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The effects of plant biostimulants and plant growth regulator applications on plant growth in lilium 'Adelante'

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Abstract

This experiment was designed, it was determined the effects of mycorrhiza, vermicompost, promalin applications on development of plant properties in a bulbous plant, Lilyum 'Adelante. Flower branch length (cm), flower branch diameter (mm), internode number, flower bud number, flower bud length (cm), flower stem length (cm), flower width (cm), flower length (cm), number of leaves and leaf length (cm) were measured. The results showed that no treatment increased plant height more than control plants, but each application had different effects on other plant characteristics. As a matter of fact, mycorrhiza increased internode number, flower bud number, flower bud length, flower stem length, flower length, number of leaves and leaf length by 6.3%, 15.6%, 14.2%, 6%, 40%, 10.3%, 2.9% and 6%, respectively. Vermicompost increased flower bud length, flower length and leaf length by 6.6% and 12%, 15.3% and 16.1%, respectively. Promalin, on the other hand, increased the flower stem length, flower length and leaf length by 56.3% and 15.4%, respectively. The application of mycorrhiza together with Promalin did not have a different effect than the application of Promalin alone, and even showed a lower effect than the application of Promalin alone. Mycorrhiza, on the other hand, was the application that showed the best effect compared to other applications. Therefore, it can be recommended for plant growth in lilies. However, due to the effect of application time and dose on flowering time, it is possible to obtain different results in plant development in lilies.

Keywords: Lily 'Adelante,' plant properties, mycorrhiza, vermicompost, Promalin

Introduction

Lily (*Lilium* spp.) is one of the popular commercially high value flowers grown worldwide. Lilies are generally grown as cut flowers in the ornamental plants industry due to their attractive shape, color and scent. Chemical fertilizers are used in flowers, which have a wide usage area, in order to meet the excess demand and increase the yield (Verma et al., 2018). In modern ornamental plant cultivation, new searches are necessary to obtain sufficient and sustainable yield and quality. This approach emerged as the application of non-fertilizer and non-polluting biostimulants or metabolic enhancer products to plants (Verma et al., 2018). The role of these products is also to increase the absorption efficiency of nutrients provided by fertilization (Frankenberger and Arshad, 2020). PGPRs vermicompost and mycorrhiza can have different effects on plants. Mycorrhiza absorbs low or insufficient nutrient elements, especially phosphorus, that the plant cannot benefit from and gives them to the plant (Hijri and Bâ, 2018). Although it is not only a microbial fertilizer, it was determined that if mycorrhiza is active in the root zone, it has a positive effect on the root and stem of the plant (Yeh et al., 2019; Yeh et al., 2021). Vermicompost is a humic substance with effects similar to growth regulators (contributes to the increase of compounds such as auxin, cytokinin and gibberellin). In addition to being a rich source of micro and macronutrients, vermicompost can help plants obtain micronutrients such as iron and zinc and macronutrients such as P, increasing plant growth and yield (Baruati et al., 2018; Subbaiah, 2019). Many studies were conducted to determine the effect of vermicompost on ornamental and flowering plants. As a matter of fact, it was stated that ornamental plants seed and flower more quickly in vermicompost application (Abacıoğlu, 2020). Promalin promotes an increase in cell division and cell elongation,

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resulting in higher production per plant (Tütüncü and Çelikel, 2022). Promalin is also used as a commercial product for delaying flowering and extending vase life, including in various types and varieties of lilies (Çelikel, 2020). In addition reported that Promalin administration in the early period significantly stimulates stem elongation. Moreover reported that Promalin application to *Lilium longiflorum*, Stargazer 'Hybrid Lilies *Sikimmia reevesiana* and *Oxalis braziliensis* increases plant growth (Grzesik et al., 1990; Suh et al., 2005; Janowska & Andrzejak, 2022).

In general, it is difficult to conduct plant nutrition experiments on ornamental bulbous plants. Because the bulb itself stores the nutrients needed by the plant, and on the other hand, most of the soil used for planting also stores the minerals necessary for the bulb. As a matter of fact, the results of plant nutrition studies on bulbous ornamental plants can be very different from the results obtained from plants without bulbs. Determination of these effects is very important for the cultivation of quality ornamental plants. For this reason, it is very important to determine the effects of organic plant nutrition promoters such as mycorrhiza, vermicompost and plant growth regulators on plant growth in ornamental plants on the basis of species and varieties. This study will contribute to the limited studies on this subject. In this study, it was aimed to determine the effects of organic plant nutrition promoters such as mycorrhiza and vermicompost, and the application of promalin, a PGR, alone or together with mycorrhiza, on the development of plant characteristics.

