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GROWTH ANALYSIS OF *Cineraria maritima* PLANTS IN GREEN FAÇADE SYSTEMS: NORTHEASTERN ROMANIA CLIMATE STUDY

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ABSTRACT. Green façades are gradually gaining popularity and may become a modern architectural solution for higher microclimate quality and better urban comfort in densely populated urban areas. This study aimed to monitor the behaviour of *Cineraria maritima* planted in green façade systems oriented towards four cardinal points in the specific climatic conditions of northeastern Romania in order to test its adaptability and growth in this system. Comparisons were made of its behaviour between the façades of the experimental structure, and between the façades of the experimental structure and the traditional 'planted in soil' variant (control variant). *Cineraria maritima* exhibited good adaptability to vertical cultivation, maintaining its aesthetic properties throughout the growing season. All specimens that overwintered on the façades successfully survived the cold season of 2021–2022 without requiring any cutting or protection measures.

Keywords: *Cineraria maritima*; urban design; green façades; vertical decor.

INTRODUCTION

Globally, there has been much interest in creating a more sustainable living environment that could help conserve energy and protect global resources. As buildings consume large amounts of energy (around 40% of the world's energy), there has been increasing focus on green buildings and green façades / as potential solutions for reducing energy consumption in warm and cold climates (Bakhshoodeh *et al.*, 2022a). Air purification, lowering the level of dust and noise, carbon dioxide absorption, and other aesthetic and psychological factors are just a few of the benefits of green façades that lead to better urban landscapes and a higher quality of life in cities (Moghaddam *et al.*, 2020). The thermal conductivity of built surfaces is higher than that of vegetation. This has a negative influence on the urban micro-climate that could be reversed by using green façades, which, through the effect of plant evapotranspiration, can restore the urban hydrological cycle (Bakhshoodeh *et al.*, 2022b). The vegetation layer of green façades also lowers the temperature on the external side of buildings to which they are applied (Moghaddam *et al.*, 2021, Coma *et al.*, 2017).

There are many benefits of green walls, which could be a component of modern urban design (Perini *et al.*, 2011). Human exposure to nature is beneficial for the body and mental health (Hung and Chang, 2021). The introduction of green walls into urban planning may improve environmental sustainability and people's quality of life (Azkorra *et al.*, 2015; Yang and Jeon, 2020). When green walls are optimized for their location and microclimate, in addition to increasing visual comfort, they can significantly lower noise and air pollution (Guo *et al.*, 2021; Liu *et al.*, 2021). Also, these green systems provide additional promising opportunities for getting higher biodiversity in cities (Benvenuti, 2014; Mayrand and Clergeau, 2018). To create a green wall with the most benefits, several issues should be taken into account, such as their structure, the selection of plants able to survive seasonal changes in climate, lighting conditions suitable for plant development, and the supply of appropriate amounts of water and nutrients and correct pH levels (Riley, 2017).

To ensure that green façades achieve their intended purpose, the planted species should develop harmoniously, with the preservation of their aesthetic features for as long as possible. They should also have a high degree of coverage, show good resistance to external factors and, importantly, require minimal maintenance.

Environmental factors influence the behaviour of species grown in an open field, therefore prior testing of plant development on vertical structures that cover the façades of buildings under local climatic conditions is needed to be able to create an assortment of plants meeting such requirements.

Cineraria maritima L. (syn. *Senecio cineraria* DC, *Senecio Bicolor* Rchb, *Jacobaea maritima*) is a perennial flowering plant often used in the decoration of parks and gardens as a mosaic plant for floral carpets. *Cineraria maritima* L. shows good adaptability to low temperatures and drought (Toma, 2009). It overwinters in the field but does not survive severe frosts. It prefers light and medium sandy soils with good drainage (Șelaru, 2007). Plant height may vary between 30–60 cm, its diameter reaching 30–40 cm (Draghia and Chelariu, 2011). It blooms in summer and autumn, but the species is more appreciated for the decorative features of its leaves than for its flowers. The lacy shape and the silvery gray colour of the leaves with their special texture (Cantor *et al.*, 2018) and their suitability for trimming make *Cineraria* plants a good choice for marking the contours of various decorative formations (Toma, 2009). It can also be grown in pots and containers for decorating terraces and balconies (Şelaru, 2007; Toma, 2009; Draghia and Chelariu, 2011). *Cineraria maritima* is very tolerant of changes in environmental conditions, maintaining its appearance from transplanting to the first frosts, regardless of the species it is associated with (Enea and Bala, 2012). A study conducted in the region Yazd in Iran reported that it is considered one of the most suitable plants for enhancing green spaces, parks, and urban boulevards, as well as improving air quality in arid and semi-arid areas (Esfandiari *et al.*, 2020).

