The Influence of Slow-Release Fertilizers on the Growth, Flowering, and the Content of Macro- and Micronutrients in the Leaves of Cyclamen persicum Mill.

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Abstract: The influence of selected fertilizer within a 6-month period of operation was assessed: Basacote Plus 6M, Osmocote Plus 6M, Plantacote Plus 6M. Plants grown in the substrate without slow-release fertilizer, which were supplied with nutrients only for top dressing, were the control. Two cultivars of the Maxi type of cyclamen were grown in greenhouse in pots during the period from the 25th to the 50th week of the year. While planting the seedlings, 2 g of slow-release fertilizer were added to the substrate directly under the roots. From the third week of cultivation, the plants of each combination were fertilized with top dressing every week. Plant height and diameter, number of leaves, weight of the above-ground part, tuber diameter, earliness of flowering, number of flowers and buds, as well as the content of macro and micronutrients were assessed. The addition of Osmocote 6M or Plantacote 6M into the substrate resulted in plants with a larger fresh weight and larger diameter and earlier flowering with more flowers and buds at the end of the experiment than with Basacote 6M or with only top dressing. The applied slow-release fertilizers had an effect on the content of K, Ca, and Fe in the leaves of Persian cyclamen. The cultivar ‘Rainier White F1’ had significantly more leaves, buds, and flowers and a higher content of P, K, Cu, Zn, and Mn than the cultivar ‘Halios Pure White Compact F1’.

Keywords: nutrients of plant; growth of cyclamen; indoor plants; pot plants

1. Introduction

For many years, the Persian cyclamen has been one of the most popular plants grown in pots for interior decoration. Numerous studies have shown that its growth and flowering is influenced by various factors, e.g., the cultivar [1–3] and growing period [2,4,5], which is related to the influence of light and temperature [6–13]. As Persian cyclamens are cultivated in a limited volume of substrate, its type [14–19] and the size of the pot [5,20,21] may determine the growth and flowering of these plants. Fertilization is one of the main factors determining the quality of plants. The growth of cyclamens is influenced by the proportion of individual components [22,23] in a fertilizer, the method of their supply (into the substrate in basic fertilization when planting plants), by fertigation [8,15,23,24] or by foliar treatment [25], and the type of fertilizer [1,2,26,27]. According to D’Angello et al. and Vlad et al. [16,28], a higher fertilization frequency increases the size of plants and the number of flowers, and according to Szczepaniak [29], it accelerates flowering.

Slow-release fertilizers are effective in the production of ornamental plants, but there is no information about which type of fertilizer best affects the growth and flowering of Persian cyclamen. The authors D’Angello et al. and Bongartz [16,30] point out that in the cultivation of Persian cyclamen, which falls in summer, it is more advantageous to use lower doses of slow-release fertilizers and systematic supplementation of nutrients in
late top dressing. The selection of the appropriate fertilizer and the optimal dose in plant cultivation affects the quality of plants and the profitability of production.

The aim of the study was to determine how a slow-release fertilizer influenced the duration of the production period and the quality of two Persian cyclamen cultivars belonging to different groups.

2. Materials and Methods

Cyclamen were grown in a greenhouse at the Experimental Research Station of the Poznań University of Life Sciences, Poland, between the 25th and 50th week of the year. The following factors were analyzed in the experiment:

- three fertilizers with a six-month nutrient-release period, which were applied into the substrate during planting: Basacote Plus 6M (16-8-12), Osmocote Plus 6M (15-10-12), Plantacote Plus 6M (14-9-15) (Tables 1 and 2);
- two cyclamen cultivars of the Maxi type: ‘Halois Pure White Compact F1’ and ‘Rainier White F1’.

