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# EFFECT OF FOLIAR APPLICATION OF MORINGA LEAF EXTRACT ON VEGETATIVE AND REPRODUCTIVE CHARACTERISTICS OF ANTIRRHINUM (*ANTIRRHINUM MAJUS*) AND STOCK (*MATTHIOLA INCANA*)

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## ABSTRACT

Moringa leaf extract (MLE) is considered to be effective in the field of crop production. Its foliar application on plants has a significant effect on the plant's vegetative and reproductive growth. This study was conducted to evaluate Moringa Leaf Extract foliar application on two floricultural crops viz. *Antirrhinum majus.* and *Matthiola incana.* Following treatments of MLE, i.e., 3, 6, 9, and 12% along with the control, were used, respectively. The experiment was laid out according to a randomized complete block design (RCBD) with three replications. Data was analyzed using Fisher's analysis of variance technique, and treatment means were compared separately at 5% level of probability by applying the LSD test. Results showed that MLE 6% ($T_2$) performed better in *Matthiola* plants regarding the majority of vegetative, floral, and physico-chemical parameters, including plant height, number of leaves, stem diameter, days to first flower bud formation, days to first flower bud opening, number of florets per spike, and NPK contents in leaves. On the other hand, in *Antirrhinum* plants, foliar application of MLE 12% (T4) performed better in the majority of growth, floral, and physico-chemical parameters. Therefore, it is concluded that there is no generalized dose of MLE for foliar application on all plants. To achieve better results from the foliar application of MLE for specific plants, the ideal concentration should be optimized.

***Keywords***: Moringa leaf extract (MLE), *Antirrhinum majus.* and *Matthiola incana*

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## 1. INTRODUCTION

Modern floriculture is a vast industry that encompasses the production and marketing of a wide variety of ornamental plants and their associated products, including trees, shrubs, ground covers, bulbs, cut flowers, foliage, potted plants, and annual flowers. The floriculture industry is growing at a rate of 6 to 9% annually, and currently, about 120 countries are actively involved in the floriculture industry globally, with the Netherlands at the epicentre of world flower production and distribution (Martsynovska, 2011; Ahmad et al., 2025).

Pakistan has a range of favorable climatic conditions for the production of cut flower crops. It provides a better opportunity to small landholders to earn comparatively better profit than that of agronomic crops (Sajid et al., 2015; Younis et al., 2018). This wide range of suitable climatic conditions enables the cultivation of numerous diverse species of cut flowers in the country, which can enhance the financial status of growers (Ahmad et al., 2010). Floriculture offers local growers the opportunity to transition from traditional agriculture to non-traditional farming methods, such as the cultivation of high-value flowering crops. That is why, over the past few years, the cultivation and marketing of flowers have also flourished (Riaz et al., 2007; Abdullah et al., 2019).

Intensive use of chemical fertilizers in farming practices may increase yields and guarantee quality production, but it also causes environmental problems. For this reason, modern researchers have focus their attention to find out sustainable and organic ways of farming which will be environment friendly (Esitken et al., 2005). Use of eco-friendly and organic means is becoming the basis of modern researches in order to minimize the harmful effect of chemicals on environment and inhibiting the possibilities to endanger the biodiversity of plant species being grown as crops. For this purpose, many tools have been developed in the past few years to encourage and foster a sustainable environment. Among these, bio-stimulants are the ones that play an important role in increasing plants' abilities to overcome many abiotic stresses and become an important substitute to chemical fertilizers. These bio-stimulants include plant growth-promoting fungi (PGPF) and plant growth-promoting rhizobacteria (PGPR) (Bhattacharyya & Jha, 2012). Plant extracts containing bioactive compounds that can increase numerous physiological processes in plants are also included in bio-stimulants. They stimulate nutrient use efficiency and increase biochemical processes in plants, ultimately improving growth and reducing the need for chemical fertilizers (Bulgari et al., 2015). The

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application of bio-stimulants in agricultural practices is gaining interest due to their ability to enhance plant physiological processes, minimize biotic and abiotic stresses, and increase crop yields without affecting quality (Kunicki et al., 2010; Ziosi et al., 2012).

