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Influence of Method and Time of Application of Selected Plant Growth Retardants on Growth of Ivy Geranium (P*elargonium peltatum*)

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Abstract

Plargonium peltatumhas a bushy growth habit with few branches, when grown in pots for cuttings, this species will grow rapidly and fall out of the pot. To overcome this problem, growers often use plant growth retardants such as Alar® (Daminozide), Cycocel® (Chlormequatchloride), Bonzi®(Paclobutrazol), and Florel®(Ethephon). This experiment was designed to evaluate the effects of the application method and timing of plant growth retardants on the growth of *Peltatum peltatum* under greenhouse. The research was carried out in a 3 x 2 x 2 factorial experimental design with three replications, in a randomized block design. In the studies, it is clearly seen that significant changes in plant height and main stem diameter are due to the interaction of plant growth retardants with the application method and timing. The shortest plant and the highest stem diameter were recorded in plants treated with Bonzi® impregnated paper in the early growth period. However, using Bonzi® in the drip form will allow you to obtain the most branches in a single tree. The important thing is that Bonzi® was administered because the injection has the shortest internode length. We therefore recommend greenhouse growers to use Bonzi® in infusion form during the active vegetative growth phase.

Keywords: Alar®, Bonzi®, Cycocel®, method and time of application, *Pelargonium peltatum*

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1. Introduction

Geraniums (*Pelargonium)* are a diverse group of plants with a wide variety of growth habits and habitats. This genus includes annual and herbaceous perennials, shrubs and sub-shrubs, and both evergreen and deciduous plants with species that range from 230 and 300 (HSA, 2006). *Pelargonium peltatum* is one of the commonly grown species in commercial nurseries, particularly in plug production systems worldwide. It is a climbing, semi-succulent perennial, trailing through other trees and shrubs in its habitat. This plant is characterized by its long straggling shoots with ivy-shaped leaves, and for this reason, it is called Ivy-leaved Geranium or Ivy-leaved *Pelargonium.* It produces clusters of flowers varying from pale purple or pinkish purple to pale pink or white (Trevor, 2005). There are around five hundred different cultivars of Ivy Geraniums that have been hybridized over the last 150 years (Jeff, 2013).

Pelargonium is one of the most popular floriculture plants throughout the world, with considerable economic importance in the ornamental market (García-Sogo et al., 2012). *Pelargonium* is native to Cape Province in South Africa (Smith, 2010). It is commercially cultivated in France, Belgium, Spain, Morocco, Madagascar, Egypt, Reunion Island, Congo, China, India, and Ethiopia (Jones and Brown, 2015). *Pelargonium* is among the most popular flowering plants grown in the United States as ground beds, planter boxes, hanging baskets, and pot plants (Bodie, 2023). The first planting of high-yielding Pelargonium graveolens, introduced from Reunion Island, was grown at Yercaud by a French planter in the early twentieth century (Taylor, 2012). At the beginning, *Pelargonium* was cultivated as a commercial crop, but only in high-altitude areas with a milder climate. However, the crop also comes up well in the South Indian plains (Ravi et al., 2020). Presently, it is being commercially cultivated mainly in the Nilgiris and Kodaikanal Hills of Tamil Nadu and in and around Bangalore in Karnataka in an area of about 2,000 ha (Kumar and Singh, 2021).

The Ethiopian floriculture industry has been recognized as one of the leading sectors in Africa, particularly known for the export of cut flowers. Ethiopia ranks among the top flower exporters in Africa, with significant contributions to the economy through horticultural exports, particularly roses. The industry has seen substantial growth over the past decade, driven by favorable climatic conditions, government support, and investments in infrastructure. The Ethiopian floriculture industry has expanded rapidly, with thousands of hectares dedicated to flower production. The country is particularly noted for its high-altitude farms that produce high-quality flowers. In recent years, Ethiopia has been a major exporter of flowers to international markets, especially Europe. As of 2023, Ethiopia is often cited as the leading flower exporter in Africa and one of the top five in the world. The country's strategic location and favorable climate contribute to its competitive advantage in the floriculture sector (EHDA, 2023; FAO, 2021).

In recent years, the number of cutting companies that produce small cutting planting materials for plug production schemes has shown a rising trend and is known to be successful in their businesses. Among these, Florensis Ethiopia PLC, Syngenta Ethiopia, Dessa Plant PLC, Maranque Plants PLC, and Red-fox PLC are the most prominent. The main plants produced in these nursery units include Pelargonium, Poinsettia, Chrysanthemum, and Mandevilla.