These features led us to focus on the species *Cineraria maritima* and its inclusion in a preliminary study investigating the behavior of various flower species cultivated in vertical systems for green façades. This study aimed to identify various ornamental species that may be used to decorate green façades in Romania's northeast.

Finding ornamental species able to survive and develop harmoniously year-round in green façades systems has become a real challenge considering the temperate continental nature of the Eastern European climate characterized by temperatures below 18°C in winter, above 35°C degrees in summer and frequent periods of drought (Cojocariu *et al.*, 2022a).

MATERIALS AND METHODS

Study material

The study material was a variety of *Cineraria maritima* (*Figure 1*). The exotic allure conferred by the lacy shape and silvery grey colour of the leaves, the compact shape of the bushes, constant decorative features over the growing season, as well as its resistance to different environmental conditions make *Cineraria maritima* a perfect choice for decorating public green spaces. The seedlings used for planting were uniform and planted in groups on the sides of an experimental structure built specifically to study the behaviour of vertically planted flower species.

The study was carried out in the experimental field of the Faculty of Horticulture (GPS decimal lat. N 47.1941, long. E 27.5555). The square-shaped experimental module has vertical surfaces oriented towards a cardinal point (*Figure 2*). The façades are identical, being made of four equal layers. The total height of the façades is 2.40 m. The control variant was put in soil near the experimental. The quantity of water distributed on the sides of the experimental structure was equal on each side (25 litres/month). No fertilizers were used in any variant.

A universal substrate containing a mixture of white peat (0–25 mm), white peat bricks (15–45 mm and 25–45 mm) and white peat fibres with a clay content of 20 kg/m^3 was used.

Before planting, the biometric features of *Cineraria* plants were as follows: average diameter = 14.2 cm; average height 14.6 cm; average number of leaves = 17.8; and average number of shoots = 1.9.

After planting, the above-mentioned parameters (diameter, height, number of leaves, number of shoots) were recorded at intervals of approximately 8 weeks.

In the experimental structure, plant diameter was the distance measured between plant extremities, parallel to the façade, horizontally (cm), while plant height was the distance measured perpendicularly to the façade, from the façade to the plant extremity (cm).

The experimental structure was not shaded by other buildings or vegetation and was exposed to the weather conditions typical for the Moldovan plateau during the experimental year. The reference parameters were the annual average temperature (*Figure 3*), quantity of precipitation and average relative humidity (*Figure 4*). The data show that 2021 was a dry year with low precipitation (max 27 l/m^2 on August 19, 2021); the air temperature ranged between – 11.1 ^{0}C on January 19, 2021, and 27.3 ^{0}C on July 18, 2021 (*Table 1*).

On each monitoring date, percentage plant attachment (degree of rooting) was calculated for each variant of the experiment. This showed the percentage of specimens that were successfully transplanted.

To test the overwintering resistance of *Cineraria* plants, especially those planted in vertical systems, they were left in place until the following spring, with half of the plants in each experimental variant being shortened to approximately 15 cm, the other half overwintering without any intervention.

The study was conducted during the year 2021 from the end of May (seedling planting) to the beginning of November 2021. The experiment described herein was part of a larger study initiated in 2019 aimed at identifying a decorative plant variety suitable for use in green façades of buildings situated in eastern European countries. The preliminary phase included monitoring several vertically planted perennial and annual flowering species in order to test their resistance to local climate conditions in different cardinal orientations. When selecting the plants, we considered their vigour, decorative appearance, maintenance needs and resistance to diseases and pests (Cojocariu *et al*., 2022a, b).

