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THE INFLUENCE OF ROOTSTOCKS ON THE SENSITIVITY OF FLOWER BUDS TO FROST AND THE MAIN PROPERTIES OF THE 'CARMEN' SWEET CHERRY CULTIVAR

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Abstract: The study examined the influence of five vegetative rootstocks on the flower bud sensitivity to frost during the period of ecological dormancy and the most important biological and pomological properties of the 'Carmen' sweet cherry cultivar. The 'Carmen' cultivar was grafted on the following rootstocks: 'Colt', 'Gisela 5', 'Gisela 6', 'MaxMa 14' and 'Oblačinska cherry'. Winter frosts occurred during the ecological dormancy of sweet cherry trees. The intensity of frost was between –5°C and –7°C. The percentage of damaged and non-damaged flower buds per fruiting branch was determined by counting (50 flower buds per tree were taken from every part of the canopy and fruiting branches). The highest rate of damage of flower buds was in trees grafted on 'Oblačinska cherry', an average of 77.2% of flower buds, while the lowest was observed in trees grafted on 'MaxMa 14', an average of 24.3% of total flower buds. The significantly higher sensitivity of flower buds was found in spur fruiting branches compared to lateral fruiting branches. The fruits of the 'Carmen' cultivar had the earliest ripening on rootstocks 'Gisela 5' and 'Oblačinska cherry'. The 'Carmen' cultivar had the highest yield per tree on the 'MaxMa 14' rootstock, while the lowest yield rate was observed in 'Oblačinska cherry', 5.4 kg and 1.9 kg, respectively. The highest mass of fruits was noticed in trees grafted on 'Gisela 6', an average of 11.6 g, while the smallest was recorded in trees grafted on 'Gisela 5'– an average of 9.4 g.

Key words: ecological dormancy, flower buds, frost, percentage of damage, yield, fruit quality.

Introduction

Sweet cherries are among the most popular summer fruits in Europe, and in most cherry growing countries, their production has an increasing trend (Deķena et al., 2020). Flowering is the crucial process affecting the possibility of obtaining a

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satisfactory fruit crop in sweet cherry (Dziedzic et al., 2019). Many authors studied the problems of sweet cherry flowering and related it with flower structures, especially generative organs, pollen-pistil interaction and the rootstock effect on fruit setting (Zhang et al., 2015; Radunić et al., 2017).

The suitability of cultivar-rootstock combinations to local climate conditions, together with soil properties and growing technologies, is one of the key factors in sweet cherry production (Pal et al., 2017). In the last two decades, the new dwarfing and semi-dwarfing cherry rootstocks have allowed obtaining high fruit yields of satisfactory quality. In many of the studies, authors have examined the following rootstocks: 'Weiroot 72', 'Weiroot 158', 'Weiroot 13', 'Gisela 5', 'Gisela 6', 'Edabriz', 'Pi-Ku 4.20', 'MaxMa 14' and 'F 12/1' (Gratacos et al., 2008; Usenik et al., 2008; Bielicki and Rozpara, 2010). The sweet cherry is a strong growing tree and requires the use of poorly growing rootstocks in contemporary production. Vegetative rootstocks are mostly used in intensive cherry production, of which the most important is 'Gisela 5' (Milatović et al., 2013). A powerful effect of poorly growing rootstocks was observed in the growth and yielding of sweet cherry cultivars (Usenik et al., 2008). Also, the rootstocks affect the intensity of flowering (Gratacos et al., 2008), the flowering time (Blažkova et al., 2010), as well as fruit quality (Balmer, 2008) in sweet cherry. Nevertheless, growers prefer dwarfing rootstocks for producing hand-picked cherries for fresh markets, which allow planting densities of up to 1.000–5.000 trees per hectare (Musacchi et al., 2015).

Also, the influence of rootstocks on grafted cultivar properties is expressed as the difference in the efficiency of water usage, advance or delay of flowering and harvesting, survival and yield efficiency (Cantin et al., 2010). The rootstocks also influence the response of grafted cultivars to cold temperatures (Hrotkó, et al., 2009). There were significant differences observed between rootstocks while assessing tree viability and winter damages. The trees on the P. *mahaleb* and 'Gisela 5' rootstocks were in the best condition (Deķena et al., 2020). Nevertheless, regarding dwarfing rootstocks, smaller tree canopies are manifested by shorter shoots and less leaf area, decreasing overall carbohydrate production for growth and storage. Stored carbohydrates are critical for allocation to new vegetative and reproductive structures in spring and are associated with negative effects on stored carbohydrates and fruit quality (Olmstead et al., 2010). Moghadam et al. (2015) recorded a direct relationship between the increased resistance of tree plants to frosts and carbohydrate content. The damage percentage is not only influenced by the temperature but also by the phenological stage.

