Effect of *Trichoderma* spp. and Fertilization on the Flowering of *Begonia × tuberhybrida* Voss. ‘Picotee Sunburst’

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**Abstract:** The aim of the study was to assess the influence of *Trichoderma* spp. and different fertilization levels on the flowering and nutritional status of *Begonia × tuberhybrida* Voss. ‘Picotee Sunburst’ plants. Before planting, the tubers were soaked in water or a mixture of spore of *Trichoderma* spp. (*T. viride* Schumach–Tv14, *T. harzianum* Rifai–Thr2, *T. hamatum* Bonord/Bainier–Th15) in the form of a suspension for 24 h. The plants were fertilized every 7 days with the multi-component Peters Professional Allrounder fertilizer (20:20:20 + microelements) at a concentration of 0.0%, 0.2%, and 0.3%. *Trichoderma* spp. accelerated the flowering of the ‘Picotee Sunburst’ cultivar by 2.7–8.7 days, stimulated the development of buds and flowers in the plants and affected their size. The plants bloomed most intensively and had the biggest flowers after the treatment with the 0.3% fertilizer. *Trichoderma* spp. and the fertilization had no effect on the height of the plants and the number of shoots regardless of the fertilizer concentration, but they stimulated the development of leaves. *Trichoderma* spp. stimulated the production of chlorophyll. They did not affect the uptake of macroelements, but they stimulated the uptake of microelements (Zn, Fe, and B). The higher the fertilizer concentration was, the higher was the content of microelements in the plants.

**Keywords:** ornamental plants; biostimulants; flowering; micro- and macroelements

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1. **Introduction**

Due to ecological restrictions, plant producers have to limit the use of chemicals, including mineral fertilizers. However, it is known that the commercial production of very high quality plants is closely related to adequate fertilization, which needs to be optimal for a particular species and cultivar. Hence, the question: How to replace mineral fertilizers, which are commonly used all over the world, without compromising the quality of plants? The problem can be solved with biostimulants, which are defined as non-nutritional substances or microorganisms stimulating the growth and yield of plants and affecting their health. They have the potential to provide sustainable and economically beneficial solutions, which could introduce new approaches so as to improve crop efficiency [1]. According to the current state of knowledge, biostimulants regulate and modify physiological processes in plants, which results in their better growth and stress relief [2].

Fungi, including those of the *Trichoderma* genus, are used as biostimulants. *Trichoderma* are saprophytic fungi used for biological protection of plants [3,4]. Many species of the *Trichoderma* genus colonize the roots of dicotyledonous and monocotyledonous plants. During this process, fungi wrap around the roots and form structures resembling appressoria to finally penetrate the root cortex. During the intercellular growth of fungi in the epidermis of the root and cortex, the plant cells surrounding the fungi are stimulated to deposit the cell wall material and produce phenolic compounds. This plant response limits the growth of *Trichoderma* spp. inside the root [5]. This interaction between the fungi and...
plants provides numerous benefits, whose diversity and significance have only recently been investigated. The interaction increases plants’ resistance to various biotic stresses through induced or acquired systemic resistance. It also increases plants’ resistance to abiotic stresses such as water deficit/excess, high salinity and extreme temperatures. The interaction also increases efficient use of nitrogen (N) by improving the mechanisms of N reduction and assimilation, and it reduces the overexpression of stress genes or the accumulation of toxic compounds during plants’ response to pathogens [6]. Fungi of the *Trichoderma* genus grow and proliferate rapidly. They can survive unfavorable conditions and stimulate the growth of plants and their defense mechanisms [4,7]. *Trichoderma* spp. can stimulate plant growth because they enable plants to absorb more nutrients and stimulate the production of vitamins and growth regulators [7–9]. Another benefit is the increased content of antioxidants in the fruit of the plants treated with *Trichoderma* spp. [9]. Moreover, investigations showed that some *Trichoderma* spp. significantly improved the fertility of the media treated with them. These observations encourage farmers to use them for crop production. The presence of fungi *Trichoderma* spp. in plants also induces their resistance. This phenomenon has been attributed to the biochemical exchange of information between the fungi and the root, involving numerous bioactive metabolites produced by biocontrol agents [7]. *Trichoderma* spp. can induce plants’ stronger response than the resistance induced by pathogens because they stimulate the production of hydrophobins, expansin-like proteins, secondary metabolites, and enzymes with direct antimicrobial activity such as peroxidase, chitinase, and glucanase. Apart from that, fungi of the *Trichoderma* spp. cause the accumulation of phytoalexins, i.e., organic chemical compounds which plants produce in response to the attack of pathogens [9]. *Trichoderma* spp. are aerobic organisms, so they develop best in the surface layers of the substrate [10]. Moreover, Benitez et al. [4] observed faster sporulation of *Trichoderma* spp. at increased access to visible light. Humidity is a very important factor influencing proper development of these fungi. According to Das et al. [11], the highest metabolic activity of the fungi can be observed at a humidity of about 80%.

