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The freezing frequency of sweet cherry generative organs after spring frosts occurrence

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Abstract. In recent years, late spring frosts were causing major damage to most fruit species in Serbia. In order to test the sensitivity of sweet cherry generative organs to frost, a screening was carried out in the spring of 2019 after a severe spring frost including various cultivars, at three different growing sites: Rimski Šančevi (Novi Sad), Agricultural Cooperative 'Agrodunav' (Karavukovo) and Agriculture Extension Service Sombor (Sombor). The growing sites differed in geographical location, altitude, distance from the Danube and phenological stage of sweet cherry cultivars. The proximity of the Danube had the greatest influence on the frequency of freezing injuries, while the freezing frequencies were lower at the higher altitude. 'Kordia' was the most sensitive cultivar to late spring frost, regardless of the phenological stage and growing site.

Key words: sweet cherry, cultivar, flowering, spring frost, geographical location

Introduction

Nowadays, a global climate change are affecting agricultural production due to changes in rain pattern, temperature, floods, droughts, and negative effects on water and land resources. The agriculture-based economies in developing countries are more affected by the climate change, facing the severe economic losses (Ali et al., 2017).

Agroclimatic conditions in Republic of Serbia are very suitable for temperate zone fruit trees growing. Extremely low winter temperatures, the sudden temperature changes in the winter period, late spring frosts, hail, extremely high summer temperatures, the insufficient precipitation and storm winds are considered the limiting factors for tree productivity and fruit quality in Serbia. Facing the climate changes, the late spring frosts are becoming more frequent in recent years. The below-zero temperatures during and after the bud break may be the limiting factor for fruit production, by damaging buds, flowers, young fruitlets and shoots (Gunes, 2006). Along with a temperature rise in spring, the water content in buds increases and budburst is occurring (Chmielewski & Gotz, 2017). By rising the temperature, the frost hardiness of fruit trees decreases, reaching the minimum with leaves occurrence (Vitasse et al., 2018). Freezing injuries occur as a consequence of ice formation inside plant tissue where ice crystals damage cell membrane system (Rodrigo, 2000). The intensity of freezing injuries depends on the ice formation positioning. Ice crystals formation can occur in intercellular spaces and permanently or temporarily protects plant cells. At the other hand, if freezing occurs quickly, ice crystals are form-

ed inside cells and cause their decay (Rodrigo, 2000). The level of damage is directly related to the intensity and duration of frost and the development stage of the bud at the moment of freezing (Salazar-Gutiérrez et al., 2016).

Late spring frosts are the limiting factors in the commercial sweet cherry production in Serbia. In the spring, frosts that occur at nights with radiative weather conditions cause significant damage to the buds (Quénol & Beltrando, 2008). In sweet cherry, generative buds are more sensitive to frosts than vegetative, while flowers are extremely sensitive to frost damage. The frost resistance is variable depending on the cultivar but also among the trees in the same orchard (Salazar-Gutiérrez et al., 2014). The earlier onset of flowering is determined in the recent years (Wenden et al., 2016). The ability of plants to resist low temperatures plays a decisive role in determining their geographic distribution (Wisniewski et al., 2014). Knowing the critical temperatures for each of the sweet cherry developmental stages can help select the appropriate cultivars for specific sites (Salazar-Gutiérrez et al., 2014).

The purpose of the research was to examine the influence of the growing site on the freezing frequency of sweet cherry generative organs after spring frost occurrence.

Material and Methods

The spring frost resistance/sensitivity of sweet cherry cultivars was assessed in 2019 at three growing sites in northern Serbia. Apart from the geographical position, the growing sites differed in elevation and the distance from Danube river (Tab. 1).

The first growing site was at the Experimental field for fruit growing of Faculty of Agriculture, located at Rimski Šančevi, near Novi Sad. The screening for frost damage was performed in sweet cherry plantation established in 2012, which includes the following cultivars: 'Summit', 'Kordia', 'Regina', 'Lapins', 'Merchant', 'Sweetheart' and 'Karina'. The cultivars were grafted on 'Gisela 5' rootstock and planted with the distance 4.0 × 1.5 *m* (1,666 *trees*/*ha*). The frequency of freezing injuries on the generative buds was assessed at the beginning of May, after the frost occurrence during the night between 27th and 28th March. The frost lasted for 8 hours, reaching the minimum at -4.8 °C (Graph 1). At the time of frost occurrence, sweet cherry trees were at stages 54 (Inflorescence enclosed by light green scales) or 55 (Single flower buds visible) BBCH (Fadón et al., 2015).