Materials And Methods

The research was carried out at the Black Sea Agricultural Research Institute, Samsun, Türkiye. (41°13'51.63"N, 39°29'47.30"E).

Plant material

In the study 'Adelante lily cultivar were used as plant material. 'Adelante' lily blooms in pink and is a fragrant variety. Bulbs were obtained from a commercial company.

Experimental design and treatments

The treatments consisted of mycorrhiza (M), vermicompost (V), Promalin (P), Promalin+ mycorrhiza (P+M) and control. Bulbs were planted in 5 L pots with peat+perlite mixture (3:1) medium in April. Before planting, the bulbs were sprayed with fungicide (Captan 50 wp) (**Figure 1**). The plants were applied once. The application was made when the plants were 10 cm. No application was made to the control group. In practice, the mycorrhiza was weighed as 5 g and mixed with 1 L of water. Vermicompost was prepared as 5 ml per 1 L of water. Promalin was prepared at 500 ppm per liter. Mycorrhiza and vermicompost were poured into each pot as 50 ml liquid on the pot surface. Promalin was sprayed with the help of a hand pump so that all parts of the plants were wet. A subject that was not applied was included in the experiment as a control. The mycorrhiza, vermicompost and promalin used in the experiment were obtained from commercial companies, and the analysis results of fertilizers declared by commercial companies are given in (**Table 1**). While the average temperature values inside the greenhouse were 25.6°C in 2021, the averange humidity values were 68%.

Figure 1. Bloomed 'Adelante' lily

Table 1. Ingredients declared by commercial companies

Application	Trade name	Ingredients
Mycorrhiza	Endo Roots Soluble (ERS)	Total living organism 1x104w/w, contained organisms:*Glomus intradices, Glomus aggregatum, Glomus mosseae, Glomus clarum, Glomus monosporum, Glomus deserticola, Glomus brasilianum, Glomus etunicatum, Gigaspora margarita.*
Promalin	Sumitomo chemical/ Promalin	18.5 g/l Gibberellin GA_{4+7}+18.8 g/l 6-Benzyladenine
Vermicompost	ORPEX	total organic matter %6, total nitrogen %0.5, organic nitrogen %0.2, water-soluble potassium oxide (K_2O) %0.2, phosphorus pentaoxide (P_2O5) %0.05

Measurements of plant characteristics

Measurement has been made on June 21, when the flowers are fully opened. Flower branch length, flower bud length, flower stem length, flower width, flower length and leaf length were measured with a ruler, and flower branch diameter was measured with a digital caliper. In addition, internode number, flower bud number and number of leaves were determined.

Data evaluation

The research was established according to a completely randomized design with fifteen replications. Four different chemicals and biological, four treatments, and a control group were used for applications. Each replication had a single seedling and 15 replications for each treatment were evaluated. Variance analysis was performed using SPSS statistical software version 20.0 and differences between threatments compared with Duncan multiple comparison test (within 5% error limits). Also, the relationships between treatments and plant characteristics were determined in Pearson's correlations (within 5% and 1% error limits).

Results and Discussion

The effect of mycorrhiza application on plant upper part properties was found to be significant. In mycorrhiza application, internode number, flower bud number, flower bud length, flower stem length, flower length, number of leaves and leaf length increased by 6.3%, 15.6%, 14.2%, 6%, 40%, 10.3%, 2.9% and 6%, respectively, compared to control. Flower branch length and flower width decreased by 1.5% and 9%, respectively (**Figure 2**, **3**, **4**). The effect of vermicompost application on plant upper part properties was found to be significant. In vermicompost application, internode number, flower bud length, flower length and leaf length increased by 6.6%, 12%, 15.3% and 16.1%, respectively, compared to the control, while flower branch length, flower bud number, flower stem length, flower width and number of leaves decreased by 5%, 23.5%, 5.8%, 9.7% and 8.7%, respectively, compared to the control (Figure 2, 3, 4). The effect of promalin application on plant upper part properties was found to be significant. In promalin application, internode number, flower stem length, flower length and leaf length increased by 6.9%, 56.3%, 15.4% and 8.1%, respectively, compared to the control. Flower branch length, flower bud number, flower bud length, flower width, number of leaves decreased by 12.3%, 5%, 5.6%, 5.2% and 2.2%, respectively (Figure 2, 3, 4). When promalin and mycorrhiza were applied together, the effect on plant upper part properties was found to be significant. When promalin and mycorrhiza were applied together, internode number, flower stem length, flower length and leaf length increased by 2.7%, 43.63%, 7.8% and 8.1% , flower branch length, flower bud length, flower width, number of leaves decreased by %4.3, %1.5, %22.3 ve %3 respectively. The flower bud number had the same value as the control. Applications had no effect on flower branch diameter (Figure 2, 3, 4).