Sweet cherry production in Serbia has a long tradition. Unfortunately, the quality of production and the quality of fruit are still at a low level. In addition, in most sweet cherry orchards, trees are grown on vigorous seedling rootstocks (P. *avium* L. and P. *mahaleb* L.) in low-density planting. The prerequisites for the successful production of sweet cherries are increased fruit quality and yields per tree and planting area. These goals can be achieved by testing new cultivars and rootstocks in different climatic and soil conditions before cultivating in a large planting area.

The study aimed to examine the influence of different vegetative rootstocks for cold hardiness in the ecological dormancy of the ‘Carmen’ sweet cherry cultivar in Belgrade’s environmental conditions. Also, the influences of those rootstocks on the fruit quality and yield of trees were examined.

Material and Methods

Plant material and growing conditions

The study was carried out at a commercial orchard located at the Faculty of Agriculture experimental estate ‘Radmilovac’, Belgrade, in the fifth growing year of the orchard (2020). The area has a temperate continental climate with an average annual rainfall of 650 mm. The orchard was established in the spring of 2016 with high-quality 1-year-old nursery trees. The ‘Carmen’ sweet cherry cultivar was grafted on five vegetative rootstocks (‘Colt’, ‘Gisela 5’, ‘Gisela 6’, ‘MaxMa 14’ and ‘Oblačinska cherry’). Trees were planted at a distance of 3.5×1.6 m (1,750 trees/ha).

The study examined the influence of winter frost on flower bud damages of the ‘Carmen’ cultivar grafted on different vegetative rootstocks. Winter frosts occurred during the ecological dormancy of sweet cherry (code 01 on the BBCH scale, according to Meier, 2018). During the early morning hours of March 14 and March 15, the temperatures were -5°C and -7°C, respectively.

Flowers sensitivity, phenological and biological properties

Sensitivity of flowers was represented as the percentage of damaged and non-damaged flowers per spur flowering shoots (SFB) and lateral fruiting shoots (LFB – shoots longer than 7 cm) separately and in total. Also, the study researched the following properties: the number of flowers per flower bud on short and long fruiting branches, time of blooming and harvesting, trunk cross-sectional area (TCSA), yield per tree and yield efficiency, the mass of fruit, a diameter of fruit, soluble solid contents (SSC), total sugars (TS) and total acids (TA).

The experiment was conducted on a random field with four repetitions (50 flower buds per tree were taken from every part of the canopy and fruiting branches, five trees were taken for a repeat). The physical properties of fruits were determined with five repetitions, and each repetition included 25 fruits. The chemical properties were determined with three repetitions. Physical properties were determined using standard morphometrics methods. SSC was determined by refractometer (Atago, pocket PAL-1. Kyoto, Japan). Titratable acidity (TA) was determined by titrating 25 g of fruits with 0.1N NaOH up to pH 7.0 and expressed in %. Total sugars (TS) were determined by the Luff-Schoorl method and expressed in %. Analysis of variance was done using the STATISTICA 9 software package. The significant differences between means were determined at P<0.05, measured by the LSD test.

Results and Discussion

The highest percentage of damaged flowers was recorded in trees of the 'Carmen' cultivar grafted on 'Oblačinska cherry' (77.2%), while trees grafted on 'MaxMa 14' (24.3%) had the lowest percentage of damaged flowers (Table 1). Trees grafted on 'Colt' and 'Gisela 5' had over 50% of damaged flowers. Milatović et al. (2013) recorded significantly sensitive flower buds in winter frost in many sweet cherry cultivars grafted on 'Gisela 5'. All trees had a higher percentage of damaged flowers on spur fruiting branches (SFB) compared to lateral fruiting branches (LFB). The percentages of damaged flowers on SFB were between 35.2% and 80.2%, while on LFB they ranged from 18.2% to 65.2%.

Table 1.The percentage of damage and the number of flowers per bud in different fruiting branches of the 'Carmen' sweet cherry cultivar grafted on vegetative rootstocks.