Figure 1 – Seedling *Cineraria maritima*

Figure 2 – Experimental structure

Table 1 – Weather conditions during the experiment

	Average air temperature (^{0}C)	Amount of precipitation (l/sqm)	Average relative humidity (%)
Minimum	– 11.10	0.00	48.00
Maximum	27.30	27.00	99.00
Mean	10.29	1.58	75.61
C.I. mean	10.29 ± 0.91	1.58 ± 0.40	75.61 ± 1.14

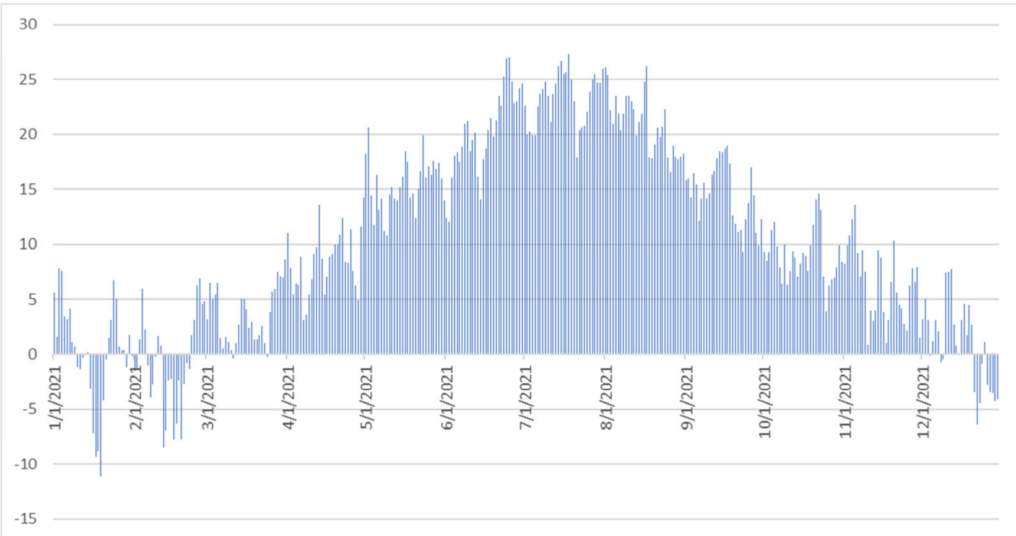

Figure 3 – Average air temperature – year 2021 (^{0}C)

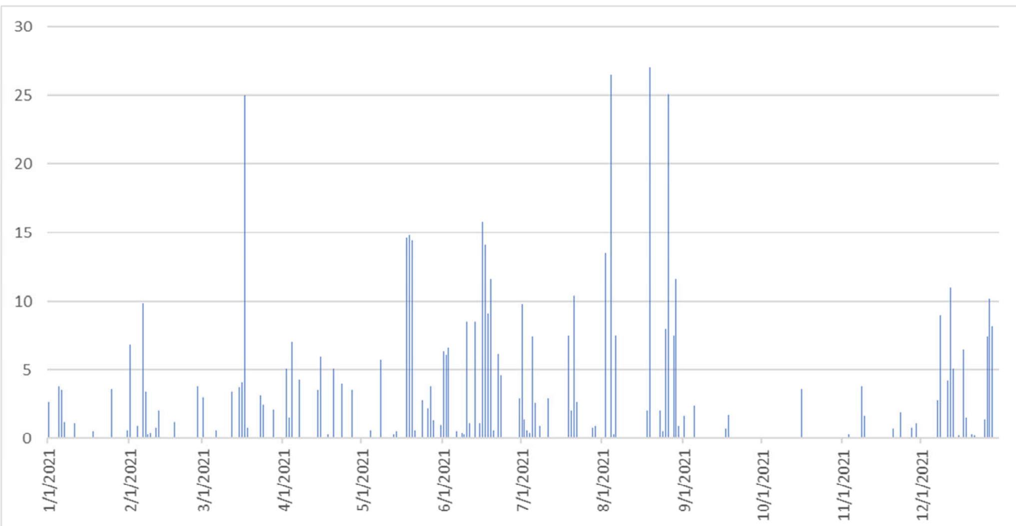

Figure 4 – Amount of precipitation – year 2021 (l/sqm)

Mathematical modelling

To statistically analyse the results we first calculated the mean and confidence interval for each parameter. We compared mean plant diameter (cm) and plant height (cm) to determine if either was influenced by the cardinal orientation of the sides of the vertical system. We conducted a one-way ANOVA to compare the means on each façade. In order for us to run a one-way ANOVA, the sample had to be drawn from a normally distributed population and all populations had to have a common variance.

