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The Influence of the GiSelA 5 Rootstock Propagation Method on the Growth and Physiological Parameters of Maiden Trees of Selected Sweet Cherry Varieties

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Abstract: The basis of orchard production are rootstocks that reduce the vigor of sweet cherry trees. However, not all rootstocks for this species can be easily propagated using traditional methods by stooling or cutting. Some of these must be propagated using the *in vitro* culture method. This results in their high price and, consequently, the price of maiden sweet cherry trees. The experiment assessed the growth of maiden trees of selected sweet cherry varieties ('Bellise', 'Earlise', 'Lapins', 'Vanda') depending on the method of the semi-dwarf GiSelA 5 rootstock propagation. Additionally the intensity of life processes taking place in the obtained maiden trees was also examined. One type of this rootstock, obtained by cheaper method from softwood cuttings, was compared with the another propagated using the *in vitro* method. There were no significant differences in the percentage of maiden trees obtained in both types of rootstocks propagation method and in the two years of study. The efficiency of maiden trees varied little and ranged from 77.43% to 87.74% depending on the factors considered. The vigor of maiden trees growth in the first year of the study was stronger than in the second one. Only the diameter of maiden trees stem varied (from 7% to 39%), depending on the variety considered. With the exception of one variety, maiden trees produced on rootstock propagated from stem cuttings were characterized by a much larger diameter for the three varieties, ranging from 23% to 29% compare to in vitro. Also with this method of propagation, the rootstocks had a better developed root system and the maiden trees had a greater fresh mass. However, most often, no significant differences were found between the methods of propagation, only when comparing the years of research. The activity of life processes of maiden sweet cherry trees varied and no constant regularities were found. The only regularity observed was that maiden trees in the second year of the experiment were more often characterized by lower levels of the tested life parameters (Pn, E, C and Int.CO2), which was associated with worse growth results.

Keywords: nursery; efficiency; vigor; side shoots; root system; leaf blade area; rate of photosynthesis; transpiration

1. Introduction

The cultivation of sweet cherry trees in Europe in the last decade has been characterized by great popularity and increased production intensity, achieved by increasing the density of tree plantings per unit area. The dominant species is the apple tree, but fruit growers, wanting to minimize the risk of production, also cultivate other species in addition to apple trees, among which sweet cherry has become the most profitable due to the price of the fruit. In Poland, the main rootstock used in orchards is 'Colt', the share of which in the production of certified trees was over 80% in 2023. The recommended rootstocks for the production of maiden sweet cherry trees also include those that reduce the vigor of trees, of which 'Colt' is not one of them. So far, the influence of semi-dwarf rootstocks, such as GiSelA 5, on the vigor and yield of sweet cherry trees in an orchard has been

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studied [1–7]. Gisela 5 is considered very good and economically important semi-dwarf rootstock for intensive sweet cherry cultivation in a moderate climate [8–13]. It was confirmed [14] that its propagation using conventional methods is not effective, hence the need to use the in vitro method. However, as research by some authors [15–17] proved with appropriate treatment of softwood cuttings, 80% rooting can be achieved.

In previous research conducted in the nursery [18], rootstocks of different vigor (PHL-A, PHL-C, Colt, F12/1, *Prunus mahaleb*, *Prunus avium*) significantly influenced the growth parameters of maiden sweet cherry trees. Papachatzis [19] confirmed the limited growth of sweet cherry trees using the 'GiSelA 5' rootstock. Cultivation of sweet cherry of the 'Stella' variety on various rootstocks (GiSelA 5, GiSelA 4, Gi-195/20, Gi-497/8, Weiroot 10, Weiroot 13, Weiroot 53, Weiroot 72, Weiroot 158) showed the weakest growth on the 'GiSelA 5' rootstock. Another study prepared by Sitarek and Grzyb [12] compared the growth of maiden sweet cherry trees of the 'Kordia' variety on rootstocks of different vigor (GiSelA 5, PHL-A, PHL-B, PHL-C, Weiroot 158, Tabel Edabriz), and here also on one of the slowest-growing sweet cherries, the trees were on the 'GiSelA 5' rootstock. Similarly, Biško et al. [20] showed the lowest vigor of six-year-old trees of the 'Regina' and 'Kordia' varieties on the GiSelA 5 rootstock. Another experiment conducted in the orchard [21] highlighted the positive effect of the GiSelA 5 rootstock on the best tree yield. According to some researchers [22,23], semi-dwarf rootstocks, including 'GiSelA 5', are recommended for orchards with increased density of tree plantings, combined with generally strongly growing sweet cherry varieties. However, their cultivation requires fertile soil and favorable climatic and soil conditions. They should not be used on shallow and light soils. The use of dwarf and semi-dwarf rootstocks results in more abundant flowering and, as a result, yield of fruit trees [23,24]. Atkinson and Else [24] claim that this impact is more intense in the case of rootstocks that reduce tree vigor, which has a clearly positive impact on the economic aspect in large-scale fruit production [22,23].