Table 1. The content of nitrogen, phosphorus, and potassium in the fertilizers applied in basic fertilization and top dressing treatments.

| Fertilizers     | N (mg dm⁻³) | P (mg dm⁻³) | K (mg dm⁻³) |
|-----------------|-------------|-------------|-------------|
| Basacote Plus 6M | 320         | 70.4        | 199.2       |
| Top dressing    | 194         | 43.5        | 251.4       |
| Summary         | 514         | 113.9       | 450.6       |
| Osmocote Plus 6M| 300         | 88.0        | 199.2       |
| Top dressing    | 194         | 43.5        | 251.4       |
| Summary         | 494         | 131.5       | 450.6       |
| Plantacote Plus 6M | 280      | 79.2        | 249.0       |
| Top dressing    | 194         | 43.5        | 251.4       |
| Summary         | 474         | 122.7       | 500.4       |
| Control         | 194         | 43.5        | 251.4       |

Table 2. The content of micronutrients in the fertilizers used in the experiment.

| Fertilizers     | Micronutrient | Fe (mg dm⁻³) | Cu (mg dm⁻³) | Zn (mg dm⁻³) | Mn (mg dm⁻³) |
|-----------------|---------------|--------------|--------------|--------------|--------------|
| Basacote Plus 6M| Fe            | 0.400        | 0.050        | 0.020        | 0.060        |
|                 | Cu            | 0.400        | 0.050        | 0.015        | 0.060        |
|                 | Zn            | 0.020        | 0.015        | 0.015        | 0.060        |
| Osmocote Plus 6M| Fe            | 0.400        | 0.050        | 0.015        | 0.060        |
|                 | Cu            | 0.400        | 0.050        | 0.015        | 0.060        |
|                 | Zn            | 0.020        | 0.015        | 0.015        | 0.060        |
| Plantacote Plus 6M | Fe        | 0.400        | 0.050        | 0.015        | 0.060        |

Controlled Release Fertilizers contain macronutrients and micronutrients in a synthetic polymer coating, which ensures even, over time, depending on the temperature of the substrate, release of nutrients to the plants. Its coating is classified as a polymeric resin and is applied in several layers. The relative thickness of the layers affects the speed and pattern of nutrient release at 21 °C (70 °F).
In order to demonstrate the effect of the type of slow-release fertilizer, the control was performed by plants grown in a substrate in which nutrients were supplied only for top dressing.

The experiment was conducted on seedlings planted in X trays of 72 pieces. The seedlings were grown in Klasmann TS-2 peat substrate, pH 5.8. The peat substrate without a slow-release fertilizer was used as the control combination. During planting, all the fertilizers were applied directly under the plants’ roots, at a dose of 2 g per pot (with a capacity of 0.625 dm$^3$). Since the third week of cultivation, every week, the plants in each combination were top-dressed with 0.1% fertilizer solutions applied at a dose of 100 cm$^3$, as recommended by the Yara company. The fertilizers were applied in the following order: Kristalon blue (19:6:20)—4 times, Kristalon yellow (13:40:13)—once, Kristalon white (15:5:30:3)—7 times. The amounts of nitrogen, phosphorus, and potassium supplied to the plants in basic fertilization and top dressing are listed in Table 1. In the greenhouse, efforts were made to maintain the temperature during the day at 20–22 °C, and at 16–18 °C at night; however, the high outside temperature and high insolation during the summer had a strong influence on its course. During cultivation, the plants were watered as needed, resulting from the ambient temperature.

The experiment was finished when most of the plants achieved the commercial value, i.e., when they developed five flowers per plant. The following parameters were used to assess the growth of the plants: the total height of the plant measured from the pot level to the tallest flower (cm), the plant diameter measured at the leaf level at the widest point (cm), the number of leaves, the weight of the aerial part of the plant (g), and the tuber diameter measured at the widest point of the cross-section (mm). The following factors were taken into account when assessing the flowering of the plants: earliness (determined by the number of days from the planting to the beginning of flowering) and the number of flowers and buds. There were 12 replicates in each combination. One plant growing in a test pot without a drainage hole was a replicate. On 18 December, four leaf samples were collected from each combination for chemical analyses. The plant material was dried in an exhaust dryer at 105 °C for 48 h. Next, it was homogenized and analyzed chemically. The content of macronutrients in the leaves was measured after wet mineralization with concentrated sulphuric acid. The following methods were used to measure the content of macronutrients: N—the Kiejdahl method, P—colorimetry with ammonium vanadomolybdate, K and Ca—photometry, Mg—atomic absorption spectrophotometry with a Zeiss AAS-5 spectrophotometer.