Detailed results of the correlation analysis of the relationships between growth characteristics in lilies are given in **Table 2**. Significant-close correlation was found between several phenotypic growth traits (Table 2). When Table 2 was examined, it was found that the relationship between applications and flower width was negative and significant at the $p<0.05$ level, a positive relationship with leaf length at the $p<0.05$ level, and a negative and insignificant relationship with all other characteristics. The relationship between flower branch length, flower branch diameter and internode number was positive, significant at the $p<0.01$ level, and a positive correlation with the number of leaves at the $p<0.05$ level. Again, a positive corelation was detected at $p<0.01$ level with flower branch diameter, number of leaves, flower bud number and flower stem length. A significant positive correlation was found between internode number and the number of leaves at the $p<0.01$ level. It was determined that the relationship between the number of leaves and flower bud number and flower stem length was significantly positive at the $p<0.01$ level. In addition, a significant positive correlation was found at $p<0.01$ level between flower bud number and the flower stem length. Similarly, it was determined that there was a significant and positive relationship at the $p<0.01$ level in the relationship between flower length and leaf length (Table 2).

It was found that while mycorrhiza application increased internode number, flower bud number, flower bud length, flower stem length, flower length, leaf number and leaf length, it had the same effect on flower branch length as the control. In mycorrhiza application, only flower width was lower than the control (Figure 2, 3, 4). Similarly, in the study examining the effects of mycorrhiza application in *Brodiaea laxa* 'Queen Fabiola' cultivar, mycorrhiza increased the number of flowers per flower stem and flower life (Scagel, 2004). Also, *Curcuma xanthorrhiza* Roxb. (turmeric) type 10 g mycorrhiza application per plant increased the number of leaves (Samanhudi et al., 2014).

In vermicompost application, while increased internode number, flower bud length, flower length and leaf length compared to the control, the flower branch