Rootstocks	Percentage of damaged flower buds			Flowers per bud	
	SFB	LFB	TOTAL	SFB	LFB
'Colt'	73.2ab	58.2ab	62.3ab	2.1c	2.5b
'Gisela 5'	56.1ab	44.6b	52.2b	2.3bc	2.5b
'Gisela 6'	44.2b	36.9bc	41.1bc	2.4bc	2.4b
'MaxMa 14'	35.2b	18.2c	24.3c	2.7a	3.1a
'Oblačinska cherry'	80.2a	65.2a	77.2a	2.4b	2.5b
LSD	27.2	14.5	19.6	0.2	0.4

SFB – spur fruiting branch; LFB – lateral fruiting branch.

The rootstocks had a significant influence on bud differentiation. The highest number of flowers per bud was found in trees grafted on 'MaxMa 14', while the lowest number of flowers per bud was recorded in trees grafted on 'Colt' (Table 1). All trees had a higher number of flowers in LFB compared to SFB. In SFB, the number of flowers per bud was between 2.1 ('Colt') and 2.7 ('MaxMa 14'), while in LFB, the number of flowers was between 2.4 ('Gisela 6') and 3.1 ('MaxMa 14').

The earliest blooming happened in the trees grafted on 'Oblačinska cherry', while trees grafted on 'Colt' and 'MaxMa 14' had the latest flowering time (Table 2). Also, trees grafted on the ‘Oblačinska cherry’ rootstock had the longest blooming period (18 days), while trees grafted on ‘Colt’ had the shortest blooming period (11 days). The earliest full blooming stage was observed in trees grafted on ‘Gisela 5’ and ‘Gisela 6’. Fruits of the ‘Carmen’ cultivar had the earliest ripening on ‘Gisela 5’ and ‘Oblačinska cherry’ rootstocks, while the trees grafted on ‘MaxMa 14’ had the latest ripening of fruits.

The trees grafted on ‘Colt’ had significantly higher values of TCSA compared to other rootstocks. Hrotkó et al. (2009) recorded significantly higher values of TCSA of ‘Carmen’ trees grafted on ‘Colt’ compared to the ‘MaxMa 14’ rootstock. The ‘Carmen’ cultivar had a higher yield per tree in ‘MaxMa 14’ (5.4 kg) and ‘Gisela 6’ (3.6 kg), while the yield had significantly lower values in ‘Oblačinska cherry’ (1.4 kg) and ‘Colt’ (2.5 kg). The obtained result could be due to a higher percentage of damaged flowers on trees grafted on ‘Oblačinska cherry’. Also, trees grafted on very dwarf or vigorous rootstocks in early bearing periods had significantly lower yield, which is consistent with the results of other authors (Whiting et al., 2005; Sitarek et al., 2008; Bielicki and Rozpara, 2010).

Table 2. Phenological properties and yield of the ‘Carmen’ sweet cherry cultivar grafted on vegetative rootstocks.

Rootstocks	Start of blooming	Full blooming	End of blooming	Bloom longevity (days)	Time of harvest	Yield (kg/tree)	TCSA (cm^2)	Yield efficiency (kg/cm^2)
‘Colt’	March 30	April 05	April 10	11	May 28	2.5bc	23.9a	0.11c
‘Gisela 5’	March 28	April 04	April 12	15	May 24	3.4b	13.8bc	0.25ab
‘Gisela 6’	March 28	April 04	April 13	16	May 26	3.8ab	15.9bc	0.24b
‘MaxMa 14’	March 30	April 07	April 13	14	June 01	5.4a	18.1b	0.30a
‘Oblacinska cherry’	March 27	April 07	April 14.	18	May 24	1.9c	11.3c	0.16c
LSD						1.6	5.4	0.05

The highest yield efficiency was found in trees grafted on ‘MaxMa 14’ (0.30 kg/cm^2), while significantly lower yield efficiency was observed in trees grafted on ‘Colt’ (0.11 kg/cm^2). Similar results were obtained by Rubauskis et al. (2014). Also, according to Hrotkó et al. (2009), trees with higher values of TCSA had significantly lower values of yield efficiency, which was confirmed in our research. The highest fruit mass was noticed in trees grafted on ‘Gisela 6’ (11.6 g), while the smallest mass was recorded in trees grafted on ‘Gisela 5’ (9.4 g). Also, the highest diameter of fruits was found in trees grafted on ‘Gisela 6’ (Table 3).