*Pelargonium peltatum (*Ivy geranium) is one of the species grown for small cuttings production in our country, mainly at Florensis Ethiopia PLC. However, this plant usually grows undesirably long and quickly with poor branching habits, which eventually results in falling over the growing pots (Trevor, 2005; Pobudkiewicz and Treder, 2006; Pobudkiewicz, 2008). To make the plant more compact and branchy, growers regularly use chemical growth retardants, among which Alar® (B-nine) (Daminozide), CCC (Cycocel®) (Chlormequat chloride), Bonzi® (Paclobutrazol), and Florel® (Ethephon) are the most common ones. These plant growth retardants are synthetic compounds that are used to reduce the shoot length of plants to a desired height without changing developmental patterns or being phytotoxic. They are known to inhibit the gibberellin synthesis originating internally. This is realized primarily by reducing cell elongation and by lowering the rate of cell division (Wilhelm, 2016).

The major limitations of the use of chemical growth retardants are associated with determining the right type of chemicals, application methods, and growth stage of treatment for specific crops. The appropriate concentration for respective chemicals also needs to be determined based on the local conditions (Currey and Lopez, 2008; Latimer, 2009).

Growth retardants are highly specific in their effect on plant growth. There is no clear association between taxonomic classification and plant response to a particular compound. Even different cultivars of the same species vary greatly in responsiveness to the applied growth retardant chemical (Dole and Wilkins, 2005). So, growers should fine-tune the application of growth retardants to specific plant species and agro-ecological conditions. In this regard, the cutting companies of our country are working without specific recommendations because of the absence of research backup. Due to this fact, growers usually fail to bring their cuttings into market destinations with the required quality standards (Ismael, 2016, personal communication). Thus, this experiment was initiated to identify the appropriate time and method of application of selected plant growth retardants on the growth of *Pelargonium peltatum* in greenhouse conditions.

Specific objectives

1. To assess the impact of different application methods (foliar spray, soil drench) and timings (early and active vegetative stage) of selected plant growth regulators (PGRs) such as Alar, Cycocel, and Bonzi on the growth performance and branching habit of ivy geranium.

2. To identify the most effective PGR, application method, and timing for enhancing the growth and development of ivy geranium.

3. To evaluate any potential harmful effects of the PGR treatments on ivy geranium plants.

2. Materials and Methods

The experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM), under greenhouse conditions. JUCAVM is found in Jimma town, which is 355 km southwest of Addis Ababa, located at about 7^0 40′N latitude and 36^0 50′ E longitudes with an altitude of 1780 meters above sea level. The area has maximum and minimum temperatures of 26.80°C °C and 11.40°C respectively. The mean maximum and minimum relative humidity are known to be 91.40% and 39.92% respectively (Woldu *et al*., 2015). The mean maximum and minimum temperatures of the greenhouse where the study was executed were 35 °C and 20°C and the mean maximum and minimum relative humidity were 83% and 40% respectively.

The rooted cuttings used for the experiment were brought from Koka Florensis Ethiopian Private Limited company, which is located at Koka town, South-central Ethiopia, 110 km away from the capital city, Addis Ababa. In the propagation unit, at Florensis Ethiopia plc., the rooted cuttings were raised at a temperature and relative humidity in the range of 24°C to 29°C and 75 to 85%, respectively, using Computerized Greenhouse Systems (Private Greenhouse Systems).

Properly packed 300 rooted cuttings of *Pelargonium peltatum* were used as the test crop, and the required amounts of chemical growth retardants for the experiment (50ml Alar®, 50ml Cycocel®, and 50g Bonzi®) were transported from Koka Florensis Ethiopian plc., nursery site to Jimma University College of Agriculture and Veterinary Medicine with the recommended caution procedures. The targeted crop species were selected based on the company's recommendation, taking into account their popularity in the international market. For repotting the received rooted cuttings, plastic pots with a 2-liter volume capacity were purchased from Jimma city. A mixture of forest soil, sand, and manure at a 3:1:1 ratio was used as a growing medium. For spraying the Plant growth retardant solutions, three hand sprayers with a holding capacity of 1000 ml were utilized.