Due to the high value of the 'GiSelA 5' rootstock in the orchard, its suitability for the production of maiden sweet cherry trees should be tested. Especially taking into account in the nursery rootstocks previously propagated using the cheaper method of stem cuttings. The aim of the experiment was to compare the efficiency of budding and growth of maiden sweet cherry trees depending on the method of propagation of GiSelA 5 rootstock and the budded variety. This was also confirmed by the examination of some life processes taking place in maiden sweet cherry trees under the influence of these factors.

2. Materials and Methods

2.1. Plant Material and Growth Conditions

The field nursery experiment consisted of two production cycles conducted in years 2016-2018. One-year old sweet cherry maiden trees of the following varieties: 'Bellise', 'Earlise', 'Lapins', 'Vanda' grown on the GiSelA 5 rootstock. This rootstock was previously propagated using soft wood cuttings and the '*in-vitro*' method. The experiment was conducted in a randomized block design. The number of combinations was 8 (4 varieties, 2 methods of propagating the rootstock). Each combination included 20 maiden sweet cherry trees in four repetitions. On rootstocks planted in the field in early spring (mid-March) with a spacing of 90x30cm, budding was carried out using the "T" method at the beginning of August. The plants were grown on podsolic soil, valuation class IVb. The content of minerals in the soil was determined before planting the rootstocks and was: phosphorus-107, potassium-145, calcium-520 and magnesium 96, the soil had a pH of 6.5. Before planting the rootstocks, only potassium sulfate fertilizer was sown, at a dose of 140 kg ha^{-1}. Nitrogen was given to the plants in three divided doses, totaling 120 kg ha^{-1}. Once, immediately after planting the rootstocks, the soil herbicide Sencor 80 WG was sprayed at a dose of 0.25 kg ha^{-1}. Diseases were prevented by chemical treatments from May to August, at two-week intervals, with the following preparations: Zato 50 WG (0.15 kg ha^{-1}), Score 250 EC (0.2 l ha^{-1}), Syllit 65 WP (1.5 kg· ha^{-1}), Topsin M 500 SC (1.5 l· ha^{-1}). Aphids were also controlled with Movento 20 SC (0.2 l· ha^{-1}). The plants were not irrigated, the amount of rainfall was 2017-590 and 2018-320 mm, respectively.

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2.2. Plant and Physiological Parameter Measurements

In both years of the study, in mid-July, physiological processes were examined by taking the following measurements: net photosynthetic intensity (Pn, µmol CO2·m^{-2}·s^{-1}), leaf transpiration coefficient (E, µmol H_2O·m^{-2}·s^{-1}), camera conductivity stomata (C, mol H_2O·m^{-2}·s^{-1}), and internal carbon dioxide concentration (CO_2, mol CO_2 mol^{-1}).These parameters were measured usinga CI 340 handheld photosynthesis system(CID Bio-Science, Camas, WA, USA).

The measurements were taken using fully developed, disease-free and undamaged leaves, located in the central part of the long shoots, from the southern, well-lit part of the maiden tree crown. For each of the eight variety-rootstock combinations, measurements were made on four randomly selected plants with similar growth dynamics.

2.3. Statistical Analyses

Statistical calculations were performed using the Statistica 13.1 program (Statsoft, Poland). Duncan's test was used to perform analyzes of variance at a significance level of $\alpha = 0.05$. The results were subjected to a two-factor analysis of variance: (year of research and two methods of propagation) separately for each variety considered. Data expressed as percentage (obtained maiden trees) were transformed using the arcsine transformation.

3. Results

The percentage of sweet cherry maiden trees obtained did not differ depending on the method of propagation in the two years of the experiment. For three out of four examined varieties, higher maiden efficiency were calculated in the first year of observation than in the second one (Table 1).

Table 1. The percentage of obtained sweet maiden trees depending way of propagation and year.

