mixed. It was sealed and digested in the Ethos Plus Microwave Digestion System (Milestone) according to the manufacturer's technique (Application Note 076) (3 min 85°C, 9 min 145°C, 4 min 200°C, and 14 min 200°C). After the teflon bombs were cooled, the digested samples were diluted to 50 mL, homogenized, and filtered (MN 640 W, Millipore) before element analysis.

2.3.1. Ascorbic Acid (Vitamin C) Measurement. The vitamin C level was evaluated by redox titration with iodine solution, as described by Ciancaglini et al., [32] ascorbic acid + $I_2 \longrightarrow 2\, I^-$ + dehydroascorbic acid.

2.3.2. Nitrate Determination. The nitrate concentration in cabbage leaves was determined using a segmented flow analyzer AA II (Bran + Luebbe, Norderstedt, Germany) at 540 nm after reduction in a copper-covered cadmium column (NO_3^- + 2e- ® NO_2^-) to generate a diazo compound, as described by Kmecl et al. [33] and Louro et al. [34].

2.3.3. Statistical Analyses. The raw data or result data were analysed using SPSS version 25.0. The statistical significance was determined by one-way analysis of variance (ANOVA) in Duncan's multiple range test and the $p \leq 0.05$ was considered to be statistically significant. Also, some Pearson correlation was performed at p levels 0.01 and 0.05 to see if there was any correlation between the physical and growth parameters.

3. Results and Discussion

3.1. Effect of MLE on Morphological Parameters on Cabbage

3.1.1. Head Weight. Head weight is one of the most essential criteria for commercially growing plants. The cabbage heads were harvested at the peak of maturity on May 20, 2022 (82 days after transplanting). The sprayed plants outweighed the control in terms of head weight. The plants treated with 10% moringa leaf extract (MLE 10%) had the biggest or significantly increased plant head weight at 1527 g plant^{-1}, whereas the lowest head weight was for the control plants (Ø) at 1169 g plant^{-1} (Table 4). This might be because MLE contains different growth hormones such as zeatin which leads to improving the cell division; as a result, the final weight would be increased [35]. Other research demonstrates that it may relate to the mineral content in MLE; having a high amount of potassium and zinc can regulate the growth and development of fruits [36]. Many research investigations have indicated that spraying plants with various concentrations of MLE improves fruit weight and size, for example, heavier fruit is produced in tomatoes when spraying plants with MLE (25 mL per plant) [37]; higher fruit lengths, diameters, and weights were recorded in pepper plants treated with different concentrations of MLE [16].

3.1.2. Head Diameter. Cabbage head diameter represents the head width or horizontal growth of the head size. This is regarded as a key physical feature in many vegetables, including lettuce, cabbage, and root vegetables. Yang et al. [38] indicate that head diameter has a strong positive regression to the head weight at $r^2 = 0.92$. According to our findings, the head diameter ranged from 14.60 to 16.10 cm head^{-1}. Our study, which agrees with the previous one, demonstrates that head diameter is quadratically related to head weight at $r^2 = 0.49$ (Figure 1).

Table 4: Some of the physical parameters were altered by spraying different amounts of moringa leaf extract.

Treatments	Head weight (g plant^{-1})	Head diameter (cm plant^{-1})	Head height (cm plant^{-1})	Stem length (cm plant^{-1})	Dry matter (%)
Control (Ø)	1169.00^{b}	14.60^{b}	13.60^{b}	6.90^{ab}	4.63^{d}
MLE 6%	1359.00^{ab}	15.70^{a}	14.30^{ab}	6.30^{b}	5.85^{a}
MLE 8%	1411.00^{ab}	16.00^{a}	14.40^{ab}	6.60^{ab}	4.87^{c}
MLE 10%	1527.00^{a}	16.10^{a}	15.10^{a}	7.60^{a}	5.04^{b}

Mean values ($n = 20$) in each column followed by different letters are significantly different at $p \leq 0.05$ by Duncan's multiple range test.