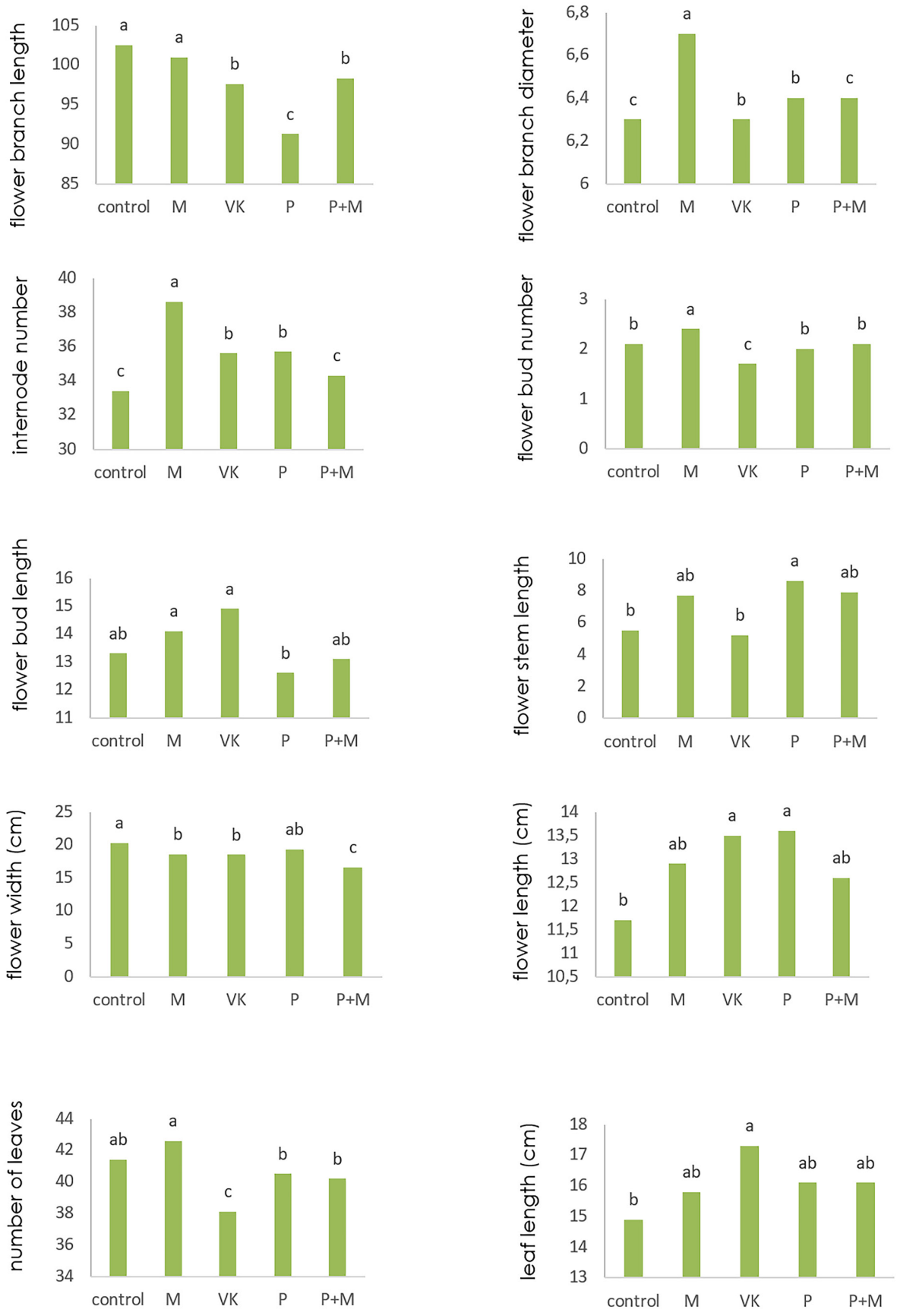

Figure 2. The effect of mycorrhiza, vermicompost and promalin aplication on plant vegetative growth features (control, mycorrhiza: M, vermicompost: V, Promalin: P, Promalin + mycorrhiza: P+M). (There is a significant difference within the error limits among the means indicated with different letters (Duncan). P≤ 0.05).

Table 2. Correlation between applications and plant characteristics

	Flower branch length (cm)	Flower branch diameter (mm)	Internode number	Number of leaves	Flower bud number	Flower bud length (cm)	Flower stem length (cm)	Flower width (cm)	Flower length (cm)	Leaf length (cm)
Aplications	-0.198	-0.053	-0.061	-0.110	-0.092	-0.152	0.290	-0.401*	0.220	0.428*
Flower branch length (cm)	-	0.392**	0.483**	0.328*	0.209	0.296	0.259	0.227	-0.343	-0.113
Flower branch diameter (mm)	-	-	0.204	0.550**	0.558**	0.087	0.403**	0.112	-0.167	0.097
Internode number	-	-	-	0.509**	0.175	0.121	0.222	0.307	-0.196	-0.055
Number of leaves	-	-	-	-	0.691**	-0.035	0.526**	0.233	-0.346	-0.241
Flower bud number	-	-	-	-	-	-0.085	0.526**	0.164	-0.175	0.052
Flower bud length (cm)	-	-	-	-	-	-	-0.188	-0.036	0.142	0.156
Flower stem length (cm)	-	-	-	-	-	-	-	-0.045	-0.295	-0.010
Flower width (cm)	-	-	-	-	-	-	-	-	-0.152	-0.105
Flower length (cm)	-	-	-	-	-	-	-	-	-	0.434*