The second growing site was at Agricultural Cooperative 'Agrodunav' located in Karavukovo. Sweet cherry plantation was established in 2015 with cultivars 'Kordia', 'Regina', 'Ferovia', 'Carmen', 'Sweet Saretta' and 'Grace Star' grafted on 'Gisela 5' (Tab. 2). The planting distance was 4.0 × 1.6 *m* (1,562 *trees*/*ha*). During the last decade in May, the minimum temperatures were continuously below 0 °C, while the absolute minimum reached -3.5 °C at the night between 27th and 28th of March.

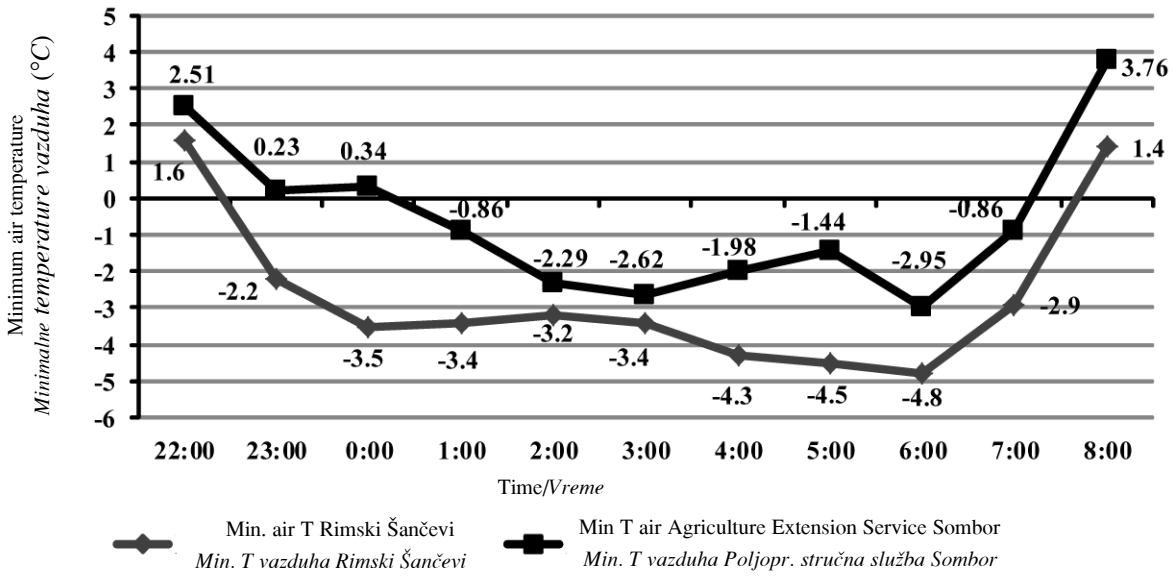
The third growing site was at Agriculture Extension Service located in Sombor. Two orchards are present at the site. The old one was planted in 2012 at the planting distance 4.0 × 1.75 *m* (1,428 *tree*/*ha*) on 'Gisela 5', with cultivars 'Kordia', 'Regina' and 'Ferrovia'. Another orchard was planted in 2016 at 4.0 × 1.5 *m* (1,666 *tree*/*ha*) on 'Gisela 5' including cultivars

Tab. 1. Geographic position, elevation and vicinity of Danube River, for three growing sites
Tab. 1. Geografski položaj, nadmorska visina i blizina Dunava, za tri lokaliteta

Growing site *Lokalitet*	Geographical position *Geografski položaj*	Altitude *Nadmorska visina (m)*	Distance from the Danube *Udaljenost od Dunava (m)*
Rimski Šančevi, Novi Sad	45°19' N 19°50' E	86	8430
Cooperative 'Agrodunav', Karavukovo *Zadruga „Agrodunav", Karavukovo*	45°29' N 19°11' E	83	200
Agriculture Extension Service, Sombor *Poljoprivredna stručna služba, Sombor*	45°78' N 19°12' E	90	1500

