Scientific Papers. Series B, Horticulture. Vol. LXVII, No. 1, 2023
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

CROWN SHAPING AND PRUNING OF SWEET CHERRY TREES WHICH OPTIMIZE THE RATIO BETWEEN GROWTH AND FRUCTIFICATION

Valerian BALAN[1], Vasile ŞARBAN[2], Igor IVANOV[1], Sergiu VAMASESCU[1], Corneliu BUZA[1], Dumitru TALPALARU[1]

[1]Technical University of Moldova, 168 Ştefan cel Mare şi Sfânt Blvd, Chisinau, Republic of Moldova
[2]Ministry of Agriculture and Food Industry, 162 Ştefan cel Mare şi Sfânt Blvd, Chisinau, Republic of Moldova

Corresponding author emails: valerianbalan@gmail.com; sarbanvasile@gmail.com

Abstract

The vigour of the variety-rootstock association, the crown shape, the planting distance, the age of the trees, and the tree pruning pattern have been examined. The studies regarding the establishment of sweet cherry orchards, as well as the growth and fruiting of the 'Valerii Cikalov', 'Record', 'Ferrovia', 'Kordia', 'Regina', 'Stella', 'Skeena', 'Bigarreau Burlat', 'Lapins', 'Early Star', 'Samba', 'Black Star' sweet cherry trees grafted on the Prunus mahaleb L., 'MaxMa 14' and 'Gisela 6' rootstocks, in different combinations and planting distances, have been carried out in the Southern and Central fruit-growing area of the Republic of Moldova. High vigorous trees are used on non-irrigated soils in association with self-fertile varieties at optimal planting distances that ensure high yields. The sweet cherry trees, grafted on the semi vigorous rootstocks ('Gisela 6') and the moderate vigour rootstocks ('MaxMa 14') are used on fertile soils and irrigated at high densities. They can provide medium vigour of trees, which can be handled completely from the ground level, produce early average yields, with low pruning and fruit harvesting costs due to increased labour productivity. The pruning done during the growing period resulted in the vegetative growth of the trees and the formation of fruiting branches that produced better flower buds compared to the pruning done during the dormant period. The rootstock-variety association should be chosen in accordance with the direct task, the growing system and the applied technology.

Key words*: Cerasus avium, variety, rootstock, crown shape, density, cultivation system.*

INTRODUCTION

Sweet cherry orchards occupy more than 440 thousand hectares on the globe, and the world fruit production is about 2,3 million tons per year, of which 35% is in Europe. In the Republic of Moldova, the sweet cherry orchards occupy 4,100 ha, which yield over 10,000 tons per year. It is a rather modest yield in comparison with the average world yield (Cimpoies, 2018). During the last decades, the sweet cherry crop has worked up the market due to the rich assortment of high-quality self-fertile varieties, and the diversity of vegetative semi dwarfing and moderate vigor rootstocks. Currently, the sweet cherry growing implies mechanized high-density orchard systems with a high consumption of pesticides and fertilizers. Therefore, in response to these requirements, sustainable integrated culture systems have been successfully introduced in the Moldovan fruit growing sector (Babuc, 2012; Balan, 2019; Cimpoies, 2018).

The modernization of the sweet cherry crop is determined by the modern technological methods and technology used, the soil being the main production resource. The early maturation, the type of fruiting, the pruning methods and crown shaping, its diseases and pest's resistance, the planting density and the rootstock used are other factors that contribute to the realization of the biological production potential of this crop. The viable technologies used provide for increasing efficiency per surface unit by adopting modern cropping systems, which ensure quantitatively and qualitatively superior yields (Balan, 2015; Balan & Sarban, 2021). Trees of narrow

fusiform crowns of 3.0-3.5 m in height, suitable for mechanized pruning both during the dormant period and the vegetation period at recommended for the orchards of tomorrow, in order to obtain high yields and fruits quality, as well as to reduces maintenance and harvesting manual labor costs (Bennewitz et al., 2010; Calabro et al., 2009; Long et al., 2014; Vercammen, 2002).

The creation of future systems in fruit growing is based on the results obtained as a result of theoretical and practical research carried out abroad and, in our country, namely:

Biological material. The various vigor of varieties and rootstocks allows good control of the tree growth. The large number of generative and vegetative rootstocks of different vigor offers the opportunity of cultivar-rootstock associations utilization in different cultivation systems and tree crown shaping, but also on less fertile soils (Gjamovski et al., 2016; Gyeviki et al., 2008; Long, 2003).