Year (A) Variety	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
'Bellise'				
2017	Stem cutting	90.88 a	87.73 a	88.72 a
	In vitro	84.18 a		84.28 a
2018	Stem cutting	86.35 a	85.38 a	
	In vitro	84.39 a		
'Earlise'				
2017	Stem cutting	89.29 b	85.94 a	86.65 a
	In vitro	82.23 a		83.59 a
2018	Stem cutting	83.77 ab	84.34 a	
	In vitro	84.91 ab		
'Lapin'				
2017	Stem cutting	87.59 a	87.74 a	86.54 a
	In vitro	87.90 a		87.24 a
2018	Stem cutting	85.46 a	86.02 a	
	In vitro	86.58 a		
'Vanda'				
2017	Stem cutting	83.08 b	81.16 a	81.33 a
	In vitro	79.17 ab		77.24 a
2018	Stem cutting	79.52 ab	77.43 a	

Means marked with the same letters within individual varieties do not differ significantly at the level of $\alpha = 0.05$, using Duncan's test.

The method of rootstock propagation had no effect on the height of maiden trees (Table 2). Most often, in the first year of research, a better height and diameter of maiden sweet cherry trees was

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found. When the rootstock was propagated by shoot cuttings, maiden trees of three varieties had a larger stem diameter (Table 3).

Table 2. The height of obtained sweet maiden trees depending way of propagation and year (cm).

Year (A) Variety	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
'Bellise'				
2017	Stem cutting	210.75 c	206.17 b	181.75 a
	In vitro	201.60 c		161.92 a
2018	Stem cutting	152.75 b	137.50 a	
	In vitro	122.25 a		
'Earlise'				
2017	Stem cutting	243.20 c	235.50 b	191.25 a
	In vitro	227.80 c		170.87 a
2018	Stem cutting	139.30 b	126.62 a	
	In vitro	113.95 a		
'Lapins'				
2017	Stem cutting	151.35 a	147.45 a	151.35 a
	In vitro	143.55 a		141.17 a
2018	Stem cutting	151.35 a	145.07 a	
	In vitro	138.80 a		
'Vanda'				
2017	Stem cutting	213.30 c	203.15 b	171.67 a
	In vitro	193.00 b		155.05 a
2018	Stem cutting	130.05 a	123.57 a	

Means marked with the same letters within individual varieties do not differ significantly at the level of α= 0.05, using Duncan's test.

Table 3. The diameter of obtained sweet maiden trees depending way of propagation and year (mm).

Year (A) Variety	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
'Bellise'				
2017	Stem cutting	20.49 c	19.50 b	17.77 b
	In vitro	18.50 c		15.63 a
2018	Stem cutting	15.06 b	13.91 a	
	In vitro	12.76 a		
'Earlise'				
2017	Stem cutting	19.76 d	18.56 b	16.80 b
	In vitro	17.37 c		14.20 a
2018	Stem cutting	13.84 b	12.44 a	
	In vitro	11.03 a		
'Lapins'				
2017	Stem cutting	15.73 b	13.00 a	16.62 b
	In vitro	10.27 a		10.12 a
2018	Stem cutting	17.50 c	13.74 a	
	In vitro	9.98 a		
'Vanda'				
2017	Stem cutting	18.15 b	17.73 b	15.70 a
	In vitro	17.32 b		14.67 a
2018	Stem cutting	13.26 a	12.64 a	

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In the first year of research, the three tested varieties were characterized by an increased number and length of side shoots. For the same three varieties, the number of shoots and for two varieties the length of side shoots was greater when rootstocks were propagated by shoot cuttings (Tables 4 and 5). Only for one variety the number of roots differed between years. Also for three varieties, maiden trees produced on a rootstock made from shoot cuttings had more roots (Table 6).

Table 4. The number of side shoots of sweet cherry maiden trees depending of way of propagation and year.

Year (A) Variety	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
'Bellise'				
2017	Stem cutting	3.10 b	2.45 b	2.23 b
	In vitro	1.80 a		1.22 a
2018	Stem cutting	1.55 a	1.10 a	
	In vitro	0.65 a		
'Earlise'				
2017	Stem cutting	4.10 c	3.05 b	3.27 b
	In vitro	2.00 b		1.20 a
2018	Stem cutting	2.45 b	1.42 a	
	In vitro	0.40 a		
'Lapins'				
2017	Stem cutting	0.00 a	0.00 a	0.00 a
	In vitro	0.00 a		0.00 a
2018	Stem cutting	0.00 a	0.00 a	
	In vitro	0.00 a		
'Vanda'				
2017	Stem cutting	6.45 c	4.27 b	3.80 b
	In vitro	3.00 b		2.00 a
2018	Stem cutting	1.15 a	1.07 a	

Means marked with the same letters within individual varieties do not differ significantly at the level of α= 0.05, using Duncan's test.

