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EVALUATION OF SOME GERANIUM CULTIVARS GROWN UNDER GREENHOUSE CONDITIONS

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Abstract

Geranium is one of the most valuable ornamental plants in commercial floriculture, appreciated all over the world, for its beautiful flowers in a wide variety of colours, decorative foliage, and abundant and continuous flowering from late spring to autumn. It is used in pots and planter boxes on patios, porches, or balconies, where it creates an impressive visual impact, as well as in flowerbeds and borders in gardens, but it can also be cultivated indoors. The research was conducted to evaluate the main growth and flowering characteristics of six geranium cultivars grown under greenhouse conditions. The results revealed significant variations between cultivars regarding the morphologically analysed traits. Among the studied cultivars, 'Morning Sun' recorded the maximum values of plant height (31.15 cm) and number of shoots per plant (5.33), 'Abelina' had the largest inflorescence diameter (10.83 cm), while the highest number of flowers in the inflorescence (39.56) was recorded in the 'Calais' cultivar.

Key words*: Pelargonium zonale, growth, flowering, cultivar.*

INTRODUCTION

Geranium (*Pelargonium zonale* (L.) L'Hér ex Aiton) is an ornamental perennial herbaceous plant belonging to the Geraniaceae family, 30-50 cm tall, with a compact, bushy growth habit and upright, branched, thick, fleshy stems. The leaves are long-petiolate, simple, alternate, velvety, slightly pubescent, round-reniform, with wavy edges and a narrow, distinctive dark green or brown band in the middle of the blade, more or less evident. The single, semi-double or double flowers grouped in large, dense, ball-shaped umbels on a long peduncle can be white or in various shades of pink, red, orange, and purple. Some varieties have bicoloured, particularly attractive flowers. Flowering usually occurs from spring to autumn. Geranium is an essential crop in commercial floriculture, providing significant economic benefits for growers and breeders (Rohith et al., 2024). New valuable cultivars are developed and introduced to the market every year, being appreciated for their various characteristics, such as the abundance and colour of flowers, attractive foliage, compactness, uniformity, long flowering period, high productivity, adaptability to both indoor and outdoor conditions, and ease of cultivation.

Geranium requires nutrient-rich, moist, well-drained soils and is sensitive to excessive humidity. Zonal geranium prefers slightly acidic soil (pH 5.8-6.5). Andrews & Hammer (2006) recommend a root medium pH of 6.4-6.5 for the greenhouse production of some geranium species. Kanwar et al. (2024) noticed that the best potting medium for producing high-quality zonal pelargonium plants is a combination of cocopeat + soil + farmyard manure (FYM)+leaf mould (2:1:1:1). Compost produced from various selected green waste or other agro-industrial by-products, as well as biochar, can be used in the preparation of growing media for geranium crops as a substitute for peat, which is the most common substrate used in floriculture, but is very expensive and non-renewable (Ribeiro et al., 2000; Conversa et al., 2015; López-Cuadrado et al., 2008; Massa et al., 2018; Gong et al., 2018; Zawadzińska & Salachna, 2018; Bonaguro et al., 2021). It grows and blooms best in full sun and can tolerate partial shade; however, prolonged periods without adequate sunlight may affect plant development, leading to elongated stems and reduced flowering. In temperate climates, it is grown as an annual plant or can be brought indoors over winter in a bright, sunny location, as it does not tolerate frost. Khattak et al. (2011) showed that light

quality, as well as temperature, has a substantial effect on the growth and flowering of geraniums.