The Kolmogorov-Smirnov test for normality revealed that the normally distributed population criterion was not met either in the case of plant diameter or plant height (*Figure 5*). We thus performed the nonparametric equivalent to the one-way ANOVA, that is, the Kruskal-Wallis test.

To determine whether the median plant diameter differed depending on the cardinal orientation (or in the control group), we ran a Kruskal-Wallis test using a 0.05 significance level (Bargagliotti and Greenwell, 2015).

The working hypothesis (the null hypothesis H_0) was that the median values of the dependent variables (plant diameter, plant height, etc.) were part of a single population regardless of the independent variable categories (in our case, the cardinal orientation from which the data were collected). The alternative hypothesis (H_1) was that the median of the dependent variable corresponding to each level of the independent variable was part of a different population.

We analysed how different the median of variables measured on the cardinally oriented sides or in the control group should be to be able to accept that they did not come from the first hypothesis population but from four different populations (depending on the cardinal orientation).

H_0 (The null hypothesis) The median plant diameter parameter was the same across the five groups.

H_1 (The alternative hypothesis) At least one of the median plant diameter parameters was different from the others.

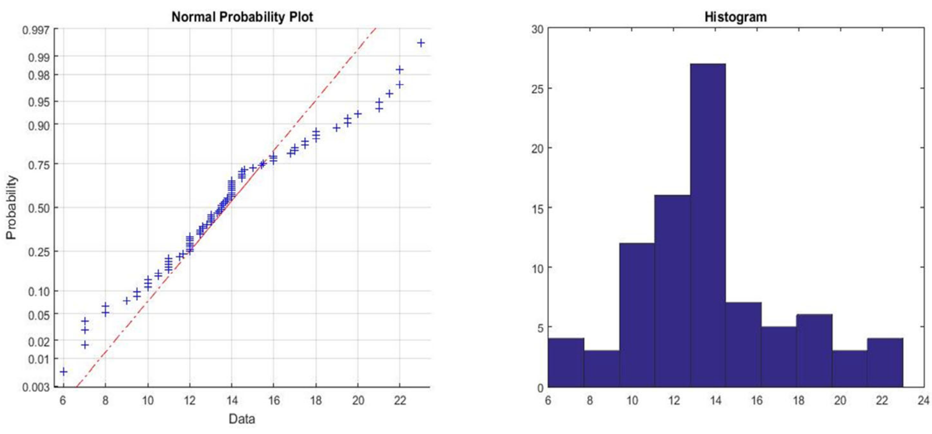

Figure 5 – Kolmogorov Smirnov test for normality

The Kruskal-Wallis test was applied using MatlabR2015a, with a level of significance of 0.05.

The recorded parameters were compared using the statistical description of the values obtained from the measurements and confidence intervals for the means of the measured values.

RESULTS AND DISCUSSION

The plants chosen to cover green walls are a key factor influencing the efficiency of such walls (Sari, 2017). Due to its favourable characteristics, *Cineraria maritima* has been the subject of several studies. For example, its ability to reduce noise was tested under laboratory conditions in a reverberation chamber. Due to its leaf shape and surface softness, it was expected that it would have noise reduction properties, and this was confirmed by the tests (Chang and Chang, 2022). Another study of 11 Mediterranean species, including *Cineraria maritima*, was carried out in order to improve the biodiversity of green roofs and expand the number of plant species that can be cultivated on their surface. *Cineraria maritima* was among the best surviving species in the 10 and 15 cm sublayers. The study was conducted under a temperate climate in Melbourne, Australia (Guo *et al.*, 2021).