Table 5. The sum of length of said shoots of sweet cherry maiden trees depending of way of propagation and year (cm).

Year (A) Variety	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
'Bellise'				
2017	Stem cutting	180.80 c	147.70 b	111.02 b
	In vitro	105.60 b		67.72 a
2018	Stem cutting	32.25 a	26.05 a	
	In vitro	19.85 a		
'Earlise'				
2017	Stem cutting	213.50 c	164.30 b	146.27 b
	In vitro	115.10 b		62.57 a
2018	Stem cutting	79.05 ab	44.55 a	
	In vitro	10.05 a		
'Lapins'				
2017	Stem cutting	0.00 a	0.00 a	0.00 a
	In vitro	0.00 a		0.00 a

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2018	Stem cutting	0.00 a	0.00 a	
	In vitro	0.00 a		
		'Vanda'		
2017	Stem cutting	321.75 c	256.95 b	179.71 a
	In vitro	192.15 b		107.17 a
2018	Stem cutting	21.89 a	22.05 a	

Means marked with the same letters within individual varieties do not differ significantly at the level of α= 0.05, using Duncan's test.

Table 6. The number of roots of sweet cherry maiden trees depending of way of propagation and year.

Year (A) Variety	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
'Bellise'				
2017	Stem cutting	13.20 b	12.30 a	12.95 b
	In vitro	11.40 a		11.10 a
2018	Stem cutting	12.70 b	11.75 a	
	In vitro	10.80 a		
'Earlise'				
2017	Stem cutting	14.20 b	13.82 b	13.40 a
	In vitro	13.45 ab		12.67 a
2018	Stem cutting	12.60 ab	12.25 a	
	In vitro	11.90 a		
'Lapins'				
2017	Stem cutting	17.40 b	16.25 a	17.60 b
	In vitro	15.10 a		15.50 a
2018	Stem cutting	17.80 b	16.85 a	
	In vitro	15.90 ab		
'Vanda'				
2017	Stem cutting	17.40 c	15.95 a	16.85 b
	In vitro	14.50 ab		13.90 a
2018	Stem cutting	16.30 bc	14.80 a	

Means marked with the same letters within individual varieties do not differ significantly at the level of α= 0.05, using Duncan's test.

The higher fresh weight of maiden sweet cherry trees was obtained for all tested varieties during first year of experiment. Only for the 'Lapins' variety, the rootstock from shoot cuttings was characterized by an increased fresh mass of maiden trees (Table 7). The fresh weight of leaves and their leaf blade area was significantly higher in the first year of observation. The rootstock propagation method had no effect on the mass and surface of the leaves (Tables 8 and 9).

Table 7. The fresh mass of sweet cherry maiden trees depending of way of propagation and year (kg).

Year (A)	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
'Bellise'				
2017	Stem cutting	1.28 b	1.23 b	1.00 a
	In vitro	1.18 b		0.89 a
2018	Stem cutting	0.72 a	0.66 a	
	In vitro	0.61 a		
'Earlise'				

2017	Stem cutting	1.33 c	1.17 b	0.97 b
	In vitro	1.01 b		0.77 a
2018	Stem cutting	0.61 a	0.57 a	
	In vitro	0.53 a		
'Lapins'				
2017	Stem cutting	1.10 c	0.99 b	0.89 a
	In vitro	0.88 b		0.79 a
2018	Stem cutting	0.71 a	0.69 a	
	In vitro	0.68 a		
'Vanda'				
2017	Stem cutting	1.35 b	1.30 b	1.17 a
	In vitro	1.25 b		1.09 a
2018	Stem cutting	0.98 a	0.95 a	

Means marked with the same letters within individual varieties do not differ significantly at the level of α= 0.05, using Duncan's test

Table 8. The fresh mass of sweet cherry maiden trees leaves depending of way of propagation and year (g).

