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THE INFLUENCE OF FERTILIZATION REGIME ON PLANTS GROWTH OF *PASSIFLORA CAERULEA*

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Abstract

Passiflora caerulea is a voluble ornamental plant appreciated in alternative medicine for its content in secondary metabolites. The aim of this research was to evaluate the influence of foliar fertilizers on the growth of biomass and ornamental characters in greenhouse-grown Passiflora, during 2019-2020. Thus, the Cropmax biostimulator and the mineral basic fertilizer Nutricomplex 20-20-20 were tested comparatively. Starting with the second week after transplanting the plant material into the soil, fertilizations were performed every 14 days, during the active growth and monthly during the winter. The plants were monitored for the main morpho-decorative characteristics, the results being interpreted statistically. The analysis of the recorded data shows that both treatments improved the growth of the tested plants compared to non-fertilized plants and the biostimulator Cropmax significantly influenced the growth of Passiflora caerulea plants compared to Nutricomplex 20-20-20.

Key words*: biostimulator, growth, mineral fertilizer, Passifora.*

INTRODUCTION

Passion flowers (*Passiflora* spp.) are tropical vines becoming more and more popular landscape plants. Climbing plants are important in the landscaping for their practical qualities because they can be used in purposes where trees and large shrubs are unsuitable (Berberich et al., 2006). The genus *Passiflora* includes approximately 550 species, of which more than 150 are native to Brazil which is one of the most important centers of passion flower diversity (Faleiro et al., 2005).

Passiflora caerulea (blue Passion flower) is the most gentle species having traditional use of its fruit as a sedative and anxiolytic. *Passiflora caerulea* is used medicinally in Uruguay. In West Indies, Mexico, Netherlands and South America, the root has been used as sedative and vermifuge. The aerial parts are used as antimicrobial agents in diseases like pneumonia (Patel et al., 2011).

Passiflora is one of the species with decorative potential in Romania for terraces and gardens due to exuberant flowers and the long period of decoration. Although due to the climatic conditions it needs protection over the winter in the conditions of this area, the decoration period is a long one, from the beginning of summer when the plant manages to reach a considerable size, until late autumn. *Passiflora* also behaves exceptionally in protected areas, decorating the interior terraces or spacious rooms of a home.

Passion flowers are fast growing plants and can make a sellable plant in approximately four months from sticking cuttings (Berberich et al., 2006).

Passion fruit is identify through a lot of uses of its different sections, such as pulp, seeds, bark, flowers, leaves, and branches (Nóbrega et al., 2017). These sections can be commercially valued in the aim of natural consumption, raw material for the food, juices, flowers for ornamentation condiment, cosmetic and pharmaceutical industries (Faleiro et al., 2015).

One of the impediments to expanding the production of *Passiflora* plants is the lack of informations or insufficient informations available to growers about growing practices necessary for the production of potted plants. Propagation by cuttings is successfully for *Passiflora caerulea*, offering the potential for economic profitability (Boboc et al., 2020). The growth and flowering of the passion flower is dependent on the fertilization regime

(Berberich et al., 2006; Borges et al., 2006 Menzel et al., 1991; Vieira Pacheco et al., 2018; Wanderley et al., 2020). Several factors influence the productivity of the passion fruit, among which can be highlight: the climate, the soil and the regime of fertilization and irrigation (Aular et al., 2014). Meeting nutritional requirements is essential to raise productivity and improve the quality of the fruits (Borges et al., 2006). Thus, the aim of the research was to establish an optimal fertilization regime for *Passiflora* grown in the greenhouse and to analyze the main morpho-decorative features to lead to the achievement of an optimal cultivation system for the conditions in Romania.

MATERIALS AND METHODS

The experience regarding the influence of fertilization regime on *Passiflora caerulea* plants growth was placed in the greenhouse of the Department of Ornamental Plants, belonging to the Institute of Advanced Horticultural Research of Transylvania, of the University of Agricultural Sciences and Veterinary Medicine (USAVM) Cluj-Napoca and was initiated on April 22, 2019. Plants were grown in a greenhouse with automatically controlled environmental conditions: 25/20°C day/night temperature, 60% relative humidity, and natural light. Plants were watered daily in the first 2 weeks after transplantation, and after that period twice a week. From the climatic point of view, the region in which the greenhouse is placed, according to the W. Köppen system is the climatic province Df, defined by the boreal climate with cold and humid winters and the lowest temperature recorded during winter below -30°C and the highest above 10°C (Bunescu et al., 2005).