Geranium can be easily propagated by seeds and vegetatively by cuttings taken in spring or late summer from healthy, vigorous plants and rooted in growing media such as peat moss, sand, or perlite. Unrooted pelargonium cuttings can be stored in paper pots maintained in greenhouses at low temperatures for up to two weeks after delivery, without compromising rooting efficiency (Szewczyk-Taranek et al., 2025). Mamba & Wahome (2010) recommend sand and a mixture of garden soil, compost, and sand for the commercial propagation of geraniums. Mutui et al. (2010) revealed that ethylene significantly increased the rooting percentage of cuttings in the two cultivars of *Pelargonium zonale* studied ('Greco' and 'Surfing') but had no effect on total root length. Kutsher et al. (2022**)** reported that applying mild water stress to stock plants improved the rooting ability, quality, and chlorophyll content of cuttings in some *Pelargonium* cultivars. Khenizy (2016) showed that spraying rooted cuttings with GA_3 at 200 mg/L before planting and storing them for four days at 5°C in imperforated polyethylene bags improved vegetative growth, flowering, and root growth parameters of *Pelargonium zonale* cv. 'Belmonte Red'. Numerous studies have investigated the in vitro regeneration potential of some geranium species and cultivars using different combinations of growth regulators, media, and culture conditions, as well as various types of explants such as cotyledon, hypocotyl, and root (Qureshi & Saxena, 1992; Chang et al., 1996; Murthy et al., 1996; Haensch, 2004; Madden et al., 2005), leaf blade and petiole (Agarwal & Ranu, 2000; Hassanein & Dorion, 2005; Winkelmann et al., 2005), and bud (Alavijeh et al., 2025).

An adequate fertilization program for geraniums during commercial production and the growing season is extremely important for promoting vigorous plant growth and prolonged, abundant flowering. Gaber (2019) reported that the application of mineral fertiliser NPK (6 or 12 g/plant) monthly, combined with foliar application of ascorbic acid (200 or 400 mg/L), improved the vegetative and flowering growth characteristics of *Pelargonium zonale* plants. Hamid & Imhmd (2024) showed that spraying 150 mgl^{-1} salicylic acid (SA), combined with the monthly application of NPK fertiliser (3 g/plant), during the geranium growing season, led to a significant increase in most of the studied parameters. Nutrient solution concentration and the type of irrigation system used affect the growth and development of geraniums grown in closed soilless systems (Rouphael et al., 2008; Cardarelli et al., 2012). The typology of the soilless system significantly enhances the commercial characteristics of plants. Thus, by using a cultivation system with continuous fertigation on the substrate (peat) and drip irrigation, more attractive geranium plants for the market can be obtained (Brentari et al.; 2020). Morrison et al. (2024) showed that using timer-based controlled irrigation systems programmed to irrigate for 1 minute in the morning, with 6 g controlled-release fertiliser (Osmocote Plus), resulted in increased plant growth and flower production, as well as more efficient water utilisation in potted geraniums.

To obtain attractive potted ornamental plants with a compact, dense and bushy appearance, preferred by consumers, commercial growers use pinching and the application of chemical growth retardants. Tayama & Carver (1990) reported that effective control of geranium plant height, without affecting the number of inflorescences, was achieved by spray application of certain growth regulators, whereas drench application severely restricted growth and reduced the number of inflorescences. Hamza et al. (2007) concluded that foliar spraying of 75 ppm paclobutrazol applied twice may be recommended for obtaining compact geranium plants, with dark green leaves and earlier flowering. Pinching and spraying of *Pelargonium zonale* plants with 60 ppm paclobutrazol promoted branching and increased stem diameter, the number of leaves, and the number of flowers per plant (Abd El-Aal & Mohamed, 2017). Paclobutrazol combined with supplemental lighting enhanced compactness in geranium seedlings (Collado et al., 2022). El-Sayed et al. (2023) recommend the application of vermicompost at 10 g/pot as a soil amendment and foliar treatments with 1000 mg/L benzyladenine (BA) to improve rooting, vegetative growth, and flowering of *P.*

zonale plants. Exogenous treatments with plant growth regulators such as thidiazuron and gibberellic acid improved chlorophyll biosynthesis, increased net photosynthesis, and reduced leaf yellowing in potted geranium plants (Toscano et al., 2018).