Year (A) Variety	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
'Bellise'				
2017	Stem cutting	264.10 c	263.10 b	210.55 a
	In vitro	262.10 c		202.78 a
2018	Stem cutting	157.01 b	150.23 a	
	In vitro	143.46 a		
'Earlise'				
2017	Stem cutting	256.34 c	258.84 b	203.32 a
	In vitro	253.34 c		193.21 a
2018	Stem cutting	150.30 b	141.69 a	
	In vitro	133.08 a		
'Lapins'				
2017	Stem cutting	274.67 b	273.67 b	217.46 a
	In vitro	172.67 b		210.99 a
2018	Stem cutting	160.25 a	154.78 a	
	In vitro	149.32 a		
'Vanda'				
2017	Stem cutting	271.65 b	266.95 b	209.26 a
	In vitro	262.25 b		202.61 a
2018	Stem cutting	146.87 a	144.92 a	

Means marked with the same letters within individual varieties do not differ significantly at the level of α= 0.05, using Duncan's test

Table 9. Leaf blades area of sweet cherry maiden trees depending of way of propagation and year (cm^{-1}).

Year (A) Variety	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
'Bellise'				
2017	Stem cutting	9754.52 b	9822.10 b	8091.34 a
	In vitro	9889.68 b		8050.06 a
2018	Stem cutting	6428.16 a	6319.31 a	

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	In vitro	6210.45 a		
'Earlise'				
2017	Stem cutting	9393.50 b	9353.04 b	7639.43 a
	In vitro	9312.58 b		7562.03 a
2018	Stem cutting	5885.37 a	5848.42 a	
	In vitro	5811.48 a		
'Lapins'				
2017	Stem cutting	9872.21 b	9877.62 b	8095.75 a
	In vitro	9883,03 b		8132.25 a
2018	Stem cutting	6319.30 a	6350.38 a	
	In vitro	6381.47 a		
'Vanda'				
2017	Stem cutting	9652.63 b	9597.64 b	7715.05 a
	In vitro	9542.65 b		7655.63 a
2018	Stem cutting	5777.47 a	5773.04 a	

Means marked with the same letters within individual varieties do not differ significantly at the level of α= 0.05, using Duncan's test

Most of the considered parameters of life processes occurring in the leaves of maiden trees of the 'Bellise' variety had higher values when propagation of rootstock was done by cuttings than by 'in vitro' method (Table 10). For two characteristics, the indicators did not differ significantly over two years, and for the remaining two they were variable. In the first year of research, maiden trees of the 'Earlise' variety only achieved a higher Int. CO_2 value (Table 11). Two higher parameters of vital processes measured for 'Lapins' variety in the first year (Table 12). For this variety, almost all parameters of life processes were higher for the rootstock propagated in vitro. The last tested variety 'Vanda', had higher levels of the considered indicators in the first year of experiment (Table 13). Also, two of four varieties considered characterized better parameters at propagating the rootstock by shoot cuttings.

Table 10. Intensity of life processes in the leaves of maiden sweet cherry trees of the 'Bellise' variety.

Year (A)	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
	Pn- net photosynthetic intensity (μmol $CO_2 \cdot m^{-2} \cdot s^{-1}$)			
2017	Stem cutting	13.26 b	11.70 a	14.20 b
	In vitro	9.69 a		11.64 a
2018	Stem cutting	15.41 c	14.14 b	
	In vitro	13.15 b		
	E-leaf transpiration coefficient (μmol $H_2O \cdot m^{-2} \cdot s^{-1}$)			
2017	Stem cutting	2.86 d	2.07 a	2.63 b
	In vitro	1.04 a		1.44 a
2018	Stem cutting	2.33 c	2.00 a	
	In vitro	1.75 b		
	C-stomatal conductivity (mol $H_2O \cdot m^{-2} \cdot s^{-1}$)			
2017	Stem cutting	101.84 d	68.93 a	94.12 b
	In vitro	26.62 a		52,24 a
2018	Stem cutting	84.19 c	77.42 a	
	In vitro	72.16 b		
	Int_CO_2- internal carbon dioxide concentration (mol $CO_2 \cdot mol^{-1}$)			
2017	Stem cutting	410.28 c	418.47 b	294.51 a
	In vitro	429.01 d		224.62 a
2018	Stem cutting	145.66 b	100.65 a	

Table 11. Intensity of life processes in the leaves of maiden sweet cherry trees of the 'Earlise' variety.