Plant material consisted of young plants, 2 months old, obtained from cuttings of two knots harvested from mature plants at the end of February, 2019 and rooted in previous doctoral studies. After the plants root system was well developed, they were transplanted to soil.

For experimental purposes, two fertilizers were tested: Cropmax®, 100% organic biostimulator and Nutricomplex® 20-20-20 + M.E., mineral fertilizer. Cropmax® (Holland Farming, Groenekan, The Netherlands) is an organic growth biostimulant for all sorts of crops, contains amino acids, macro- and micro-elements, vitamins and polysaccharides. This fertiliser contains N (0.2%), P (0.4%), K (0.02%), Fe (220 mg/l), Mg (550 mg/l), Zn (49 mg/l), Mn (54 mg/l), Cu (35 mg/l), Bo (70 mg/l), Ca + Mo + Cb + Ni (10 mg/l), vitamins C and E, enzymes and carotenoids. Recommended concentration rate in greenhouse crops is 0.05 - 0.2%, every 7-10 days (Balint et al., 2018). Nutricomplex® 20-20-20 + M.E (Trade Corporation International, Madrid Spain) is manufactured with high pure raw materials, enriched with chelated micro-nutrients and it's free of chloride, sodium and carbonates. This fertiliser contains N (20% w/w), P_2O_5 (20% w/w), K_2O (20% w/w), Fe (0.06% w/w), Mn (0.04% w/w), Zn (0.02% w/w), Cu (0.01% w/w), B (0.02% w/w), Mo (0.003% w/w). In foliar application, the recommended dosage is 250-400 g/hl.

Nutricomplex® 20-20-20 (n.d.)

The bifactorial experience was carried out during 2019-2020, in randomised block method with three repetitions (Ardelean et al., 2007) as follows:

Factor A - the fertilizer:

a_1 - Nutricomplex

a_2 - Cropmax

a_3 - unfertilized (control)

Factor B - the dose applied:

b_1 - 0.05%

b_2 - 0.1%

b_3 - 0.2%

From the interaction of the two factors resulted 7 experimental variants.

The application of fertilizers (Cropmax and Nutricomplex) was done every 14 days by foliar spraying throughout the vegetation period. The treatments were applied after the first week after transplantation until the flowering. The results were compared to control, where *Passiflora caerulea* plants were treated with the same volume of water (without fertilizer). Tillage of plants was done using good agricultural practices.

Biometric variables have been used to assess the quality of *Passiflora caerulea* plant species. The morphological indices were represented by: average plant length (PL), average number

of shoots per plant (ShNo), average number of internodes on the main stem (InNo), average length of internodes (InL) (cm), average number of leaves/plant (LeNo) and stem diameter at 50 cm from the ground (StD) (mm) and the relative growth rate RGR. Regarding flowering and fruiting, were made determinations on the first node at which the flower on the shoot was occured (FNFl), the average number of flowers per plant (FlNo), the flower diameter (FlD) and the average number of fruit per plant (FrNo). As different growth rates were observed during the growing season, four time intervals were established (22 April - 3 June, 4 June - 5 August, 6 August - 7 October, 8 October - 30 December) for which calculated the evolution of the relative daily growth rate (RGR). RGR was determined using the formula:

RGR = W2-W1/T,

Where: W1 = first measurement, W2 = second measurement, and T = the number of days between each.

The average values obtained in the period 2019-2020 were analyzed processed using the analysis of variance (ANOVA) followed by Duncan's multiple comparison test.

RESULTS AND DISCUSSIONS

Based on research conducted on the species *Passiflora caerulea*, the influence of fertilizer and dose applied on morpho-decorative features was analyzed.

Regarding the average growth of *Passiflora caerulea* plants in the first year after planting, the determinations were performed weekly, from transplanting date (April 22, 2019) until the end of the year (Figure 1). The plants fertilized with Cropmax recorded the highest average growth, with a value of 418.4 cm and the plants fertilized with Nutricomplex reaching an average height of 334.5 cm and unfertilized plants reached at 175.55 cm at the end of the year.

