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THE IMPACT OF THE CULTIVATION SYSTEM ON THE YIELD AND QUALITY OF SWEET CHERRIES

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Abstract

The goal of this study, which was conducted between 2010 and 2022, was to evaluate the impact of the variety-rootstock association, the crown shape and the planting distance on the production and quality parameters of sweet cherries. Stationary experiments have been carried out using diverse sweet cherry varieties, such as Valerii Cikalov, Record, Ferrovia, Kordia, Regina, Stella, Skeena, Bigarreau Burlat, Lapins, grafted on Cerasus mahaleb, L. and Gisela-6 rootstocks, in various combinations, and which have been planted at diverse planting distances. The trees grafted on the Cerasus mahaleb, L., rootstock have shown rapid growth and an average fruit yield of 15.58-16.12 t/ha during the period of their full productivity. The harvest of the trees grafted on the Gisela 6 and MaxMa 14 rootstocks has been early and amounted to 12.50-14.58 t/ha. The varieties Bigarro Burlat, Ferrovia and Lapins, planted at a distance of 5 x 1.5 m, have given a yield of 17.98-20.07 t/ha, which is 12.2-24.9% higher than that of the trees which have been planted at a distance of 4 x 2.5 m.

Key words*: sweet cherry variety, cultivation system, rootstock, density, crown shape.*

INTRODUCTION

The assortment is the main factor in solving the requirements and difficulties of modern fruit growing at the disposal of the producer and consumer. The susceptibility to disease and pest attack of the existing varieties has negative effects on the environment and human health. Other major challenges facing fruit growers are the technology used and climate change.

The sweet cherry tree cultivation has developed a lot thanks to the assortment of vegetative rootstocks and high-quality self-fertile varieties. Due to the multiple variety-rootstock combinations, the numerous planting distances, as well as the ways of grouping the trees as a result of the diversity of the existing biological material, numerous researches regarding the tree crown shaping systems have been conducted (Long et al, 2014; Balan et al., 2022; 2023).

The research has shown that it is possible to grow orchards of high density, which, under favourable conditions of intensified technological processes, can produce the desired yields from a biological and technical point of view (Gjamovski et al., 2016; Long, 2003; Long et al., 2005; Sumedrea et al., 2014).

The range of moderate vigour and semi dwarfing vegetative rootstocks made it possible to plant sweet cherry orchards of high density, with trees with spindle-shaped crowns, as well as orchards with high yields per hectare and low production costs (Aglar et Yildiz, 2014; Aglar et al., 2016; Gyeviki et al., 2008; Long, 2003; Usenik et al., 2010; Vercammen, 2002; Balan et al., 2022).

The various vigour of the variety-rootstock combinations allows a good management of the orchard structure (Balan, 2009; 2015; Cimpoies, 2018; Mitre, 2020) and has a significant role in the vegetative growth, tree yield and fruit quality (Aglar et al., 2019; Aglar et al., 2016; Bujdosó et al., 2012). Thus, the variety-rootstock combination directly determines the cultivation system, the way of crown shaping and tree pruning, the orchard maintenance and work system (Calabro et al., 2009; Long et al., 2014; Pesteanu, 2022; Balan et al., 2023).

The issue related to the cultivation systems is quite controversial in specialized literature and in fruit growing practice. Currently, in the Republic of Moldova, the wild sweet cherry

generative rootstocks (*Cerasus avium* L.), Mahaleb (*Cerasus mahaleb* L.) are still used in sweet cherry tree growing; the semi dwarfing vegetative rootstocks (Gisela 5), semi vigorous rootstocks (Gisela 6, PHL-C, Krymsk 6) and moderate vigour rootstocks (Maxima 14, Krymsk 5, Piku 1, Piku 4) are used less (Long et al., 2014; Balan et al., 2021; 2023).
That is why, the impact of the Gisela 6 and Mahaleb rootstocks on the growth and development of the Valerii Cikalov, Record, Ferrovia, Kordia, Regina, Stella, Skeena, Bigarreau Burlat and Lapins sweet cherry varieties, in different combinations and at different planting distances, has been studied. The aim of the research is to increase the productivity of sweet cherry orchards by identifying the highly productive variety-rootstock associations, which correspond to the climatic conditions, the biological production potential of the orchard, the technological procedures used to shape the tree crowns, the degree of mechanization, the amount of manual work and the management of pursued economic interests.