For all these reasons *Trichoderma* spp. can be used as biostimulants in horticultural production to control soil pathogens, induce plants’ resistance or promote their growth. To date, the interaction of *Trichoderma* spp. with ornamental plants has been poorly investigated. Therefore, the aim of this study was to assess the influence of these fungi and different fertilization levels on the flowering and nutritional status of *Begonia × tuberhybrida* Voss. ‘Picotee Sunburst’ plants. *Begonia × tuberhybrida* blooms long and very profusely. It is a valued species planted in green areas and on balconies and terraces. Commercially available cultivars vary in height, growth character, color, and size of flowers. Of the species offered for summer compositions, *Begonia × tuberhybrida* is one of the most important.

2. Materials and Methods

2.1. Cultivation of Plants

The experiment was conducted during the growing season in 2018 and 2019, from April to September, in a greenhouse at the Marcelin Experimental Station, Department of Phytopathology, Seed Science and Technology, Poznań University of Life Sciences, Poland. The study assessed the flowering and nutritional status of *Begonia × tuberhybrida* Voss. ‘Picotee Sunburst’ plants treated with *Trichoderma* spp.

Tubers were planted in pots with a diameter of 20 cm, filled with a peat substrate (pH 6.5), enriched with multi-component Peters Professional Allrounder fertilizer (20:20:20 + microelements) at a dose of 1 g/1 L of the substrate.

Plants were cultivated at the temperature of 20–22 °C in day and 18–20 °C in night. On very warm and sunny days, the greenhouse was shaded. Relative humidity was maintained at 60%.

In each year of the study, there were six treatments with three replications and three plants in each. There were nine plants in each treatment. Before planting, the tubers were soaked in water or a mixture of spore of *Trichoderma* spp. (*T. viride* Schumach–Tv14, *T.
harzianum Rifai–Thr2, T. hamatum/Bonord/Bainier–Th15) in the form of a suspension for 24 h. The isolates came from a collection from the Department of Phytopathology, Seed Science and Technology.

After five weeks of cultivation, when the tops of shoots were visible above the surface of the substrate, the plants were fertilized every 7 days with the multi-component Peters Professional Allrounder fertilizer (20:20:20 + microelements). Water solutions of the fertilizer at a concentration of 0.0%, 0.2%, and 0.3% (20 mL per plant) were applied within the treatments in which both the tubers soaked in water and those soaked in a suspension containing a mixture of spores of Trichoderma spp. were planted.

2.2. Inoculum of Trichoderma spp.

An inoculum of Trichoderma hamatum, T. harzianum, and T. viride was prepared in laboratory of Department of Phytopathology, Seed Science and Technology, Poznań University of Life Sciences, in sterile plastic Petri dishes with a diameter of 90 mm. PDA (16 mL) medium was poured into each dish. When it solidified, a 5 mm disc of the nutrient medium overgrown with the mycelium of an appropriate isolate was placed in the central part of the plate. The disc had been cut from the circumference of a 10-day-old culture. Next, the cultures were incubated at 20 °C for three weeks; 20 mL of distilled water was poured onto the sporulating cultures, and the resulting suspension was poured into a flask. A spore suspension of the three tested Trichoderma isolates was prepared from a three-week culture. Trichoderma isolates were flooded with 20 mL of sterilized distilled water and scraped with a sterile glass rod. The suspension was filtered and the spore concentration of the three Trichoderma species in the mixture was adjusted to a concentration of $10^6$ per mL using a hemocytometer under light microscopy.

2.3. Parameters

The percentage of root colonization by Trichoderma spp. was assessed, after the end of the cultivation experiment (after 24 weeks of cultivation). The earliness of flowering was assessed on the basis of the weighted average of the number of days from the planting of tubers to the appearance of the first colored flower bud. The evaluation of parameters began when three flowers were found on the plants. The number of flowers and buds, the flower diameter, the number of shoots and leaves, and the plant height were determined. The leaf greenness index was also measured with the Chlorophyll Meter-SPAD-502 apparatus. The content of macroelements (nitrogen—N, phosphorus—P, potassium—K, calcium—Ca, magnesium—Mg) and micronutrients (iron—Fe, manganese—Mn, zinc—Zn, copper—Cu, boron—B) in leaves was also measured.