Trees grafted on ‘Gisela 6’ and ‘MaxMa 14’ had marketable fruits whose diameters were higher than 28 mm. Significantly higher contents of soluble solids and total sugars were determined in fruits of the ‘Carmen’ cultivar grafted on ‘Oblačinska cherry' (19.2% and 18.1%, respectively), while fruits of trees grafted on 'Gisela 5' had the lowest contents of those parameters (17.2% and 15.3%, respectively).

Table 3. Physical and chemical properties of fruits of the 'Carmen' sweet cherry cultivar grafted on vegetative rootstocks.

Rootstocks	Mass of fruit (g)	Diameter of fruits (mm)	Soluble solids (%)	Total sugars (%)	Total acids (%)
'Colt'	9.8b	26.8b	18.2b	16.5b	0.9a
'Gisela 5'	9.4b	25.7b	17.2c	15.3c	0.8ab
'Gisela 6'	11.6a	30.2a	17.5bc	15.5bc	0.9a
'MaxMa 14'	10.2b	28.9ab	18.1b	17.1ab	0.8ab
'Oblacinska cherry'	9.5b	25.9b	19.2a	18.1a	0.7b
LSD	1.2	1.4	0.7	1.1	0.1

Compared to the results of other authors (Hrotkó et al., 2009; Cantin et al., 2010; Rubauskis et al., 2014), higher values of SSC and TS in fruits of the 'Carmen' cultivar on all examined rootstocks were obtained. Higher values might be due to more favourable agro-ecological conditions for growing.

Conclusion

Considering the importance of sweet cherries for fruit growers, determining the influence of vegetative rootstocks on biological and pomological properties of cultivars is very important. The results obtained in this study indicated that the 'Carmen' cultivar grafted on 'MaxMa 14' and 'Gisela 6' had the lowest percentage of damaged flower buds (less than 50%). Also, trees grafted on these rootstocks had a higher yield and better physical properties of fruits. According to recorded results, a growing of the 'Carmen' cultivar on 'MaxMa 14' and 'Gisela 6' rootstocks could be recommended to producers of sweet cherries in similar agro-ecological conditions. Also, to obtain more complete results of rootstock effects on cultivars, it is necessary to continue with further examinations.

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UTICAJ RAZLIČITIH PODLOGA NA OSETLJIVOST CVETNIH PUPOLJAKA NA MRAZ I NAJZNAČAJNIJE OSOBINE SORTE TREŠNJE KARMEN

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R e z i m e

U radu je ispitivan uticaj pet vegetativnih podloga na osetljivost cvetnih pupoljaka na mraz i proizvodna svojstava sorte trešnje Karmen. Istraživanje je sprovedeno u komercijalnom voćnjaku na OFD Radmilovac, Beograd. Sorta Karmen okalemljena je na sledeće vegetativne podloge: Colt, Gisela 5, Gisela 6, MaxMa 14 i Oblačinska višnja. Zimski mrazevi su se desili tokom ekološkog mirovanja stabala, u ranim jutarnjim časovima 14. i 15. marta. Intenzitet mraza bio je od -5°C do -7°C. Procenat oštećenih i neoštećenih cvetova na rodnim granama utvrđen je brojanjem (po 50 cvetnih pupoljaka po drvetu, sa svakog dela krošnje i rodne grane). Najveće oštećenje cvetova imala su stabla okalemljena na Oblačinskoj višnji, u proseku 77,2%, dok su najmanja oštećenja zabeležena na stablima koja su kalemljena na MaxMa 14, u proseku 24,3% od ukupnog broja cvetova. Znatno veći stepen oštećenja cvetnih pupoljaka utvrđen je na majskim buketićima u odnosu na mešovite grane. Plodovi sorte Karmen najranije su sazreli na podlogama Gizela 5 i Oblačinska višnja, dok su najpoznije sazrevali na stablima gajenim na podlozi MaxMa 14. Sorta Karmen imala je najveći prinos po stablu na podlozi MaxMa 14 (5,4 kg), dok je najmanji prinos zabeležen na podlozi Oblačinska višnja (1,9 kg). Visokom produktivnošću su se odlikovala i stabla kalemljena na podlozi Gizela 6. Najveću masu plodova imala su stabla na podlozi Gizela 6 (11,6 g), a najmanju na podlozi Gizela 5 (9,4 g).

Ključne reči: ekološko mirovanje, cvetni pupoljci, procenat oštećenja, prinos, kvalitet plodova.

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