**: p<0.01, *: p<0.05.

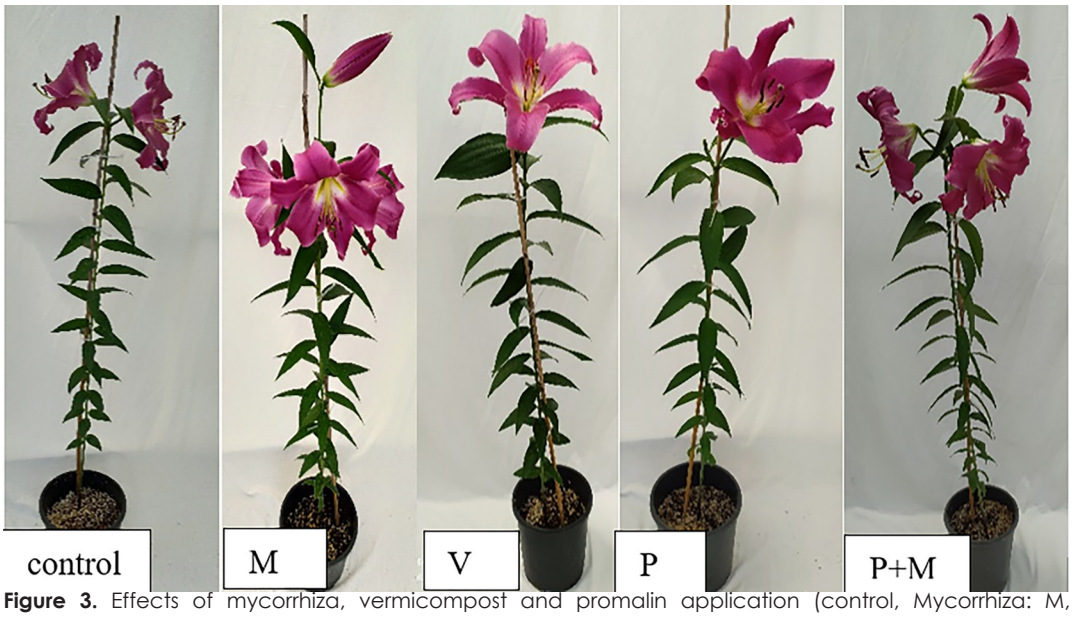

Figure 3. Effects of mycorrhiza, vermicompost and promalin application (control, Mycorrhiza: M, vermicompost: V, Promalin: P, Promalin+ mycorrhiza: P+M).

length, flower bud number, flower stem length, flower width and leaf number decreased (Figure 2, 3, 4). Balode (2017) also showed that vermicompost had a significant positive effect on plant height and leaf length in his study using two lily cultivars, Asiatic lily 'Staburags' and LA lily (*Lilium longiflorum* × *Asiatic lily*) 'Sonora'. Nazarideljou and Heidari (2014) reported in *Zinnia elegance* 'Dreamland Red' that vermicompost application increased plant growth, number of flowers and leaves. Similar results were found in marigolds (Tagetes) (Shivsubramanian and Ganeshkumar, 2004). There is also *L. asiatic* hybrid. navona in a study on the application of 20% and 30% vermicompost had stimulating effects on the number of leaves, stem height and diameter, number and diameter of flowers, and decreasing the flowering period. However, 75% and 100% applications caused a decrease in plant height. As a result, it was reported that the application of vermicompost above the optimum dose may have an inhibitory effect on plant growth and development (Moghadam et al., 2012).

In promalin application, while internode number, flower stem length, flower length and leaf length increased compared to the control, flower branch length, flower bud number, flower bud length, flower width and leaf number decreased. When promalin and mycorrhiza were applied together, internode number, flower stem length, flower length and leaf length increased compared to the control, while flower branch length, flower bud length, flower width and number of leaves decreased (Figure 2, 3, 4). According to Grzesik et al. (1990) 250, 500 and 1000 ppm doses of Promalin were applied to rooted plants of *Sikimmia reevesiana*, and as a result, it was reported that 250 ppm Promalin dose increased the number of shoots and plant growth. In addition, Hatamzadeh et al. (2010) investigated the effect of GA_{4+7} on flower bud development, flowering time, quality and vegetative properties at different application times in their study on the Longiflorum / Asiatic hybrid lily "Menorca". Application of GA_{4+7} at a dose of 200 µg / plant, It was determined that it caused optimum effect on the number of flowers,