Currently, for the sweet cherry crop, it is recommended to use super-intensive orchards with trees grafted on semi dwarfing rootstocks ('Gisela 5'), semi vigorous rootstocks ('Gisela 6', 'P-HL-C', 'Krymsk 6') and moderate vigor rootstocks ('Krymsk 5', 'MaxMa 14', 'Piku 1', 'Piku 4') planted at a distance of 3-4.5 x 0.5-2.5 m using trellises and wires, or individual poles installed in the year of the planting of the trees, or intensive orchards with trees grafted on the vegetative 'Colt', 'CAB 6' 'Krymsk 5', 'MaxMa 14', 'Piku 1' and 'Piku 4' rootstocks at a planting distance of 5-6 x 2.5-5 m, without any support for the fruit trees, and classic orchards with trees grafted on the vigorous rootstocks (Seedlings *Prunus avium*; 'Colt', 'SL 64') which are planted at a distance of 6-7 x 5-6 m, without any support for the fruit trees (Vercammen, 2002; Long, 2003; Aglar et al., 2016; Şarban & Balan, 2021; Usenik et al., 2010).

The tree crown shaping and pruning depends on the variety-rootstock association, climate (wind, temperature, relief, light, precipitation, etc.) and soil; but it certainly depends on tradition in order to maximize the biological potential of a sweet cherry orchard (Long et al., 2014; Ivanov & Balan, 2017; Balan et al., 2018). The high-volume globular crown shape, which is specific to extensive orchards, is progressively replaced by the fusiform crown shape. The tree crown shape must provide simplicity both in the process of crown shaping and, in the methods, and periods of branch pruning (Long et al., 2014).

Thanks to the large number of cultivar-rootstock associations and the planting distance, the sweet cherry tree can use all cultivation systems. As a result of the diversity of the existing biological material, numerous researches regarding the crown shape have been required. The following crown shaping systems can be mentioned: the crown shape for the extensive system - Rained Tiered Pyramid, Thinned Tiered Pyramid with semi-open center, Non-tiered Pyramid, Mixed Pyramid, Kym Green Bush - KGB etc.); for the intensive system – naturally improved low volume crown, improved slender spindle crown, Oblique-armed palmetto, Horizontal-armed palmetto, Loosely flattened palmetto, Vertical cordon, Drapeau Marchand, Tall Spindle Ax (TSA), Spanish Bush (SB), etc.; for the super-intensive system - Upright Fruiting Offshoot (UFO), Super Slender Ax (SSA) etc. (Musacchi et al., 2015; Sumedrea et al., 2014).

Currently, in the Republic of Moldova, all cultivation systems are used. That is why, the diversity of methods and technical opportunities, as well as the climatic conditions in the area, must be an object of study that will be the basis of the cultivation systems in the future. At the same time, it is considered appropriate to identify the theoretical elements that condition the effectiveness of the orchard (precocity, yields, fruit quality, etc.) and to study all the elements that define the cultivation systems and the relationships between them (Babuc, 2012; Aglar et al., 2019; Bujdosó & Hrotkó, 2012).

The aim of this research was to increase the productivity of a sweet cherry orchard (*Prunus avium* L.) by identifying highly productive cultivar-rootstock associations and establishing some strategies for tree crown pruning and shaping, and developing methods to maintain a balance between growth and fructification.

MATERIALS AND METHODS

The investigations regarding the development of systems of high-yielding sweet cherries cultivation were carried out on common semi

deep, humus, clayey chernozem in the Southern, Central and Northern fruit-growing areas of the Republic of Moldova, caring out 6 stationary experiments. The orchard belonging to the "ProdCar" Ltd in the village of Negureni, the district of Telenesti, was planted in the spring of 2010 with sweet cherry trees of 'Adriana', 'Ferrovia' and 'Skeena' varieties grafted on 'Gisela 6' vegetative rootstock at a distance of 4 x 2 m. The trees had naturally improved low volume and improved slender spindle shaped crowns. The orchard belonging to the "Terra-Vitis" Ltd in the village of Burlacu, the district of Cahul, was established in the Southern fruit-growing area of the Republic of Moldova, in the spring of 2010, with sweet cherry trees of 'Bigarreau Burlat', 'Ferrovia', 'Lapins' varieties grafted on the vegetative 'Gisela 6' rootstocks, planted at a distance of 5 x 1.5 m, 5 x 2 m and 5 x 2.5 m. The trees had naturally improved low volume and improved slender spindle shaped crowns.