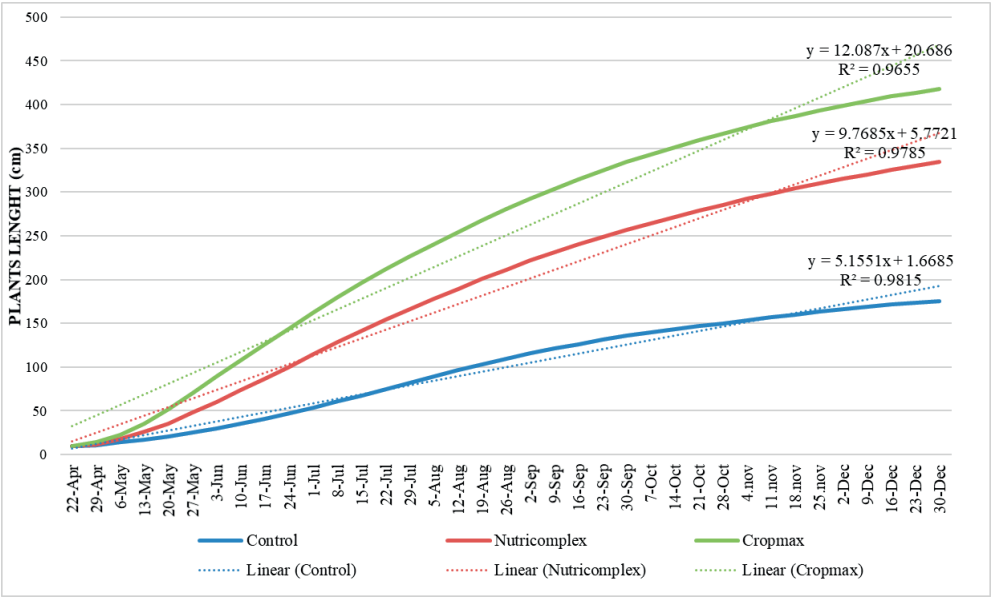

Figure 1. The evolution of average growths at *Passiflora caerulea* in 2019

Because a brief analysis of Figure 1 shows different growth rates, four time intervals were established for which the evolution of the relative growth rate was calculated. As shown in Figure 2, the highest RGR in all four time intervals (1.84, 2.44, 1.65, 0.92) and the highest average RGR/year (1.64) were recorded for Cropmax biofertilizer.

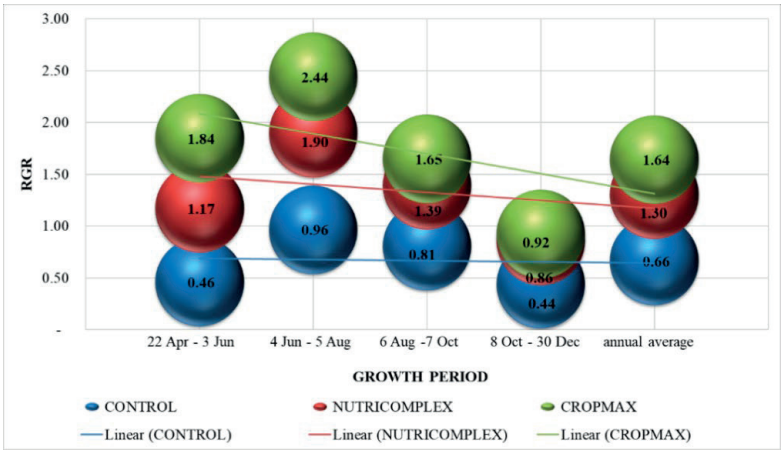

Figure 2. Relative growth rate (RGR) on growth intervals in 2019

Figure 3. *Passiflora caerulea* aspects of culture in the greenhouse didactic USAVM Cluj-Napoca: a, b - rooted cuttings; c - after 2 months from planting; d - specimen fertilized with Nutricomplex; e - specimen fertilized with Cropmax; f - fruiting, specimen fertilized with Cropmax; g, i - flowers of *P. caerulea*; i - fruit formation

According to Table 1, a bifactorial analysis of RGR was performed for the experimental years 2019 and 2020. On average, in 2019 the RGR (1.2) was higher than in 2020 (0.89). In the two years, Cropmax biofertilizer determines the highest RGR (1.64 and 1.35), followed by Nutricomplex (1.30 and 1.15) (Figure 3).