In this experiment, three types of Plant growth retardants, Alar®, Cycocel®, and Bonzi®, were used at recommended rates. For this experiment, 1000ppm of Alar®(Daminozide), 1000ppm of Cycocel® (Chlormequat chloride), and 15ml of Bonzi®
(Paclobutrazo) were used (Latimer, 2009; Douglas and Brian, 1998; Brian, 2013). Two application methods of Plant growth retardants (spray and drench) and two stages of applications (at their early and active vegetative stage) were combined in a 3x2x2 factorial arrangement with three replications in Randomized Complete Block Design (RCBD). For this experiment Early Stage is when 50% of the

repotted root cuttings develop 4 new leaves per plant, and the Active Vegetative Stage is when 50% of the repotted root cuttings develop 2 branches per plant.

The spacing between blocks, plots, and pots was maintained at 50 cm, 25 cm, and 10 cm, respectively. Each of the twelve treatment combinations was applied as per the set arrangement for three consecutive weeks. Two weeks after the last treatments, data was collected to investigate the influence of the applied treatment combinations. Accordingly, plant height, main stem diameter, internode length, number, and branches per plant were determined as

i. **Plant height (cm):** The height of the main stem was measured from five randomly selected plants starting from the crown (the point where the root and stem join) to the uppermost part of the plant using a standard ruler at the flowering stage (when 50% of the plants open their flower).

ii. **Main Stem Diameter (mm):** Stem diameter of the main stems of the sampled three plants was measured just 5cm above the surface of the media using a digital Caliper, and the average data was recorded at the flowering stage (when 50% of the plants open their flower).

iii. **Inter-node Length (cm):** The length between two nodes of the main stem was measured using a standard ruler from three randomly selected plants by taking the average length between two successive nodes starting from the second node of the bottom of the plant at the flowering stage (when 50% of the plants open their flower).

iv. **Number of Branches per Plant (number):** The number of main branches was counted from five randomly selected plants at the flowering stage (when 50% of the plants open their flower).

The collected data of all parameters of the experiment were subjected to the Analysis of Variance (ANOVA) using SAS computer software (version 9.3). Least significant difference (LSD) procedures at a 0.05 probability level of significance were used to find out differences between treatment means. In addition to ANOVA Pearson's correlation coefficient was used to determine the strength of association between evaluated parameters in the experiment.

3. Results and Discussion

3.1. Plant Height

The application of chemical plant growth retardants (PGRs) on the height of *Pelargonium peltatum* was highly significant ($p < 0.01$); however, method of application and time of application were nonsignificant (p> 0.05) on plant height of the test plant. All the two-way interactions and the three-way interactions were highly significant (p< 0.01) on this parameter.

About plant height, there was a highly significant variation attributable to the interaction effect of plant growth retardants, method of application, and time of application, and the result depicted in Figure 1 indicates that all the treatment combinations suppressed the height as compared to the control. The maximum height of the test plant (43.47 cm) was recorded from plants that were not treated with plant growth retardants, while the minimum height (12.00 cm) was recorded from plants treated with Bonzi in drench form at the early growth stage of the plant.
This may be due to the slow absorption of Bonzi® into the tissues through the medium used as a ba
th compared to other treatments, resulting in a longer recovery period, affecting the internode lengt
h and ultimately the plant height (Boldt, 2008). Internode and stem elongation are largely controlled
by the hormone gibberellin,
and plant growth retardants are known to inhibit the biosynthesis of these chemicals in cells (Carva
lho et al., 2008).

The results of this study are consistent with the findings of Harry and Stephen (2001), who reported
that plants treated with Bonzi® irrigation had the highest plant density, while plants not treated wi
th Plant Growth Flame Retardant had the highest plant growth. Similarly, Jain *et al.* (2014) reported that a significant dwarfing effect was observed on *Bougainvillea* spp treated with Bonzi® and Alar® in the form of foliar spray. Dogra (2013) also observed significant differences in plant height of *Primula malacoides* due to the application of Bonzi® and Alar®.