As it is able to capture particles of matter with its pubescent leaves, *Cineraria maritima* was one of the species analysed in a preliminary study looking into the use of medicinal and decorative plants in peri-urban gardens with an environmental protection role (Hangan *et al.*, 2020). In 2007, it was planted along with other species on an experimental green wall placed on the itd-UPM building (Madrid) in a study conducted to estimate the amount of irrigation water needed for green walls (Segovia-Cadozo *et al.*, 2018).

The current study focused on the behaviour of *Cineraria maritima* planted on a vertical system. In July, on the first monitoring date, in addition to biometric parameters (plant diameter, plant height, number of leaves, and number of shoots), we also calculated the percentage plant attachment for all experimental variants. In the control variant, the percentage plant attachment was 100%. On the sides of the experimental structure, the highest percentage attachment was on the east-facing façade, where it amounted to 95.45%, with the lowest of 89.47% being recorded on the west-facing façade. The other two orientations reached 90.47% (south) and 94.11% (north).

On the north and south sides of the experimental module and on the control variant, later losses were small, with the percentage plant attachment varying between 73% and 85% at the beginning of November. Most losses were on the western façade, where the percentage plant attachment recorded on the last monitoring date was a little over 30% of the number of originally planted specimens.

For each monitoring date (July, September, and November), we calculated the confidence intervals of the monitored parameters using data from the measurements with a confidence level of 0.95, matching the significance threshold of 0.05 (*Table 2*, *Table 3* and *Table 4*).

In July, a comparison of all five variants (control, north, east, south, and west) showed that all four biometric parameters had the highest mean values in the control variant. Comparison of the module sides with each other revealed different patterns of variation in the mean values of parameters. For example, plant diameter had mean values between 12.40 cm on the western side and 13.79 cm on the southern side (*Figure 6a*). For plant height, the mean values ranged between 11.68 cm and 12.61 cm on the western and northern sides, respectively (*Figure 7a*).

Regarding the other two parameters (number of leaves and number of shoots), the lowest and highest mean values were observed on the eastern and southern orientations, respectively (*Table 2*).

In September, comparison of all five variants (control, north, east, south, west) indicated that only two of the four monitored biometric parameters had the highest mean values in the control variant: plant diameter with a mean value of 25.75 cm (*Figure 6b*) and number of leaves with a mean value of 72.94. Comparison of the sides of the module with each other revealed that the mean values of parameters varied, as follows: the highest values were for plant diameter and number of shoots on the southern side, for plant height on the northern side (*Figure 7b*) and for the number of leaves on the western side. The lowest values were for plant diameter and height on the western side, and for the number of leaves and shoots on the northern side (*Table 3*).

In November, comparison of all five variants (control, north, east, south, and west) illustrated that there was no highest or lowest value for any monitored parameter in the control variant (*Table 4*). Comparison of the different sides indicated that the mean values for plant diameter ranged between 25.97 cm on the western side and 29.73 cm on the northern side (*Figure 6c*), and for the plant height, between 19.54 and 27.68 cm on the southern and northern sides, respectively (*Figure 7c*). Regarding the number of leaves and number of shoots, the lowest and highest mean values were on the northern and southern sides, respectively. Therefore, the southern orientation favoured more leaves and shoots and shorter plants.

The plant diameter graphs reveal that although the mean values on the sides of the study module were equal, over time the southern orientation had the highest amplitude of values (highest-lowest).

Overall, for plant height, comparison of the mean values for the sides of the study module indicated that vertical planting favoured the appearance of a higher range of values. In the control variant, the values were better grouped around the mean.

For a better understanding of the measured values in July, a Kruskal-Wallis test was performed, where the dependent variable was the plant diameter (*Figure 8*) or plant height (*Figure 9*), and the independent variables were the values measured on the four cardinally oriented sides. The results helped us differentiate the influence of the orientation to the north or east, or to the south or west, or the combined influence of these cardinal orientations on the analysed parameters.

The Kruskal-Wallis test for plant diameter gave a p-*value* of 0.00179 (< 0.05), indicating that the median of the values recorded for this parameter differed significantly between experimental variants and the control variant. This suggests that plant development (measured as plant diameter) in the control variant differs from that of plants placed on the vertical structure. There were no differences between module orientations, which indicates a uniformity in plant diameter in *Cineraria* plants placed on the vertical system.