2.4. Macro- and Microelements Content

In each treatment, 10 cm long tops of leaves were collected for chemical analyses. The leaves were dried at a temperature of 45–50 °C and then ground. To determine the total content of N, P, K, Ca, and Mg, the leaves were mineralized in concentrated sulphuric acid (H$_2$SO$_4$). The following methods were used to measure the content of the nutrients: total N–Kjeldahl digestion with distillation in a Parnas–Wagner apparatus, P—the colorimetric method with ammonium molybdate (after Schillak), K, Ca, and Mg–atomic absorption spectrometry (AAS).

To determine the total iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) content, the leaves were mineralized in a mixture of nitric (HNO$_3$) and perchloric acids (HClO$_4$) (3:1, v/v). To measure the sodium (Na) content, they were mineralized in concentrated sulphuric acid (H$_2$SO$_4$) [12]. After the mineralization, the Na, Fe, Mn, Zn, and Cu content was measured with the AAS method (in a Carl Zeiss Jena apparatus).

2.5. Root Colonisation

At the end of the experiment, after 24 weeks of cultivation, the shoots were removed and the tubers were dug up with the roots. Then they were rinsed in water until the
substrate was removed. Root samples were taken and cut into 1 cm long pieces. Samples were surface disinfected by immersion for 2 min in 2% sodium hypochlorite (NaOCl) solution. Root fragments (5 each) were placed in a Petri dish with PDA medium and incubated at 20 °C for 14 days. They were then placed on sterile filter paper and dried in a laminar airflow chamber. The percentage of root colonization was assessed on the basis of the number of roots colonized by *Trichoderma* spp.

### 2.6. Data Analysis

The results were analyzed statistically with two-way analysis of variance. Fertilization was the first-order factor, and *Trichoderma* spp. were the second-order factor (the mean values from the two years were taken into account). The experiment was set up in a Randomized Complete Block Design. The averages were grouped by means of the Duncan test at a significance level of $\alpha = 0.05$. The program, Statistica version 13.3 was used.

### 3. Results

#### 3.1. Root Colonisation

The study showed that 30.5%, 29.5%, and 30.0% of the root fragments of the *Begonia × tuberhybrida* 'Picotee Sunburst' plants in the treatments treated with *Trichoderma* spp. were colonized by these fungi, regardless of the concentration of the fertilizer applied to feed the plants (Table 1).

| Concentration of Fertilizer (%) | Trichoderma spp. |          |          |        |        |        |
|---------------------------------|------------------|----------|----------|--------|--------|--------|
|                                 | No               | 2018     | 2019     | Mean   | 2018   | 2019   | Mean   |
| 0.0                             | 0.0              | 0.0      | 0.0      | 0.0 a  | 27.5   | 33.5   | 30.5 b |
| 0.2                             | 0.0              | 0.0      | 0.0      | 0.0 a  | 30.5   | 28.5   | 29.5 b |
| 0.3                             | 0.0              | 0.0      | 0.0      | 0.0 a  | 29.0   | 31.0   | 30.0 b |

#### 3.2. Earliness of Flowering

The earliness of flowering of the *Begonia × tuberhybrida* 'Picotee Sunburst' plants significantly depended on both the concentration of the fertilizer and *Trichoderma* spp. (Table 2). The plants, which had not been fertilized during the growing season, were significantly the latest to start flowering, no matter if they had been treated with *Trichoderma* spp. or not. The plants treated with the 0.3% fertilizer and supplemented with *Trichoderma* spp. were significantly the earliest to start flowering. The plants in the other treatments started flowering at similar times, i.e., 84.5–85.5 days after the tubers had been planted.

| Concentration of Fertilizer (%) | Trichoderma spp. |          |          |        |        |        |
|---------------------------------|------------------|----------|----------|--------|--------|--------|
|                                 | No               | 2018     | 2019     | Mean   | 2018   | 2019   | Mean   |
| 0.0                             | 88.5             | 87.0     | 87.7 c   | 87.5   | 86.5   | 87.0 c |
| 0.2                             | 84.5             | 85.0     | 84.7 b   | 84.5   | 85.5   | 85.0 b |
| 0.3                             | 85.0             | 84.0     | 84.5 b   | 78.0   | 80.0   | 79.0 a |
| Mean                            | 86.0 b           | 85.3 b   | 83.5 a   | 84.0 a | 84.0 a |        |

Table 1. Root colonization percentage of *Begonia × tuberhybrida* ‘Picotee Sunburst’ after application of *Trichoderma* spp. and different fertilization level. Means followed by the same letter for column-wise and row-wise do not differ significantly at $\alpha = 0.05$.