MATERIALS AND METHODS

Four stationary experiments have been performed to carry the studies. The Valerii Cikalov, Record, Ferrovia, Kordia, Regina, Stella, Skeena, Bigarreau Burlat and Lapins sweet cherry varieties, grafted on *Cerasus mahaleb* L. and Gisela-6 rootstocks in different combinations and at various planting distances, have been used. Four groups of eight representative trees each have been created to conduct the experiments. The scheme has been developed according to the polyfactorial principle with the placement of the groups through the randomized block system on two rows in the middle of the strip for each variety (Moiseicenco et al., 1994; Balan et al., 2001).
Experiment 1 was carried in the spring of 2010. The orchard was planted with Gisela 6 vegetative rootstocks, which had been bought in Greece, grafted with two buds of the Adriana, Ferrovia and Skeena sweet cherry varieties. The rows of trees were planted in a north-south direction at a distance of 4 x 2 m. The varieties were grouped in strips of 10 rows of each variety. Three shapes of crown were used: G1 – Small naturally improved crowns (the control group); G2 – Improved slender spindle crowns; G3 – Improved oblate vessel.
Experiment 2 was performed in the southern orchard area in the spring of 2010. The orchards were planted with Gisela 6 sweet cherry rootstocks, bought in Greece, which were grafted with two buds of the Bigarreau Burlat, Ferrovia and Lapins sweet cherry varieties. The rows of trees were planted in a north-south direction at a distance of 5 m between the rows and at a distance of 1.5 m, 2 m and 2.5 m on the row. The tree crowns were small: G1 – Small naturally improved crowns (the control group); G2 – Improved slender spindle crowns.
The interaction between the planting distance and the crown shape, as basic factors that determine the fruiting, the fruit yield and quality was studied.
Experiment 3 was conducted in the orchard which was planted in the autumn of 2003 in the village of Malaiesti. The Valerii Cikalov and Record sweet cherry tree varieties with big naturally improved crowns, grafted on the Mahaleb generative rootstocks and planted at a distance of 6 x 5 m were used.
Experiment 4 was conducted in 2011. The orchard was planted with sweet cherry trees of the Ferrovia, Kordia and Regina varieties which were grafted on Gisela 6 rootstock and planted at a distance of 4 x 2.5 m. Small crowns were studied: G1 – Small naturally improved crowns (the control group); G2 – Improved slender spindle crowns; G3 – Improved oblate vessel.
The interaction between the planting distance and the crown shape, as the basic factors that determine the fruiting, the fruit yield and quality was studied. Morphological descriptions, biometric measurements and statistical processing of the results were carried out. The methods of analysis, synthesis, tabulation, comparison and graphics were used to interpret the scientific results. The processed data are presented in average values for the 3-8 years of research. The difference between variants were compared with 5% probability (Dospehov, 1985).
Orchard management. In experiment 1, the soil was weeded naturally; in experiments 4 and 5, the soil in the orchards was weeded

artificially. The strips of land 1.5-2 m wide were kept weed-free by weeding or superficial thinning to a depth of 5 cm with the feeler tiller. In experiment 2 and 3 the soil was maintained as a cultivated field. The trees in experiments 1, 4, 5 were drip irrigated, and the Watermark transducers installed at 20, 40 and 60 cm deep in each plot were used to monitor the soil moisture. The water was distributed by droppers fixed at a height of 40 cm from the ground in the direction of the row. Weather stations were installed in the orchards to determine the state of the environment and the plants.

RESULTS AND DISCUSSIONS

The sweet cherry trees, grafted on the Mahaleb rootstock and planted at a distance of 6 x 5 m, reached the optimal height and the diameter of the crown at the age of 11-14 (Table 1). Higher values of the tree height were recorded in the Valerii Cikalov variety (4.2 m), and of the crown diameter – in the Record variety (5.1 m). The varieties studied behaved similarly from the statistical point of view.

Table 1. The height and crown diameter of the sweet cherry trees, m (Mahaleb rootstock, the planting distance – 6 x 5 m)

Variety	The age of the trees			
	11 years old	12 years old	13 years old	14 years old
The height of the crown				
Valerii Cikalov	4.2	3.9	4.0	4.2
Record	3.9	3.7	3.5	4.0
LSD 5%	-	-	0.62	0.27
The diameter of the crown				
Valerii Cikalov	3.7	4.7	4.3	3.9
Record	4.3	4.7	5.1	4.2
LSD 5%	-	-	1.12	0.34

During the period of heavy bearing, the Valerii Cikalov and Record varieties, grafted on the Mahaleb rootstock, recorded a yield of 6.69 t/ha in 2012, and 28.2 t/ha in 2017 (Figure 1). The yield varied significantly from year to year and was not always statistically proved for each variety. Thus, in 2012, 2013, 2017 and 2018, the yield of the varieties was identical. In 2014, 2015, 2016 and 2017, a statistically proved yield of the varieties was recorded. During the eight experimental years, similar average yields of 15.71 t/ha were recorded for the Valerii Cikalov variety and 16.13 t/ha for the Record variety.

