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ESTIMATION OF THE GROWTH OF 'VANDA' MAIDEN SWEET CHERRY TREES ON THREE ROOTSTOCKS AND AFTER APLICATION OF FOLIAR FERTILIZATION IN A NURSERY

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ABSTRACT

Cultivation of sweet cherry trees is growing in popularity in Poland thus there is an increasing demand for good quality nursery material. The growth of maiden sweet cherry trees of 'Vanda' depending on three rootstocks was compared within three years of the nursery experiment. Also the nutritional status as well as photosynthetic activity of maiden trees after the use of four foliar preparations were in the scope of interest. On the basis of the size of the trunk diameter and weight of maiden sweet cherry tree fresh mass as well as on the basis of dry mass of leaves, the strongest vigor of growth was observed on Colt rootstock, contrary to the vigor on GiSeLa 5 rootstock, in which it was the weakest. Maidens produced on Colt rootstock formed more lateral shoots in comparison to other rootstocks. After foliar fertilization, maiden sweet cherry trees growing on Colt rootstock did not show better parameters of growth, except for Maxi Grow Excel preparation that caused better results of growth. The influence of preparations used on the content of macro and microelements was differentiated. A positive effect of all preparations was noted as far as gas exchange parameters were concerned, especially in the case of Maxi Grow Excel.

Key words: leaf minerals content, leaf area index, photosynthetic activity parameters

INTRODUCTION

Intensive studies on rootstocks in cherry trees production in orchards are being carried out [Franken 2010, Sansavini and Lugli 2014, Stachowiak et al. 2014, Hrotko 2016, Lopez-Ortega et al. 2016]. However, there are very few publications concerning the influence of the rootstock on the growth of maiden sweet cherry trees in a nursery [Sitarek and Grzyb 2007, Baryła et al. 2014, Zenginbal et al. 2017]. Advisability of research on rootstocks for sweet cherry trees is connected with a growing interest in the production of this species in Poland. One of the barriers in the production of sweet cherries is late fruition of trees, which signifi-

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cantly lengthens the investment period. A requirement for the intensification of orchard cultivation is a possibility of obtaining the trees with a large number of fruit-bearing shoots. To obtain this goal and improve the quality of the nursery material, as well as the intensification of the tree growth and formation of lateral shoots, a variety of natural products, including mineral fertilizers, are used [Grzyb et al. 2014, 2015].

A prerequisite of modern agriculture as well as horticulture is the care for the protection of environment. Bio-fertilization is nowadays a very important method for providing the plants with their nutritional needs without having an undesirable impact on the environment [Abou El-Yazied and Sellim 2007]. Raghuwanshi [2012] stated that bio-fertilizers have a great potential as supplementary, renewable and environmentally friendly sources of plant nutrients. The application of bio-stimulants allowed a reduction in fertilizers without affecting the yield and quality [Bulgari et al. 2015]. Plant bio-stimulants – phytostimulants – are various non-toxic substances mostly of natural origin that improve and stimulate plant life processes differentially than fertilizers or phytohormones [Posmyk and Szafrańska 2016]. Biopreparations contain one or a few biologically active organic compounds (amino acids, vitamins, enzymes, plant hormones), and also macro- and microelements [Tarozzi et al. 2008]. In the scientific literature, there are several definitions of bio-stimulants. According to Vernieri et al. [2006], bio-stimulants are environmentally friendly, natural substances that are able to promote vegetative growth, mineral nutrient uptake, plant response to different pedoclimatic conditions and tolerance to abiotic stresses.

So far, there has been studied the foliar application of bio-preparations, while rooting of *Prunus mahaleb* (L.) cuttings [Szabo et al. 2016]. A much wider application of the bio-preparations were studied in case of different orchard species cultivation, for example, strawberry [Masny et al. 2004, Laugale et al. 2006], grapevine [El-Sabagh et al. 2011, Mohamed et al. 2013], apple [Thalheimer and Paoli 2002, Von Bennewitz et al. 2008, Bradshaw et al. 2013, Derkowska et al. 2017], chokeberry [Krawiec 2008], raspberry [Krok and Wieniarska 2008]. In a nursery, however, soil-applied bio-preparations have been used so far in apple and sour cherry trees cultivation [Grzyb et al. 2014, 2015].