Table 2 – Confidence intervals for the means of the measured parameters – July

	Control	North	East	South	West
Plant diameter (cm)	**18.00 ± 2.85**	13.03 ± 1.43	12.68 ± 1.06	**13.79 ± 1.52**	**12.40 ±1.27**
Plant height (cm)	**15.11 ± 1.80**	**12.61 ± 1.51**	12.00 ± 1.75	12.60 ± 1.12	**11.68 ± 1.16**
Leaf number	**31.79 ± 7.81**	23.13 ± 4.73	**23.00 ± 4.24**	**28.00 ± 5.53**	23.59 ± 4.77
Shoot number	**3.36 ± 0.98**	2.50 ± 0.48	**2.48 ± 0.53**	**3.00 ± 0.70**	2.53 ± 0.58

Table 3 – Confidence intervals for the means of the measured parameters – September

	Control	North	East	South	West
Plant diameter (cm)	**25.75 ± 2.70**	22.86 ± 2.93	25.22 ± 4.50	**22.89 ± 3.38**	**22.67 ± 5.38**
Plant height (cm)	22.13 ± 2.24	**23.07 ± 3.90**	22.46 ± 4.44	21.32 ± 2.85	**18.67 ± 6.21**
Leaf number	**72.94 ± 21.79**	**37.36 ± 8.83**	51.77 ± 17.82	53.00 ± 14.05	**54.50 ± 20.79**
Shoot number	3.16 ± 0.89	**3.07 ± 0.89**	3.23 ± 1.16	**4.07 ± 0.83**	3.67 ± 1.43

Table 4 – Confidence intervals for the means of the measured parameters – November

	Control	North	East	South	West
Plant diameter (cm)	27.41 ± 2.50	28.54 ± 2.99	**29.73 ± 5.86**	28.12 ± 3.81	**25.97 ± 4.78**
Plant height (cm)	24.21 ± 1.77	**27.68 ± 4.46**	23.98 ± 5.16	**19.54 ± 5.28**	21.83 ± 5.20
Leaf number	72.92 ± 21.79	**62.83 ± 12.71**	82.08 ± 25.09	**101.23 ± 27.63**	77.83 ± 14.88
Shoot number	3.83 ± 0.89	**3.33 ± 1.03**	4.00 ± 1.05	**4.46 ± 0.80**	4.00 ± 2.20

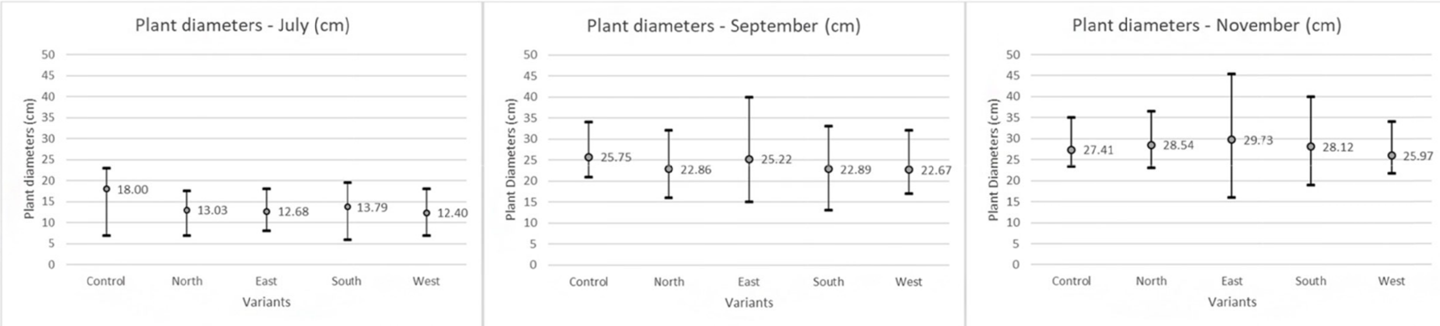

Figure 6 – Plant diameter of *Cineraria maritima* (a – July, b – September, c – November)

