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Evaluation of some cherry varieties grafted on Gisela 5 rootstock

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Abstract: The results of the evaluation of yield and pomological characteristics of 9 cherry varieties (Sylvia, Kordia, Sunburst, Van, Summit, Stark Hardy Giant, Regina, Octavia, and Sum) and the local cherry variety Dolga siska, grafted on dwarfing rootstock Gisela 5, are presented in this paper. The research was conducted in an experimental orchard located in the village of Kosel in the Ohrid region. The orchard was planted in 2009 with a planting distance of 3.8 × 2 m. The training system of the trees is the central leader system. Intensive agricultural techniques are implemented in the orchard. The orchard is under a drip irrigation system. The study was performed during 3 consecutive years: 2011, 2012, and 2013. The following parameters were investigated: diameter of the rootstock and scion, trunk cross section area, volume of the tree crown and tree crown area, yield and yield efficiency, and quality characteristics of the fruits. All varieties had good compatibility with the rootstock. According to the diameter of the trunk, the most vigorous variety is Kordia. The local cherry variety Dolga siska had the lowest vigorousness among the evaluated varieties. The highest cumulative yield and yield efficiency were seen in the Octavia variety (41.25 kg, 0.46 kg/cm^2) and the lowest in Sunburst (13.14 kg, 0.16 kg/cm^2). The fruits from Dolga siska and Sunburst had the highest average fruit weight (11.70 g and 11.43 g), whereas the fruits from Sylvia had the lowest value for this parameter (7.79 g). All varieties had a very high ratio of fruit weight/stone weight. It ranged from 93.58% in Sylvia to 97.02% in Summit. Most of the studied varieties showed positive characteristics and can be recommended for mass growing in the Ohrid region. Besides the local variety Dolga siska as the best option, Stark Hardy Giant, Kordia, Sunburst, and Van can also be emphasized.

Key words: Fruit quality, productivity, sweet cherry, yield

1. Introduction

The choice of cherry rootstock depends on several key factors such as the variety to be used, the soil texture, the depth to water table, or the training system. Although we do not know yet which rootstocks are the best for new, high-density training systems, it seems that dwarfing rootstock is likely crucial.

There is no longer a place for very tall trees in modern cherry production. As was the case with apple and pear, the demand for less vigorous trees that are easier to control increased at the end of the 1970s and the beginning of the 1980s (Vercammen et al., 2006).

Vigorous sweet cherry trees are still common in Macedonian fruit orchards. Mahaleb (*Prunus mahaleb* L.) and mazard (*Prunus avium* L.) seedlings are the major rootstocks used for sweet cherry production. Trees on these rootstocks are vigorous and difficult to maintain, especially during harvesting. Mahaleb seedlings have slightly reduced tree growth vigor but perform poorly in heavier soils (Gyeviki et al., 2008). According to some authors (Perry, 1987), the compatibility of different sweet cherry varieties grafted on *P. mahaleb* is unpredictable.

In the last few years, farmers in Macedonia have shown increased interest for new high-density cherry orchards established on dwarfing rootstock. The Gisela 5 cherry rootstock is among the best dwarfing, precocious, and productive rootstocks for modern intensive sweet cherry growing (Zimmermann, 1994). It is slowly starting to replace the mahaleb and mazard rootstocks in Macedonia because of its ability to produce dwarfing and precocious trees. Preliminary observations of this rootstock show very good adaptation in the Ohrid region's soil and climatic conditions.

It is thought that there are several hundred varieties of sweet cherry grown commercially worldwide, but most of these are simply cultivated and marketed locally. Only a few of these several hundred varieties are suitable for wide-scale production and sale on the global market, due to their quality attributes matching market and grower requirements (Revell, 2008). However, the tree's growth

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and production depends on climatic conditions like chilling hours (Mahmood et al., 2000), light intensity, rain, and temperature during blossoming (Roversi and Ughini, 1996).

The aim of this research was to provide information about the growth of the trees, their productivity, and their fruit quality characteristics under local climate conditions for a number of promising cherry varieties grafted on Gisela 5 rootstock.