As given by [Thalheimer and Paoli 2002, Masny et al. 2004, Krok and Wieniarska 2008, Rosłon et al. 2011, Michalak and Chojnacka 2016], bio-preparations do not always have a positive influence on the plants' growth.

Foliar application of extracts from different plants or soil application of humic compounds are procedures improving plants' nutritional status [Malusa et al. 2006]. Nutritional status of sweet cherry trees depending on a rootstock and cultivar, has also been studied before [Usenik et al. 2008, Hrotko et al. 2014, Milošević et al. 2015], however, there have not been any observations concerning the influence of foliar fertilization on the growth of sweet cherry maiden trees.

Mineral plant nutrition is crucial to plants functioning at a photosynthesis level. As it was previously found, lower nutrition can cause decrease in net photosynthesis rate due to stomatal closure [Longstreth and Nobel 1980]. Also environmental aspects of plant nutrition are highly important, hence the effect of biostimulants without mineral fertilizers was also analyzed. Similarly, as for mineral nutrition, an increase in the net photosynthesis rate, stomatal conductance and transpiration rate were also observed [Anjum et. al. 2011, Díaz-Leguizamón et al. 2016].

In the considered experiment, the influence of rootstocks and foliar fertilization on the growth of 'Vanda' sweet cherry maiden trees in a nursery as well as their nutritional status and photosynthesis activity, was studied.

MATERIAL AND METHODS

The experiment was conducted in the Experimental Station Marcelin of Poznan University of Life Sciences in 2015–2017. Two parallel studies in random blocks of 25 plants on each field in three repetitions were carried out. In the first experiment, the growth of 'Vanda' maiden sweet cherry trees on three rootstocks: GiSeLa 5, PHL-A and Colt, was compared. In the second one, maiden sweet cherry trees of the same cultivar grown on Colt rootstock were treated with foliar sprays with three bio-stimulants: Black Jak 0.25%, Biopuls Original 1.0%, Biopuls Forte 1.0% and a foliar fertilizer Maxi Grow Excel 0.1%. Plants in the control combination were sprayed only with water. Black Jak contains humins, fulvic acids and other mineral components; Maxi Grow Excel has Cu 1.1%, Fe 1.1%, Mn 1.3%, Zn

2.5% in its composition; Biopuls Original contains Yarrowia lipolytica yeasts, yeasts metabolites, rhizobacteria, actinomycetes, vitamins from B group, bioactive substances and natural antibiotics; Biopuls Forte: vitamins from B group, bioactive substances, natural antibiotics and microelements Cu, Fe, Mn, Zn and B. In spring 2014−2016, the rootstocks were planted in a nursery at 90 × 30 cm spacing. Letter, T-budding was carried out at the beginning of August every year. In the second year of the nursery, from the end of May till the middle of July in the growth period, the maiden trees were treated with foliar preparations four times every third week. Podzolic soil in the nursery was developed from dusty medium loam containing 2.0% of organic matter and its pH was 7.1. The following content of assimilable forms of three macroelements was observed in the soil arable layer (in mg 100 g soil^{-1}) in the middle of August: phosphorus (P) – 8.19 (average level), potassium (K) – 12.8 (average level) and magnesium (Mg) – 13.2 (high level). The average sum of rainfall in 2015 was 420 mm, in 2016 − 554 mm, in 2017 – 667 mm. Meteorological data were obtained from the nearest Agrometeorological Station of the University of Life Sciences in Poznan located in Experimental Station in Marcelin.