Year (A)	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
	Pn- net photosynthetic intensity (µmol $CO_2 \cdot m^{-2} \cdot s^{-1}$)			
2017	Stem cutting	10.87 b	7.13 a	8.49 a
	In vitro	5.26 a		7.21 a
2018	Stem cutting	6.10 a	8.38 a	
	In vitro	10.01 b		
	E-leaf transpiration coefficient (µmol $H_2O \cdot m^{-2} \cdot s^{-1}$)			
2017	Stem cutting	2.19 b	1.60 a	1.74 a
	In vitro	1.30 a		1.62 a
2018	Stem cutting	1.29 a	1.76 a	
	In vitro	2.09 b		
	C-stomatal conductivity (mol $H_2O \cdot m^{-2} \cdot s^{-1}$)			
2017	Stem cutting	71.09 b	42.31 a	52.00 a
	In vitro	27.93 a		49.13 a
2018	Stem cutting	32.91 a	60.04 a	
	In vitro	79.42 b		
	Int_CO_2- internal carbon dioxide concentration (mol $CO_2 \cdot mol^{-1}$)			
2017	Stem cutting	412.08 c	420.75 b	261.68 a
	In vitro	425.09 c		312.54 a
2018	Stem cutting	111.28 a	134.89 a	
	In vitro	151.76 b		

Means marked with the same letters within individual varieties do not differ significantly at the level of α= 0.05, using Duncan's test

Table 12. Intensity of life processes in the leaves of maiden sweet cherry trees of the 'Lapins' variety.

Year (A)	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
	Pn- net photosynthetic intensity (µmol $CO_2 \cdot m^{-2} \cdot s^{-1}$)			
2017	Stem cutting	10.06 b	11.99 b	9.22 a
	In vitro	13.12 c		11.90 b
2018	Stem cutting	8.70 a	9.65 a	
	In vitro	10.59 b		
	E-leaf transpiration coefficient (µmol $H_2O \cdot m^{-2} \cdot s^{-1}$)			
2017	Stem cutting	1.88 a	2.56 a	2.00 a
	In vitro	2.98 c		2.80 b
2018	Stem cutting	2.07 a	2.35 a	
	In vitro	2.62 b		
	C-stomatal conductivity (mol $H_2O \cdot m^{-2} \cdot s^{-1}$)			
2017	Stem cutting	70.74 a	82.15 a	75.52 a
	In vitro	89.29 c		89.03 b
2018	Stem cutting	78.50 b	83.63 a	
	In vitro	88.76 c		
	Int_CO_2- internal carbon dioxide concentration (mol $CO_2 \cdot mol^{-1}$)			
2017	Stem cutting	424.54 a	435.96 b	424.88 a
	In vitro	443,10 b		433.92 b
2018	Stem cutting	425.09 a	424.91 a	

Means marked with the same letters within individual varieties do not differ significantly at the level of α= 0.05, using Duncan's

Table 13. Intensity of life processes in the leaves of maiden sweet cherry trees of the 'Vanda' variety.

Year (A)	Way of propagation (B)	Interaction A x B	Mean for A	Mean for B
		Pn- net photosynthetic intensity (μmol $CO_2 \cdot m^{-2} \cdot s^{-1}$)		
2017	Stem cutting	20.61 d	15.36 b	15.38 b
	In vitro	8.36 a		9.75 a
2018	Stem cutting	9.41 b	10.20 a	
	In vitro	11.14 c		
		E-leaf transpiration coefficient (μmol $H_2O \cdot m^{-2} \cdot s^{-1}$)		
2017	Stem cutting	3.61 c	2.84 b	2.98 b
	In vitro	1.82 a		1.87 a
2018	Stem cutting	2.26 b	2.10 a	
	In vitro	1.92 a		
		C-stomatal conductivity (mol $H_2O \cdot m^{-2} \cdot s^{-1}$)		
2017	Stem cutting	128.71 c	87. 35 a	107.97 a
	In vitro	32.19 a		82.24 a
2018	Stem cutting	84.27 b	106.43 a	
	In vitro	132.28 c		
		Int_CO_2- internal carbon dioxide concentration (mol $CO_2 \cdot mol^{-1}$)		
2017	Stem cutting	414.19 b	438.12 b	322.04 a
	In vitro	470.03 c		342.65 a
2018	Stem cutting	216.73 a	216.05 a	

Means marked with the same letters within individual varieties do not differ significantly at the level of α= 0.05, using Duncan's