In the research years 2012-2014, the crown width of the Bigarreau Burlat variety varied in the control group from 120 cm to 262 cm (Table 2). For the trees with improved slender spindle-shaped crowns, the increase in the crown width was greater with the increase in the distance between the trees in a row. Thus, in the 2014 research year, the width of the crown of the trees, which had been planted at a distance of 5 x 1.5 m, was 245 cm, and of those which had been planted at a distance of 5 x 2.5 m – 260 cm.

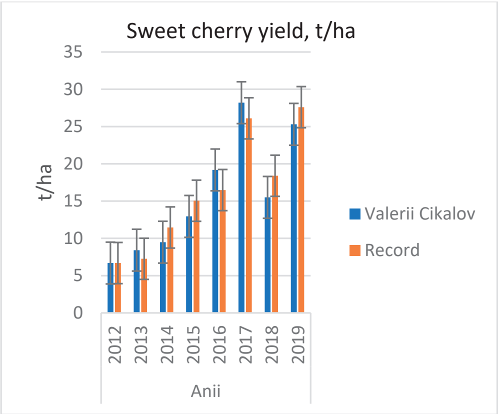

Figure 1. The yield of the sweet cherry trees, t/ha (Mahaleb rootstock, the planting distance – 6 x 5 m, the tree age – 10-17 years old)

In the Ferrovia variety in the control group, the lowest indices were obtained in the first research years (2012-2013), and in the trees with improved slender spindle-shaped crowns, which were planted at a distance of 5 x 1.5 m, higher crown width values were recorded in 2014 (261 cm). In the Lapins variety in the control group, the crowns of which were small and naturally improved, the highest indices were recorded during the years 2013-2014 when the trees had been planted at the distance of 5 x 2 m, namely 172 cm and 262 cm, respectively. In the trees with improved slender spindle-shaped crowns, planted at a distance of 5 x 2 m, the highest indices were recorded in 2013-2014.

Table 2. The crown width of the sweet cherry trees depending on the planting distance and crown shape, cm (Gisela 6 rootstock, the tree age – 3-5 years old)

The shape of the crown	Planting distance, m	Bigarreau Burlat variety			Ferrovia variety			Lapins variety		
		2012	2013	2014	2012	2013	2014	2012	2013	2014
Small naturally improved crowns (control group)	5 x 1.5	120	147	258	132	150	254	130	165	254
	5 x 2	120	159	250	110	140	262	120	172	262
	5 x 2.5	120	150	249	135	180	248	130	152	254
Improved slender spindle crowns	5 x 1.5	116	140	245	128	162	261	140	169	260
	5 x 2	125	158	262	140	160	250	140	180	271
	5 x 2.5	110	165	260	128	175	250	140	180	260
LSD 5%	-	-	38.4	12.9	-	38.4	12.9	-	38.4	12.9

During the first 4 years, the yield of the Bigarreau Burlat, Ferrovia and Lapins varieties, grafted on Gisela 6, increased progressively from year to year. For example, in the Bigarreau Burlat variety, planted at a distance of 5 x 1.5 m, the fruit yield was 0.6; 4.47; 8.56 and 13.49 kg/tree, respectively (Figure 2). During the first two fruiting years, the yield did not depend on the distance between the trees in a row. Starting with the third year, the fruit yield per tree increased when the distance between the trees in a row was larger. Thus, in 2015, in the Bigarreau Burlat variety, which had been planted at the distance of 5 x 1.5 m, the fruit harvest was 8.56-6.93 kg/tree, and the trees, which had been planted at a distance of 5 x 2.5 m, yielded a better harvest which amounted to 10.0-12.75 kg/tree. In the seventh year of fruiting, the difference in yield between the groups was significantly greater than in previous years. Thus, in the trees of Bigarreau Burlat variety, which were planted at a distance of 5 x 1.5 m, the fruit yield was 13.49-14.21 kg/tree, while the trees, which were planted at the distance of 5 x 2.5 m, yielded a better harvest which amounted to 18.27-19.54 kg/tree i.e. it was better by 35.4-37.5% and was statistically proved. The Ferrovia and Lapins varieties yielded the same harvest; the harvest of the trees which were planted at smaller distances were worse and statistically proved.

In the first four years of fruiting, the positive impact of low densities on the yield per tree was evident; the increases were 7.8-34.3% in the Bigarreau Burlat variety, 19.2-41.1% in the Ferrovia variety and 14.4-35.9% in the Lapins variety. In the southern area, the orchards of 800 trees her hectare, in which the trees were planted at a distance of 5 x 2.5 m, produced a 34.3-35.9% better yield compared to the orchards in which the trees were planted at a distance of 5 x 1.5 m.