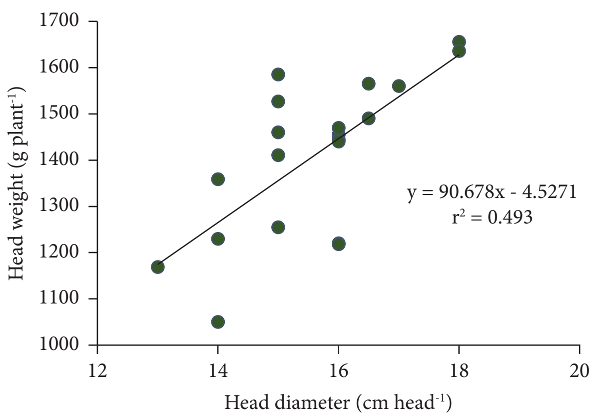

Figure 1: Scatter plots and regression equations between diameter and head weight.

The application of foliar moringa leaf extract had a significant impact on the enhancement of cabbage head diameter. Increasing the concentration of MLE leads to an increase in head diameter. Plants treated with 10% MLE had the largest head diameter at 16.10 cm head^{-1}, followed by plants treated with 8 and 6% MLE at 16.0 and 15.70 cm head^{-1}, respectively (Table 4).

Moringa aqueous extract contain cytokines, macro- and micronutrients, and other components that might be a reason for the significant improvement in head diameter. In addition to other substances that promote growth, such as phenols and ascorbic acid, MLE contains the cytokine zeatin [39, 40]. Additionally, MLE includes essential plant pigments such as carotenoids and chlorophyll, which are crucial for enhancing photosynthesis and thus boosting plant growth [41]. Abd-Elkafie et al. [42] observed maximum vegetative growth in coriander (*Coriandrum sativum* L.) sprayed with MLE.

3.1.3. Head Height. The above-ground growth of the cabbage head was measured as head height. According to the analysis of variance, spraying plants with MLE gradually improved the above-head height in cabbage. However, the only significant difference was identified when using a high concentration of 10% MLE, whereas 6 and 8% MLE did not affect head height (Table 4). Rayorath et al. [43] showed that higher concentrations of seaweed biostimulants (1 g L^{-1}) are required to significantly boost Arabidopsis plant height, although lower concentrations (0.1 g L^{-1}) can improve root weight. Hoque et al. [17] observed comparable results spraying MLE onto cabbage leaves 2 weeks and 4 weeks after transplanting, and 2 weeks after transplanting, and after every two weeks thereafter.

Gibberellic acid and cytokines, two plant hormones, have given plant extract the value of a growth promoter and are most likely the cause of the cabbage plant's increased head height. Additionally, several physiological characteristics of the plant can be influenced by the micro- and macronutrients in MLE [44]. Culver [45] observed comparable outcomes regarding the enhancement of height in rape and cabbage plants that received foliar MLE spraying every two weeks.

3.1.4. Stem Length. Cabbage has a short stem that the leaves connect to, giving the head its round shape. Improving stem length produces rapid seed stalk and early maturity in the Brassicaceae family, resulting in a lower overall product quality. Many factors, including genetics, temperature, plant hormones [46–48], and agricultural techniques such as gibberellin A3 (GA3) spraying, can trigger steam development and bolting in cabbages [49]. Moringa leaf extract contains plenty of growth-promoting hormones (auxins, gibberellins, and cytokinins) [50, 51]; however, low concentration of 6–8% had no significant improvement in stem length, while by increasing the concentration of MLE to 10%, the stem length has a slight improvement but not significant (Table 4). This finding is intriguing since it demonstrates that applying MLE biostimulant has no negative effect on cabbage as bolting or early maturity.