In order to measure the content of micronutrients, the dried material was homogenized in a laboratory mill. Next, it was wet-mineralized in a mixture of concentrated (ultra-pure) HNO$_3$ and HClO$_4$ (reagent grade) at a 3:1 ratio [31,32]. The contents of iron, copper, zinc, and manganese were measured by means of atomic absorption spectrophotometry with a Zeiss AAS-5 spectrophotometer.

The results of measurements of the content of selected macro- and micronutrients were analyzed statistically with the STAT BAT program. Two-way analysis of variance was applied for the content of nutrients in the dry matter of Persian cyclamen leaves. The differences between the means were determined with Duncan’s test at a significance level $p = 0.05$.

3. Results and Discussion

The research showed that the height and the number of leaves of Persian cyclamens did not depend on the slow-release fertilizer (Table 3). Cieciora et al. [1] also found that the type of the fertilizer applied to cyclamens from the Halios group had no effect on their height. The plants treated with Osmocote Plus $6^M$ or Plantacote Plus $6^M$ had significantly greater diameters and fresh weights than those treated with Basacote Plus $6^M$. Growth inhibition with Basacote Plus $6^M$ could have resulted from a higher nitrogen content in the fertilizer, which, if released, could adversely lead to a higher concentration of nutrients.
Table 3. The growth of Persian cyclamens depending on the slow-release fertilizer and cultivar.

| Fertilizers          | Cultivars               | Mean  |
|----------------------|-------------------------|-------|
|                      | Height of plant (cm)    |       |
| Halios Pure White    | 17.1 a *                | 17.4 a|
| Compact F1 Rainier White F1 | 17.8 a | 19.2 a|
| Basacote Plus 6M     | 18.4 a                  | 18.9 a|
| Osmocote Plus 6M     | 18.6 a                  | 19.5 a|
| Plantacote Plus 6M   | 18.2 a                  | 18.7 a|
| Control              | 18.2 a                  | 19.0 a|
| Mean                 | 18.0 a                  | 19.0 a|

|                      | Diameter of plant (cm)  |       |
|----------------------|-------------------------|-------|
| Basacote Plus 6M     | 28.7 ab                 | 27.4 a|
| Osmocote Plus 6M     | 31.8 c                  | 31.3 bc|
| Plantacote Plus 6M   | 30.2 abc                | 29.9 abc|
| Control              | 28.7 a                  | 29.9 abc|
| Mean                 | 29.9 a                  | 29.6 a|

|                      | Number of leaves        |       |
|----------------------|-------------------------|-------|
| Basacote Plus 6M     | 44.9 ab                 | 54.3 bc|
| Osmocote Plus 6M     | 46.3 abc                | 53.1 abc|
| Plantacote Plus 6M   | 47.6 abc                | 56.5 c |
| Control              | 42.3 a                  | 50.9 abc|
| Mean                 | 45.3 a                  | 53.7 b |

|                      | Fresh weight of plant with tuber (g) |       |
|----------------------|--------------------------------------|-------|
| Basacote Plus 6M     | 134.9 b                              | 116.2 a|
| Osmocote Plus 6M     | 171.8 d                              | 154.9 b|
| Plantacote Plus 6M   | 147.1 cd                             | 140.4 b|
| Control              | 113.8 ab                             | 112.0 a|
| Mean                 | 141.9 b                              | 119.9 a|

|                      | Diameter of tuber (cm)  |       |
|----------------------|-------------------------|-------|
| Basacote Plus 6M     | 1.7 ab                  | 1.5 a |
| Osmocote Plus 6M     | 1.9 bc                  | 1.7 ab|
| Plantacote Plus 6M   | 1.7 ab                  | 1.8 ab|
| Control              | 1.7 ab                  | 2.1 c |
| Mean                 | 1.8 a                   | 1.8 a |

*followed by the same letters do not differ significantly at (α = 0.05).