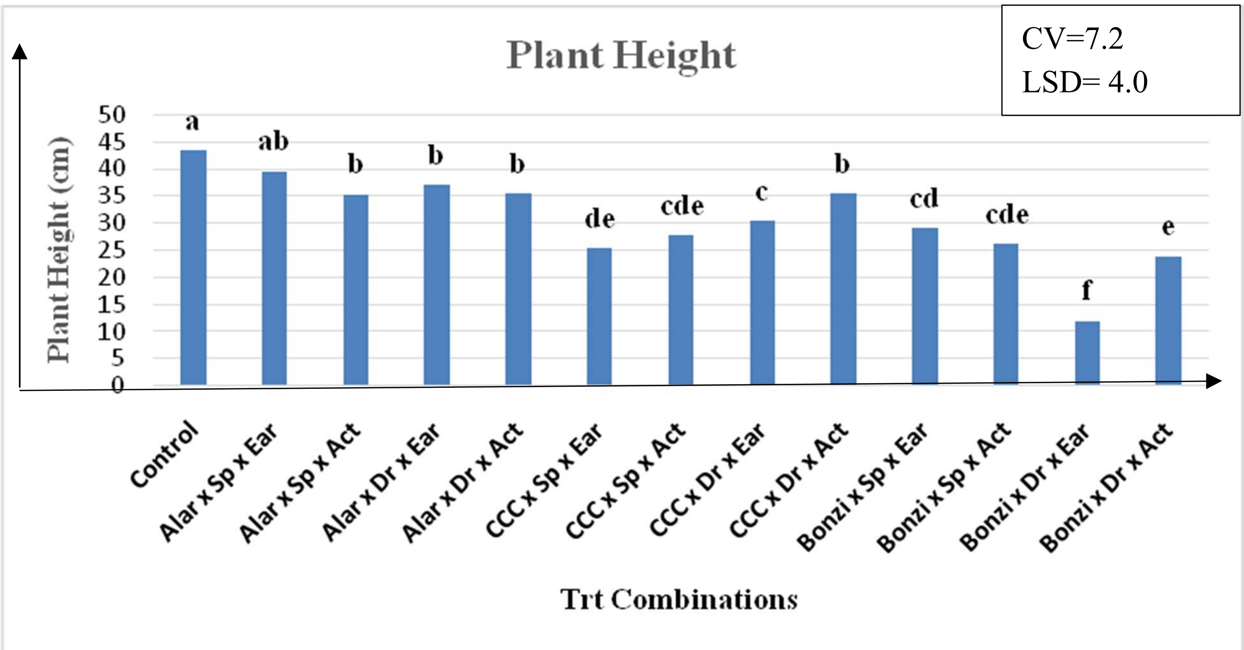

Figure 1. Means for plant height as influenced by the interaction of selected Plant Growth Retardants, Method, and Time of Applications. Means followed by different letters differ significantly at the 5% level of probability; Ear = Early growth stage; Act = Active growth stage; Sp = Spray application; Dr = Drench application.

3.2. Main Stem Diameter

A highly significant (P<0.01) interaction effect was detected among treatments when referring to the main stem diameter. Accordingly, the highest main stem diameter (3.5 mm) was recorded from plants treated with Bonzi® applied in drench form at the early growth stage. A similar scenario was also observed from test plants treated with Cycocel® applied in spray form at the early stage of growth. This value, however, is not statistically different from the application of Alar® in drench form at the early stage of growth (3.2 mm). Conversely, the lowest main stem diameter (1.1 mm) was obtained from plants that were not treated with the tested plant growth retardants (Figure 2). This result may be related to the reduction of internode length and plant height, resulting in an acceleration of cell division and expansion (Blanchard et al., 2008). Cell production in the cambium, when complemented by a delay in cell differentiation and an increase in cell volume of the parenchymatous cortical reaction due to the interference of plant growth retardants, may result in a thickened stem (Ismael Y. *et al.*, 2013). The result of this finding conforms with the findings of Asgarian et al (2013), who experimented on the effects of Bonzi® and Cycocel® for height control of *Zinnia*. The authors reported that all Bonzi® treatments caused a significant increase in main stem diameter as compared with Cycocel® treatments. Mansuroglu et al (2009) also reported that Bonzi® increased the stem diameter of *Consolida orientalis*. Harry and Stephen (2001), on the contrary, reported that *Pelargonium* treated with six known plant growth retardants exhibited lower stem diameter as compared to untreated ones.