Manual weeding was a major caring treatment. The plants were sprayed with Discus 50WG, Topsin 500SC, Syllit 80WP against *Blumeriella jaapi*. Also aphids was fought by preparation Pirimor 80WG. The nursery was not irrigated. In autumn 2015−2017, the following measurements of the maiden trees and observations were conducted: height (cm), diameter (mm) measured at the height of 20 cm above the budding place, number of lateral shoots and their length (cm). Also the fresh mass of maiden trees and fresh and dry mass of maiden trees' leaves were weighed. Measurement of total leaf area (cm^2) was made as well by means of Squer program. The nutrition status of maiden trees was also evaluated by determining the content of macro- and microelements and sodium in leaves. The samples of leaves were collected in the middle of August from the middle part of long shoots – 5 leaves from the sample of 20 maiden trees in each combination.

The leaves were dried at 60°C for 48 hours and later they were ground and the content of macroelements, microelements and sodium was evaluated. In order to measure the content of general forms of nitrogen, the plant material was subjected to mineralization in sulfosalicylic acid, where sodium thiosulfate was applied as a reducing agent and a selenium mixture as a catalyst. Next, the material was measured in a Parnas and Wagner apparatus by distillation according to the Kjeldahl method [Kozik and Golcz 2011]. To measure general forms of phosphorus, potassium, calcium, magnesium and sodium, the plant material was mineralized in concentrated sulfuric acid. After the mineralization process, the colorimetric method was applied to measure the phosphorus content by means of a Spekol 210 apparatus with ammonium molybdate. The content of potassium, calcium and sodium was determined by means of flame photometry with a Zeiss AAS 3 apparatus, whereas the content of magnesium was measured by means of flame atomic absorption spectroscopy (FAAS) with a Zeiss AAS 3 apparatus [Kozik and Golcz 2011]. The same plant material was dry-mineralized at the temperature of 450°C in a Linn Elektro Therm furnace. The content of copper, zinc, manganese and iron in plant material was measured by means of flame atomic absorption spectroscopy (FAAS) with an AAS-3 spectrophotometer (Zeiss). The accuracy and precision of analytic measurements were verified by analyzing the Rye Grass ERM®-CD281 reference material (certified by European Commission, Joint Research Centre, Institute for Reference Materials and Measurements /IRMM, Geel BE/).

The photosynthetic activity parameters were measured with the aid of handheld photosynthesis system Ci 340aa (CID BioScience Inc., Camas, USA). The following parameters were analyzed: net photosynthetic rate (P_N), stomatal conductance (g_s), transpiration rate (E) and intercellular CO_2 (C_i) concentration. To achieve comparable results, constant conditions of measurements in the leaf chamber were maintained: CO_2 inflow concentration (390 µmol (CO_2)mol^{-1}), photosynthetic photon flux density (PPFD) 1000 µmol (photon) m^{-2} s^{-1}, chamber temperature 23°C, relative humidity 40 ±3%. Four replications were performed for each treatment; mature and intact leaves were selected for this purpose.

Results of combination in one-way analysis of variance (separately for rootstocks or preparations) were separated by Duncan's Multiple Range test at P ≤ 0.05. Percentage values were transformed onto the Bliss grades.

RESULTS

The studied rootstocks differentiated significantly the results of maiden cherry trees growth. The trees growing on PHL-A and Colt rootstocks had significantly higher growth parameters in comparison to those growing on GiSeLa 5. Only the height of trees did not differ considerably depending on the rootstock, and the largest diameter of the trunk was observed on PHL-A (Tab. 1). Dry mass of leaves of maiden trees growing on Colt was larger than the one of those growing on GiSeLa 5 (Tab. 2). On the other hand, fresh mass of leaves and their total area on the maiden tree did not differ with the rootstock.