In Pakistan, most of the cultivated soils are nutrient-deficient, in which available nitrogen and potassium are not adequate, and micro-nutrients, including boron, zinc, iron, etc., are also not available in the required amounts. Poor management, reduced use of organic fertilizers to increase soil fertility and unprofessional use of inorganic nutrients are some causes which are responsible for lower fertilizer use efficiency (Iqbal & Ahmad, 2005). Foliar application of nutrition is one of the best methods to reduce the failure of plants to absorb certain nutrients that are necessary for their normal growth. Foliar application of nutrition is an alternate method when nutrient deficiencies of plant cannot be corrected by applications of nutrients through soil (Cakmak, 2008; Cornea-Cipcigan et al., 2020; Irshad et al., 2025; Fayyad & Al Shaheen, 2023; Ghanim et al., 2024).

*Moringa oleifera* is indigenous to South Asia, where it grows in the Himalayan foothills from north-eastern Pakistan to northern West Bengal, India. It has been introduced and naturalized in other parts of India, Pakistan, Afghanistan, Bangladesh, Sri Lanka, Southeast Asia, West Asia, the Arabian Peninsula, East and West Africa, southern Florida, throughout the West Indies, and from Mexico to Peru, Paraguay, and Brazil. In Puerto Rico, it is primarily grown as an ornamental plant in fencerows and hedges, and has become naturalized along roadsides on the coastal plains and lower hills (Mahmood et al., 2010). Moringa is a remarkable and beneficial plant due to its proven, trusted, and potential benefits from both nutritional and therapeutic perspectives. This friendly plant is of great significance, as it has been shown to be useful in water purification, cosmetics, livestock fodder, plant growth enhancer, and biogas production. An inspiring effect of nearly all parts of the Moringa (Moringa oleifera) tree in medicines and its uses in food and also its usage in industries places it among the most valuable trees in the world (Khalafalla et al., 2010; Adebayo et al., 2011; Moyo et al., 2011). Hundreds of research articles on Moringa are published as thesis in newspapers and journals etc. (Fuglie, 1999; Fuglie, 2000).

Moringa leaves are rich in cytokinins, macro and micro nutrients, as well as in anti-oxidants. The leaf extract of moringa also contains Ca, K, and Fe; it also comprises amino acids, ascorbate, and hormones such as zeatin, which makes it an ideal plant growth enhancer (Makkar & Becker, 1996; Basra et al., 2009; Jan, 2021). Moringa leaf extract (MLE) contains zeatin which is a purine adenine derivative of the hormonal group cytokinin. Zeatin protects cells from the aging effects of reactive oxygen species by enhancing the antioxidant properties of various enzymes (Zhang & Ervin, 2004). Experiments had shown that (MLE) spray had a wide range of beneficial effects on plant crops including accelerated growth rate, plants became firmer, develop resistance against pests and disease, increase life-span of plants, increased volume of roots, stems and leaves, produced more and larger fruits resulted in increased yield of plants by 20-35% (Foidl et al., 2001). *Antirrhinum majus* commonly known as Snapdragon is basically a Mediterranean perennial plant that flowers in spring, but different hybrids which were introduced lately can also flower in winter (Ball, 1991). It belongs to the family Scrophulariaceae and often planted in gardens due to its showy flowers. It is also grown for cut flowers production due to its wide range of petal colors (Asrar, 2012). The plant has many large, colored flowers with zygomorphic symmetry. The snapdragon plant is usually characterized by showy multi-colored flowers which are arranged in racemes (Reeves and Olmstead, 1998).

*Mathiola incana*, commonly known as Stock, belongs to the Brassicaceae family and is a popular bedding or cut flower plant with various flower colors (Tatsuzawa et al., 2012). Its long stem and flowering spikes make it a high-value specialty cut flower (Regan & Dole, 2010). Stock has become increasingly important in recent years in floriculture trade due to its wide range of colors, interesting forms, and intense fragrance (Çelikel & Reid, 2002). Considering the harmful effects of agrochemicals on the environment and the potential to endanger the biodiversity of plant species grown as crops, there is a need to explore alternative products that are beneficial for plant growth and eco-friendly. Foliar application of MLE has been proven to be beneficial in improving growth and quality in many crops, is eco-friendly, easily accessible, and economical. Therefore, this study aimed to investigate the potential effect of foliar application of moringa leaf extract on vegetative and flowering attributes, as well as vase life, of Stock (cv. Miracle Blue) and Antirrhinum (cv. Rocket Red) flowers.