Table 2. Earliness of flowering and quality of plants of *Begonia × tuberhybrida* ‘Picotee Sunburst’ after application of *Trichoderma* spp. and different fertilization level. Means followed by the same letter for column-wise and row-wise do not differ significantly at $\alpha = 0.05$. 

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Table 2. Cont.

| Concentration of Fertilizer (%) | Trichoderma spp. | | | | | |
|---|---|---|---|---|---|---|
|  | 2018 | 2019 | Mean | 2018 | 2019 | Mean |
| Height of plants (cm) | | | | | | |
| 0.0 | 29.0 | 28.0 | 28.5 a | 28.0 | 27.5 | 27.7 a |
| 0.2 | 26.0 | 27.0 | 26.5 a | 26.5 | 27.0 | 26.7 a |
| 0.3 | 29.0 | 27.0 | 28.0 a | 27.0 | 28.0 | 27.5 a |
| Mean | 28.0 a | 27.3 a | 27.2 a | 27.5 a | | |
| Number of shoots | | | | | | |
| 0.0 | 1.5 | 1.8 | 1.6 a | 2.5 | 2.0 | 2.2 a |
| 0.2 | 2.0 | 1.8 | 1.9 a | 2.5 | 1.8 | 2.1 a |
| 0.3 | 2.0 | 2.1 | 2.0 a | 2.8 | 2.2 | 2.5 a |
| Mean | 1.8 a | 1.9 a | 2.6 a | 2.0 a | | |
| Number of leaves | | | | | | |
| 0.0 | 8.2 | 9.0 | 8.6 a | 12.5 | 11.5 | 12.0 b |
| 0.2 | 12.5 | 11.0 | 11.7 b | 14.2 | 13.0 | 13.6 c |
| 0.3 | 12.0 | 11.0 | 11.5 b | 12.0 | 12.0 | 12.0 b |
| Mean | 10.9 a | 10.3 a | 12.9 b | 12.2 b | | |
| Leaf greenness index (SPAD) | | | | | | |
| 0.0 | 40.2 | 42.6 | 41.4 a | 51.0 | 52.5 | 51.7 b |
| 0.2 | 55.5 | 56.2 | 55.8 c | 65.4 | 63.2 | 64.3 d |
| 0.3 | 55.7 | 54.2 | 55.0 c | 54.4 | 55.5 | 55.0 c |
| Mean | 50.5 a | 51.0 a | 57.4 b | 57.1 b | | |
| Number of buds and flowers | | | | | | |
| 0.0 | 4.2 | 3.5 | 3.8 a | 5.7 | 6.0 | 5.8 b |
| 0.2 | 5.5 | 6.0 | 5.7 b | 6.2 | 5.8 | 6.0 b |
| 0.3 | 7.0 | 6.5 | 6.7 c | 8.0 | 7.8 | 7.9 d |
| Mean | 5.6 a | 5.3 a | 6.6 b | 6.5 b | | |
| Diameter of flower (cm) | | | | | | |
| 0.0 | 11.0 | 10.5 | 10.7 a | 12.0 | 11.8 | 11.9 b |
| 0.2 | 12.0 | 11.5 | 11.7 b | 12.0 | 12.5 | 12.2 c |
| 0.3 | 12.5 | 11.0 | 11.7 b | 16.5 | 15.5 | 16.0 d |
| Mean | 11.8 a | 11.0 a | 13.5 b | 13.3 b | | |

3.3. Height of Plants and Number of Shoots

The height of the plants and their number of shoots were not significantly affected by the fertilization or *Trichoderma* spp. (Table 2). Regardless of the fertilizer concentration, the plants grew to a height of 26.5–28.5 cm and had 1.6–2.5 shoots. The plants grew to a height of 27.2–28.0 cm and had 1.8–2.6 shoots, no matter if they had been treated with *Trichoderma* spp. during the growing season or not.

3.4. Number of Leaves

The number of leaves significantly depended on both the fertilization and *Trichoderma* spp. (Table 2). Regardless of the fertilizer concentration, there were significantly more leaves on the plants treated with the *Trichoderma* spp. There were, significantly, the fewest leaves on the plants which had not been fertilized or treated with *Trichoderma* spp. The most leaves were found in the plants treated with the 0.2% fertilizer and *Trichoderma* spp. fungi. The treatment of non-fertilized plants with the fungi of the *Trichoderma* spp. stimulated the development of leaves. However, the number of leaves on the plants from this treatment
did not differ significantly from the number of leaves in the treatment in which the plants were grown without the *Trichoderma* spp. but supplemented with the fertilizer concentrated at 0.2% and 0.3%, as well as from the number of leaves in the treatment in which the plants were grown with the *Trichoderma* spp. and supplemented with the fertilizer at a concentration of 0.3%.