Table 1. Parameters of the growth of maiden sweet cherry trees depending on rootstock used

Rootstocks	Height (cm)	Diameter (mm)	Number of lateral shoots	Sum of lengths of shoots (cm)	Fresh mass of maidens (kg)
GiSeLa 5	209.9 a*	18.2 a	5.3 a	296.8 a	1.4 a
PHL-A	206.7 a	23.4 c	8.9 b	602.3 b	1.4 a
Colt	209.2 a	20.2 b	8.7 b	609.8 b	1.7 b

* One-way analysis of variance; data marked with the same letter within given feature are not significantly different at α = 0.05 (Duncan's test)

Table 2. Parameters of leaves depending on rootstocks used

Rootstocks	Fresh weight of leaves (g)	Dry weight of leaves (g)	Total area of leaves (cm^2)
GiSeLa 5	225.0 a *	102.0 a	129.5 a
PHL-A	296.0 a	123.0 ab	141.3 a
Colt	331.5 a	140.0 b	166.9 a

* One-way analysis of variance; data marked with the same letter within given feature are not significantly different at α = 0.05 (Duncan's test)

Table 3. Parameters of the growth of maiden sweet cherry trees on Colt rootstock after the application of foliar fertilization

Treatments	Height (cm)	Diameter (mm)	Number of lateral shoots	Sum of lengths of shoots (cm)	Fresh mass of maidens (kg)
Black Jak	208.1 a*	21.1 ab	9.1 a	661.9 ab	1.6 a
Biopuls Original	212.9 a	22.2 ab	8.9 a	638.9 ab	1.7 a
Biopuls Forte	224.8 a	20.5 a	10.2 ab	754.2 ab	1.7 a
Maxi Grow Excel	223.3 a	23.3 b	12.3 b	788.7 b	2.5 b
Control	209.2 a	20.2 a	8.7 a	609.8 a	1.7 a

* One-way analysis of variance; data marked with the same letter within given feature are not significantly different at α= 0.05 (Duncan's test)

Table 4. Parameters of leaves depending on used foliar fertilization

Treatments	Fresh weight of leaves (g)	Dry weight of leaves (g)	Total area of leaves (cm^2)
Black Jak	303.5 a *	104.6 a	156. 7 a
Biopuls Original	408.3 a	181.0 a	183.2 b
Biopuls Forte	380.3 a	167.0 a	167.4 a
Maxi Grow Excel	327.0 a	105.0 a	199.3 c
Control	331.5 a	140.0 a	166.9 a

* One-way analyses of variance; data marked with the same letter within given feature are not significantly different at α= 0.05 (Duncan's test)

Table 5. The content of macronutrients in leaves (% dry matter)

Treatments	N	P	K	Ca	Mg
Black Jak	2.64 c *	0.21 c	2.78 ab	1.38 d	0.26 a
Biopuls Original	2.70 c	0.24 d	2.77 ab	0.64 a	0.26 a
Biopuls Forte	2.35 b	0.20 bc	3.05 c	0.77 b	0.26 a
Maxi Grow Excel	2.05 a	0.19 ab	2.85 b	1.07 c	0.27 a
Control	2.09 a	0.18 a	2.71 a	0.73 b	0.27 a

* One-way analysis of variance; data marked with the same letter within given feature are not significantly different at α = 0.05 (Duncan's test)

Table 6. The content of selected micronutrients and sodium in leaves (mg kg^{-1} d.w.)

Treatments	Na	Fe	Mn	Zn	Cu
Black Jak	0.006 b*	122.9 a	31.9 a	21.8 a	8.3 ab
Biopuls Original	0.004 ab	134.7 b	32.3 a	24.6 ab	10.9 c
Biopuls Forte	0.004 ab	166.2 c	46.6 c	25.8 b	10.0 bc
Maxi Grow Excel	0.005 b	126.5 ab	38.8 b	27.3 b	10.4 c
Control	0.003 a	162.2 c	40.4 b	26.6 b	7.9 a

* One-way analysis of variance; data marked with the same letter within given feature are not significantly different at α = 0.05 (Duncan's test)