3.1.5. Dry Matter Content. Dry matter is an important quality criterion in cabbages because plants with poor dry matter can have deformed leaves; as a result, ununiform shape occurs [52]. Many factors influence the nutritional quality including dry matter content in cabbages such as plant varieties, agricultural practices, and physiology of the plant [53, 54]. Cabbage plants treated with 6, 8, and 10% MLE significantly increased total dry matter content compared to untreated plants. The lowest dry matter content was found in the control (Ø) plants at 4.63%, while plants foliar sprayed with 6% MLE had the higher dry matter content at 5.85% (Table 4).

3.2. The Effect of MLE on the Development of Pigment Contents in Cabbage Leaves

3.2.1. Chlorophyll and Carotenoid Contents. Chlorophyll (Chl) and carotenoids are important phytochemical pigments because they play the main role in essential plant metabolisms such as photosynthesis process which relates to plant improvement and increasing the total yield [55].

Chlorophyll and carotenoids are light-harvesting pigments that play vital physiological functions in all photosynthetic organisms [56]. Many research studies had shown the positive role of MLE in improving chlorophyll and carotenoid content in different plants as in rice (*Oryza sativa* L.) under water stress conditions [57], peppers [16], fennel plants [58], SPAD value in lettuce [13, 14], and common bean (*Phaseolus vulgaris* L.) [59, 60].

Similar to the previous investigations, our findings show that cabbages treated with MLE had considerably higher levels of chlorophyll a, chlorophyll b, and carotenoids than control plants (Ø). This could be due to moringa leaf extract inducing cytokinin, which leads to increased leaf area and higher chlorophyll levels in plant leaves [61]. Plants treated with 6, 8, and 10% MLE improved chlorophyll a and carotenoids significantly, while only plants treated with 10% MLE improved chlorophyll b significantly (Table 5).

3.3. Effects of MLE on Nutritional Quality and Mineral Content of Vitamin C. Vitamin C, commonly known as ascorbic acid, is a six-carbon molecule related to glucose. Its primary biological function is to act as a reducing agent in a variety of essential hydroxylation processes in the human body. The recommended daily allowance (RDA) of vitamin C for an adult is 60 mg per day, although this amount is debatable [32]. Another benefit of ascorbic acid is that it protects the body from several disorders caused by faulty collagen assemblies, such as skin lesions, unstable blood vessels, bleeding gums, osteoporosis, hemorrhages, and anemia [32, 62]. Our results show that plants treated with MLE could significantly improve the concentration of vitamin C. Among the treatments, MLE 6% could have a significant result of 33.10 (mg 100 g^{-1}) followed by the plants treated with 10% and 8% of moringa leaf extract (Table 6).

It has been stated that moringa leaf extract is a valuable product in hormones such as zeatin, a plant hormone cytokine [50, 63]. This could be the reason for increasing antioxidants and, as a result, ensuring plant vitality [64, 65]. Our findings agree with those of Toscano et al. [66], who discovered a significant increase in vitamin C content in baby leaf kale plants treated with MLE with the amount of 200 mg L^{-1}. In a study conducted by Yaseen and Takacs-Hajos [14], vitamin C levels in lettuce leaves of the Great Lakes variety were dramatically increased when 6% MLE was applied.

3.3.1. Nitrate Content. Nitrate or nitrate salts are the main components of fertilizers that have been used largely to boost crop development and increase vegetable yield in recent decades. The level of human nitrate exposure has risen considerably in recent years, which could be attributed to the enrichment of the biosphere with reactive nitrogen, as well as an increase in vegetable and preserved animal product consumption [67]. Recent research shows that the physiological role of nitrate or nitrite is responsible for their harmful function in our food and water supplies. About 80% of nitrate comes from vegetables we eat, followed by drinking water (10–20% or higher in various Asian and African countries), preserved meat (5%), and other sources. The primary two disadvantages of higher nitrate intake in our meals are increasing methemoglobinemia (MetHb) disorder in infants and the possibility of an increase in cancer disease in adults [68].