Pelargonium zonale is cultivated in pots and window boxes, on balconies and terraces, and is appreciated due to its hardiness, abundant blooming, ease of cultivation, and availability in a wide range of cultivars with varied flower colours (Krzymińska et al., 2020). This versatile plant is also used in flowerbeds, borders, and along pathways, in combination with other annual or perennial ornamental plants, to create attractive and harmonious floral compositions in gardens (Nooh et al., 2015), and as an indoor plant or even as a cut flower. Geraniums contain active substances with biological and pharmacological activities, such as antibacterial and antioxidant (Iancu et al., 2023; Harzallah et al., 2022; Celi et al., 2024), antimicrobial (Koheil et al., 2012), antifungal and anticancer (Saraswathi et al., 2011; Lewtak et al., 2014), hemostatic (Páez & Hernández, 2003), anti-inflammatory, and many other properties (Matarrita Brenes et al., 2024). Numerous studies have indicated that Pelargonium leaf extracts, due to their various natural bioactive compounds, can be used for the synthesis of selenium, gold, cerium dioxide (CeO_2), zinc oxide (ZnO), silver nanoparticles by several physical, chemical, and biological methods (Jafarizad et al., 2015; Mohammadlou et al., 2017; Rivera-Rangel et al., 2018; Fardsadegh et al., 2019; Vahidi et al., 2019; Mahabadi et al., 2021; Abdelbaky et al., 2022; Lopez-Ayuso et al., 2023). Nanoparticles have unique physicochemical properties, which allow their use in various biomedical applications. The objective of this study was to evaluate several geranium cultivars under greenhouse conditions based on growth and flowering parameters.

MATERIALS AND METHODS

The research was conducted on six geranium cultivars with different flower colours, namely 'Clara' (white), 'Abelina' (dark red), 'Calais' (salmon pink), 'Spanish Wine Rose' (rose-pink), 'Morning Sun' (orange) and 'Ellen' (violet), in the Floriculture Research Area of the Faculty of Horticulture, University of Craiova, in order to analyse their growth and flowering performance under greenhouse conditions. The plant material consisted of high-quality young plants obtained from cuttings and was purchased from the company Gruppo Padana (Italy). The plants were transplanted in February 2024 into plastic pots with a diameter of 12 cm (one plant per pot), using as a growing substrate a mixture of peat and perlite (2:1), and a slow-release fertiliser (Osmocote) was applied. The ambient temperature inside the greenhouse ranged from 20-22°C and the relative humidity was 50-60%. The experiment was carried out using a randomized complete block design with three replications. Observations were made at the full flowering stage on growth parameters (plant height, number of branches and leaves per plant, leaf length and width) and flowering parameters (number of inflorescences per plant, inflorescence diameter, number of flowers per inflorescence, flower diameter), which were measured and recorded for each cultivar. All experimental data were statistically analysed using one-way analysis of variance (ANOVA), followed by Duncan's Multiple Range Test at a significance level of $p \leq 0.05$, in order to determine significant differences among the studied cultivars.

RESULTS AND DISCUSSIONS

Vegetative growth parameters

The results regarding the growth performance of the six geranium cultivars under greenhouse conditions are presented in Table 1. According to the obtained data, there were significant differences among the analysed cultivars in terms of plant height. The maximum value of this parameter was recorded in 'Morning Sun' (31.15 cm) followed by 'Abelina' (29.56 cm), while 'Spanish Wine Rose' had the lowest value (23.78 cm). A significant variation was also observed in the number of branches per plant, which was highest in 'Morning Sun', with an average of 5.33 branches per plant, compared with the other cultivars. The lowest value was obtained in 'Calais', with an average of 2.71 branches per plant. Plant growth and development are influenced by a complex

interaction of multiple genetic and environmental factors (light, temperature, humidity, water and nutrient availability, soil quality, etc.) (Vagner, 2025). Variations in vegetative characteristics, such as plant height, leaf size, and shape, are due to the influence of these factors.

The number of leaves per plant and leaf morphological traits (length and width) differed significantly among the studied cultivars. The mean data indicate that the maximum number of leaves per plant was recorded in 'Clara' (38.75), while the minimum number of leaves was observed in 'Calais' (25.46). In terms of average leaf size, the cultivar 'Abelina' showed the highest values for both leaf length (7.25 cm) and leaf width (8.31 cm), whereas 'Spanish Wine Rose' had the lowest values for leaf length (5.00 cm) and leaf width (6.22 cm), respectively. Leaf colour ranged from light green in 'Calais' and 'Morning Sun' to dark green in 'Abelina', 'Clara', and 'Spanish Wine Rose' cultivars.