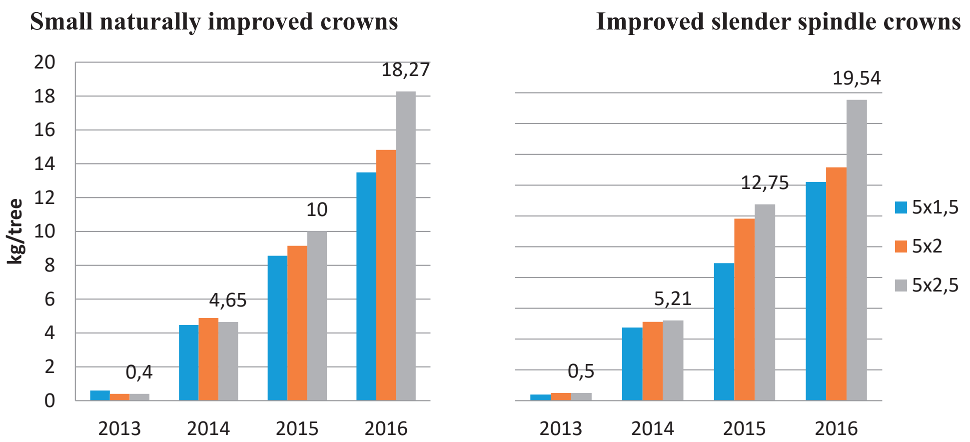

Figure 2. The yield of the sweet cherry trees of the Bigarreau Burlat variety depending on the planting distance and the crown shape, kg/tree (Gisela 6 rootstock, the age of the trees – 4-7 years old, *Terra-Vitis* Ltd)

It is worth mentioning that, during the period of tree growth and fruiting, the average fruit yield of the Bigarreau Burlat sweet cherry variety, related to the surface unit, varied from 6.66 to 9.51 t/ha, being higher by 13.3-24.9%, when the trees were planted at a distance of 5 x 1.5 m (Figure 3). The same trend was recorded with the Ferrovia and Lapins varieties – in high density orchards, the fruit yield was higher. In the Ferrovia variety planted at a distance of 5 x 1.5 m, the fruit harvest was better by 15.1-24.5%, and in the Lapins variety – by 12.2-18.9% compared to the varieties planted at a distance of 4 x 2.5 m.

In the fourth fruiting year, the Bigarreau Burlat, Ferrovia and Lapins varieties with improved slender spindle-shaped crowns, which were planted at a distance of 5 x 1.5 m, recorded productions of 17.98-20.07 t/ha. The studied varieties proved to be less valuable when they were planted at the distance of 5 x 2.5 m (14.61-17.54 t/ha) and in the trees with naturally improved crowns (14.61-16.15 t/ha), while the 5 x 2 m planting distance can be considered as medium valuable (15.16-17.24 t/ha) in terms of fruit production.

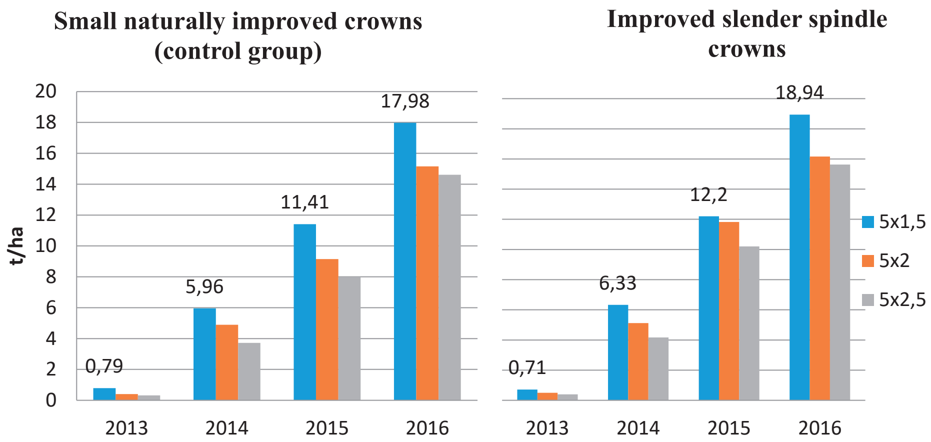

Figure 3. The yield of the Bigarreau Burlat sweet cherry variety depending on the planting distance and the crown shape, t/ha (the Gisela 6 rootstock, the tree age – 4-7 years old, *Terra-Vitis* Ltd)