4. Discussion

A very important factor influencing the possibility of using a given rootstock for the propagation of sweet cherry varieties is the high percentage of maiden trees obtained [18]. In the experiment under consideration, the GiSelA 5 rootstock was characterized by very good compatibility with the tested sweet cherry varieties, which is consistent with the opinion of other authors [25,26]. The high efficiency of maidens of the 'Lapins' variety, very similar in both years, confirms the opinion of Sitarek [27] about the good compatibility of this variety with the GiSelA 5 rootstock. In the described experiment, efficiency of maiden trees depending on the variety, and was at the level of 75.3 to 89.3%. The above-mentioned author [27] also found a similar budding efficiency, ranging from 74.0 to 97.0% depending on the variety and didn't influencing of rootstock, similarly to the experiment under consideration. A more varied budding efficiency of sweet cherries on the GiSelA 5 rootstock was observed by Zengibal et al. [28], who, under the influence of the budding variety and the year of study, showed from 33.3% to 100.0% maiden trees. However, in these researchers, during the two years of experiment, these values differed significantly between individual varieties, which was not statistically compared in the experiment under consideration, but the results were similar between individual varieties. It did not depend on the method of propagation of the rootstock and, to a small extent, on the year of research. In a similar experiment, Bryła and Kapłan [29] found different budding efficiency of one sweet cherry variety, which was influenced by the type of rootstock used and the year of observation. During three years of observation, these authors obtained a high percentage of maiden trees of the 'Regina' variety on the 'GiSelA 5' rootstock in one year only, which was 90.8%, and in the remaining years no more than 60%. Similarly, Bujdoso and Hrotko [30] observe variable efficiency of maiden sweet cherry trees on the 'GiSelA 5' rootstock depending on the variety considered (56.0-86.0%). The experiences of most of the above-mentioned researchers and others [28,31] confirmed the differential impact of the budded variety. However, this was particularly related to the genetic diversity of the tested varieties. Perhaps in the experiment described, the small number of varieties used did not cause such a large difference in results. Moreover, it is believed that

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differences in budding efficiency may result from the physiological incompatibility of the rootstock with the variety, which in the case of sweet cherries has already been found by some researchers [32,33]. Additionally, the high number of maiden trees obtained in the experiment is contrary to the research of Janes and Pae [34], who found lower effectiveness of maiden trees of three sweet cherry varieties on the GiSelA 5 rootstock (average 60%). These authors attribute the reasons for this state of affairs to a long period of drought and high temperatures in summer and low temperatures in winter. In the experiment in question, in winter the lowest temperature was only -15°C, and no such unfavorable weather conditions were recorded as in the experiment of the above-mentioned authors, where the winter temperature dropped to -32°C. Such a low temperature could have resulted in the freezing of established leaf buds and resulted in a low number of maiden trees obtained.

In an experiment on the Gisela 5 rootstock propagated using stem cuttings, maiden sweet cherry trees with a larger trunk height and diameter were obtained. In the case of most of the tested varieties, these differences were statistically confirmed. The trunk diameter of maiden trees found by Janes and Pae [34] varied to a lesser extent (from 16.48 to 19.41 mm) depending on the variety and year of study. A similar height of maiden trees of several sweet cherry varieties on the GiSelA 5 rootstock was obtained in a nursery by Zengibal et al. [28] and ranged from 136.70 to 204.33 cm. This amount did not change that much depending on the year of observation. A significantly lower height of maiden sweet cherry trees on the 'GiSelA 5' rootstock was found by Bujdoso and Hrotko [30], who obtained values ranging from 103 cm to 149 cm, depending on the seven varieties tested. A similar height of maiden trees of the 'Lapins' variety on the rootstock under consideration was observed by Sitarek and Grzyb [35] of approximately 145 cm. However, in the case of these authors, maiden trees of this variety were characterized by a much higher height than the other examined varieties, the height of which was similar. In the presented experiment, in the first year of observation, this variety was much lower and in the second year slightly higher than the other varieties. Baryla et al. [6] found sweet cherry maiden trees of the 'Regina' variety on the 'GiSelA 5' rootstock with a diameter of 14.2 mm. This value was between the values from the first and second year of research in the experiment under consideration. A smaller diameter (11-14mm) of maiden trees on the 'GiSelA 5' rootstock was found by Bujdoso and Hrotko [30]. It should be noted, however, that the smaller diameter obtained by these authors was due to the higher place of diameter measurement, which was 30 cm above the budding site. In the experiment under consideration it was only 10 cm above the budding site. The differences in the results of the compared experiments resulted primarily from different soil and climatic conditions for the growth of maiden trees. Differences may also result from different genetic conditions of the compared varieties, which is confirmed by other authors [7,28,31,33]. In the experiment conducted, the growth results of maiden trees of individual sweet cherry varieties were not statistically compared, but they varied. These results are consistent with the results obtained by Gjamovski et al. [36] and Milić et al. [37], where in an orchard, trees of the ‘Kordia’ and ‘Summit’ varieties had stronger vigor than the Regina variety on the Gisela 5 rootstock.