2. Materials and methods

Ten sweet cherry varieties (Table 1) were planted in the experimental orchard in 2009. The orchard was established in the village of Kosel (41°10′N, 20°50′E; 890 m a.s.l.) near the city of Ohrid in southwestern Macedonia. The Ohrid region is the most significant region producing 50%–55% of the state's cherry production. Sweet cherry is one of the major fruit crops grown in the Ohrid region. The assortment is primarily based on autochthonous genotypes and many of the cultivars that are grown have great economic and agronomic value.

The local variety, Dolga siska, an old variety that is well adapted to the local conditions, was used as a control. All varieties were grafted on Gisela 5 rootstock. All introduced and evaluated varieties are characterized with mid-late to late ripening time. They originated from different selection centers and are well known in modern cherry production, and some of them are highly appreciated by consumers. All of them have large attractive fruits, which is a very important aspect in production.

Different growing regions tend to grow differing varieties. The Ohrid region has forged a reputation for growing later maturing varieties due to its climatic conditions. Accordingly, evaluation of these varieties is very important for their future introduction into production practice.

On the other hand, the local variety Dolga siska is well known and highly appreciated by the producers, traders, and consumers. It is a late ripening variety, ripening just after Kordia. Fruits are very large and very firm. Productivity on *P. avium* has been consistently light.

Table 1. Evaluated sweet cherry varieties.

Sweet cherry varieties	
Sylvia	Octavia
Stark Hardy Giant	Van
Kordia	Sum
Regina	Summit
Sunburst	Dolga siska

When ripe, the skin and flesh colors are dark red. The taste is mildly sweet and pleasant.

The experiment was arranged in a randomized block design with four replications of five trees per plot. The planting distances were 3.8 × 2 m, while the trees were trained to a central leader canopy. The study was conducted during the period of 2011–2013. The orchard was planted on a fertile loam soil. The agroclimatic conditions registered in the area are shown in Table 2.

In order to describe the tree condition and fruit quality characteristics, the following parameters were evaluated: blossom and harvest period, diameter of the rootstock and scion, yield per tree, yield efficiency, and fruit quality.

The dynamics of the growth of the diameters of the trunk were followed each year. The diameter of the rootstock and scion, tree height, and spread into and along the tree row were measured during the harvest season. The trunk cross-sectional area (TCSA) and tree canopy volume (TCV) using cone formulae (Wertheim et al., 1989) and the crown area (CA) were calculated from those measurements. The yield per tree and the cumulative yield per tree were computed from the harvest data. The yield efficiency was calculated as kg/cm^2 TCSA, kg/m^3 TCV, and kg/m^2 CA.

The fruit quality was determined based on weight, dimensions, and physical and chemical characteristics. In general, the analyzed fruits were sampled during the first commercial harvest. The fruits were collected on three occasions and the average values from measurements were presented. Fruit from each variety was randomly harvested from 20 different trees and 30 representative fruits were processed for all analysis. Fruit weight was measured using a digital balance. Fruit length (L), fruit width (W), and fruit thickness (T) were determined using a Vernier caliper. Fruit volume was calculated using the formula $4/3pr^3$, where r = [L + W + T]/6, and fruit sphericity (ø) was calculated using the following equation: ø = $([LWT])^{0.333}$/L (Perez-Sanchez et al., 2010). Total soluble solid (TSS) content (°Brix) was determined using a refractometer. Titratable acidity (TA) was determined based on three juice samples diluted in distilled water and microtitrated with NaOH 0.1 N (Daza et al., 2008).

Statistical analyses were performed using SPSS 14.0 (SPSS Inc., Chicago, IL, USA). The differences were evaluated by ANOVA with the general linear model (GLM) procedure. After GLM analyses post hoc comparisons of means were calculated by the least significant difference test. Results were expressed at the $P < 0.05$ level of significance.

3. Results and discussion

The blooming period dates (from beginning to end) were recorded for all varieties in the experimental fields and the

Table 2. Climate conditions of 2011–2013.