Table 1. Evaluation of vegetative parameters of geranium cultivars under greenhouse conditions

Cultivar	Plant height (cm)	Number of branches per plant	Number of leaves per plant	Leaf length (cm)	Leaf width (cm)
Abelina	29.56 ab	3.48 bc	32.33 bc	7.25 a	8.31 a
Calais	26.83 bc	2.71 c	25.46 e	5.92 bc	7.28 ab
Clara	24.61 c	4.12 b	38.75 a	6.33 ab	7.16 ab
Ellen	27.92 b	4.26 ab	34.51 b	5.76 bc	6.95 ab
Morning Sun	31.15 a	5.33 a	30.82 cd	6.14 b	7.43 ab
Spanish Wine Rose	23.78 c	3.25 bc	27.66 de	5.00 c	6.22 b
Mean	27.31	3.86	31.59	6.07	7.23

Means with same letter(s) in a column are statistically non-significant at the 5% significance level according to Duncan's multiple range test.

Flowering parameters

The data recorded for flowering characteristics are shown in Table 2. Significant differences were found among the six cultivars for three parameters (number of inflorescences per plant, inflorescence diameter, and number of flowers per inflorescence).

The number of inflorescences per plant ranged from 3.14 to 6.33. The highest value for this parameter was observed in 'Ellen', while the 'Abelina' cultivar presented the lowest number of inflorescences per plant.

Regarding the average inflorescence diameter, the highest values were recorded in 'Abelina' (10.83 cm) and 'Clara' (10.66 cm) compared with the other cultivars. The minimum value was obtained in 'Spanish Wine Rose', whose inflorescences had an average diameter of 8.91 cm. The number of flowers per inflorescence varied depending on the cultivar. Statistical analysis revealed that there were no significant differences among cultivars with respect to flower diameter.

Table 2. Evaluation of flowering parameters of geranium cultivars under greenhouse conditions

Cultivar	Number of inflorescences per plant	Diameter of inflorescence (cm)	Number of flowers per inflorescence	Diameter of flower (cm)
Abelina	3.14 b	10.83 a	22.41 cd	4.76 a
Calais	3.45 b	10.31 ab	39.56 a	4.38 a
Clara	4.18 b	10.66 a	18.35 e	4.53 a
Ellen	6.33 a	9.12 b	17.68 e	4.16 a
Morning Sun	4.27 b	9.75 ab	33.16 b	4.22 a
Spanish Wine Rose	3.62 b	8.91 b	21.82 d	4.13 a
Mean	4.17	9.93	25.50	4.36

Means with the same letter(s) in a column are statistically non-significant at the 5% significance level according to Duncan's multiple range test.

Flower colour is an important quality feature that directly influences the aesthetic and commercial value of ornamental plants. It is primarily determined by pigments such as flavonoids, carotenoids, and alkaloids and is influenced by several internal and external factors (Zhao & Tao, 2015). The wide range of flower colours is mainly due to differences in pigment composition and concentration. Tilney-Bassett et al. (1995) reported that the interaction of two complementary genes (R1/r1 and R2/r2) controls the inheritance of red flower colour in zonal pelargoniums. Flower colour is salmon (when R2 is present and R1 is absent in the genotype of a plant's genotype), rose-pink (when R1 is present and R2 is absent), and soft-pink (when both R1 and R2 are absent). Flower colour, along with other quantitative and qualitative morphological characters, is essential in the development of new cultivars in *Pelargonium*.

The evaluated geranium cultivars exhibited various flower colours, ranging from white ('Clara'), salmon pink ('Calais'), rose-pink ('Spanish Wine Rose'), orange ('Morning Sun'), dark red ('Abelina') to violet ('Ellen').

CONCLUSIONS

The results revealed that the geranium cultivars showed significant variation in all analysed growth and flowering parameters, except for flower diameter. 'Morning Sun' recorded the highest values for plant height and number of branches per plant, 'Ellen' stood out for the greater number of inflorescences per plant, while 'Abelina' and 'Clara' had the largest inflorescence diameter. 'Calais' performed best in terms of number of flowers per inflorescence. Due to their special decorative qualities and abundant flowering, the studied cultivars can be used as indoor potted plants, as well as for decorating balconies, terraces, and windows in urban spaces.

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