Szczepaniak and Czuchaj [2] also found that the plants fertilized with Osmocote + Peters had greater diameters and weights than those fertilized with Hydrocote + Kristalon or Polyon + Hortimex. On the other hand, Nowak and Strojny [33] did not observe significant differences between the Homalomena ‘Emerald Gem’ plants fertilized with Osmocote Plus 5–6M or Plantacote 6M at a dose of 3–5 g/m³. The application of slow-release fertilizers resulted in significantly greater values of the plant growth parameters than in the control plants which were only top-dressed with each irrigation. In our study, the Basacote 6M fertilizer applied into the substrate had no effect on the plant growth parameters, except the tuber diameter, which was greater than in the control plants. Although the ‘Rainier White F1’ cultivar had a significantly greater number of leaves, their total fresh weight was lower than that of the ‘Halios Pure White Compact F1’ cultivar.

The slow-release fertilizers applied to the cyclamens in our study affected their flowering (Table 4). The Osmocote Plus 6M fertilizer applied to the cyclamens resulted in their fastest flowering, regardless of the cultivar. Only 3 days later, the cyclamens fertilized with Plantacote Plus 6M started flowering. The plants which had not been treated with a slow-release fertilizer under the roots were the last to start flowering. The ‘Halios Pure White Compact F1’ and ‘Rainier White F1’ cultivars did not differ significantly in their
flowering time. The number of flowers and buds on the plants depended on both the fertilizer applied to the cyclamens and their cultivar. Regardless of the cultivar, the plants fertilized with Osmocote Plus 6M had the most flowers and buds. The plants grown in the substrate fertilized with Plantacote Plus 6M had a similar, not significantly different, number of flowers and buds. The plants which had not been treated with a slow-release fertilizer had the fewest flowers and buds. The plants of the ‘Rainier White F1’ cultivar had more flowers and buds (23–39) than the ‘Halios Pure White Compact F1’ plants (21–33). Szczepaniak and Czuchaj [3] also observed significant cultivar-dependent differences in the flowering of cyclamens. According to Cieciora et al. [1], the average number of flowers and buds for cyclamens from the Halios group was 26–27.

Table 4. The flowering of Persian cyclamens depending on the slow-release fertilizer and cultivar.

| Fertilizers          | Cultivars                      | Mean    |
|----------------------|--------------------------------|---------|
|                      | Halios Pure White Compact F1   |         |
|                      | Rainier White F1               |         |
| Number of days to flowering |                         |         |
| Basacote Plus 6M     | 164.4 c *                      | 154.9 abc| 159.7 bc |
| Osmocote Plus 6M     | 152.4 ab                       | 148.3 a | 150.4 a  |
| Plantacote Plus 6M   | 151.5 ab                       | 155.0 abc| 153.3 ab |
| Control              | 162.1 bc                       | 159.2 abc| 160.7 c  |
| Mean                 | 157.6 a                        | 154.4 a |         |
| Number of flowers and buds |                         |         |
| Basacote Plus 6M     | 26.2 ab                        | 32.0 bcd | 29.1 b   |
| Osmocote Plus 6M     | 33.2 cde                       | 39.5 e  | 36.4 c   |
| Plantacote Plus 6M   | 28.1 abc                       | 36.2 de | 32.1 bc  |
| Control              | 21.5 a                         | 23.0 a  | 22.3 a   |
| Mean                 | 27.3 a                         | 32.7 b  |         |

* followed by the same letters do not differ significantly at (α = 0.05).