The trees of the Ferrovia, Kordia and Regina varieties, grafted on Gisela 6 rootstock and planted at a distance of 4 x 2.5 m, began to bear fruit in the fourth year of vegetation, yielding 400-500 kg/ha. In the second fruiting year, a harvest of 4,600-5,000 kg/ha was recorded, which was not statistically proved (Figure 4). Starting with the third fruiting year, the yield increased significantly, being higher and statistically proved in the Ferrovia (12310-13290 kg/ha) and Kordia (11270-12830 kg/ha) varieties. In 2017 and 2020, the harvest decreased significantly due to unfavourable climatic conditions during the blossoming season – it was foggy, rainy and cold. Yields higher than 10000 kg/ha were recorded only in two out of seven years of tree fruiting, namely in 2016 and 2019. It should be mentioned that the crown shaping system did have a significant impact on the productivity of the studied varieties. The average yield during the first seven fruiting years recorded average indices for such orchards and was 8193-8308 kg/ha for the Ferrovia variety, 7650-8314 kg/ha for the Kordia variety and 7208-7877 kg/ha for the Regina variety.

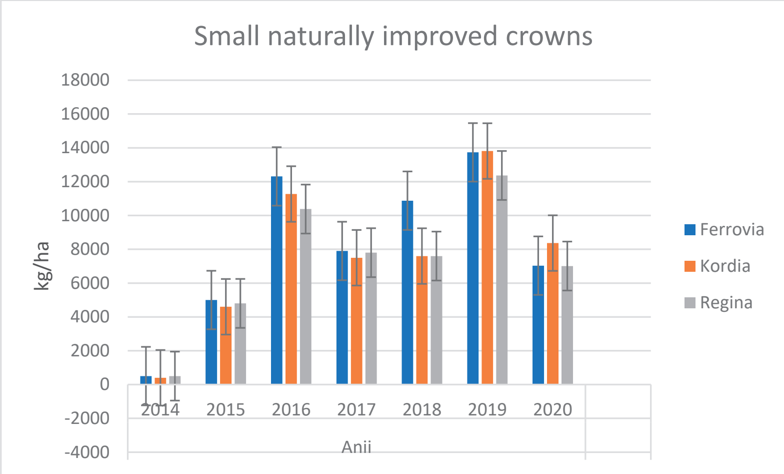

Figure 4. The yield of the sweet cherry trees, kg/ha (the Gisela 6 rootstock, the planting distance – 4 x 2.5 m, small naturally improved crowns, the age of trees – 4-10 years old)

The data regarding the crown parameters in the Adriana, Ferrovia and Skeena sweet cherry varieties, grafted on Gisela 6 and planted at a distance of 4 x 2 m, demonstrate that, during the growth and fruiting periods, the highest indices of the crown length were recorded in the Ferrovia variety (172 cm) in the trees with improved slender spindle-shaped crowns (Table 3). In the fifth year, the trees in the rows had intertwined, and the crown length was 195-220 cm. The width of the crowns also increased once the trees became older – from 110-190 cm in the third year to 195-245 cm in the fifth year of vegetation. Over the years, the Ferrovia variety proved to be more vigorous compared to the Adriana and Skeena varieties, but the growth indices were not distinctly significant.

Analysing the growth indices of the crowns of the sweet cherry trees, grafted on the Gisela 6 rootstock and planted at a distance of 4 x 2 m, it would be reasonable to say that they reached the optimal level once the trees entered the fruiting and growth periods.

In the fifth year of vegetation, the total length of the branches, including the annual branches, in the Adriana, Skeena and Ferrovia varieties was 50.7-56.2 m/tree, which was more than 80% (Table 4). In the first two years of vegetation, the number of annual branches increased moderately.

Table 3. The crown length and width of the sweet cherry trees depending on the variety and crown shape, cm (the Gisela 6 rootstock, the planting distance – 4 x 2 m, the tree age – 3-5 years old)

Variety	Crown length			Crown width		
	2014	2015	2016	2014	2015	2016
Small naturally improved crown						
Adriana	132	168	201	110	157	225
Ferrovia	150	173	215	160	173	224
Skeena	120	146	195	124	146	198
Improved slender spindle crown						
Adriana	120	168	195	124	157	214
Ferrovia	172	222	220	190	222	245
Skeena	135	165	200	142	164	195
LSD 5%	-	27	32	-	52	63

In the following two years it increased progressively geometrically; in the fifth year of vegetation, it was 64.3-72.3 pcs per tree. The average length of the annual branches is about 65 cm, which is a basic index that demonstrates the level of tree maintenance in the crown formation process. It is well known that the most suitable length of the annual branches, in order to accelerate the tree formation and fruiting, is 80-90 cm (Balan et al., 2001; Gradinariu, Istrate, 2009; Bucarciuc, 2022).