## 2. MATERIALS AND METHODS

### 2.1. Nursery Raising and Transplanting

Nursery of the respective flowering crops i.e. Stock (cv. Miracle blue) and Antirrhinum (cv. Rocket red) was raised at Rose Project area, IHS, University of Agriculture, Faisalabad in seedling trays containing growing media comprised of press mud, silt and coco coir with (1:1:1) ratio. Seeds of Antirrhinum and Stock were sown on 1$^{st}$ and 20$^{th}$ November 2018 respectively. Seedlings were transplanted to the field after 50±5 days of seed sowing when they developed three to five true leafs. Before transplantation, soil was ploughed thoroughly and levelled. Flat beds were prepared, plant to plant and line to line distance was kept at nine inches for both the crops.

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### 2.2. Moringa Leaf Extract (MLE) Preparation

Garden-fresh leaves of *Moringa oleifera.* were collected from the Forestry and Range Management research area, University of Agriculture, Faisalabad. After washing leaves with tap water, they were stored in a freezer for 15-20 hours at -5°C. After that, the juice was extracted from leaves by a locally developed extraction machine. Moringa leaf extract was diluted to 3, 6, 9, and 12% concentrations by adding distilled water, according to the experimental treatments.

### 2.3. Layout of Experiment

Experiments were laid out according to RCBD design with three replications, having twenty plants in each experimental unit. Foliar application of MLE to the plants was done five times, with the first application after seven days of seedling transplantation, followed by a fifteen-day interval. First irrigation was applied just after transplanting the seedlings and subsequent irrigations were applied when required. All other cultural practices such as IPM, hoeing and weeding etc. were similar for all the treatments.

### 2.4. Soil Analysis

Before transplanting of seedling, soil samples from three different experimental units of all blocks of experimental area were collected randomly to evaluate various properties of soil like pH, EC, organic matter, N, P and K contents.

### 2.5. Data Collection

Five plants were randomly selected from each experimental unit, tagged, and data regarding various vegetative and reproductive parameters were collected as follows.

***2.5.1. Vegetative Parameters:*** The Plant height (cm) was measured just before harvesting, i.e., 90±2 days after transplanting, with a measuring rod from the base to the top of the plant. The total number of leaves per plant was counted from five randomly selected plants, and the average was computed at the time of harvesting. The stem diameter (cm) just below the third-to-last leaf was measured with a digital caliper in the lab at the time of harvesting, and the average was calculated. Chlorophyll Content (SPAD value) was measured from two healthy and recently mature leaves from each plant. Leaf total chlorophyll contents were recorded from three points of the leaf with a digital leaf chlorophyll meter (Leafat+, FT green, LLC, USA), and the average was computed.

***2.5.2. Floral Parameters:*** Days to first flower bud formation were counted starting from the day of transplanting till the first flower bud formation, and the average was calculated. The days to the first lateral flower bud opening were counted from the time the plant was transplanted into the field until the first flower bud opened, and the average was calculated. The number of florets per spike was counted from five randomly selected plants in each replicate at the time of full maturity, and the average was computed.

***2.5.3. Determination of Leaf Nitrogen, Phosphorous and Potassium content (%):*** The grinded fine powder leaf sample (0.1g) was digested with sulphuric acid and hydrogen peroxide ($H_2O_2$) according to the method of Wolf (1982) and the leaf nitrogen, phosphorous and potassium contents were determined according to the method described by Chapman & Parker (1961).

### 2.6. Data Analysis

The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications. Data on vegetative (plant height, number of leaves, stem diameter, and chlorophyll content), floral (days to first flower bud formation, days to first flower opening, and number of florets per spike), and physio-chemical parameters (leaf N, P, and K contents) were subjected to Analysis of Variance (ANOVA) using Fisher's analysis of variance technique (Steel & Torrie, 1981). Treatment means were compared using the Least Significant Difference (LSD) test at a 5% significance level ($P \leq 0.05$) to determine significant differences among treatments. All analyses were performed using Statistix 8.1 software, and results were presented as mean±SE.