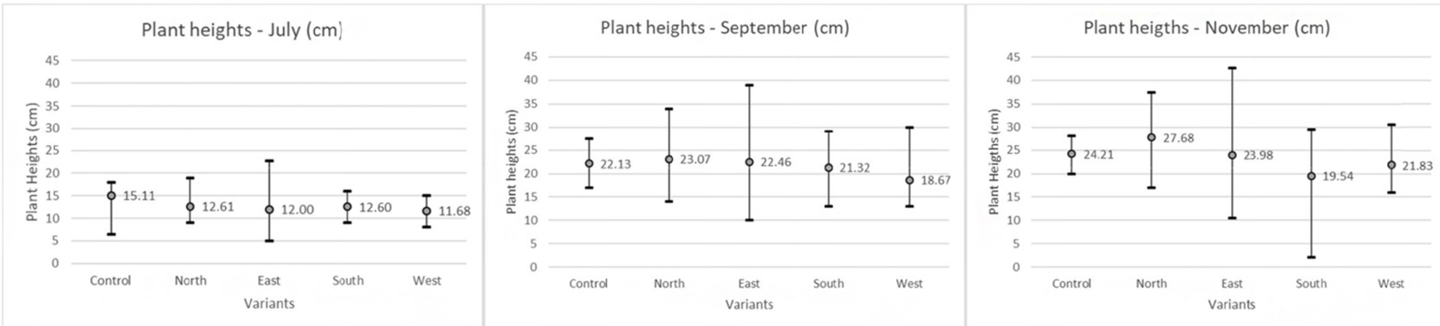

Figure 7 – Plant height of *Cineraria maritima* (a – July, b – September, c – November)