Table 7. Mean values of photosynthetic activity parameters

Treatments	P_N [μmol(CO_2) m^{-2} s^{-1}]	g_s [μmol (H_2O) m^{-2} s^{-1}]	E [mmol (H_2O) m^{-2} s^{-1}]	C_i [μmol (CO_2) mol]
Black Jak	25.4 b *	156.8 b	2.3 b	281.6 b
Biopuls Original	26.5 c	232.5 c	2.6 c	354.1d
Biopuls Forte	26.2 bc	238.7 c	2.7 d	363.9 e
Maxi Grow Excel	27.8 d	250.3 d	3.0 e	260.0 a
Control	19.7 a	136.3 a	1.8 a	304.7 c

* One-way analysis of variance; data marked with the same letter within given feature are not significantly different at α = 0.05 (Duncan's test)

Used foliar preparations, except for Maxi Grow Excel, did not have any significant influence on the improvement of growth parameters of 'Vanda' maiden trees. After the use of this preparation, the increase in diameter, number and sum of the lengths of lateral shoots and fresh mass of sweet cherry trees was observed (Tab. 3). Taking into consideration the foliage of maiden trees, only the total area of leaves was increased after the use of Maxi Grow Excel and Biopuls Original preparations (Tab. 4).

The influence of bio-stimulants on the content of macroelements present in leaves was differentiated. The highest content of nitrogen and phosphorus was found after the use of Biopuls Original and Black Jak; potassium for Biopuls Forte and calcium for Black Jak (Tab. 5). In the case of magnesium content, no differences were detected concerning the preparation used. The highest amount of sodium was found in the combination for Black Jak and Maxi Grow Excel, iron for Biopuls Forte and control combinations. Manganese concentration was the highest in leaves after the use of Biopuls Forte and copper for Biopuls Original and Maxi Grow Excel. The lowest content of zinc was observed for Black Jak preparation (Tab. 6).

The lowest net photosynthesis rate (P_N) was noted for control plants, while all of treated plants revealed an increase in this parameter. Significantly highest level was recorded for plants treated with Maxi Grow Excel. Increased P_N level was connected with elevated stomatal conductance (g_s), and it was especially important for Maxi Grow Excel. Transpiration rate of Maxi Grow Excel treated plants was almost twice as high as for the control. The lowest CO_2 accumulation (C_i) in leaves was recorded in plants treated with Maxi Grow Excel, while the highest one was found in plants, for which Biopuls Forte was applied (Tab. 7).

DISCUSSION

A strong growth of sweet cherry maiden trees was observed for those growing on Colt and PHL-A rootstocks in comparison with those growing on GiSeLa 5, which was manifested in all growth parameters, except from height. Significantly smaller diameter of maiden trees in a nursery, however, was observed on GiSeLa 5 and PHL-A in comparison with other studied rootstocks [Sitarek and Grzyb 2007]. It is not confirmed in the present experiment, in which diameter of maiden trees on PHL-A rootstock was considerably larger than that of trees growing on GiSeLa 5 rootstock. In earlier studies [Sitarek and Grzyb 2010], also sweet cherry trees growing on PHL-A rootstock grew stronger than those on GiSeLa 5. In another experiment in an orchard [Bielicki and Rozpara 2010], the growth of sweet cherry trees of 'Kordia' on Colt rootstock was twice weaker than on Colt. However, in the experiment of Tomaszewska and Nychnerewicz [2006], sweet cherry trees growing on GiSeLa 5 and PHL-A rootstocks had similar vigor of growth, but significantly weaker than on Colt. The results of the orchard experiments conducted by the above mentioned authors did not find any confirmation in the present experiment that was carried out in a nursery.

Majority of studied preparations did not improve the growth of sweet cherry maiden trees. Only one out of four used foliar preparations, namely Maxi Grow Excel, significantly improved the results of growth of sweet cherry maiden trees. In its content, it contains selected microelements. Also other authors [Thalheimer and Paoli 2002, Masny et al. 2004, Michalski 2004, Krok and Wieniarska 2008, Rosłon et al. 2011, Michalak and Chojnacka 2016] did not always get positive growth results of orchard plants after the use of studied preparations.