Parameter	Months												Year.	Veg.
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		
Mean air temperature, °C	1.9	2.8	6.5	10.5	15.6	19.4	22	21.8	16.6	12.1	7.7	3.4	11.7	16.9
Rain, mm	86.3	52.8	64.5	68.5	48.3	33.2	31.5	26.3	63.6	92.3	79.5	86.9	773.7	363.7
Mean air humidity, %	78	71	68	67	67	63	58	59	67	74	76	79	69	65

average values from 2011, 2012, and 2013 are presented in Figure 1. The variety with the latest blooming period is Sunburst, followed by Sylvia and Sum. On the contrary, Van and Kordia had the earliest blooming among the studied varieties and flowered in the second 10 days of April. According to Milatovic et al. (2013), the Sunburst and Sum varieties have later flowering periods compared to the Van variety. This was confirmed in our research.

Harvest dates for a cultivar may be modified by climatic conditions in the growing season (Milosevic et al., 2015). Considering all cultivars in the study, the harvest lasted 29 days, beginning on 20 June with Van and finishing with Regina (Figure 2). This may allow continuity and also a long marketing period, with the potential to extend marketing up to the middle of August with postharvest practices such as modified atmosphere packages. Considering the length of the harvest period, the longest period was observed for Summit (12 days), and the variety with the shortest period of harvest was Sum (7 days). According to Gratacos et al. (2008), the Summit variety has a long harvesting period of 14 days, which was confirmed in our research.

The diameter of the trunk is an indicator of the vegetative potential of a tree. It depends on the combination of variety and rootstock (Lanauskas et al., 2012), ecological conditions, training system, applied agrotechnical measures (Blazkova and Hlusickova, 2008), etc. Gisela 5 is usually ranked as a dwarf rootstock (Cmelik et al., 2004; Balmer and Blanke, 2005), and it rapidly decreases trunk diameter and total vegetative growth of the trees. Among the evaluated varieties in 2013, the trees from cultivar Kordia (110.97 mm) had the highest trunk diameter of scions (Figure 3), followed by Octavia and Summit (107.50 mm and 106.44 mm), whereas the trees from local cultivar Dolga siska (85.12 mm) had the lowest value for this parameter.

Similar results were obtained for the rootstock diameter (Figure 4). Again, the trees from Kordia had a higher diameter of the rootstock, followed by Octavia and Sunburst, while the lower values for this parameter were found in the trees from varieties Sum, Sylvia, and Dolga siska. Only Regina and Dolga siska in 2011 had a higher diameter of rootstock than the diameter of the scion.

Selection of an appropriate graft combination is crucial for the production of deciduous orchard species, because the scion–rootstock interaction influences water relations, leaf gas exchange, mineral uptake, tree vigor, blossoming,

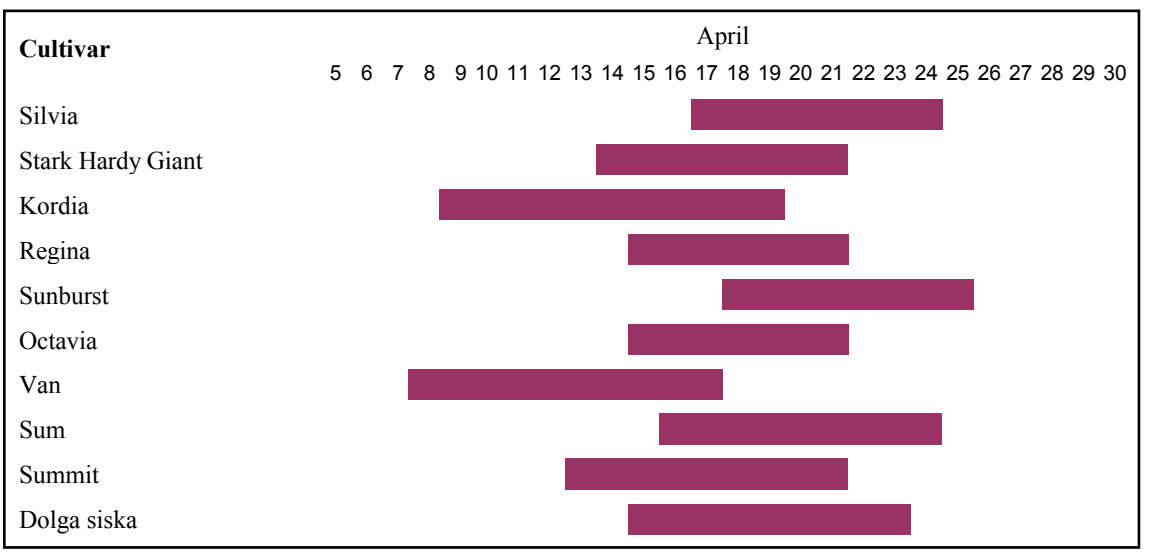

Figure 1. Blooming period of different varieties.