3.5. Leaf Greenness Index

The comparison of the results showed that the leaf greenness index depended significantly on the fertilizer concentration and *Trichoderma* spp. (Table 2). Regardless of the fertilizer concentration, there was a significantly higher value of the leaf greenness index in the plants grown with the *Trichoderma* spp. The lowest leaf greenness index was noted in the plants which had not been fertilized and grown without the *Trichoderma* spp. The highest leaf greenness index was noted in the plants which had been treated with the 0.2% fertilizer and grown with the *Trichoderma* spp. The treatment of non-fertilized plants with the *Trichoderma* spp. significantly increased their leaf greenness index. The leaf greenness index was significantly higher in the other treatments—it ranged from 55.0 to 55.8.

3.6. Number of Buds and Flowers

The number of buds and flowers on the plants of the ‘Picotee Sunburst’ cultivar significantly depended on the fertilizer concentration and *Trichoderma* spp. (Table 2). The fewest flowers developed on the non-fertilized and were grown without the *Trichoderma* spp. plants. The largest significant number of buds and flowers was noted on the plants supplemented with *Trichoderma* spp. and treated with the 0.3% fertilizer. The number of buds and flowers on the plants treated with the fertilizer concentrated at 0.2% and 0.3% but not supplemented with the *Trichoderma* spp. was directly proportional to the fertilizer concentration. The number of buds and flowers on the plants supplemented with the *Trichoderma* spp. fungi but not fertilized, as well as the plants treated with the 0.2% fertilizer, was similar to the number of buds and flowers on the plants grown without the *Trichoderma* spp. but treated with the 0.2% fertilizer.

3.7. Flower Diameter

The diameter of flowers developed by the plants of the ‘Picotee Sunburst’ cultivar significantly depended on the fertilizer concentration and *Trichoderma* spp. (Table 2). The non-supplemented and non-fertilized plants developed flowers with the smallest diameter. The plants grown with the *Trichoderma* spp. and treated with the 0.3% fertilizer had significantly the largest flowers. The plants grown without the *Trichoderma* spp. but treated with the fertilizer concentrated at 0.2% and 0.3% had significantly larger flowers than the non-fertilized plants. The non-fertilized plants supplemented with the *Trichoderma* spp. developed flowers with a similar diameter. The plants treated with the 0.2% fertilizer and supplemented with the *Trichoderma* spp. had flowers with a significantly larger diameter.

3.8. Content of Macroulements

The comparison of the content of macroulements in the leaves of the plants of the ‘Picotee Sunburst’ cultivar revealed significant differences only in the nitrogen content. The differences were influenced only by the fertilizer concentration (Table 3). The leaves of the non-fertilized plants had the lowest N content regardless of the fact whether the plants had been supplemented with the *Trichoderma* spp. or not. The treatment of the plants with the fertilizer concentrated at 0.2% and 0.3% increased the N content in the leaves by 20%.
Table 3. Content of macroelements (% DW) in leaves of *Begonia × tuberhybrida* ‘Picotee Sunburst’ after application of *Trichoderma* spp. and different fertilization level. Means followed by the same letter for column-wise and row-wise do not differ significantly at $\alpha = 0.05$.