Table 4. The morphology of sweet cherry trees (the Gisela 6 rootstock, the planting distance – 4 x 2 m, the tree age – 5 years old, naturally improved crown)

Age of branch, years	The total length of the branches, m/tree			Number of branches, pcs/tree			The average length of the branches, cm		
	Adriana	Ferrovia	Skeena	Adriana	Ferrovia	Skeena	Adriana	Ferrovia	Skeena
1	43.3	42.2	46.3	64.3	65.3	72.3	67.2	64.1	64.1
2	5.8	5.9	5.8	10.3	12.0	10.3	57.4	49.0	56.8
3	2.4	2.5	3.0	5.6	6.0	6.0	41.2	42.4	50.9
4	1.2	1.2	1.1	3.3	3.3	6.0	36.9	36.9	31.3
Total	52.8	50.7	56.2	83.5	86.6	94.6	-	-	-

The Adriana, Ferrovia and Skeena sweet cherry varieties, grafted on Gisela 6 rootstock, began to bear fruit in the fourth year after planting – they yielded a harvest of 625-1562 kg/ha (Table 5). The Ferrovia variety proved to be more productive compared to the Adriana and Skeena varieties – it yielded a harvest of 1125-1562 kg/ha. In the second fruiting year, the mentioned varieties yielded a considerably better harvest which amounted to 4250-5000 kg/ha. As the trees grew, the fruit harvest tripled; in 2016, the Adriana variety yielded 11875-13000 kg/ha, the Ferrovia variety yielded 13250-14125 kg/ha and the Skeena variety yielded 16000 kg/ha. In the seventh year after planting, the sweet cherry yield doubled compared to the previous year and amounted to 21875-22500 kg/tree for the Adriana variety, and to 26250-28000 kg/ha for the Skeena variety.

The Ferrovia and Skeena varieties with both types of crown shapes gave better yields compared to the Adrian variety. In the following year (2017), the fruit yield decreased remarkably and was only 10750-10875 kg/ha in the Adriana variety, 12700-15750 kg/ha in the Ferrovia variety and 14000-16785 kg/ha in the Skeena variety. In the following years, the fruit yield remained at the level of 9316-18986 kg/ha, being higher in comparison with the Ferrovia and Skeena varieties.

Analysing the fruit yield indicators in the eighth to tenth years of tree growing season (2017-2020), and comparing them with the data presented by other authors (Long et al., 2014; Miter et al., 2012), it can be said that they are average for the sweet cherry orchards with trees grafted on the Gisela 6 moderate vigour rootstock.

As regards the impact of the variety and the crown shaping system, the Skeena variety with improved slender spindle-shaped crowns yielded the best harvest (14581 kg/ha), followed by the Ferrovia variety (12931 kg/ha). The lowest average yield was recorded for the Adriana variety (10659 kg/ha) in the group in which the trees had small naturally improved crowns.

Table 5. The yield of sweet cherry trees, kg/ha (the Gisela 6 rootstock, the planting distance – 4 x 2 m, the tree age – 4-12 years old)

Variety	Years								The average index (2013-2020)
	2013	2014	2015	2016	2017	2018	2019	2020	
Small naturally improved crowns									
Adriana	625	4375	11875	21875	10875	12958	13375	9319	10659
Ferrovia	1125	4875	13250	24750	15750	15222	10791	14277	12505
Skeena	625	4250	16000	26250	16875	17583	17042	16652	14409
Improved slender spindle crowns									
Adriana	875	4500	13000	22500	10750	14820	13125	10819	11298
Ferrovia	1562	5000	14125	24500	12700	15388	13541	16638	12931
Skeena	375	4375	16000	28000	14000	17500	17416	18986	14581
LSD 5%	-	435.2	971.8	1315.2	1429.1	1423.6	2305.7	1314.8	-

The total number of buds, including the flowering ones on annual branches, in sweet cherry trees depends on their length (Table 6). In the Ferrovia variety, as the length of the annual branch increased, the diameter of the branches increased from 4.7 to 11.7 mm, the total number of buds increased from 16.7 to 35.4 pcs, and the number of flower buds decreased from 9.0 to 3.8 pcs. The Skeena variety, being a self-fertile variety, constantly and moderately produces fruit on annual branches; flower buds on annual branches practically develop in the lower third of the branches, namely up to 1.9 pcs on long branches (20-100 cm) and up to 7 pcs on the short ones (20-40 cm).