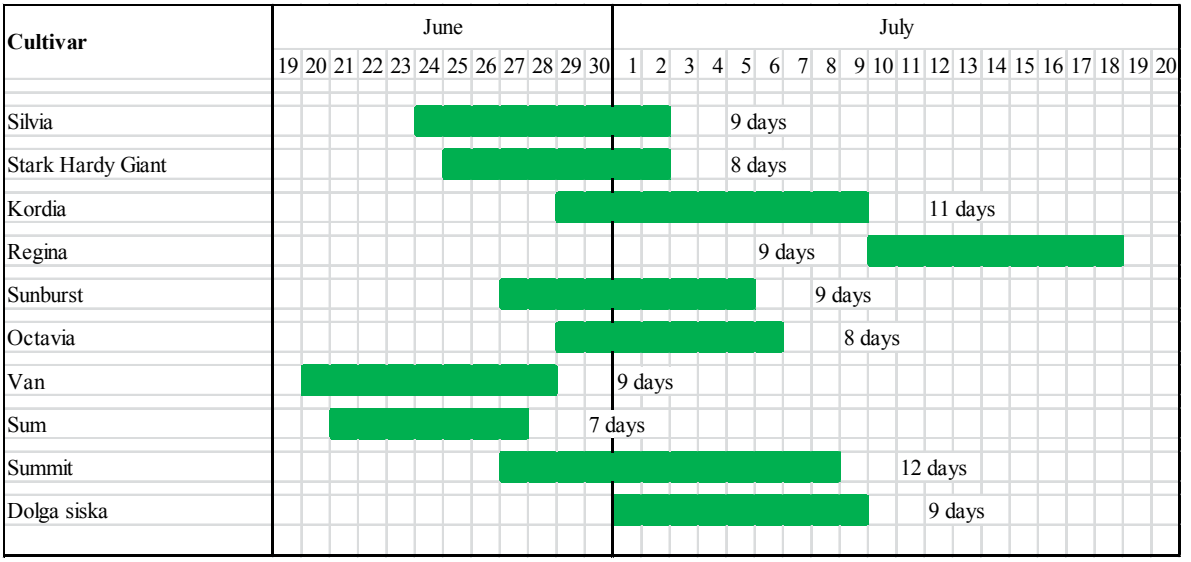

Figure 2. Harvest period of different varieties.

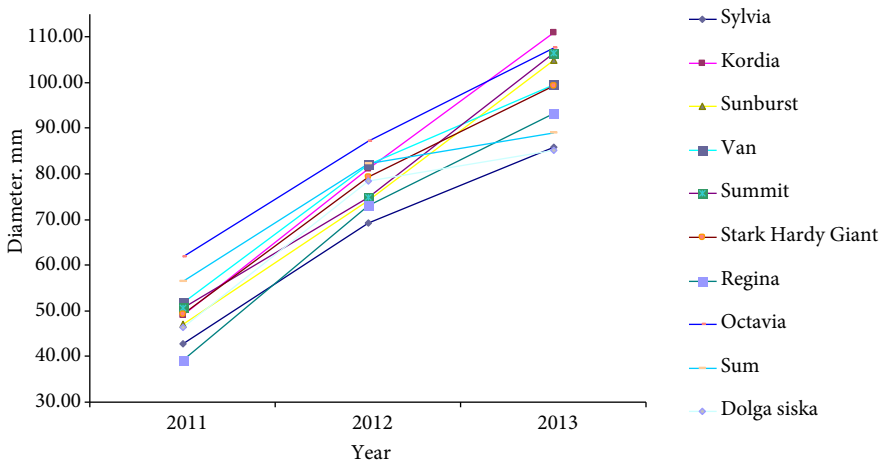

Figure 3. Growth dynamics of the scion diameter.