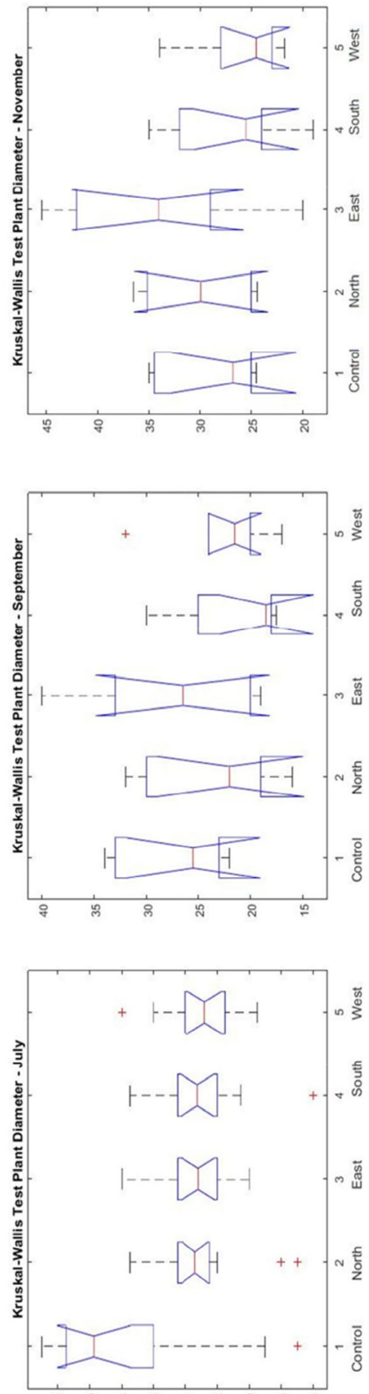

Figure 8 – Kruskal-Wallis test for plant diameter

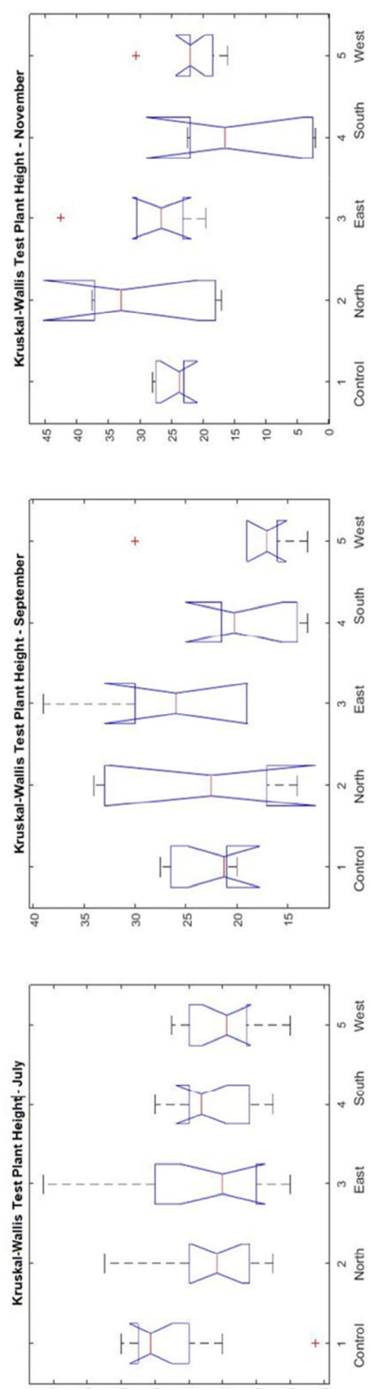

Figure 9 – Kruskal-Wallis test for plant height

The Kruskal-Wallis test for plant height gave a p-*value* of 0.00853 (< 0.05), showing that the median values for this parameter differed significantly. The differences were less significant between the control variant and the eastern and southern sides, respectively. This suggests that plant development in the control variant (in terms of plant height) differed from that of plants placed on the vertical structure. There were no differences between orientations, which indicates uniform development in the height of *Cineraria* plants grown on a vertical system.

For the months of September and November (*Table 5*), the p-*value* was higher than the 0.05 significance level, which indicates that plant development during these months in terms of plant diameter and height was similar. In the first part of the experiment, the plants needed a period of adaptation, so development during this period differed in the control variant and on the vertical structure. Later, the plants tended to develop similarly in all variants.

All plants that were left to overwinter without intervention survived in all four variants of the experimental module. Those plants that were shortened to about 15 cm did not survive. On the other hand, in the control variant, only one of the shortened plants died. The rest of the plants in the control variant, together with those left to overwinter without intervention, survived.

CONCLUSIONS

This study aimed to monitor the behaviour of *Cineraria maritima* planted in green façade systems oriented towards four cardinal points in the specific climatic conditions of north-eastern Romania in order to test its adaptability and evolution in this system. The results obtained confirm that *Cineraria maritima* can adapt to vertical planting on systems for green façades in the local climatic conditions.

In our study the degree of attachment (rooting) of *Cineraria maritima* was good: between 89.47% on the west-facing façade and 100% in the control group. The plant exhibited good resistance to irrigation conditions and low levels of precipitation.

In all variants, except for the western orientation, later losses were small, with percentage survival varying between 73% and 85% at the beginning of November. On the west-facing side of the module, the percentage plant survival was just over 30%".

During the first part of the experiment, while the plants adjusted to the vertical planting system, we recorded differences in plant diameter and height between the vertical structure and the control variant. Later, the median values of the parameters were similar across all sides of the module and the control (p-values 0.44342, 0.52585, 0.82043, 0.13875).

Table 5 – P-values after performing the Kruskal-Wallis test

	July	September	November
Plant diameter	0.00179	0.44342	0.82043
Plant height	0.00853	0.52585	0.13875

Over the winter, plants that were shortened were lost whereas all those left to overwinter without intervention survived in all four variants on the experimental module.

Cineraria maritima maintained its aesthetic properties in all experimental variants. Both as a solitary species and in connection with other species, it should be planted in groups next to plants that have leaves or blooms that have vivid colours for the maximum decorative impact.

Study limitations are due to several variables intervening on the development of plants in vertical systems, such as façade size and orientation, type of used substrate, weather conditions, light intensity, maintenance work, etc. The results are encouraging and we will continue the studies on this species by testing it in different types of substrates, irrigation variants, planting boxes, etc.

Specific aspects identified in this experiment will be looked into more deeply in future studies.

Author Contributions: Conceptualization (MC, CC), methodology (ELC), analysis (CC), investigation (MC, CC), resources (MC), data curation (MC, CC), writing (MC, CC), review (MC, CC), supervision (ELC). All authors declare that they have read and approved the publication of the manuscript in its present form.

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