There were statistically assured differences between all the experimental variants

Table 1. Results on the influence of fertilizer on relative growth rate in 2019 and 2020 in *Passiflora caerulea*

Var. no.	Fertilizer	RGR	
		2019	2020
a_1	Nutricomplex	1.30 c	1.15 d
a_2	Cropmax	1.64 a	1.35 b
a_3	Unfertilized (C)	0.66 e	0.17 f
DS 5%		0.03	

Note: The difference between any two values followed by at least one common letter is insignificant.

According to Table 2, the morphological indices showed increases in the application of all treatment variants compared to the control variant (V7).

Regarding the average length of the plants, there were statistically assured differences between each experimental variant (V1-V7), the average values ranged between 136.77 cm (V7) and 421.17 cm (V6).

The average number of shoots recorded values between 8.07 (V7) and 32.07 (V6). Cropmax-fertilized plants obtained significantly higher values, but there were no statistically assured differences (V4-V6) between the three applied doses.

The average number of internodes was shown to be directly proportional to the length of the plants. Thus, the average values varied between 25.27 (V7) and 63.33 (V6).

The average length of the internodes was between 4.85 cm (V7) and 6.65 cm (V7) but statistically assured differences were obtained only in the case of V2 (6.07 cm) and V7 (4.85 cm) variants.

The average number of leaves per plant ranged from 111.9 (V7) to 296.3 (V6). Each variant for which Cropmax was applied recorded statistically assured differences (V4, V5, V6), as well as for V1 fertilized with Nutricomplex and V7 (control).

The average diameter of the stem at 50 cm from the ground recorded values between 5.13 mm (V7) and 6.59 mm (V6), differences statistically ensured obtained in the case of variants V3, V5, V6 and V7.

Table 2. Results on the interaction of fertilizer and applied dose on morphological characters of *Passiflora caerulea*

Var. no.	Fertilizer	Doze	Morphological characters					
			Average plant length (cm)	Average number of shoots	Average number of internodes on the main stem	Average length of internodes (cm)	Average number of leaves / plant	Stem diameter at 50 cm from the ground (mm)
V_1	Nutricomplex	0.05%	325.17 e	24.81 b	56.10 d	5.79 c	217.67 e	6.18 c
V_2		0.1%	344.8 d	28.43 ab	56.83 cd	6.07 b	224.97 d	6.30 c
V_3		0.2%	385.83 c	26.83 ab	58.43 bcd	6.56 a	229.37 d	6.36 bc
V_4	Cropmax	0.05%	351.83 d	30.40 a	60.10 abc	5.82 c	273.6 c	6.28 c
V_5		0.1%	399.23 b	30.80 a	61.23 ab	6.53 a	282.00 b	6.54 ab
V_6		0.2%	421.17 a	32.07 a	63.33 a	6.65 a	296.73 a	6.59 a
V_7	Unfertilized (C)		136.77 f	8.07 c	25.27 e	4.85 d	111.9 f	5.13 d
DS 5%			12.05-13.57	4.92-5.54	3.52-3.97	0.19-0.21	6.62-7.8	0.21-0.24

Note: The difference between any two values followed by at least one common letter is insignificant.

Regarding the unilateral influence of the fertilizer on the morphological indices (Table 3), there were significant value differences between the two fertilizers, the plants treated with Cropmax biofertilizer demonstrating values higher than those treated with Nutricomplex for each morphological index analyzed.

Table 3. Results on the influence of fertilizer on the morphological characteristics of *Passiflora caerulea*

Var. no.	Fertilizer	Morphological characters					
		Average plant length (cm)	Average number of shoots	Average number of internodes on the main stem	Average length of internodes (cm)	Average number of leaves / plant	Stem diameter at 50 cm from the ground (mm)
a_1	Nutricomplex	351.93 b	26.69 a	57.12 b	6.14 b	224.00 b	6.28 a
a_2	Cropmax	390.74 a	31.09 a	61.56 a	6.33 a	284.11 a	6.47 a
a_3	Unfertilized (C)	136.77 c	8.07 b	25.27 c	4.85 c	111.90 c	5.13 b
DS 5%		17.72 - 18.08	4.78-4.87	3.35-3.42	0.08	25.04-25.55	0.30-0.31

Note: The difference between any two values followed by at least one common letter is insignificant.