Table 6. The distribution of buds on sweet cherry trees depending on variety and the length of annual branches (the Gisela 6 rootstock, the planting distance – 4 x 2 m, naturally improved crowns, the tree age – 6 years old)

The length of the annual branches	Diameter of annual branches, mm		Number of buds, pcs		Number of fruiting buds, pcs	
	Ferrovia	Skeena	Ferrovia	Skeena	Ferrovia	Skeena
20-40	4.7	4	16.7	14	9.0	7
20-60	6.7	8	19.7	18	6.4	5
20-80	8.2	8.2	27	23,8	5.2	5.4
20-100	11.7	10.8	35.4	33.4	3.8	1.9

When the trees are 5 years old, most of the short fruiting branches 2-5 cm long with a vegetative apical bud were found on 2-year-old branches (Table 7). Thus, in the Adriana variety, 139.1 short fruiting branches developed on 2-year-old branches, 46.3 pcs – on 3-year-old branches and 6.6 pcs on 4-year-old branches. The number of short fruiting branches decreased as the branches got older. The number of the short fruiting branches on most of the trees amounted to 192.0 pcs/tree. The number of short fruiting branches in the Ferrovia and Skeena varieties slightly differed from the Adriana variety, and was not statistically proved.

Table 7. The number of short fruiting branches in sweet cherry trees depending on variety and crown shape, pcs/tree (the Gisela 6 rootstock, the planting distance – 4x2m, the tree age – 5 years old, small naturally improved crown)

Variety	The number of the short fruiting branches			Total, pcs/tree
	Two-years-old branches	Three-years-old branches	Four-years-old branches	
Adriana	139.1	46.3	6.6	192.0
Ferrovia	119.9	54.6	6.3	180.8
Skeena	132.2	49.0	7.0	188.2
LSD 5%	37.45	17.42	4.33	-

During the growth and fruiting periods of the trees, the impact of the annual branches' length on the yield and quality of sweet cherries of the Kordia variety was also studied (Table 8). The sweet cherry tree is a species which produces many fruit. Under favourable climatic conditions, this fruit tree can produce 30-50% of the total number of flowers (Cimpoies, 2018). The research showed that, regardless of the length of the annual branches, the number of fruit was 34.0-44.4%. The diameter and weight of the sweet cherries, as well as the soluble dry matter, changed according to the length of the annual branches. As the branch length increased (40 cm), the diameter of the cherries (28.2 mm), their weight (10 g) and soluble dry substance (16.55%) increased compared to cherries that grew on shorter annual branches. Thus, the branches 40 cm long born higher quality fruit compared to shorter branches.

Table 8. The impact of the length of annual branches on the yield of the Kordia variety. (the Gisela 6 rootstock, the planting distance – 4 x 2.5 m, the tree age – 5 years old)

Length of the annual branches, cm	Number of sweet cherries, pcs	Fruit formation, %	Diameter of sweet cherries mm	Weight of sweet cherries g/fruit	Soluble dry matter Brix%
10 ± 2	99	38.0	22.7	7.4	14.02
20 ± 2	85	34.0	25.8	8.4	16.51
30 ± 2	131	44.4	26.0	8.7	16.46
40 ± 2	111	38.9	28.2	10.0	16.55

The data presented in Table 9 indicate the close interdependencies among the features considered as cherry quality elements, namely the fruit diameter (mm), the fruit weight (g), the fruit firmness (kg/cm^2), the soluble solids content (SSC, % Brix) and the titratable acidity (%). The variability of the indices of the sweet cherry diameter and weight was high and it depended on the variety, the shape of the crown, the fruit harvesting period and the climatic conditions. In the sixth year after planting, at harvest, the sweet cherry trees of the Skeena variety yielded fruit which had a diameter of 26.0-28.1 mm and a weight of 8.59-9.18 g/fruit. The diameter of the fruit produced by the trees with improved oblate vessel-shaped crowns was 28.1 mm, and the indices were statistically proved, compared to the fruit produced by the trees with small and naturally improved crowns and those with improved slender spindle-shaped crowns.

The SSC content of the sweet cherries varied between 18.0 and 18.6 % Brix. The trees with improved crowns of oblate vessel shape produced fruit with the highest concentration of soluble solids (18.6% Brix). The titratable acidity of the fruit was 0.85-0.89%, and the firmness was 2.87-2.98 kg/cm^2, which gave the sweet cherries a balanced acidity and firmness required by consumers.

Table 9. The impact of the crown formation system on the quality of fruit of the Skeena variety (the Gisela 6 rootstock, the planting distance – 4 x 2 m)

Crown shape	Fruit diameter, mm	Fruit weight, g	SSC, % Brix	Titratable acidity, %	Fruit firmness, kg/cm^2
Small naturally improved crowns	26.0	8.59	18.0	0.89	2.98
Improved slender spindle crowns	26.3	8.60	18.0	0.85	2.87
Improved oblate vessel	28.1	9.18	18,6	0.88	2.90
LSD 5%	1.13	0.42	0.85	0.33	0.21

The soluble solid content in sweet cherries was determined dynamically from the time of fruit reddening to the time of their harvesting (Table 10).