Table 2. Phenological stages of sweet cherry generative organs at Cooperative 'Agrodunav', according to BBCH scale
Tab. 2. Fenološki stadijumi generativnih organa trešnje na lokalitetu zadruge „Agrodunav", prema BBCH skali

Cultivar/*Sorta*	Phenological phase/*Fenološka faza*	
'Kordia'	Sepals open/*Otvoreni čašični listići*	BBCH 57
'Ferovia'	Sepals open/*Otvoreni čašični listići*	BBCH 57
'Regina'	Balloon/*Balon-faza*	BBCH 59
'Carmen'	30% of flowers open/*30% otvorenih cvetova*	BBCH 63
'Sweet Saretta'	30% of flowers open/*30% otvorenih cvetova*	BBCH 63
'Grace Star'	30% of flowers open/*30% otvorenih cvetova*	BBCH 63



Graph 1. Minimum air temperatures during the night between March 27th and 28th measured at iMetos station at Rimski Šančevi, and at Agriculture Extension Service Sombor
Graf. 1. Minimalne temperature vazduha u noći između 27. i 28. marta, merene u iMetos stanici na lokalitetu Rimski Šančevi i lokalitetu Poljoprivredne stručne službe Sombor

'Ferrovia', 'Carmen', 'Sweet Saretta' and 'Grace Star'. The time and severity of frost incidence and the phenological stages of sweet cherry were the same as at the previous site.

The samples containing 200 flower buds were collected from the different positions of tree crown. Flower bud were brought to the laboratory and transversely cut in order to determine the frost damage as the dark coloration of flower ovaries (Matzneller et al., 2016). Two categories of flower buds were recorded: damaged and undamaged.

Results and Discussion

Rötzer & Chmielewski (2001) described the dependence of tree phenological phases on latitude and altitude in Europe. In wild cherry (*Prunus avium* L.), flowering begins 2.9 days later per 100 *m* altitude and 3.7 days later per 100 *km* from south to north, while ripening begins 3.7 days later per 100 *m* altitude and 3.2 days later per 100 *km* from the south to the north. The frost severity differed among the growing sites, thus cultivars differed in the freezing frequencies depen-

ding on the growing site. Sweet cherry cultivars grown at Rimski Šančevi had later onset of the growing stages when compared to other two growing sites.

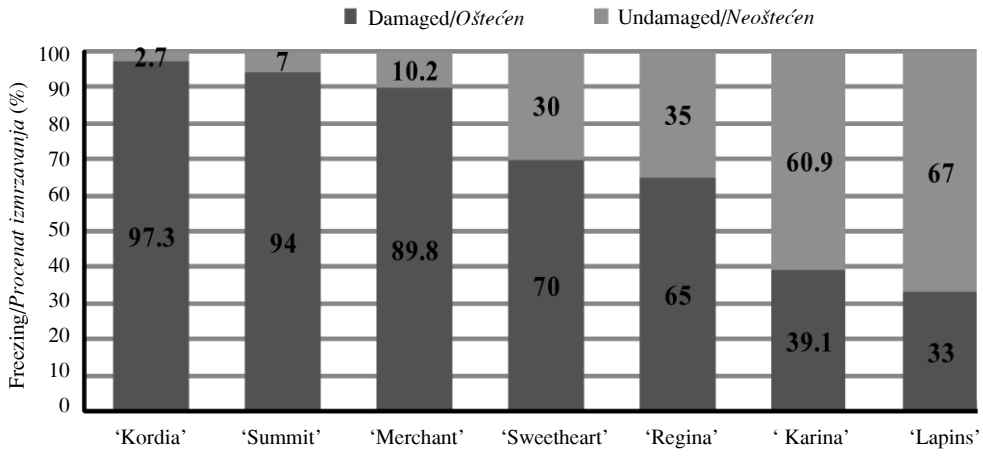
'Merchant', 'Summit' and 'Lapins' had slightly earlier onset of growing stages (BBCH 54) compared to 'Kordia', 'Regina', 'Sweetheart' and 'Karina' (BBCH 55). 'Lapins' appeared to be the most resistant to spring frosts while 'Kordia' was the most sensitive, which is not in accordance with Matzneller et al. (2016), who determined the higher sensitivity at more advanced growing stages.