Statistically assured differences between the two fertilizers were obtained only in terms of average plant length, average number of internodes on the main stem, average length of internodes, average number of leaves per plant. In the study conducted by Balint et al., (2018) fertilizations were performed on the commmon bean crop, and Cropmax significantly influenced the length and width of the bean pod. The comparative analysis of the unilateral influence of additional fertilization on ordinary pod beans shows a very significant positive difference (+0.04 cm) using Cropmax.

According to Table 4, the morphological indices regarding flowering and fruiting recorded average values higher than the control variant (V7). Thus, the first node at which a flower formed varied on average from 2.05 (V6) and 2.42 (V7), statistically assured differences were obtained only for V2 (2.23) and V6 (2.05). For this index, a lower average numerical value denotes a higher ornamental potential, with a higher number of flowers per shoot.

The average number of flowers per plant varies between 17.6 (V7) for non-fertilized plants and 193.6 (V6) for Cropmax fertilization 0.2%. Between each experimental variant, statistically assured differences were obtained, the number of flowers per plant being directly proportional to the applied fertilizer dose, thus V3 (173.66) and V6 represented significantly higher values compared to the rest of the variants.

The average diameter of the flower varies between 6.55 cm (V7) and 8.29 cm (V6), the differences being statistically ensured for the limit values.

The average number of fruits per plant ranges between 0.20 (V7) and 47.63 (V6). Plants fertilized with Cropmax produced a higher number of fruits compared to those treated with Nutricomplex, regardless of dose. Between each experimental variant, statistically assured differences were obtained.

Table 4. Results on the interaction of the fertilizer and the dose applied on the morphological-decorative characters in *Passiflora caerulea*

Var. no.	Fertilizer	Doze	Morphological characters			
			The first node at which the flower occurred	Average number of flowers / plant	Average flower diameter (cm)	Average number of fruits / plant
V_1	Nutricomplex	0.05%	2.34 a	111.35 f	7.67 c	14.67 e
V_2		0.1%	2.23 b	141.83 d	7.70 c	29.57 c
V_3		0.2%	2.14 bc	173.77 b	8.04 b	37.43 b
V_4	Cropmax	0.05%	2.34 a	126.33 e	8.05 b	21.30 d
V_5		0.1%	2.15 bc	154.6 c	8.14 ab	36.63 b
V_6		0.2%	2.05 c	193.6 a	8.29 a	47.63 a
V_7	Unfertilized (C)		2.42 a	17.6 g	6.55 d	0.20 f
DS 5%			0.10-0.11	9.49-10.69	0.15-0.17	4.20-4.74

Note: The difference between any two values followed by at least one common letter is insignificant.

Analyzing Table 5. on the influence of fertilizer on morphological and decorative characters in *Passiflora caerulea*, it is found that the application of a fertilizer does not statistically influence the first node at which the flower occurs on the shoot

Table 5. Results on the influence of fertilizer on morphological and decorative characters in *Passiflora caerulea*

Var. no.	Fertilizer	Morphological characters			
		The first node at which the flower occurred	Average number of flowers / plant	Average flower diameter (cm)	Average number of fruits / plant
a_1	Nutricomplex	2.18 a	142.32 b	7.80 a	27.22 b
a_2	Cropmax	2.24 a	158.18 a	8.16 a	35.19 a
a_3	Unfertilized (C)	2.18 a	17.6 c	6.55 b	0.20 c
DS 5%		0.34-0.35	8.01-8.17	0.40	1.52-1.56

Note: The difference between any two values followed by at least one common letter is insignificant.

Regarding the average number of flowers and fruits per plant, between the two fertilizers there are statistically assured differences, in both cases Cropmax records higher values (on average 158.18 flowers and 35.19 fruits per plant) compared to Nutricomplex (which determined in average production of 142.32 flowers and 27.22 fruits per plant).