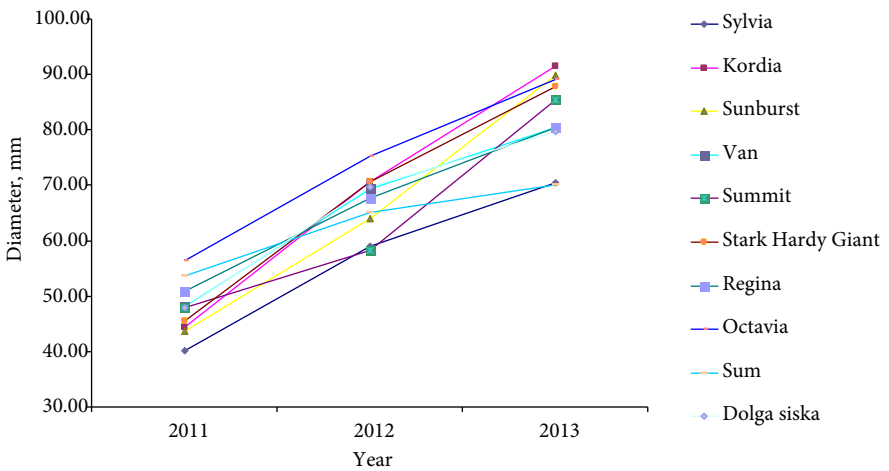

Figure 4. Growth dynamics of the rootstock diameter.

timing of fruit set, fruit quality, and yield efficiency (Schmitt et al. 1989; Nielsen and Kappel, 1996; Gonçalves et al., 2003). In grafted trees, the control of plant size is mainly exerted through the rootstock.

In our research, we found a strong positive correlation between the diameter of the rootstock and the scion (Figure 5).

According to Akcay et al. (2008), the sweet cherries varieties Octavia and Sunburst belong to the group with the strongest growth of the trunk diameter. This is confirmed in our research, where the values for this parameter in these two varieties are ranked in the second and third place immediately after Kordia.

Among the tested varieties, Kordia had the highest value for TCSA, followed by Octavia, Summit, and Sunburst. The lowest mean values for TCSA at the end of the 5th vegetation were observed in Sylvia and a statistically significant difference was observed in comparison to the other varieties, besides the local variety Dolga siska and Sum (Table 3). Statistically higher TCSA in varieties Kordia and Octavia grafted on rootstock Weiroot 158 compared to Regina and Sum were found by Cmelik and Druzic Orlic (2008).

The trees from the Stark Hardy Giant variety had the greatest TCV, and these values were statistically different from the other evaluated varieties. The lowest value for this parameter was observed in trees from the variety Sum (2.87 m^3), but without statistical differences from Regina. Cmelik and Druzic Orlic pointed out similar findings (2008). In their research, the varieties Regina and Sum grafted on rootstock Weiroot 158 had statistically lower values for canopy volume than those of variety Kordia.

A similar finding was observed when analyzing the values for CA. The trees from Sunburst, Van, Stark Hardy Giant, Kordia, Octavia, and Sylvia had high values for this parameter with statistical differences from Summit, Regina, Dolga siska, and Sum.

Appearance is essential as it is often the initial sensory attribute that can determine a consumer's decision to purchase a product or not. There are three important characteristics associated with the appearance of fruit: color, size and shape, and surface texture. These are the only characteristics a consumer can use as indicators of cherry quality or ripeness as the two are closely related prior to purchase (Revell, 2008).

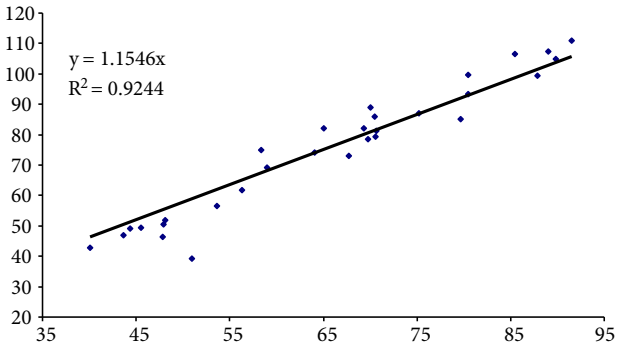

Figure 5. The relationship between diameter of the rootstock and scion for evaluated varieties.