## 3. RESULTS

### 3.1. Vegetative Parameters

***3.1.1. Plant Height (cm):*** The foliar application of MLE on *Matthiola* plants with a concentration of 6% (v/v) increased the plant height (76.4 cm) significantly more than all other treatments (Table 1). On the other hand, minimum plant height (70 cm) was noted in the plants which does not receive any MLE application ($T_0$). While no

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significant difference was observed between $T_1$ and $T_3$. Whereas Antirrhinum plants gained significantly more plant height (106.70cm) as compared to all other treatments with the foliar application of MLE at 12% (v/v) concentration. On the contrary, minimum plant height (88.5 cm) was noted in the plants which did not receive any MLE application i.e. $T_0$. Data is also presented in graphical form in Table 1.

**Table 1:** Vegetative Characters of antirrhinum and stock as affected by foliar application of moringa leaf extract (MLE)

| Treatments | Plant Height* | | Number of Leaves* | | Stem Diameter* | | Total leaf chlorophyll contents* | |
|---|---|---|---|---|---|---|---|---|
| | Matthiola | Antirrhinum | Matthiola | Antirrhinum | Matthiola | Antirrhinum | Matthiola | Antirrhinum |
| $T_0$- Control | 70.0±0.46d | 88.5±0.87e | 27.1±0.4c | 493.1±0.11c | 1.2±0.095b | 0.47±0.01e | 69.6±0.50c | 61.0±0.38c |
| $T_1$- MLE 3% | 74.1±0.48b | 91.1±0.43d | 31.8±0.27ab | 495.8±0.59c | 1.3±0.079b | 0.57±0.01d | 75.3±0.37a | 60.9±0.41c |
| $T_2$- MLE 6% | 76.4±0.47a | 96.6±0.67c | 33.7±1.16a | 517.3±3.61b | 2.6±0.28a | 0.62±0.02c | 72.5±0.52b | 63.8±0.29b |
| $T_3$- MLE 9% | 74.7±0.54b | 102.7±0.28b | 29.3±0.39bc | 520.9±2.14b | 1.3±0.03b | 0.77±0.02b | 72.1±0.73b | 67.5±0.19a |
| $T_4$- MLE12% | 72.4±0.56c | 106.7±1.66a | 29.3±0.2bc | 540.9±1.49a | 1.3±0.06b | 0.86±0.01a | 71.7±0.83b | 68.4±0.65a |
| P value | 0.0001 | <0.0001 | 0.0026 | <0.0001 | 0.0011 | <0.0001 | 0.0017 | <0.0001 |

*=Average of 15 plants. Values (Mean±SE) with different alphabets in a column differ significantly (P<0.05).

***3.1.2. Number of Leaves:*** Maximum number of leaves (33.73) attained by *Mathiola* plants when sprayed with 6% MLE (v/v). However, this number was statistically at par as observed in ($T_1$) but greater than the number of leaves counted in all other treatments (Table 1). The minimum number of leaves was found in T0 (27.133), which was statistically the same as the number of leaves counted in $T_3$ (9% MLE v/v) and $T_4$ (12% MLE v/v). Data is also presented in graphical form. While in Antirrhinum plants, the maximum number of leaves (540.9) was attained by plants when sprayed with 12% MLE (v/v). The minimum number of leaves (493.1) was counted in plants that were not sprayed with any treatment, which was statistically the same as the number of leaves counted in $T_1$ (3% MLE v/v). And also, no statistical difference was observed between $T_2$ (6% Moringa leaf extract v/v) and $T_3$ (9%). (Table 1).

***3.1.3. Stem Diameter:*** The Matthiola plants that were sprayed with MLE 6% (v/v) gained maximum stem diameter (2.57 cm). No statistical difference was noted among the stem diameters of Matthiola plants treated with T0 (No MLE application), $T_2$ (3% MLE v/v), $T_3$ (9% MLE v/v) and T4 (12% MLE v/v). Minimum stem diameter (1.18 cm) was noted in T0 (Table 1). Whereas Antirrhinum plants which were sprayed by MLE 12% (v/v) gained maximum stem diameter (0.86 cm) and was greater than the stem diameters of Antirrhinum plants noted in all other treatments. Whereas, minimum stem diameter (0.47 cm) was noted in the plants which does not receive any MLE application. (Table 1)

***3.1.4. Total Leaf Chlorophyll Contents:*** Data regarding total leaf chlorophyll contents (SPAD value) of the *Matthiola* plants depicted significantly high SPAD value of chlorophyll contents (75.3) in T1 which was significantly greater than the SPAD value in all other treatments (Table 1). Whereas, the minimum SPAD value of chlorophyll contents (69.6) was noted in the control treatment (T0). Data regarding total leaf chlorophyll contents (SPAD value) of the Antirrhinum plants depicted significantly high SPAD value of chlorophyll contents (68.391) in T4 (12% MLE v/v), which was statistically similar to the chlorophyll content of the plants treated with T3 (9% MLE v/v) but significantly greater than all other treatments. On the other hand, the minimum SPAD value of chlorophyll contents (60.900) was observed in plants that were not treated with any MLE concentration (T0). (Table 1).