The content of nitrogen, phosphorus, and magnesium in the leaves of cyclamens of the ‘Halios Pure White Compact F1’ and ‘Rainier White F1’ cultivars (Table 5) did not depend on the type of slow-release fertilizer applied to these plants. The content of nitrogen ranged from 2.53% to 2.73%. According to de Kreij et al. [34], the optimal content of nitrogen in the cyclamen leaves should be 2.52%; according to D’Angello et al. [16]—2.7–2.9%, and according to Bongartz [30]—2.5–3.5%. Bik [15] observed that the nitrogen content of 2.19–2.63% in the leaves of Persian cyclamens depended on the quality of water used for fertigation. Cattivello et al. [16] found that the plants growing in a compost-based substrate had less nitrogen and phosphorus in the leaves than those growing in a peat substrate. In our study, the phosphorus content in the plants ranged from 0.30% to 0.47%. These values were greater than those observed by Milles and Jones [35]—0.14–0.22% and by de Kreij et al. [34]—0.25%. According to D’Angello et al. [16], the optimal phosphorus content should be 0.2–0.4%, whereas according to Bongartz [30], it should be 0.25–0.40%. The potassium content in the leaves of the cyclamens grown in the substrate fertilized with Basacote Plus 6M or Plantacote Plus 6M was significantly higher than that of the plants grown in the substrate fertilized with Osmocote Plus 6M. The higher potassium content could have been due to poor plant growth with Basacote Plus 6M and the higher potassium content introduced with Plantacote Plus 6M.

In our study, the potassium content in the cyclamen leaves exceeded the reference values of 1.6–1.9% provided by D’Angello et al. [16]. However, they were lower than the potassium content measured in the study conducted by Bik [15]—5.75–6.32%, or by de Kreij et al. [34]—5.86%, which was considered optimal. The content of calcium measured in the leaves of the cyclamen cultivars analyzed in our study significantly exceeded the optimal values specified in the study conducted by Milles and Jones [35]—0.80% as well as those measured by Bik [15]—1.12–1.62%. Both cultivars had the highest calcium content
after fertilization with Osmocote Plus 6M. However, these calcium levels did not differ significantly from those measured in the plants treated with Basacote Plus 6M. The leaves of the plants grown in the control substrate and those fertilized with Plantacote Plus 6M or Basacote Plus 6M had similar calcium content. The content of magnesium in the leaves ranged from 0.59% to 0.81%. It was more than twice as high as the magnesium levels measured by de Kreij et al. [34] and Milles and Jones [35]—0.30%. Bik [15] noted that the magnesium level ranged from 0.35% to 0.57%. Regardless of the type of slow-release fertilizer, the content of phosphorus and potassium in the leaves of the ‘Rainier White F1’ cultivar was higher than in the ‘Halios Pure White Compact F1’ plants.

Table 5. The content of macronutrients in the leaves of the Persian cyclamens treated with slow-release fertilizers (% of dry matter).

| Macronutrients | Fertilizers          | Cultivars                  | Mean    |
|----------------|----------------------|----------------------------|---------|
|                |                      | Halios Pure White Compact F1 | Rainier White F1 |       |
| N              | Basacote Plus 6M     | 2.60 b *                   | 2.71 b   | 2.66 b |
|                | Osmocote Plus 6M     | 2.58 b                     | 2.64 b   | 2.61 b |
|                | Plantacote Plus 6M   | 2.59 b                     | 2.73 b   | 2.66 b |
|                | Control              | 2.53 b                     | 2.10 a   | 2.31 a |
|                | Mean                 | 2.57 a                     | 2.54 a   |        |
| P              | Basacote Plus 6M     | 0.38 bc                    | 0.40 cd  | 0.39 b |
|                | Osmocote Plus 6M     | 0.33 a                     | 0.44 de  | 0.38 b |
|                | Plantacote Plus 6M   | 0.34 ab                    | 0.47 e   | 0.40 b |
|                | Control              | 0.31 a                     | 0.30 a   | 0.30 a |
|                | Mean                 | 0.34 a                     | 0.40 b   |        |
| K              | Basacote Plus 6M     | 3.09 bc                    | 4.51 e   | 3.80 c |
|                | Osmocote Plus 6M     | 3.09 bc                    | 3.36 c   | 3.23 b |
|                | Plantacote Plus 6M   | 3.55 cd                    | 3.93 d   | 3.74 c |
|                | Control              | 2.85 ab                    | 2.61 a   | 2.73 a |
|                | Mean                 | 3.14 a                     | 3.60 b   |        |
| Ca             | Basacote Plus 6M     | 2.03 ab                    | 1.72 ab  | 1.87 ab |
|                | Osmocote Plus 6M     | 2.17 b                     | 1.99 ab  | 2.08 b |
|                | Plantacote Plus 6M   | 1.59 ab                    | 1.49 a   | 1.54 a |
|                | Control              | 1.84 ab                    | 1.42 a   | 1.63 a |
|                | Mean                 | 1.91 a                     | 1.65 a   |        |
| Mg             | Basacote Plus 6M     | 0.59 a                     | 0.73 a   | 0.66 a |
|                | Osmocote Plus 6M     | 0.81 a                     | 0.80 a   | 0.81 a |
|                | Plantacote Plus 6M   | 0.69 a                     | 0.68 a   | 0.68 a |
|                | Control              | 0.77 a                     | 0.76 a   | 0.76 a |
|                | Mean                 | 0.72 a                     | 0.74 a   |        |