Size is a factor, with bigger fruits taking preference as they are thought to be more appealing to the eye and are perceived to be of a higher quality than their smaller counterparts. The fruit size is an important characteristic for commercial market value (Vittrup Christensen, 1995). Perez-Sanchez et al. (2010) indicated that fruit weight is the most important physical attribute of the fruit, upon which the fruit value (price) depends. Table 4 shows the data for the average fruit weight of evaluated varieties. The highest fruit weight was seen with local variety Dolga siska (11.70 g), with significant statistical differences from all the other evaluated varieties besides Sunburst. This variety has probably been improved by local growers of this region over the decades. Fruits produced from Sylvia had the lowest fruit weight, but without significant differences from Regina or Summit. The lowest value for fruit weight of the variety Sylvia is comparable to the fruits from Summit without statistical differences, as pointed out by Gratacos et al. (2008).

Some authors reported that optimum size, based on average weight, is between 11 and 12 g (Kappel et al., 1996). It is important to indicate that consumers generally prefer swee cherries with large pulp amounts (ratio of fruit weight/stone weight). Our study shows that all evaluated varieties are characterized by high values for this parameter, ranging from 93.58% in Sylvia up to 97.20% in Summit.

The stalk length is an important attribute for consumers. They generally prefer sweet cherries with short peduncles. Cordeiro et al. (2008) indicated that improved varieties have short peduncles. However, according to Perez-Sanchez et al. (2010), local varieties generally had long fruit peduncles, which made harvesting more difficult. This was confirmed in our study. The local variety Dolga siska has fruits with the highest length of stalk, but this was not statistically different from the fruits of Stark Hardy Giant. The fruits from variety Van had the shortest stalk, statistically significantly different from all the other evaluated varieties (Table 4).

In relation to the physical parameters of the fruits, the largest fruit length was produced by Dolga siska, Regina, and Sunburst (Table 5). In contrast, the shortest fruit length was obtained from the fruits from Sylvia and Summit. The fruit width of the cherry is one of the most important quality factors for attaining a high price. According to EU standards of quality, cherries with 25 mm of equatorial diameter belong to the "Extra Category" (Perez-Sanchez

Table 3. Vegetative characteristics of the trees, 2013.

Variety	TCSA (cm^2)	TCV (m^3)	CA (m^2)
Sylvia	58.99^{f}	3.70^{cd}	4.44^{a}
Kordia	96.95^{a}	4.69^{b}	4.66^{a}
Sunburst	84.65^{abcd}	4.53^{b}	4.80^{a}
Van	73.65^{cd}	4.58^{b}	4.78^{a}
Summit	86.16^{abc}	3.73^{cd}	3.98^{b}
Stark Hardy Giant	78.95^{bcde}	5.41^{a}	4.68^{a}
Regina	75.51^{de}	3.43^{de}	3.89^{b}
Octavia	90.74^{ab}	4.20^{bc}	4.61^{a}
Sum	68.23^{ef}	2.87^{e}	3.29^{c}
Dolga siska	69.88^{ef}	3.82^{cd}	3.34^{c}

Values followed by the same letter in a column are not statistically different at $P < 0.05$.

et al., 2010). The fruit width among the evaluated varieties varied from 21.50 mm to 28.69 mm, with Octavia being the one with the smallest fruit width. Fruits from Dolga siska have the greatest width, statistically different from all the other evaluated varieties. Again, this variety has the greatest fruit thickness. The Regina, Van, and Sunburst varieties showed high values of this parameter (Table 5).

Fruit volume is the indicator for fruit size. Dolga siska is a very interesting local variety in relation to fruit size parameters. It showed the largest fruits, at 9.78 cm^3 fruit volume, statistically different from the other varieties. Sunburst, Regina, and Van among the introduced cherry varieties have higher fruit volumes, followed by Stark Hardy Giant and Kordia. Again for this parameter, the fruits from Sylvia showed the lowest values, but without statistical differences from Octavia (Table 5). Perez-Sanchez et al. (2010), while evaluating local cherry varieties in Spain, indicated that fruit volume ranged from 4.01 cm^3 to 8.56 cm^3. In their experiment, Van had fruit volume of 6.87 cm^3, which is slightly lower than in our research.