**3.2. Floral Parameters**

***3.2.1. Days to first flower bud formation:*** The data showed (Table 2) that the maximum number of days (67.4 d) to first flower bud formation was taken by the Matthiola plants sprayed with T2 (6% MLE v/v). While there was no significant difference regarding this parameter in T1, T3, and T4. Significantly fewer days to start first flower bud formation (58.7 d) were observed in plants that didn't receive any MLE treatment. The days taken by Antirrhinum plants for the formation of the first flower bud were 79.5 days when sprayed with T4 (12% MLE v/v). On the other hand, the number of days taken by Antirrhinum plants to first flower bud formation in T2 and T3 were statistically same. Significantly less days to start first flower bud formation (67.8 days) were observed in plants that didn't receive any MLE treatment i.e. $T_0$ (Table 2).

***3.2.2. Days to first flower bud opening:*** The MLE having concentration of 6% (v/v) was able to increase the days to first flower bud opening (73.9 days) in Matthiola plants followed by (72.2 days) in T1 (Table 2). Contrary to that the minimum days taken by Matthiola plants to first lateral flower bud opening were (65.8 days) observed in the plants of control treatment (T0). Non-significant difference was observed in T3 and T4 treatments regarding this parameter. In case of Antirrhinum, MLE having a concentration of 12% (v/v) was able to increase the number of days to first flower bud opening (89.2 days), followed by (84.40 days) in T3 (9% MLE v/v). Contrary to that the minimum number of days (75.3 days) to first flower bud opening was observed in the plants in control treatment ($T_0$) (Table 2).

**Table 2:** Floral Characters of antirrhinum and stock as affected by foliar application of moringa leaf extract (MLE)

| Treatments | Days to first flower bud formation* | | Days to first lateral flower bud opening* | | Number of florets per spike* | |
|---|---|---|---|---|---|---|
| | Matthiola | Antirrhinum | Matthiola | Antirrhinum | Matthiola | Antirrhinum |
| $T_0$- Control | 58.7±0.29c | 67.8±0.36d | 65.8±0.39c | 75.3±0.11d | 28.7±0.47d | 32.5±0.38 |
| $T_1$- MLE 3% | 64.2±0.34b | 75.3±0.09c | 72.2±0.28ab | 81.5±0.16c | 37.3±0.61b | 32.5±0.19 |
| $T_2$- MLE 6% | 67.4±0.73a | 77.2±0.27b | 73.0±0.82a | 83.7±0.55b | 42.4±0.41a | 33.2±0.48 |
| $T_3$- MLE 9% | 63.2±0.52b | 77.3±0.52b | 71.4±0.73b | 84.4±0.84b | 33.1±0.53c | 34.1±0.55 |
| $T_4$- MLE12% | 63.1±0.24b | 79.5±0.30a | 71.3±0.38b | 89.2±0.38a | 32.7±0.53c | 34.1±0.45 |
| P value | 0.0011 | <0.0001 | 0.0005 | <0.0001 | <0.001 | 0.5694 |

*=Average of 15 plants. Values (Mean±SE) with different alphabets in a column differ significantly (P<0.05).

***3.2.3. Number of florets per spike:*** Data regarding number of florets per spike showed the maximum number of florets (42.4) were counted in *Matthiola* plants sprayed with MLE 6% (v/v) $T_2$ and this number was significantly higher than all other treatments, followed by (37.3) in the plants treated with MLE 3% (v/v). Minimum number of florets per spike (28.7) were observed in the plants of control treatment ($T_0$). In the case of Antirrhinum, no significant difference was found regarding this parameter among all the treatments applied to plants Table 2. However, this number ranged between 32.1 to 34.1 (Table 2).