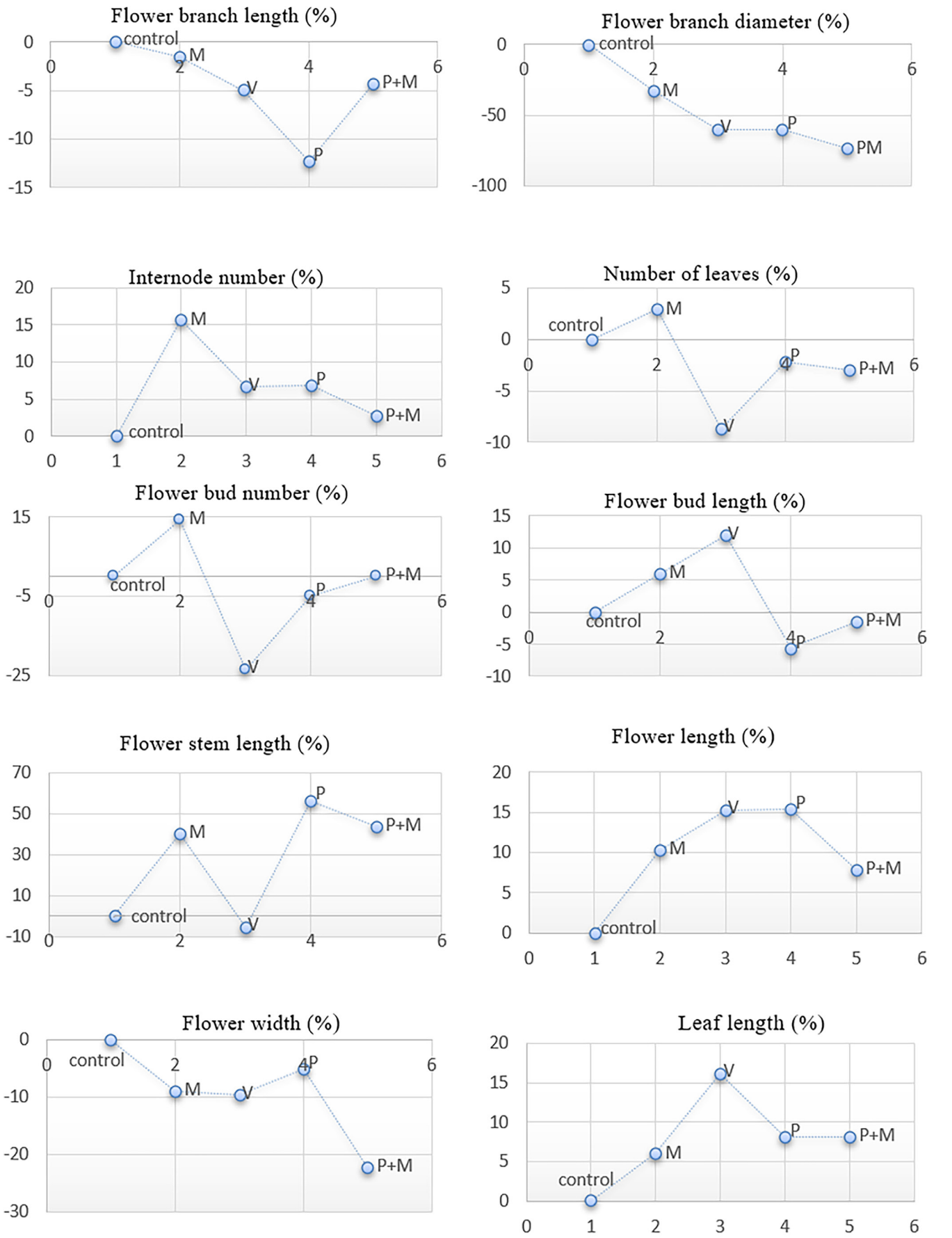

Figure 4. Increase or decrease % rates of mycorrhiza, vermicompost and Promalin applications on plant properties. (Control, Mycorrhiza: M, vermicompost: V, Promalin: P, Promalin+ mycorrhiza: P+M).

flower bud growth rate and plant height. Researchers have determined that a higher dose (2000 µg / plant) decreases the measured properties. As a matter of fact, the responses of plant species to chemical applications differ. They reported that concentrations of Promalin higher than the optimum application dose had a low and adverse effect on cell division and possibly on increasing stem diameter. In this study, the applications had no effect on the flower branch diameter (Figure 2, 3, 4).