With regard to sphericity (Table 5), Sum and Kordia were the varieties with the most elongated fruit (94.43% and 95.74%, respectively). Van and Stark Hardy Giant were the varieties with the most flattened fruit (104.42% and 101.26%, respectively). Moreno and Trujillo (2006) also observed kidney-shaped fruits in Van. According to Perez-Sanchez et al. (2010), the sphericity of the fruits from Van was 105.35% in the agroecological conditions of Spain, similar to our data.

The results of the productivity of the varieties are given in Table 6. It has to be pointed out that these are preliminary data; first cropping years (3rd, 4th, and 5th leaf) cannot give relevant information about the productivity of a specific variety under specific growing conditions. However, trees from Octavia were mostly productive with a cumulative yield of 41.25 kg, statistically different from all the other evaluated varieties. These data indicate early precocity of this variety. Among the rest of the evaluated varieties, Kordia, Van, Stark Hardy Giant, and Sum were the ones with higher yields. Lower productivity was determined in Sunburst at 13.14 kg without statistical differences from Sylvia. A large number of researchers have pointed out higher productivity of

Table 4. Pomological characteristics of the fruits, average, 2011–2013.

Variety	Fruit weight, g	Stone weight, g	Ratio of fruit weight/ stone weight, %	Stalk length, mm
Sylvia	7.79^{d}	0.50	93.58	41.16^{e}
Kordia	9.02^{c}	0.45	95.01	49.79^{d}
Sunburst	11.43^{a}	0.37	96.76	41.32^{e}
Van	8.73^{c}	0.45	94.84	30.90^{g}
Summit	8.57^{cd}	0.24	97.20	40.87^{ef}
Stark Hardy Giant	10.58^{b}	0.57	94.61	59.92^{ab}
Regina	8.28^{cd}	0.49	94.08	53.19^{c}
Octavia	8.60^{c}	0.48	94.42	58.09^{b}
Sum	8.78^{c}	0.28	96.81	37.15^{f}
Dolga siska	11.70^{a}	0.56	95.21	63.17^{a}

Values followed by the same letter in a column are not statistically different at $P < 0.05$.

Table 5. Physical characteristics of the fruits, average, 2011–2013.

Variety	Fruit length, mm	Fruit width, mm	Fruit thickness, mm	Fruit volume, cm^3	Sphericity, %
Sylvia	19.96^{e}	21.77^{de}	18.52^{cd}	4.80^{e}	100.69^{b}
Kordia	22.13^{cd}	23.07^{d}	18.95^{cd}	5.97^{cd}	95.74^{e}
Sunburst	23.35^{bc}	25.19^{bc}	21.29^{b}	7.40^{b}	101.16^{b}
Van	22.09^{c}	26.07^{b}	21.43^{b}	6.71^{bc}	104.42^{a}
Summit	21.66^{d}	22.92^{d}	18.55^{d}	5.63^{d}	97.43^{cde}
Stark Hardy Giant	21.96^{d}	23.72^{d}	20.68^{c}	6.38^{c}	101.26^{ab}
Regina	23.95^{b}	24.57^{c}	21.73^{b}	6.82^{b}	97.61^{cd}
Octavia	21.20^{de}	21.50^{e}	18.78^{cd}	5.29^{de}	96.94^{de}
Sum	21.94^{d}	21.79^{e}	18.52^{d}	5.46^{d}	94.43^{e}
Dolga siska	26.62^{a}	28.69^{a}	23.90^{a}	9.78^{a}	98.77^{c}

Values followed by the same letter in a column are not statistically different at $P < 0.05$.

varieties Kordia and Octavia compared to Sunburst and Sum (Franken-Bembenk, 2005; Cmelik and Druzic Orlic, 2008; Kolev and Dzuvinov, 2008).

Higher yield efficiency was also determined for Octavia, with statistical difference from the others except for cultivar Sum, which had the highest cumulative yield efficiency at 11.44 kg/m^3 as expressed by tree crown volume (Table 7). The trees from Sunburst had the lowest yield efficiency; this was statistically not different only with Summit (Table 7).