Table 10. The soluble solid content (SSC) in sweet cherries according to the colour, % (the Gisela 6 rootstock, the planting distance – 4 x 2.5 m, small naturally improved crown, the age of the tree – 6-7 years old)

Variety	Skin colour				
	Red	Bright ruddy	Dark red	Dark reddish brown	Dark brown
Year 2016					
Ferrovia	4.3	6.8	12.8	17.5	18.5
Regina	3.9	7.0	13.3	17.0	18.3
Year 2017					
Ferrovia	3.5	6.4	13.4	17.2	18.8
Regina	3.5	6.0	13.8	17.4	18.5

From the moment the fruit were red, the content of soluble solids grew much. In 2016, the soluble solid content (SSC) in the Ferrovia variety increased from 4.3%, in red fruit, to 18.5%, in dark brown fruit, and respectively from 3.9% to 18.3%, in the sweet cherries of the Regina variety. The same trend was observed in 2017, namely, starting from the phase when the fruit became red, the SSC increased until the sweet cherries became dark reddish-brown, then the rate of SSC storage decreased. The maximum SSC value was recorded during the phase of rapid skin colour change, which can be used to determine the optimal harvest time.

The size of fruit born by branches 20, 30 and 40 cm long recorded significantly higher indices compared to fruit born on branches 10 cm long. (Table 11). Thus, the diameter of the sweet cherries on 20-centimetres-long branches was larger by 14.2% (Adriana), by 23.6% (Ferrovia) and by 20.6% (Skeena) compared to the fruit born by 10-centimetres-long branches. The size of the sweet cherries on the 30- and 40-centimetres-long branches was larger compared to the sweet cherries formed on the 20-centimetres-long branches, but it was not significantly proved.

Table 11. The diameter of sweet cherries according to the length of the biennial branches, mm (the Gisela 6 rootstock, the planting distance – 4 x 2 m, small naturally improved crown, the age of trees – 6 years old)

Variety	The length of the branch								LSD 5%
	10 cm		20 cm		30 cm		40 cm		
	mm	%	mm	%	mm	%	mm	%	
Adriana	21.2	100	24.2	114.2	29.4	138.7	30.0	141.5	3.42
Ferrovia	21.2	100	26.2	123.6	27.4	129.3	29.0	136.8	4.36
Skeena	21.4	100	25.8	120.6	29.0	135.5	28.8	134.6	3.72

The position of branches in space plays a decisive role in growing quality sweet cherries. (Table 12). It is worth mentioning that the diameter and weight of the fruit decreased from branches oriented upward to branches oriented downward. Thus, the diameter of the fruit on the two-year-old branches with a spatial position upward increased in the Adriana variety by 23.1%, in the Ferrovia variety by 27.1%, and in the Skeena variety by 7.8% compared to the branches oriented downward; horizontal branches occupied an intermediate position. The results highlight the importance of controlling the direction of branch growth as needed.

Table 12. The diameter of the sweet cherries according to the position of annual branches in space, mm (the Gisela 6 rootstock, the planting distance – 4 x 2 m, small naturally improved crowns, the age of the trees – 6 years old)

Variety	Position of biennial branches						LSD 5%
	Upward		Horizontal		Downward		
	mm	%	mm	%	mm	%	
Adriana	29.3	123.1	29.0	121.8	23.8	100	4.95
Ferrovia	28.6	127.1	27.3	121.3	22.5	100	3.78
Skeena	29.0	107.8	29.0	107.8	26.9	100	2.36

The information analysis of the experimental data made it possible, through deduction and calculation, to establish the interdependence of the fruit diameter and weight according to the following formula: **Y = 1.39X + 13.72**, where Y is the diameter of sweet cherries, mm; X is the weight of sweet cherries, g. (Balan et al, 2023).

CONCLUSIONS

The esearch was aimed at promoting sustainable integrated cultivation systems that would ensure early economic fruiting of sweet cherry trees and the production of quality, healthy fruit that is marketable. All these problems can be solved by determining the most suitable planting distance, crown formation and pruning systems, and by maintaining a balance between growth and fruiting. Currently, all sustainable integrated fruit growing systems are successfully used, which are based on geographical conditions, the degree of natural soil fertility, the relative strength of the variety-rootstock association, planting density, simple crown shape, and which are aimed at obtaining early high-quality yields.

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