At the second growing site, at Cooperative 'Agrodunav', the frost damage was less severe compared to those at Rimski Šančevi. The highest frequency of freezing damage was recorded in 'Carmen' and 'Kordia', while the lowest was in 'Grace Star' (Graph 3).

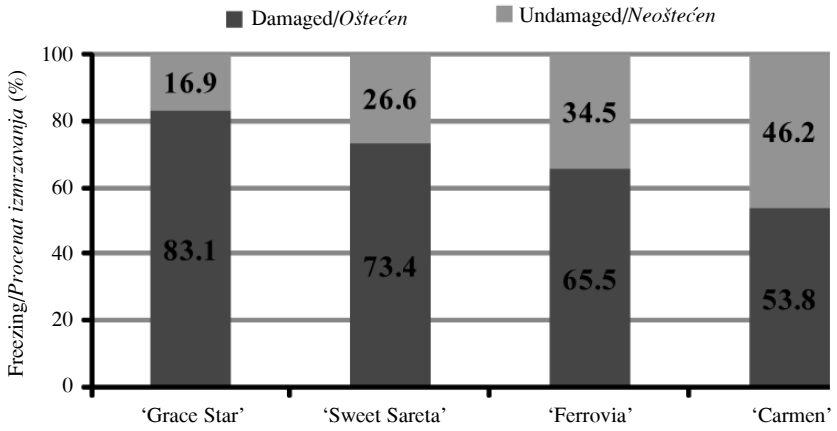
On the other hand, at the third growing site 'Grace Star' appeared to be the most sensitive cultivar to the frosts. That could be due to the position of the cultivar in the orchard, and the direction of cold air flow. Cultivar 'Ferrovia' was recorded with the higher freezing frequency in the old (2012) than in the new plantation (2016). The same was recorded in 'Carmen', where old trees were more sensitive to frosts than the young trees.

The highest freezing frequencies among sweet cherry cultivars were recorded in 'Kordia' at three growing sites which confirms its sensitivity to spring frosts (Vercammen & Vanrykel, 2009). The freezing frequencies among cultivars were variable depending on the growing site. At Rimski Šančevi, the cultivars differed regarding their freezing frequencies, while at the second site in Karavukovo the cultivars differed slightly. This could be due to the vicinity of Danube River. The relative humidity is increased near large water flow. By decreasing air temperature near to dew point, a fog is forming and spreading through the valley of the river. The fog absorbs the heat from the soil and prevents further lowering of the temperature (Young, 1940).

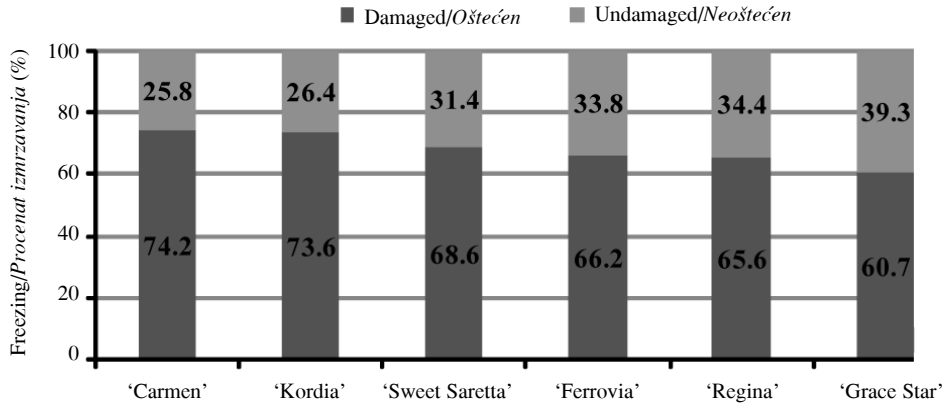
The higher elevation and the vicinity of Danube River affected the air temperature and thus the freezing severity. The freezing severity was the highest at Rimski Šančevi. The research confirms that the selection of the growing site i s the determinant factor for the successful fruit production (Wenden et al., 2016). In the recent years, the highest winter and spring temperatures were recorded as well as the higher increase in maximum compared to the minimum air temperatures (Vitasse et al., 2018; Matiu et al., 2016). Keeping on mind the severity of damage that might occur, the frequency and the average date of the last frost are important factors when deciding on the growing site for sweet cherries (Cittadini et al., 2006).