* followed by the same letters do not differ significantly at (α = 0.05).

The iron content in plants can range from 10 to over 1000 mg·kg\(^{-1}\) of dry weight [36]. Such a wide range of the iron content depends on the plant species, variety, and organ. According to Kozik and Komosa [37], the average iron content in plants ranges from 50 to 300 mg·kg\(^{-1}\) of dry weight. The slow-release fertilizers applied to the Persian cyclamens in our study significantly influenced the iron content in their leaves (Table 6).
The Plantacote Plus \(^6\text{M}\) fertilizer applied into the substrate under the cyclamens of the ‘Halios Pure White Compact F1’ cultivar resulted in the highest content of this micronutrient (216.1 mg·kg\(^{-1}\) d.m.) in the leaves of these plants. The lowest Fe content in this cultivar (114.3 mg·kg\(^{-1}\) d.m.) was found in the leaves of the plants grown in the control substrate. This value did not differ significantly from the Fe content in the leaves of the plants fertilized with Osmocote Plus \(^6\text{M}\) or Basacote Plus \(^6\text{M}\). The lowest iron content (116 mg·kg\(^{-1}\) d.m.) in the leaves of the ‘Rainier White F1’ cyclamens was found in the plants grown in the control substrate. This value did not differ significantly from the Fe content in the leaves of the cyclamens fertilized with Basacote Plus \(^6\text{M}\). The highest iron content (215.8 mg·kg\(^{-1}\) d.m.) was found in the leaves of the plants fertilized with Plantacote Plus \(^6\text{M}\).

**Table 6.** The content of micronutrients in the leaves of the Persian cyclamens treated with slow-release fertilizers (mg·kg\(^{-1}\) dry matter).

| Micronutrients | Fertilizers | Cultivars | Mean |
|----------------|-------------|----------|------|
|                |             | Halios Pure White Compact F1 | Rainier White F1 | |
| Fe             | Basacote Plus \(^6\text{M}\) | 129.1 a * | 177.3 ab | 153.2 ab |
|                | Osmocote Plus \(^6\text{M}\) | 198.2 ab | 215.3 b | 206.7 bc |
|                | Plantacote Plus \(^6\text{M}\) | 216.1 b | 215.8 b | 215.9 c |
|                | Control     | 114.3 a | 116.0 a | 115.2 a |
|                | Mean        | 164.4 a | 181.1 a | |
| Cu             | Basacote Plus \(^6\text{M}\) | 4.2 ab | 5.2 cd | 4.7 b |
|                | Osmocote Plus \(^6\text{M}\) | 4.7 bc | 5.1 cd | 4.9 b |
|                | Plantacote Plus \(^6\text{M}\) | 4.7 bcd | 5.3 d | 5.0 b |
|                | Control     | 4.2 ab | 4.0 a | 4.1 a |
|                | Mean        | 4.5 a | 4.9 b | |
| Zn             | Basacote Plus \(^6\text{M}\) | 24.7 b | 37.7 d | 31.2 b |
|                | Osmocote Plus \(^6\text{M}\) | 30.5 bc | 38.2 d | 34.4 b |
|                | Plantacote Plus \(^6\text{M}\) | 34.7 cd | 34.7 cd | 34.7 b |
|                | Control     | 17.4 a | 25.0 b | 21.2 a |
|                | Mean        | 26.8 a | 33.9 b | |
| Mn             | Basacote Plus \(^6\text{M}\) | 93.1 ab | 187.9 d | 140.5 b |
|                | Osmocote Plus \(^6\text{M}\) | 134.2 bcd | 169.5 cd | 151.9 b |
|                | Plantacote Plus \(^6\text{M}\) | 131.2 bc | 149.9 cd | 140.5 b |
|                | Control     | 68.8 a | 74.8 a | 71.8 a |
|                | Mean        | 106.8 a | 145.5 b | |