Regarding the average diameter of the flower, there are no statistically assured differences between the two tested fertilizers.

The results obtained from the correlation between each morphological index were presented in Figure 4. Using the Pearson correlation coefficient, indicates almost perfectly positive correlated direct links ($p < 0.001$) between PL ($r = 0.91$-0.99) and the rest of the analyzed characters except FNF1 together with which it achieves a strong negative correlation ($r = -0.89$). As can be seen, the FNF1 indicator makes direct connections negatively correlated with each indicator followed.

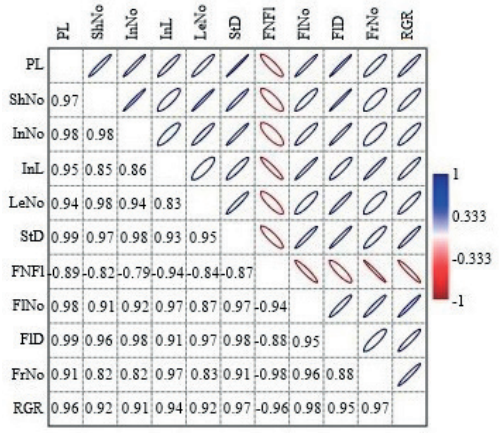

Figure 4. Correlation matrix with Pearson significance levels and graphical representation of the dispersion of each pair of variables in *Passsiflora caerulea*

In their research, Şesan et al. (2020) determined the effect of foliar treatments with a *Trichoderma* consortium on *Passiflora caerulea* on morphological, physiological and ultrastructural characteristics. Thus, the higher concentration of *Trichoderma* consortium was associated with larger leaves, increased number and size of chloroplasts, improved plant physiology characteristics, and an increased yield.

Pacheco et al. (2017) performed three types of fertilizers in the culture of *Passiflora edulis* for fruit: recommended mineral fertilizer, organic fertilizer represented by manure and the equivalence of recommended fertilization with potassium for the culture of *Passiflora edulis* by double dose of organic fertilizer. The single dose of organic fertilizer proved to be insufficient to maintain the quality of the fruit, but the fruit obtained from double-dose fertilized plants maintained their commercial quality better.

In another study on *Passiflora edulis*, Nascimento et al. (2016) evaluated the effects of bovine biofertilizer and mineral fertilization with NPK on the growth and production of fruit in passion flower plants irrigated with moderate salt water. Thus, the biofertilizer applied at the maximum dose combined with mineral fertilization with NPK led to a greater increase in stem diameter and increased plant productivity. Even in the treatments without mineral fertilizers, the biofertilizer increased the productivity to values close to 24 t ha^{-1} at the level of 60.65%.

In their research, Campos et al. (2015) demonstrated that organic fertilization had a positive effect on the *Passiflora incarnata* plant´s growth, improving the biomass production (dry matter). However, the synthesizing of bioactive compounds such as polyphenols, total flavonoids and the antioxidant capacity were not influenced by the effect of organic fertilization.

According to the study of Boechat et al. (2010), the application of NPK fertilizer is not enough to avoid adverse effects on plant growth or to correct the nutritional balance. Manure is the best option for the production of high quality seedlings under the conditions studied at *Passiflora edulis*.

In their research, Dinu et al. (2008) demonstrated that the treatments with 0.2% Cropmax and Vitaflora contribute for increase the starkness for the tomatoes plants, to increase plants resistance during the dryied time. The Cropmax biofertilizer can imporove the construct of tomatoes fruit.

CONCLUSIONS

Foliar fertilization influenced the culture of *Passiflora caerulea* in the first two years after cultivation. Regarding RGR, significant influences were found especially in the first year. The ecological foliar biofertilizer Cropmax has strongly influenced all the morphological and flowering characteristics of *Passiflora* plants. Regarding plant growth, differences between the two fertilizers can be seen from the first month of application, differences that have become more pronounced over time. This confirms the need for a fertilization regime and demonstrates its effectiveness. Thus, foliar fertilization is recommended for the cultivation of *Passiflora caerulea* from an ornamental point of view, or using organic fertilizers as a medicinal plant for its important therapeutic properties.

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