***3.2.4. Leaf Nitrogen Content (%):*** Data regarding leaf nitrogen contents of Matthiola plants showed that maximum leaf nitrogen contents (1.25%) were found in plants sprayed with $T_2$ (6% MLE v/v) whereas minimum leaf nitrogen contents (0.8133%) were recorded in plants which were not treated with *Moringa* leaf extract i.e. Control. On the other hand, data in Antirrhinum plants maximum leaf nitrogen contents (1.2%) were found in the plants which were sprayed with $T_4$ (12% MLE v/v) which was statitically same with $T_3$ (9% MLE v/v) whereas minimum leaf nitrogen contents (0.61%) were recorded in Antirrhinum plants which were not treated with any concentration of *Moringa* leaf extract i.e. Control (Table 3).

***3.2.5. Leaf Phosphorus Content (%):*** Results revealed the *Matthiola* plants which were sprayed by $T_2$ (6% MLE v/v) produced maximum leaf phosphorus contents (0.64%) while, minimum leaf phosphorus contents (0.35%) were recorded in *Matthiola* plants which were not treated with any concentration of *Moringa* leaf extract i.e. Control. Whereas, data regarding leaf phosphorus contents of Antirrhinum plants showed that maximum leaf phosphorus contents (0.46%) were found in the plants which were sprayed with $T_4$ (12% MLE v/v) whereas minimum leaf phosphorus contents (0.29%) were recorded in *Antirrhinum* plants which were not treated with any concentration of *Moringa* leaf extract i.e. Control (Table 3).

***3.2.6. Leaf Potassium Content (%):*** Mathhiola plants that were sprayed by $T_2$ (6% MLE v/v) produced maximum leaf potassium contents (0.63%). While minimum leaf potassium contents (0.29%) were recorded in Matthiola plants, which were not treated with any concentration of Moringa leaf extract, i.e., Control. Whereas, Antirrhinum plants which were sprayed with $T_4$ (12% MLE v/v) produced maximum leaf potassium contents (0.0036%). While minimum leaf potassium contents (0.0028%) were recorded in Antirrhinum plants which were not treated with any concentration of MLE, i.e., Control (Table 3).

**Table 3:** Physio-chemical analysis of antirrhinum and stock as affected by foliar application of moringa leaf extract (MLE)

| Treatments | Leaf nitrogen contents | | Leaf phosphorus contents | | Leaf potassium contents | |
|---|---|---|---|---|---|---|
| | Matthiola | Antirrhinum | Matthiola | Antirrhinum | Matthiola | Antirrhinum |
| Control | 0.8133±0.0027e | 0.61±0.016d | 0.35±0.0027e | 0.29±0.0046e | 0.29±0.0027e | 0.00283±5.42E-06e |
| MLE 3% | 1.14±0.0054b | 0.84±0.018c | 0.56±0.0027b | 0.34±0.0027d | 0.51±0.0054b | 0.0031±5.41E-06d |
| MLE 6% | 1.25±0.0097a | 1.07±0.010b | 0.64±0.0027a | 0.38±0.0054c | 0.63±0.0027a | 0.0033±2.70E-06c |
| MLE 9% | 1.10±0.0071c | 1.17±0.014a | 0.49±0.0046c | 0.41±0.0054b | 0.48±0.0054c | 0.0034±2.71E-06b |
| MLE12% | 1.02±0.002d | 1.20±0.0093a | 0.46±0.0046d | 0.45±0.0027a | 0.44±0.0027d | 0.0036±1.43E-05a |
| P value | <0.001 | 0.0001 | <0.001 | 0.0001 | <0.001 | 0.0001 |

*=Average of 15 plants. Values (Mean±SE) with different alphabets in a column differ significantly (P<0.05).

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## 4. DISCUSSION

In present experiment it is observed that plant height and number of leaves of both Matthiola and Antirrhinum crops increased with the application of MLE and are in line with the findings of Culver et al. (2012) who observed that Moringa leaf extract was able to increase the growth parameters in *Brassica napus* (commonly known as rape) and *Brassica oleracia* (commonly known as cabbage) crops. Same results were also reported by Dunsin and Odeghe (2015) when they applied leaf extract of *Morimga* tree and observed a significant increase in growth parameters including plant height, number of leaves and yield of sweet bell paper. The results are also in line with the findings of (Hala et al., 2017) who observed that the number of leaves, plant height, leaf area and other such growth parameters were significantly enhanced by the foliar spray of *Moringa* leaf extract at 4% v/v in *Capsicum* plants. Same results were also reported by (Abou-Sreea and Matter, 2016) who observed a significant increase in all the growth characters of fennel plants including number of leaves, when sprayed with *Moringa* tree leaf extract. The leaf extract of Moringa is rich in Ca, K, Fe, amino acids, ascorbate, and hormones such as zeatin; which makes it an ideal plant growth enhancer Makkar and Becker (1996), Basra et al. (2009). Due to the presence of these growth promoting agents, application of Moringa leaf extract on different crops may improve plant growth characters such as plant height and number of leaves (El-Sayed et al., 2024).