It was determined that mycorrhiza application was the most effective application on plant upper parts. Flower branch length was not higher than control plants in any application (Figure 2, 3, 4). Because it is thought that with the effect of the applications, the plant may show early flowering and stop the plant growth and cause its length to be short. As a matter of fact, it was reported that mycorrhiza application shortens the flowering start time. In addition, mycorrhiza changed the carbohydrate metabolism in roses, shortened the flowering period, increased plant height, number of flowers per plant and flower life. Nonetheless, mycorrhiza application in gladiolus caused an increase in plant height and an increase in the number of flowers (Xie et al., 2020; Rydlova and Püschel, 2020). However, it cannot be said that Promalin application causes early flowering. Overall, Promalin is a commercial product used to delay the opening of flowers and extend the vase life, including various lilium varieties. Also, plant height increased with Promalin application in *Oxalis braziliensis*. In addition to thatreported that Promalin administration in the early period significantly stimulates stem elongation (Suh et al., 2005). Promalin (0.75, 1, 1.25, 2 and 3 mL L^{-1}) application significantly accelerated and increased flower development and as well peduncle length in *Cyclamen persicum* (Alshakhaly and Qrunfleh, 2019). On the contrary, it has been reported that high-dose applications strongly inhibit plant growth (Jones and MacMillan, 1985; Hatamzadeh et al., 2010). Parallel to this, it is thought that the reducing effect of Promalin on flower branch length in this study may be due to the high dose applied, unlike other applications (Figure 2, 3, 4).

While all applications increased internode number, only mycorrhiza application increased the flower bud number. In the flower bud length, the application of mycorrhiza and vermicompost increased with the same effect. While mycorrhiza, Promalin and Promalin+mycorrhiza applications increased the flower stem length, it was found that the most effective application was Promalin. All applications increased flower length, while all applications have an effect on flower length, the most effective applications are vermicompost and Promalin applications that provide an increase in the same degree. On the number of leaves, it only had an increasing effect on mycorrhiza. Nonetheless, all applications increased the leaf length, but the highest increase was detected in vermicompost application. In addition, while internode number, flower bud number and number of leaves were highest in mycorrhiza application, the best results were obtained in vermicompost application in flower bud length and leaf length, and Promalin application in flower stem length and flower length (Figure 2, 3, 4). Thus, the effects of certain nutrients and hormones in vermicompost and Promalin contents are limited only by the effects of their contents. However, mycorrhiza have a wider range of action and therefore they can provide the plant with the nutrients in the environment and needed by the plant. As a matter of fact, mycorrhiza are sources of nitrogen, phosphorus, potassium and minerals for plants (Hijri and Bâ, 2018). Having more mineral resources in the plant promotes growth (Yeh et al., 2019). In addition, in this study, it was concluded that each application was effective on different plant upper parts, and that these applications were caused by the content and mechanism of action. However, in this study, it can be said based on the results of the study that mycorrhiza are more effective in establishing the interaction between the soil and the plant, and that it regulates the exchange between the plant and the soil effectively. This mechanism of action is thought to be more powerful and comprehensive than other applications. As a matter of fact, P in vermicompost must be mineralized before it can be used by plants. Mineralization and uptake of organic P can occur if microorganisms, an arbuscular mycorrhizal fungus, are present in the soil (Smith and Read, 2008). This result shows that even in order for the plant to absorb the nutrients contained in vermicompost, they need mycorrhiza in the plant root zone. However, in this study, the application doses were found to be very important. As a result, it can be said that mycorrhiza cause a more balanced development of the plant.

Conclusions

It was determined that no application increased the plant height, but each application had different effects on other plant characteristics. As a matter of fact, the results obtained from vermicompost application are interesting. That is, vermicompost application was found to be effective in increasing the traits that indicate menstruation, such as the flower bud number and the number of leaves, while it was effective in increasing the properties expressed by length, such as flower bud

length, flower length and leaf length. In addition, it was determined that Promalin and Promalin + mycorrhiza applications had a similar effect on plant upper part properties and the applications increased the same properties. Due to this similar effect, it was found that the application of mycorrhiza together with Promalin did not have a different effect than the application of Promalin alone, and even had a lower effect than the application of Promalin alone. Based on the results of the study, it is thought that the application of mycorrhiza together with Promalin will not be beneficial. However, more studies are needed to come to a definite conclusion. As the most effective application of mycorrhiza application compared to other applications, it can be recommended for the development of plant upper part characteristics. However, it is possible to obtain different results in plant development due to the effect of application time and dose on flowering time, especially in flowering plants. As a result, it has emerged in this study that it is important to determine the application time and dose clearly for each plant species and variety.

Conflict of interest

The author declare that they have no conflict of interest.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.