* followed by the same letters do not differ significantly at (\(\alpha = 0.05\)).

The comparison of the mean iron content in the leaves of the cyclamen cultivars did not reveal significant differences, regardless of the type of fertilizer applied. The comparison of the mean Fe content in the cyclamen leaves depending on the type of fertilizer showed that regardless of the cultivar, the highest content of this micronutrient was found in the plants fertilized with Plantacote Plus \(^6\text{M}\), whereas the lowest Fe content was noted in the control substrate.

Copper is an important element for the flowering of plants. Its deficiency causes leaf distortion and inhibits the growth of shoots [37]. The copper content in the leaves of the Persian cyclamens analyzed in our study ranged from 4.0 to 5.3 mg·kg\(^{-1}\) d.m. (Table 6). There were no significant differences in the copper content in the leaves of the ‘Halios Pure
White Compact F1’ cultivar, regardless of the fertilizer applied (Table 6). However, there were significant differences in the content of this micronutrient in the ‘Rainier White F1’ cultivar. The lowest Cu content (4.0 mg·kg\(^{-1}\)·d.m.) was found in the leaves grown in the control substrate, whereas the highest content (5.3 mg·kg\(^{-1}\)·d.m.) was noted in the leaves of the plants fertilized with Plantacote Plus \(^{6M}\). The comparison of the mean copper content in the leaves of the cyclamen cultivars showed that regardless of the type of fertilizer, the ‘Rainier White F1’ cultivar was more abundant in this nutrient. Regardless of the cultivar, the plants grown in the substrate treated with one of the fertilizers under analysis had a higher Cu content than the plants grown in the control substrate.

The zinc content in the leaves of both Persian cyclamen cultivars ranged from 17.4 to 38.2 mg·kg\(^{-1}\)·d.m. Ref. [35] found a zinc content of 52 mg·kg\(^{-1}\)·d.m. in the leaves of Persian cyclamen grown in containers in a greenhouse. According to Kreij et al. [34], the optimal zinc content in cyclamen leaves is 52 mg·kg\(^{-1}\)·d.m. The highest zinc content was found in the leaves of the plants grown in the control substrate. The highest (34.7 mg·kg\(^{-1}\)·d.m.) Zn content was found in the plants fertilized with Plantacote Plus \(^{6M}\) (Table 6). The leaves of the plants fertilized with Osmocote Plus \(^{6M}\) did not differ significantly in their zinc content from those fertilized with Plantacote Plus \(^{6M}\). Similarly to the ‘Halios Pure White Compact F1’ cultivar, the lowest Zn content (25.0 mg·kg\(^{-1}\)·d.m.) in the ‘Rainier White F1’ cultivar was found in the leaves of the plants grown in the control substrate. The highest content (38.2 mg·kg\(^{-1}\)·d.m.) was found in the plants fertilized with Osmocote Plus \(^{6M}\), but it was not significantly different from the Zn content observed in the leaves of the plants from the other substrates treated with the slow-release fertilizers. The comparison of the mean zinc content in the leaves of the cyclamen cultivars showed that regardless of the type of fertilizer applied, the leaves of the ‘Rainier White F1’ cultivar were more abundant in this component (33.9 mg·kg\(^{-1}\)·d.m.). None of the slow-release fertilizers applied into the substrate in our study caused significant cultivar-dependent differences in the zinc content in the cyclamen leaves. However, the plants treated with any of the fertilizers had a significantly higher Zn content than those grown in the control substrate.