Total soluble solids ranged from 17.4 °Brix in Regina to 14.0 °Brix in Summit (Table 8). High concentrations of total soluble solids were also determined in Van and Octavia. In general, these varieties have high contents of total soluble solids compared to other sweet cherry varieties (Girard and Koop, 1998; Serrano et al., 2009). The fruits from Summit had higher concentrations of total acids (TA) and the lowest sweetness, which gives a slight sour taste to the fruits. The fruits from Sunburst had a higher TSS/TA ratio (30.40) and a sweeter taste of the fruits than all other evaluated varieties.

All evaluated varieties showed positive adaptation to the specific agroecological conditions of the Ohrid region of Macedonia. This research has shown that intensive production of quality sweet cherries grafted on dwarfing rootstock Gisela 5 in this region is possible. Although all

Table 6. Yield and cumulative yield per tree (kg).

Variety	Year			Cumulative yield
	2011	2012	2013	
Sylvia	1.35^{bc}	3.55^{b}	11.75^{e}	16.65^{fg}
Kordia	1.39^{bc}	3.62^{b}	26.10^{a}	31.11^{b}
Sunburst	1.24^{bc}	3.50^{b}	8.40^{f}	13.14^{g}
Van	1.07^{bc}	3.15^{b}	21.86^{b}	26.08^{c}
Summit	0.90^{c}	3.03^{b}	13.15^{e}	17.08^{f}
Stark Hardy Giant	1.58^{b}	4.35^{b}	20.30^{bc}	26.23^{c}
Regina	1.22^{bc}	4.08^{b}	16.55^{cd}	21.85^{e}
Octavia	3.20^{a}	9.60^{a}	28.45^{a}	41.25^{a}
Sum	3.43^{a}	9.30^{a}	14.03^{de}	26.76^{c}
Dolga siska	1.36^{bc}	4.27^{b}	18.13^{c}	23.76^{de}

Values followed by the same letter in a column are not statistically different at $P < 0.05$.

Table 7. Cumulative yield efficiency at 5th leaf.

Variety	Yield/TCSA (kg/cm^2)	Yield/TCV (kg/m^3)	Yield/CA (kg/m^2)
Sylvia	0.30^{cd}	4.58^{bc}	3.76^{d}
Kordia	0.33^{cd}	6.79^{b}	6.71^{b}
Sunburst	0.16^{e}	2.95^{c}	2.77^{d}
Van	0.36^{bc}	5.71^{b}	5.47^{bc}
Summit	0.21^{e}	4.71^{bc}	4.36^{cd}
Stark Hardy Giant	0.35^{bcd}	4.88^{bc}	5.62^{bc}
Regina	0.30^{cd}	6.44^{b}	5.64^{bc}
Octavia	0.46^{a}	9.84^{a}	8.95^{a}
Sum	0.40^{ab}	11.44^{a}	8.79^{ab}
Dolga siska	0.34^{bcd}	6.21^{b}	7.10^{ab}

Values followed by the same letter in a column are not statistically different at $P < 0.05$.

Table 8. Chemical characteristics of the fruits, average, 2011–2013.

Variety	TSS, °Brix	TA, %	TSS/TA ratio
Sylvia	14.8	0.49	30.20
Kordia	15.3	0.63	24.29
Sunburst	15.2	0.50	30.40
Van	16.7	0.60	27.83
Summit	14.0	0.76	18.42
Stark Hardy Giant	15.1	0.55	27.45
Regina	17.4	0.67	25.97
Octavia	16.1	0.58	27.76
Sum	14.2	0.61	23.28
Dolga siska	15.7	0.55	28.55

evaluated varieties showed lower results concerning fruit quality parameters than the local variety Dolga siska, some of them can be recommended for mass production in this region. Among them, Stark Hardy Giant, Kordia, Sunburst, and Van can be distinguished. They are outstanding for their large fruits size and quality, and except Sunburst they are very productive.

For a better and more precise evaluation of the behavior of these varieties under the agroecological conditions of the Ohrid region, further investigation is necessary.

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