The researches at the "Vindex-Agro" Ltd in the village of Malaiesti, the district of Orhei, were conducted in the orchard established in the fall of 2003 which was planted with trees of the 'Valerii Cikalov' and 'Record' varieties grafted on *Prunus mahaleb* L. saplings; the planting distance was of 6x5m. The trees had naturally improved high volume shaped crowns. To achieve the intended purpose, the following pruning systems were studied: V1 - the maintenance and fruiting pruning during the dormant period (the control group); V2 - the maintenance and fruiting pruning during the vegetation period; V3 - the reduction cut done during the dormant period in 3- to 5-year-old branches; V4 - the reduction cut done during the vegetative period in 3- to 5-year-old branches. The same kind of works were done in the orchard established in 2011, with sweet cherry trees of the 'Ferrovia', 'Kordia', 'Regina' varieties grafted on the 'Gisela 6' rootstock, at a planting distance of 4x2.5m; the trees had naturally improved reduced volume and improved slender spindle shaped crowns.

Studies were carried out in the Central fruit-growing area of the Republic of Moldova, namely at the "StarAgro Group" Ltd in the village of Ustia, in the district of Criuleni, using the 'Kordia', 'Regina', 'Stella', 'Ferrovia' and 'Skeena' sweet cherry trees grafted on the 'MaxMa 14' rootstock. One of the orchards was planted in the fall of 2012, using trees of naturally improved reduced volume shaped crowns, planted at a distance of 5 x 3 m. Another orchard was established in the fall of 2015 with 'Early Star', 'Samba', 'Black Star' sweet cherry trees grafted on the 'Gisela 6'rootstock at a distance of 4 x 2 m.

Research methodology. The experiments were organized using four groups of eight representative trees each. The scheme was made according to the polyfactorial principle, with the placement of the groups through the randomized block system on 2 rows in the middle of the strip for each variety (Мойсейченко et al., 1994). The interdependence of the planting distance, crown shape, tree pruning system and time, as the basic factors that determine the tree fruiting, yield and fruits quality, was studied. Morphological, physiological and biochemical analyses, biometric measurements and the statistical processing of results were performed. The processed data are presented in average values over the 3-8 years of research. A 5% significance level test was used to compare the differences between the variants (Доспехов, 1985).

The orchard maintenance. The agrotechnical works in orchards were carried out in accordance with the regulations in force. In the orchards of the villages of Negureni, the district of Telenesti, the village of Burlacu, the district of Cahul and the village of Malaiesti, the district of Orhei, weather stations were installed to determine the state of the environment and the plants. The orchards of the "ProdCar" Ltd, the "Vindex-Agro" Ltd and the "StarAgro Group" Ltd were drip-irrigated, and Watermark transducers were installed at 20, 40 and 60 cm deep in each plot to monitor the soil moisture. Water was distributed by droppers fixed at a height of 40 cm from the ground in the direction of the row.

In the first two years after the planting of the trees, the soil was maintained as a worked field; during the following years, the soil between the tree rows was naturally or artificially grassed. The weeds on the 2-2.5 m wide strips of land between the rows were mowed when necessary and kept as mulches. The weeds were killed with herbicides applied along the rows, or mechanically weeded twice or three times using sensitive weeding equipment.

RESULTS AND DISCUSSIONS

The research conducted by the State Agricultural University of Moldova, on the increase of efficiency of sweet cherry orchards, by obtaining early bumper qualitative harvests, has led to the use of trees with preformed crowns thickened up to 90-100 cm which are planted more densely, to the development of methods to maintain a balance between growth and fruiting by minimizing pruning in the first years after planting, and to the utilization of inclined branches, irrigation and fertilization (Balan, 2015; Şarban & Balan 2021; Ivanov & Balan, 2017; Ivanov et al., 2019; Balan et al., 2022).

It is very important to know the natural potential of an ecosystem in order to implement a cultivation system which would lead to a larger and more qualitative crop, to lower maintenance costs and even to the improvement of the natural fertility of the ecosystem (Babuc, 2012; Balan et al., 2001; Sumedrea et al., 2014). Most soil types, with the exception of clay and anoxic soils, are suitable for growing sweet cherry trees, grafted on an appropriate rootstock (Cimpoieș, 2018). The traditional rootstocks such as Wild Cherry (*Prunus avium* L.), 'Mahaleb' (*Prunus mahaleb* L.), 'Sante Lucie' ('SL 64'), 'Mazzard' (*Prunus avium*) are still good for calcareous, rocky, dry or hilly soils. The vegetative 'Colt' (*P. avium* x *P. pseudocerasus*) rootstocks are used instead of the seedlings of Wild Cherry, 'Mahaleb' and 'Santé Lucie' on fertile and moist soils (Babuc, 2012).