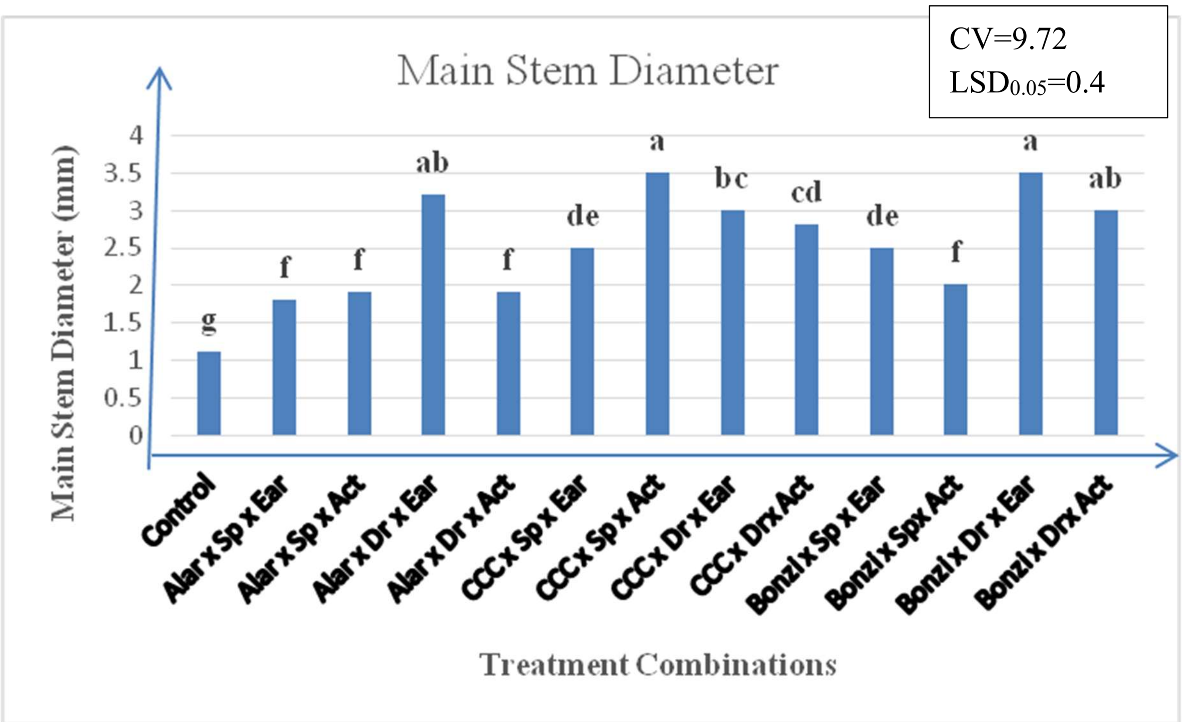

Figure 2. Means for main stem diameter as influenced by the interaction of selected Plant Growth Retardants, Method, and Time of Applications. Means followed by different letters differ significantly at the 5% level of probability; Ear = Early growth stage; Act = Active growth stage; Sp = Spray application; Dr = Drench application.

3.3. Internode Length

This experiment also discovered the significant interaction effect between the tested growth retardants and methods of application concerning internode length ($p< 0.05$). Consequently, the maximum length of the internode (4.23 cm) was obtained from non-treated plants, whereas the minimum length (2.17 cm) was from plants treated with Bonzi® in drench applications (Table 1). The possible reason for this might be associated with the growth-regulating property of Bonzi®which is known to change the synthesis of plant hormones by inhibiting gibberellin and elevating cytokinin levels, resulting in the reduction of internode and stem elongation. Moreover, Bonzi® is more effective when applied to the growing media in the form of a drench by allowing longer absorption time than foliar spray (Boldt, 2008; Bizuayehu and Getachew, 2021). The result of this finding agrees with the report of Dogra (2013), who confirmed that the application of Bonzi® and Alar® on *Primula malachites* revealed a significant reduction in inter-nodal length.

Table 1. Interaction effects of selected plant growth retardants and method of application on internode length (cm) and number of branches per plant

Plant growth retardants X method of application	Mean-internode length (cm)	Mean number of branches per plant
Control	4.23^{a}	1.87^{c}
Alar® x Sp	2.90^{b}	4.17^{b}
Alar® x Dr	2.92^{b}	4.27^{b}
Cycocel® x Sp	2.77^{b}	4.30^{b}
Cycocel® x Dr	2.73^{b}	4.93^{b}
Bonzi® x Sp	2.95^{b}	4.70^{b}
Bonzi® x Dr	2.17^{c}	6.20^{a}
$LSD_{0.05}$	0.40	0.92
CV (%)	7.60	13.66

Means followed by different letters differ significantly at the 5% level of probability; Sp = Spray application; Dr = Drench application.