| Concentration of Fertilizer (%) | Trichoderma spp. |  |  |  |  |  |  |
|-------------------------------|------------------|---|---|---|---|---|---|
|                               | 2018  | 2019  | Mean | 2018  | 2019  | Mean |  |
| N                             |       |       |      |       |       |      |  |
| 0.0                           | 3.7   | 3.3   | 3.5 a | 3.6   | 3.6   | 3.6 a |  |
| 0.2                           | 4.4   | 4.0   | 4.2 b | 4.2   | 4.4   | 4.3 b |  |
| 0.3                           | 4.5   | 4.0   | 4.2 b | 4.2   | 4.4   | 4.3 b |  |
| Mean                          | 4.2 a | 3.8 a | 4.0 a | 4.0 a | 4.1 a | 4.1 a |  |
| P                             |       |       |      |       |       |      |  |
| 0.0                           | 0.9   | 0.8   | 0.8 a | 0.8   | 0.9   | 0.8 a |  |
| 0.2                           | 0.8   | 0.7   | 0.7 a | 0.9   | 0.8   | 0.8 a |  |
| 0.3                           | 0.9   | 0.8   | 0.8 a | 0.8   | 0.9   | 0.8 a |  |
| Mean                          | 0.9 a | 0.8 a | 0.8 a | 0.8 a | 0.9 a | 0.9 a |  |
| K                             |       |       |      |       |       |      |  |
| 0.0                           | 3.5   | 2.8   | 3.1 a | 3.0   | 3.2   | 3.1 a |  |
| 0.2                           | 3.9   | 3.3   | 3.6 a | 3.3   | 3.8   | 3.5 a |  |
| 0.3                           | 3.9   | 3.5   | 3.7 a | 3.7   | 4.0   | 3.8 a |  |
| Mean                          | 3.8 a | 3.2 a | 3.3 a | 3.7 a | 3.7 a | 3.7 a |  |
| Mg                            |       |       |      |       |       |      |  |
| 0.0                           | 0.5   | 0.5   | 0.5 a | 0.5   | 0.4   | 0.4 a |  |
| 0.2                           | 0.4   | 0.5   | 0.4 a | 0.4   | 0.5   | 0.4 a |  |
| 0.3                           | 0.4   | 0.5   | 0.4 a | 0.5   | 0.4   | 0.4 a |  |
| Mean                          | 0.4 a | 0.5 a | 0.5 a | 0.4 a | 0.4 a | 0.4 a |  |
| Ca                            |       |       |      |       |       |      |  |
| 0.0                           | 2.8   | 2.9   | 2.8 a | 3.0   | 2.8   | 2.9 a |  |
| 0.2                           | 2.8   | 2.9   | 2.8 a | 2.8   | 3.1   | 2.9 a |  |
| 0.3                           | 2.8   | 2.8   | 2.8 a | 2.9   | 3.0   | 3.0 a |  |
| Mean                          | 2.8 a | 2.9 a | 2.9 a | 3.0 a | 3.0 a | 3.0 a |  |

3.9. Content of Microelements

The content of microelements, except Cu and Na, significantly depended on the fertilizer concentration and the supplementation of the plants with the *Trichoderma* spp. (Table 4). The Mn content increased along with the fertilizer concentration both in the plants supplemented with the *Trichoderma* spp. fungi and in those grown without the fungal supplementation. The lowest Zn content was found in the non-fertilized plants which were grown without *Trichoderma* spp. There was significantly higher content of this element in the leaves of the plants grown without *Trichoderma* spp. and treated with the fertilizer concentrated at 0.2% and 0.3% as well as in the plants supplemented with the *Trichoderma* spp. fungi but not fertilized or treated with the fertilizer at a concentration of 0.2%. The Zn content was significantly the highest in the leaves of the plants supplemented with the *Trichoderma* spp. fungi but not fertilized or treated with the fertilizer at a concentration of 0.2%. The Fe content in the plants grown without the *Trichoderma* spp. was found in the treatment treated with the fertilizer at a concentration of 0.3%. There was a significantly higher content of this element in the plants grown with the *Trichoderma* spp. and treated with the fertilizer at a concentration of 0.2%. The Fe content was significantly the highest in the plants supplemented with the *Trichoderma* spp. and treated with the fertilizer at the highest concentration. The B content in the fertilized plants grown without the *Trichoderma*
spp. increased along with the fertilizer concentration. There was a similar phenomenon observed in the plants grown with the *Trichoderma* spp. However, it is noteworthy that the B content in the non-fertilized plants was similar to the content of this element in the plants which had neither been fertilized nor supplemented with the *Trichoderma* spp.

Table 4. Content of microelements (MG kg DW) in leaves of *Begonia × tuberhybrida* ‘Picotee Sunburst’ after application of *Trichoderma* spp. and different fertilization level. Means followed by the same letter for column-wise and row-wise do not differ significantly at $\alpha = 0.05$.