Results of present experiment showed that MLE application generally increased the stem diameters and total leaf chlorophyll contents in both plant species which are in line with the findings of (Taha, 2016) who observed that the foliar spray of *Moringa* leaf extract not only improved the stem anatomy of the sunflower crop but also enhanced the length and dry weight of the shoot. He also concluded that MLE foliar spray was responsible for the improvement of yield and growth of sunflowers. Same results were also reported by (Soliman and Shanan, 2017) who conducted an experiment on *Lagerstroemia indica* crop to evaluate the effect of MLE on various growth parameters. They reported that all the growth parameters were improved significantly with the foliar application of *Moringa* leaf extract. Whereas, Ali et al. (2018) observed a significant increase in total leaf chlorophyll and carotenoid contents of *Pelargonium graveolens* plants, which were sprayed with MLE as a growth-promoting substance. Same results were also observed by Rady and Mohamed (2015), in their experiment in which foliar application of Moringa leaf extract on bean plants significantly increased total leaf chlorophyll contents along with NPK and total soluble sugar contents of the leaves.

MLE has growth-promoting agents that delay crop maturity and filling period, leading to greater seed and more yield Basra et al., 2011). Due to this reason, MLE may promote vegetative growth and delay flower bud formation in *Matthiola* and Antirrhinum plants. These results are also in line with Soliman and Shanan (2017), who reported that when Lagerstroemia indica plants were treated with Moringa leaf extract, it caused an increase in the days to inflorescence of the *Lagerstroemia* plants. It also improved the N, P, and K content percentage in the leaves (Eisa et al., 2023). There is a possibility that the presence of growth-promoting substances in MLE foliar spray can extend blooming time and delay crop maturity. Therefore, the increased time of first flower bud opening is due to the presence of these growth-promoting substances, which also causes a significant delay in flower bud formation.

Results regarding the number of florets per spike in Matthiola and Antirrhinum plants are in line with Younis et al. (2018), who reported a significant increase in the number of florets per spike in the Gladiolus crop as affected by the foliar spray of MLE. It also increased the vase life of Gladiolus crop. El-Mageed et al. (2017) studied the growth, yield, physio-biochemical attributes, and water use efficiency of squash plants and observed that all the parameters were improved under the application of Moringa leaf extract, including water use efficiency of the plants. Due to this improved WUE, plants may be able to uptake more water, which causes an increase in vase life of the plants.

One possible reason for the increased nutritional content of the leaves may be that MLE contains various hormones and numerous beneficial micronutrients, which enable plants to enhance their water and nutritional uptake from the soil. Current study results are in line with El-Enien et al. (2015), who demonstrated similar results in an experiment in which MLE treatments were able to increase potassium and nitrogen contents in the leaves of *Citrus sinensis*. Rady and Mohamed (2015) also observed similar results when plants of Phaseolus vulgaris showed increased amounts of nitrogen, potassium, and phosphorus in their leaves, along with TSS and carotenoid contents.

## 5. CONCLUSION

The results of the current study indicate that, in *Matthiola incana* and *Antirrhinum majus*, foliar application of MLE at 6 and 12% concentrations, respectively, performed better in the majority of vegetative and floral parameters studied. Therefore, it is concluded that there is no generalized dose of MLE for foliar application on all plants. So, to get better results from foliar application of MLE for any specific plants, the ideal concentration should be optimized.

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## DECLARATIONS

**Conflicts of Interest:** The authors declare that they have no conflict of interest.

**Data Availability:** All data are available within the article.

**Author's Contributions:** Idea and supervision: MA Write-up and editing: MB, Visualization: MF, MB. Validation: MA.

**Generative AI Statements:** The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

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