The most important quality parameter of maiden trees is the number and length of side shoots. As stated by Baryła et al. [6], the vigor and intensity of branching of maiden trees depend on both the rootstock and the variety. Research by these authors conducted on maiden trees 'Regina' variety showed the sum of the lengths of side shoots of 160 cm, this was a worse result than that considered experiment in the first year and much better than in the second year. Zec et al. [7] obtained a 3-4 times higher number of side shoots of maiden sweet cherry trees of three varieties ('Carmen', 'Kordia' and 'Regina'), which varied depending on the variety and ranged between 8.3-20.0 shoots and changed its values almost twice in two years of research, similarly to the described experiment. Bajduso and Hrotko [30] did not obtain lateral branches on the maiden trees of six sweet cherry varieties on the rootstock GiSelA 5, which is not consistent with the experiment conducted, where only one of the four varieties also did not have side shoots. This is confirmed by the very large influence, especially of climatic factors prevailing in a given year, on the stimulation of the formation of side shoots. In the described experience, a greater amount of rainfall in the first year intensified the growth of side shoots. This was also influenced by the quality of the soil and the applied care treatments, which are difficult to compare in individual experiments. The small number of side shoots of maiden trees may also result from the low vigor of the GiselA 5 rootstock, which results in the formation of short and thin side shoots on maiden trees and does not reflect the growth potential of the tested sweet cherry varieties, which was also found in the experiment conducted by Zec et al. [7]. According to these researchers, the low vigor of this rootstock, manifested by short and thin side shoots, is largely genetically determined, but may also result from inadequate soil quality and care treatments during the growth of maiden trees. This opinion is collective with other authors [7,38] who found that the 'Gisela 5' rootstock requires good soil conditions and careful care, and does not perform well in suboptimal conditions. In the first year of the experiment, the fresh weight of maiden trees and their leaves was similar to that previously obtained by Świerczyński et al. [39] who obtained 1.4 kg and 225 g for the 'Vanda' variety, respectively, which confirms the growth potential of this variety in the nursery compare to others.

As stated by some researchers [40–42], sweet cherry rootstocks influence the parameters of photosynthesis occurring in the leaves. The measurements of the physiological processes of maiden trees showed differences for some varieties between the years compared and the method of rootstock propagation. As a rule, higher intensity of these life processes was obtained in the case of maiden trees from the first year of research, which confirmed a much more intense growth of maiden trees this year. This was not a rule that was confirmed for all varieties. More often, maiden trees obtained from cutting propagation method had two-three parameters higher for two of the four varieties considered ('Bellise' and 'Vanda'), and only for one variety ('Earlise') the relationship was reversed. Similar research was conducted by Świerczyński et al. [39] analyzing the impact of biostimulants on the parameters of photosynthetic activity of maiden sweet cherry trees of the 'Vanda' variety. They confirmed variable values of the assessed parameters, which did not always coincide with the growth dynamics of maiden sweet cherry trees. However, comparing results from different years of research is difficult due to differences in climatic and soil conditions. Nevertheless, many authors confirm the relationship between the increase in the intensity of photosynthesis and the increase in stomatal conductance [43–45], which was not demonstrated in the experiment. However, a strong relationship was observed between stomatal conductance and internal carbon dioxide concentration, which was previously observed by Świerczyński et al. [46]. According to the opinion of some researchers [45,47], a greater intensity of plant life processes usually results in stronger tree growth, which was not always confirmed in the analyzed experiment in the case of the assessed maiden sweet cherry trees.

5. Conclusions

Taking into account the fact that maiden sweet cherry trees obtained on the GiSelA 5 rootstock derived from shoot cuttings were most often higher and had a bigger stem diameter compared to those obtained by *in vitro*. We can suggest the usefulness of this cheaper method of propagation, which is not inferior to the more expensive *in vitro* method. This significantly reduces the production costs of this rootstock and does not deteriorate the quality of the maiden sweet cherry trees obtained from it. The difficulty lies in the inability to refer to the results of other authors, as this rootstock propagated by stem cuttings has not been studied so far, but only *in vitro*. Measurement of life processes taking place in maiden sweet cherry is not always a reliable source of information about the growth dynamics of the tested plants. In addition to the influence of variable soil and climatic factors, there is an additional correlation between the rootstock and the variety. Therefore, this requires further research.

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