Among vegetables, lettuce, spinach, celery, and beetroot have the highest nitrate contents (above 1000 mg kg^{-1}), whereas potatoes, cabbage, and spring greens contain about 100–1000 mg kg^{-1}, and tomatoes have the lowest concentrations lower than 100 mg kg^{-1} [69]. According to studies, the ADI (acceptable daily intake) must be 3.65 mg kg^{-1} body weight [70]; nevertheless, the estimated dietary intake of nitrate in various European countries ranges from 31 to 185 mg/day^{-1}.

Our research studies show that spraying of MLE with the concentration of 6, 8, and 10% had a significant reduction in nitrate content compared to the control plants; however, by increasing the concentration of MLE by 10%, the nitrate content was gradually increased (Table 6).

This could be because a larger concentration of MLE allows the plant to absorb more nitrogen [71]. Furthermore, moringa leaf extract contains a high concentration of nitrate and other essential nutrients [72], which allows the plant to accumulate a higher concentration of nitrate in the leaves. Sardar et al. [73] discovered that spraying stevia (*Stevia rebaudiana* Bertoni) with 20% MLE could considerably enhance N, P, K, Ca, Mg, Na, and Zn accumulation in plant leaves, whereas Yaseen and Takacs-Hajos [14] initiate nitrate reduction in lettuce leaves by spraying with low concentration (6%) of moringa leaf extract.

3.3.2. Mineral Content in Cabbage Leaves. Moringa leaf extract contains a high concentration of macro- and micronutrients (Table 3), which provides additional nutrition to the treated plants. Our mineral enhancement findings are consistent with previous research on vegetable crops. Table 7 shows significant increases for plants treated with 6, 8, and 10% MLE. Increasing MLE concentrations, except for nitrogen, has resulted in enhanced nutritional content such as Ca, K, Mg, and P. This could be because moringa leaf extract reduces nitrate levels in plant leaves [13, 66]. Various studies on other vegetables suggest that treatment with MLE can increase macro and micronutrient levels in many plants.

This could be because MLE promotes nutrient uptake by increasing root membrane permeability and nutrient mobility [50], as well as the extract's nutrient content. High concentrations of 10, 20, and 30% MLE could improve the leaf's N, P, K, Ca, Mg, Na, and Zn concentrations in stevia (*Stevia rebaudiana* Bertoni) [73], nutrient improvement in basil plant (*Ocimum basilicum*) under salt stress [74]; also, N, P, K, Ca, Mg, and Fe improvement was found in pea seeds (*Pisum sativum*) through foliar sprayed with 1, 2, 3, and 4% MLE [75].

3.4. Correlation of the Vegetation Growth of Cabbage to Some Growth Measurements. Table 8 clearly shows that all vegetative parameters have a favourable correlation to growth

Table 5: Chlorophyll *a*, chlorophyll *b*, and carotenoid content in cabbage fresh leaves.

Treatments	Chlorophyll *a* ($\mu g\ mL^{-1}$)	Chlorophyll *b* ($\mu g\ mL^{-1}$)	Carotenoids ($\mu g\ mL^{-1}$)
Control (Ø)	13.09^{c}	4.23^{b}	4.86^{c}
MLE 6%	14.96^{b}	4.80^{ab}	5.98^{b}
MLE 8%	16.61^{ab}	5.00^{ab}	6.07^{b}
MLE 10%	17.95^{a}	5.64^{a}	7.29^{a}

Mean values ($n = 20$) in each column followed by different letters are significantly different at $p \leq 0.05$ by Duncan's multiple range test.

Table 6: Ascorbic acid (vitamin C) and nitrate content in cabbage fresh leaves.

Treatments	Vitamin C ($mg\ 100\,g^{-1}$)	NO_3^- ($mg\ kg^{-1}$)
Control Ø	28.56^{c}	527.00^{a}
MLE 6%	33.10^{a}	428.66^{b}
MLE 8%	29.90^{b}	462.33^{b}
MLE 10%	30.46^{b}	470.33^{b}

Mean values ($n = 20$) in each column followed by different letters are significantly different at $p \leq 0.05$ by Duncan's multiple range test.