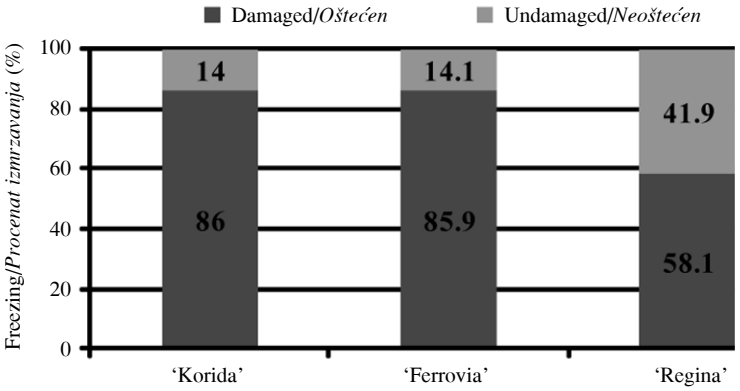
Graph 2. The frequency of freezing damage of sweet cherry cultivars' flower buds at Rimski Šančevi
Graf. 2. Učestalost pojave mrazom oštećenih cvetnih pupoljaka sorti trešnje na lokalitetu Rimski Šančevi



Graph 3. The frequency of freezing damage of sweet cherry cultivars' flower buds at Cooperative 'Agrodunav', Karavukovo
Graf. 3. Učestalost pojave mrazom oštećenih cvetnih pupoljaka sorti trešnje na lokalitetu Zadruge Agrodunav, Karavukovo



Graph 4. The frequency of freezing damage of sweet cherry cultivars' flower buds at Agriculture Extension Service Sombor (young orchard)
Graf. 4. Učestalost pojave mrazom oštećenih cvetnih pupoljaka sorti trešnje na lokalitetu Poljoprivredne stručne službe Sombor (mladi zasad)



Graph 5. The frequency of freezing damage of sweet cherry cultivars' flower buds at Agriculture Extension Service Sombor (old orchard)
Graf. 5. Učestalost pojave mrazom oštećenih cvetnih pupoljaka sorti trešnje na lokalitetu Poljoprivredne stručne službe Sombor (stari zasad)

Conclusions

On the basis of spring frost damage screening in sweet cherry cultivars, it can be concluded that 'Kordia' is the least resistant to low temperatures at bud break, and therefore we do not recommend its cultivation in areas of prevalent occurrence of spring frosts. Although the resistance to frost of sweet cherry generative organs is genetically conditioned, the influence of altitude and proximity of water flows on the intensity of freezing injuries has been confirmed. Growing more sensitive varieties to frosts at higher altitudes or near water courses is recommended, while frost resistant fruit species and cultivars can be grown at lowlands.

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FREKVENCIJA IZMRZAVANJA GENERATIVNIH ORGANA TREŠNJE NAKON POJAVE PROLEĆNIH MRAZEVA

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Rezime

Poslednjih godina su pozni prolećni mrazevi prouzrokovali velike štete kod većine vrsta voćaka u Republici Srbiji. U cilju ispitivanja otpornosti generativnih organa trešnje sprovedeno je istraživanje u proleće 2019. godine posle jakog prolećnog mraza, na različitim sortama trešnje, na tri razlličita lokaliteta: Rimski Šančevi, ZZ Agrodunav i PSS Sombor. Lokaliteti su se razlikovali po geografskom položaju, nadmorskoj visini, udaljenosti od reke Dunav i fenološkoj fazi generativnih organa sorti trešnje. Blizina reke imala je najveći uticaj na intenzitet izmrzavanja, dok je na većim nadmorskim visinama intenzitet izmrzavanje bio manji. Sorta Kordia je bila najosetljivija na mraz, bez obzira na fenološku fazu i lokalitet.

Ključne reči: trešnja, sorta, cvetanje, prolećni mraz, geografski položaj