| Concentration of Fertilizer (%) | Trichoderma spp. |          |          |          |          |          |          |          |
|--------------------------------|------------------|----------|----------|----------|----------|----------|----------|----------|
|                                |                  | 2018     | 2019     | Mean     | 2018     | 2019     | Mean     |          |
|                                |                  | Mn       | Mn       | Mn       | Mn       | Mn       | Mn       |          |
| 0.0                            |                  | 104.2    | 103.4    | 103.8 a  | 105.0    | 104.6    | 104.8 a  |          |
| 0.2                            |                  | 126.9    | 125.2    | 126.0 b  | 128.3    | 125.2    | 126.7 b  |          |
| 0.3                            |                  | 140.5    | 137.2    | 138.8 c  | 138.3    | 140.2    | 139.2 c  |          |
| Mean                           |                  | 123.9 a  | 121.9 a  | 123.9 a  | 123.3 a  |          |          |          |
|                                |                  | Cu       | Cu       | Cu       | Cu       | Cu       | Cu       |          |
| 0.0                            |                  | 11.5     | 10.7     | 11.1 a   | 11.0     | 10.9     | 11.0 a   |          |
| 0.2                            |                  | 11.0     | 11.0     | 11.0 a   | 10.9     | 11.2     | 11.0 a   |          |
| 0.3                            |                  | 11.2     | 10.8     | 11.0 a   | 10.9     | 10.9     | 10.8 a   |          |
| Mean                           |                  | 11.2 a   | 10.8 a   | 10.9 a   | 11.0 a   |          |          |          |
|                                |                  | Zn       | Zn       | Zn       | Zn       | Zn       | Zn       |          |
| 0.0                            |                  | 27.6     | 26.6     | 27.1 a   | 29.1     | 28.7     | 28.9 b   |          |
| 0.2                            |                  | 30.0     | 28.2     | 29.1 b   | 30.0     | 31.5     | 30.7 b   |          |
| 0.3                            |                  | 32.7     | 30.2     | 31.4 b   | 35.3     | 34.9     | 35.1 c   |          |
| Mean                           |                  | 30.1 a   | 28.3 a   | 31.5 b   | 31.7 b   |          |          |          |
|                                |                  | Fe       | Fe       | Fe       | Fe       | Fe       | Fe       |          |
| 0.0                            |                  | 231.9    | 230.0    | 231.0 a  | 230.0    | 232.2    | 231.1 a  |          |
| 0.2                            |                  | 231.5    | 230.3    | 230.9 a  | 260.4    | 258.4    | 259.4 c  |          |
| 0.3                            |                  | 246.5    | 245.0    | 245.7 b  | 273.0    | 269.0    | 271.0 d  |          |
| Mean                           |                  | 236.6 a  | 235.1 a  | 254.5 b  | 253.2 b  |          |          |          |
|                                |                  | B        | B        | B        | B        | B        | B        |          |
| 0.0                            |                  | 13.4     | 14.0     | 13.7 a   | 22.6     | 23.4     | 23.0 c   |          |
| 0.2                            |                  | 23.7     | 19.3     | 21.5 b   | 26.6     | 27.3     | 27.0 d   |          |
| 0.3                            |                  | 25.2     | 24.0     | 24.6 c   | 28.2     | 30.0     | 29.1 e   |          |
| Mean                           |                  | 20.8 a   | 19.1 a   | 25.8 b   | 26.9 b   |          |          |          |
|                                |                  | Na       | Na       | Na       | Na       | Na       | Na       |          |
| 0.0                            |                  | 1.3      | 1.2      | 1.2 a    | 1.2      | 1.1      | 1.1 a    |          |
| 0.2                            |                  | 1.3      | 1.1      | 1.2 a    | 1.1      | 1.0      | 1.0 a    |          |
| 0.3                            |                  | 1.3      | 1.2      | 1.2 a    | 1.1      | 1.2      | 1.2 a    |          |
| Mean                           |                  | 1.3 a    | 1.2 a    | 1.1 a    | 1.1 a    |          |          |          |

4. Discussion

The study showed that 30.5%, 29.5%, and 30.0% of the roots of the *Begonia × tuberhybrida* ‘Picotee Sunburst’ plants were colonized by the fungi of the *Trichoderma* spp. Janowska et al. [13] conducted a study on *Freesia reflacta* ‘Argentea’ and observed a similar percentage of root colonization by *Trichoderma* spp., i.e., 32% in underexposed to light plants and 33% in exposed to the assimilation lighting ones. The authors concluded that the high rate of root colonization with the fungi resulted from the successful application of the fungal suspension to the substrate directly above the tubers, because, as Kosicka
et al. [10] indicated, *Trichoderma* spp. are aerobic organisms, so they develop best in the surface layers of the substrate. Moreover, Benítez et al. [4] noted that increased access to visible light accelerated the sporulation of *Trichoderma* spp. The rate of root colonization with these fungi may be very high. Pris et al. [14] conducted a study on *Limonium sinuatum* and observed that 100% of the roots were colonized by *Trichoderma* spp. Early flowering is very important in floral production, because it gives a possibility to plan the flowering date. Our study showed that the *Trichoderma* spp. slightly accelerated the flowering of the *Begonia × tuberhybrida* ‘Picotee Sunburst’ plants when they were treated with the fertilizer at a concentration of 0.2%. However, a higher concentration of the fertilizer accelerated the flowering of the plants by 8.7 days. Apart from that, the fungi of the *Trichoderma* genus stimulated the development of buds and flowers on the ‘Picotee Sunburst’ plants and had influence on their size. The most intensive flowering and the largest flowers were observed after the plants had been treated with the 0.3% fertilizer. These results are consistent with the findings of the study by Janowska et al. [13], who conducted a study on *Freesia refracta* ‘Argentea’ plants grown in winter without assimilation lighting. The authors observed that *Trichoderma* spp. accelerated the flowering of these plants by about one week. Apart from that, additionally, the assimilation lighting of the plants of the ‘Argentea’ cultivar and supplementation with *Trichoderma* spp. stimulated the development of lateral inflorescence shoots and flowers. This effect was particularly noticeable in the plants cultivated with assimilation lighting. According to Pris [15], *Trichoderma* spp. also stimulated the flowering of *Pachyphytum oepferum* and *Crassula falcata*.