Table 7: Mineral elements and nitrate in cabbage samples treated with moringa leaf extract (MLE).

Treatments	Ca (m/m) %	K (m/m) %	Mg (m/m) %	P (m/m) %	N (m/m) %
Control (Ø)	0.48^{c}	3.62^{c}	0.17^{b}	0.54^{b}	2.30^{c}
MLE 6%	0.56^{b}	3.95^{b}	0.21^{a}	0.58^{a}	2.68^{b}
MLE 8%	0.60^{ab}	4.16^{b}	0.22^{a}	0.59^{a}	2.71^{a}
MLE 10%	0.64^{a}	4.46^{a}	0.26^{a}	0.61^{a}	2.62^{b}

Mean values ($n = 20$) in each column followed by different letters are significantly different at $p \leq 0.05$ by Duncan's multiple range test.

Table 8: Pearson correlation between vegetative parameters and growth measurements in cabbage (*Brassica oleracea* L. var. *capitata*).

Parameters	Head weight	Stem length	Head diameter	Head height	Dry matter	Chl a	Chl b	Carotenoids	Vitamin C	Nitrate
Head weight	1									
Stem length	0.414	1								
Head diameter	0.702**	0.28	1							
Head height	0.671**	0.178	0.798**	1						
Dry matter	0.319	−0.143	0.241	0.229	1					
Chl a	0.750**	0.334	0.637*	0.465	0.123	1				
Chl b	0.635*	0.142	0.498	0.38	0.089	0.925**	1			
Carotenoids	0.758**	0.333	0.663*	0.516	0.136	0.990**	0.903**	1		
Vitamin C	0.635*	−0.197	0.516	0.432	0.870**	0.442	0.414	0.44	1	
Nitrate	0.311	0.554	0.252	0.31	−0.462	0.458	0.459	0.472	−0.308	1

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

measurements. The only negative correlation detected was between vitamin C and nitrate level, which accords with the findings of Koh et al. [76], who discovered a negative correlation between nitrate, ascorbic acid, and vitamin C in spinach (*Spinacia oleracea* L.) leaves. This finding will be advantageous because a research study has revealed that ascorbic acid and flavonoids can reduce the harmful effects of nitrites [77].

Head weight correlated significantly with head diameter, head height, chlorophyll a, and carotenoids at the p level 0.01, while chlorophyll b and vitamin C correlated significantly at the p level 0.05. However, no significant association was observed across stem length and head height and growth factors. Head diameter, on the other hand, was found to have a significantly positive correlation with head height at p level 0.01, as well as a positive correlation with chlorophyll a and carotenoids at p level 0.05. The dry matter has a significant positive correlation with vitamin C at p level 0.01, whereas a negative correlation with nitrate. Chlorophyll a and chlorophyll b had a substantial positive association with carotenoids among the growth parameters, while chlorophyll a had a positive correlation to chlorophyll b at p level 0.01. Our result shows that cabbage plants with greater chlorophyll content can produce better physical parameters in terms of growth performance and delaying flowering or bolting.

4. Conclusion

We can conclude that MLE is an effective plant biostimulant to be used to improve nutritional and physical parameters in cabbage (*Brassica oleracea* var. *capitata*). This study suggests that foliar application of 10% MLE to cabbage had a significant positive effect on morphological parameters, mineral absorption, nutrient content, and bioactive compounds without improving stem length, resulting in a significant increase in the gross and marketable yield of the vegetable crop and nitrate content in cabbage leaves. However, by increasing the percentage of MLE from 6% to 10%, the nitrate reduction is decreasing by about half. Nitrate had a negative correlation with vitamin C and dry matter. These findings imply that plants with higher pigment content have higher morphological and nutrient value.

Data Availability

The data used to support the study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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