The manganese content in the leaves of the Persian cyclamen ranged from 68.8 to 187.9 mg·kg\(^{-1}\)·d.m. (Table 6). Mills and Jones [35] found a manganese content of 49 mg·kg\(^{-1}\)·d.m. in the leaves of Persian cyclamen grown in containers in a greenhouse. According to de Kreij et al. [34], the optimal manganese content in cyclamen leaves should be 50 mg·kg\(^{-1}\)·d.m. According to Kozik and Komosa [37], a manganese content higher than 500 mg·kg\(^{-1}\)·d.m. is toxic to plants. The analysis of the manganese content in the plants of both cultivars showed that the leaves of the ‘Halios Pure White Compact F1’ cyclamens grown in the control substrate had the lowest concentration of this element. The highest Mn content was found in the plants fertilized with Osmocote Plus \(^{6M}\). The lowest manganese content in the ‘Rainier White F1’ cultivar was found in the leaves of the plants grown in the control substrate. The highest Mn content was noted in the leaves of the cyclamen grown in the substrate fertilized with Basacote Plus \(^{6M}\), but this value did not differ significantly from the Mn levels measured in the leaves of the plants treated with the other fertilizers.

To sum up, the leaves of the ‘Halios Pure White Compact F1’ Persian cyclamens grown in the substrate without slow-release fertilizers had the following content of micronutrients (mg·kg\(^{-1}\)·d.m.): Fe—114.3, Cu—4.2, Zn—17.4, Mn—68.8. The leaves of the ‘Rainier White F1’ cyclamens grown in the substrate without slow-release fertilizers had the following content of these micronutrients (mg·kg\(^{-1}\)·d.m.): Fe—116, Cu—4, Zn—25, Mn—74.8. The content of micronutrients in the leaves of the ‘Halios Pure White Compact F1’ Persian cyclamens grown in the substrate treated with slow-release fertilizers ranged as follows (mg·kg\(^{-1}\)·d.m.): Fe—129.1–216.1, Cu—4.2–5.0, Zn—24.7–34.7, Mn—93.1–134.2. The leaves of the ‘Rainier White F1’ cyclamens grown in the substrate treated with slow-release fertilizers had the following content of these micronutrients (mg·kg\(^{-1}\)·d.m.): Fe—177.3–263.8, Cu—5.1–5.3, Zn—33.7–38.2, Mn—105.9–187.9.
4. Conclusions

Both our research and that of other authors have shown that in the cultivation of Persian cyclamen it is advantageous to use a slow-release fertilizer rather than providing only nutrients in late top dressing. Although the response of the cultivars to the fertilizer applied was different, a type of slow-release fertilizer had a greater influence on the growth and flowering of Persian cyclamen. Fertilizing the substrate with Osmocote Plus 6M or Plantacote Plus 6M resulted in plants with a larger fresh weight and larger diameter and earlier flowering with more flowers and buds at the end of the experiment than with Basacote Plus 6M. The content of nitrogen and phosphorus in the leaves of cyclamen cv. ‘Halios Pure White Compact F1’ and ‘Rainier White F1’ did not depend on the type of slow-release fertilizer used, while potassium in the leaves was less in the plants grown in the substrate with Osmocote Plus 6M than in the substrate with Basacote Plus 6M or Plantacote Plus 6M. The ‘Rainier White F1’ cultivar showed a stronger reaction to the applied type of slow-release fertilizer than the ‘Halios Pure White Compact F1’ cultivar. The leaves of the ‘Rainier White F1’ cultivar, with more leaves and more buds and flowers, showed a higher content of phosphorus and potassium than in the ‘Halios Pure White Compact F1’ cultivar, which creates plants with a greater mass. Persian cyclamen leaves fertilized with Basacote Plus 6M, Osmocote Plus 6M, and Plantacote Plus 6M did not differ significantly in the content of copper and manganese in both tested cultivars, nor in the content of iron and zinc in the cultivar ‘Rainier White F1’.

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