Thalheimer and Paoli [2002] concluded that under standard circumstances, bio-stimulant applications are not likely to lead to commercial benefits for apple fruit growers. On the other hand, Von-Bennewitz and Hlusek [2006] reported that bio-fertilization is beneficial in stimulating the growth and fruiting of pome and stone fruits. Besides, Rozpara et al. [2014] and Mosa et al. [2016] found also that bio-preparation had a positive influence on the growth and development of apple trees cultivation. Also Tomala et al. [2006] showed that 3-fold and 4-fold application of Goëmar BM 86 preparation on apple trees of Gala encouraged the growth of apples. In the production of other berry species of small bushes, the influence of bio-stimulants was differentiated depending on the preparation used, the cultivar and species. While conducting studies on the cultivation of chokeberry, Krawiec [2008] found that a combination of Goëmar BM 86 and Asahi SL preparations, even at stressful conditions, did not result in a significant growth of mass of 100 fruits. A similar phenomenon was recorded by Masny et al. [2004], who used Goëmar BM 86 preparation for spraying the strawberry plantation and by Krok and Wieniarska [2008] in raspberry cultivation. In the experiment of the latter authors, the influence of bio-preparations depended on the year of studies as well as the cultivar considered.

As Krawiec [2008] reported, application of biostimulants is especially beneficial in a year of long-term drought. Application of bio-preparations when no stressful factor was present, for example drought or spring frost, did not give any positive effect. This opinion found its confirmation in the present experiment, where also the amount of atmospheric precipitation was clearly enough for a proper growth of plants, and the content of basic macroelements in the soil was optimal for their growth. Also Colt rootstock belongs to strongly growing ones, which limits the effectiveness of foliar fertilization of sweet cherry maiden trees produced on this particular rootstock. At present, studies are being carried out on the application of foliar plant preparations in the production of maiden sweet cherry trees growing on semi-dwarf rootstock, where more significant influence on the improvement of the trees' growth parameters in a nursery can be seen.

Majority of studied preparations increased the content of N, P, Ca, Cu in leaves. Other researchers like Hassan et al. [2010], reported an increase in the content of N, K, Fe, Zn, Mn and a decrease in P using Aminofert preparation. However, after using bio-fertilizers, Fawzi et al. [2010] found a higher content of N, P, K and Mg in the leaves of pear trees. On the other hand, the experiment of Chitu et al. [2010] did not confirm the influence of foliar treatment of apple trees with ecological products on the content of macroelements in leaves. However, the results of such studies depend on various factors, among others, on the content of studied preparations, change in weather conditions, wealth and quality of soil, the rootstock used and cultivated species. Therefore, it is difficult to compare the obtained results.

Foliar preparations used in the present experiment significantly increased the photosynthetic activity of leaves. Measurements of studied parameters confirmed the increase in growth intensity of sweet cherry maiden trees after foliar application, especially Maxi Grow Excel preparation. As it is reported by Veberic et al. [2002], apple trees sprayed with phosphorus and by Hascon M with potassium showed the lowest photosynthesis rate, which does not find any confirmation in the present experiment. However, in the study of Świetlik et al. [1982], potassium foliar fertilizer did not influence the stomatal conductance and photosynthesis in non-stressed apple trees.

CONCLUSIONS

A stronger vigor of maiden sweet cherry trees was obtained on Colt and PHL-A rootstocks and weaker on GiSeLa 5.

Preparations used in experiments did not influence the growth parameters of maiden sweet cherry trees, except from Maxi Grow Excel, the application of which increased the intensity of growth.

The influence of preparations used on the concentration of macro and micronutrients was not obvious.

All preparations positively influenced the gas exchange parameters. However, the highest effect was noted for plants treated with Maxi Grow Excel.

For recommendation of the application of foliar fertilization in nursery production on commercial scale, economical effectiveness must be considered.

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