Our study showed that the height of ‘Picotee Sunburst’ plants and their number of shoots were not affected by supplementation with *Trichoderma* spp. or fertilization regardless of the fertilizer concentration. However, the treatments stimulated leaf development. The most leaves were found on the plants grown with the *Trichoderma* spp. and treated with the fertilizer at a concentration of 0.2%. Additionally, the *Trichoderma* spp. stimulated the production of chlorophyll, as evidenced by the value of the leaf greenness index. According to Harman et al. [7], the treatment of plants with fungi of the *Trichoderma* spp. stimulates the growth of roots, results in longer and thicker shoots, larger leaf surface, higher chlorophyll content and yield, expressed by the number of flowers or fruits. However, according to Lorito et al. [9], the mechanisms responsible for these beneficial effects on plant growth have not been fully investigated and explanations are based on the suggestion that plant growth is stimulated by increased availability of nutrients.

In our study, the *Trichoderma* spp. did not affect the uptake of macronutrients by the ‘Picotee Sunburst’ plants, but stimulated the uptake of micronutrients—Zn, Fe, and B. Their content increased along with the concentration of the fertilizer. According to data in available scientific publications, the *Trichoderma* spp. stimulate the uptake of micro- and macroelements by ornamental plants, but there is no clear answer to the question of which of them and under what conditions are most often absorbed by plants. Janowska et al. [15] observed that fungi of the *Trichoderma* spp. stimulated the P and Ca uptake by underexposed to assimilation lighting *Freesia refracta* ‘Argentea’ plants and the K uptake by plants cultivated with the assimilation lighting. Moreover, *Trichoderma* spp. stimulated the uptake of Fe, Mn, and Zn by both the exposed or underexposed to light plants of this cultivar. On the other hand, the plants exposed to assimilation lighting and supplemented with the fungi of the *Trichoderma* spp. took up Cu intensively. Alpa et al. [16] observed that arbuscular mycorrhizal fungi (AMF) in treatment with *Trichoderma viride* stimulated the uptake of nutrients, especially P, by *Helianthus annuus*, because they improved the conditions in the root zone and thus affected the plants’ physiological and biochemical properties. According to Altomare et al. [17], *Trichoderma* spp. increase plants’ uptake of various elements, including Pb, Mn, Zn, and Al. They also increase plants’ ability to dissolve some nutrients in the substrate, e.g., phosphates, Fe$^{3+}$, Cu$^{2+}$, and Mn$^{4+}$ ions, which are usually difficult for plants to access. According to Vinale et al. [5], both plant and fungal regulators may stimulate plant growth and nutrition. This observation was also made
by Janowska et al. [18,19] in a study on Gladiolous hybridus ‘Black Velvet’ plants, and by Sajjad et al. [20] in a study on the ‘White Prosperity’ cultivar.

The results obtained indicate that the research undertaken is important not only for science but also for practitioners. The use of Trichoderma spp. results in early and abundant flowering plants.

5. Conclusions

The Trichoderma spp. accelerated the flowering of the Begonia × tuberhybrida ‘Picotee Sunburst’ plants by 2.7–8.7 days. Trichoderma spp. stimulated the development of buds and flowers in the plants of the ‘Picotee Sunburst’ cultivar and affected their size. The plants bloomed most intensively and had the biggest flowers after the treatment with the 0.3% fertilizer. Trichoderma spp. and the fertilization had no effect on the height of the plants and the number of shoots regardless of the fertiliser concentration, but they stimulated the development of leaves. Trichoderma spp. stimulated the production of chlorophyll, as evidenced by the value of the leaf greenness index. They did not affect the uptake of macroelements, but they stimulated the uptake of microelements (Zn, Fe, and B). The higher the fertiliser concentration was, the higher was the content of microelements in the plants.

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