3.4. Number of Branches per Plant

In terms of the number of branches per plant, the two-way interaction between the plant growth retardants and application method,
and between the application method and the application time was found to be significant ($p < 0.01$).

In the interaction of chemical and method of application, the highest number of branches (6.20) was recorded from plants treated with Bonzi in drench form, and the lowest number of branches (1.87) was obtained from plants that were not treated with plant growth retardants (Table 1). In case of the interaction between method of application and time of application, the highest number of branches (4.47) was recorded from plants treated in the drench application of PGRs at the early growth stage of the test plant. This result was not statistically different from the drench application of PGRs at the active vegetative state (4.17) and spray application of PGRs at the active vegetative state (4.20). The lowest number of branches (3.32) was obtained from plants treated with spray application of PGRs at the early growth stage of the test plant. This result was also not statistically different from the drench application of PGRs at the active vegetative state (4.17) and spray application of PGRs at the active vegetative state (4.20) (Table 2). This increase in the number of branches per plant might be due to the ability of PGRs to increase the branching habit of plants (Li, 2013).

The result of this finding is in agreement with Youssef and El-Aal (2013), who investigated the effect of Bonzi and CCC on potted *Tabernaemontana coronaria*, and the authors reported the same trend of results that Bonzi plant growth retardants increased the number of branches per plant, and CCC gave the best results, followed by Bonzi. The result of this finding is also in line with the findings of Shanan and Soliman (2011), the authors reported that application of Bonzi increased the number of branches on snapdragon plants.

Table 2. Interaction effects of application methods and time of applications on the number of branches per plant

Interaction	Mean number of branches per plant
Control	1.87^{c}
Dr x Ear	4.47^{a}
Dr x Act	4.17^{ab}
Sp x Ear	3.32^{b}
Sp x Act	4.20^{ab}
$LSD_{0.05}$ = 0.92	
CV (%) = 13.66	

Means followed by different letters differ significantly at the 5% level of probability; Sp = Spray application; Dr = Drench application.

3.5. Correlation Coefficient

Pearson's correlation coefficient was used to determine the association among evaluated parameters, including branch number per plant, plant height, internode length, and main stem diameter of the test plant. The number of branches per plant was highly significant and negatively correlated with plant height (-0.80**) and internode length (-0.90**). Conversely, the number of branches per plant revealed a strong positive association with main stem diameter (0.83**). In addition, plant height was highly significant and negatively correlated with main stem diameter (-0.73**). The reduction in plant height and internode length can be associated with the ability of the tested plant growth retardants to inhibit apical dominance by altering the synthesis of indigenous plant hormones, in particular gibberellins (Table 3). This phenomenon contributed to the increment of branch numbers per plant and main stem diameter (Bizuayehu and Getachew, 2021; Jain *et al.,* 2014; Yassin *et al.*, 2013; Boldt, 2008).

Table 3. Correlation coefficients among evaluated parameters

	BN	PH	IL	MD
BN	1	-0.80**	-0.90**	0.83**
PH		1	0.80**	-0.73**
IL			1	-0.79**
MD				1

Where, * Significant at P< 0.05, ** significant at P<0.01, BN=Number of Branches per Plant; PH=Plant Height; IL=Inter-node Length; MD=Main Stem Diameter.

4. Conclusion

This study verified the existence of a valid influence on most of the evaluated parameters of *Pelargonium peltatum*. Subsequently, significant variations were observed from plant height and main stem diameter, attributed to the interaction effect of plant growth retardants and their method and time of application on *Pelargonium peltatum*. The shortest plant height (12.00 cm) and highest main stem diameter (3.5 mm) were recorded from plants treated with Bonzi® in drench form at the early growth stage of *Pelargonium peltatum*. Whilst the application of Bonzi® in drench form resulted in the highest number of branches per plant (6.20) of the test plant *Pelargonium peltatum*. With respect to internode length of Pelargonium *peltatum*, highly reduction was detected from Bonzi® applied in drench form (2.17 cm). Commercial nurseries that specialize in producing small cuttings and plugs are always striving to make their stock plants compact and branchy with thick stems in order to supply maximum saleable products with the desired quality standards. To this effect, application of Bonzi® in drench form at the active vegetative growth stage can be recommended for our greenhouse growers, though further multi-locational and multi-seasonal studies may be required to come up with comprehensive suggestions.

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Data availability statement: The data used in the research are taken from the experimental site, and the citations used in the document are well acknowledged.

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