The tree pruning works have developed considerably; researches have focused on the pruning during the vegetation period rather than on the pruning during the dormant period. The basic objective of pruning is to maintain the optimal parameters of the crown structure and the balance of growth and fruiting in order to control the development of a tree from the earliest stage to maturity.

Regarding the effect of the types of pruning on the average fruit production, according to the data presented in Table 1, it can be said that during the years 2012-2019, the largest crop was produced when the fructification pruning was done by reduction cuts in 3- to 5-year-old branches during the vegetative period (V4) with 46.8 kg/tree in the 'Valerii Cikalov' variety and 48.4 kg/tree in the 'Record' variety, followed by the fructification pruning done by reduction cuts in 3- to 5-year-old branches during the dormant period(V3) with 42.5 kg/tree in the 'Valerii Cikalov' variety and 45.4 kg/tree in the 'Record' variety. The fruiting and maintenance pruning during the dormant period (V1) and during the vegetation period (V2) led to a smaller crop compared to the fructification pruning done by reduction cuts in 3- to 5-year-old branches during the dormant period (V3) and during the vegetation period (V4). The obtained results prove the fact that the pruning type significantly influenced the fruit harvest recorded in the 'Valerii Cikalov' and 'Record' sweet cherries trees grafted on the 'Mahaleb' rootstock during the fruiting period.

Table 1. The yield of cherry trees depending on the variety and pruning type, kg/tree ('Mahaleb' rootstock, planting distance - 6 x 5m, the age of the trees - 10-17, *Vindex Agro* Ltd)

Pruning type	Years						Average yield (2012-2019)
	2012	2013	2014	2015	2016	2019	
'Valerii Cikalov' variety							
V1 (control)	20.1	25.3	28.5	38.9	57.6	68.5	39.8
V2	22.7*	27.9	32.9	41.7	58.2	65.6	41.5
V3	21.8	30.2*	31.3	42.5	58.0	71.3	42.5
V4	23.4*	33.4*	39.4*	49.7*	62.9*	71.7	46.8
'Record' variety							
V1 (control)	20.1	21.8	34.4	45.2	49.5	87.8	43.1
V2	22.3*	23.7	35.9	47.3	49.9	88.7	44.6
V3	19.2	25.7*	37.0	49.1	55.4*	85.9	45.4
V4	18.9	26.4*	41.4*	52.3*	57.1*	4.2*	48.4
LSD 5%	2.14	3.12	4.16	4.74	4.51	5.04	-

The 'Ferrovia', 'Kordia' and 'Regina' sweet cherry trees, grafted on the 'Gisela 6' rootstock and planted at a distance of 4 x 2.5 min the orchard with 0.4-0.5 t/ha, began to bear fruit in

the 4th vegetation year, and in the 5th they yielded 4.6-5 t/ha, but the values are not statistically proved. Starting with the 3rd fruiting year, the harvest tripled, being statistically assured, amounting to 12.31-13.29 t/ha in the 'Ferrovia' variety and to 11.27-12.83 t/ha in the 'Kordia' variety. In the years 2017 and 2020, the fog, rain and cold during the flowering period had a negative influence on the harvest. The average yield during the first 7 years of the tree fruiting was of 8.19-8.31 t/ha in the 'Ferrovia' variety, 7.65-8.31 t/ha in the 'Kordia' variety, and 7.21-7.88 t/ha in the 'Queen' variety (Table 2).

Table 2. The productivity of cherry trees depending on the variety and crown shape, t/ha.
('Gisela 6' rootstock, planting distance - 4 x 2.5 m, naturally improved low volume crown, the age of the trees - 4-10, *Vindex-Agro* Ltd)

Variety	Years							Average yield (2014-2020)
	2014	2015	2016	2017	2018	2019	2020	
Naturally improved low volume crown								
Ferrovia	0.50	5.00	2.31*	7.90	10.88	3.73*	7.03	8.19
Kordia	0.40	4.60	11.27	7.50	7.60	3.81*	8.37*	7.65
Regina	0.50	4.80	10.38	7.80	7.60	12.37	7.01	7.21
Improved slender spindle crown								
Ferrovia	0.50	4.90	13.29*	793	11.78	12.94	6.82	8.31
Kordia	0.40	4.70	12.83	8.88*	8.94	13.32*	9.12*	8.31
Regina	0.40	5.00	11.89	7.57	11.29*	11.99	6.99	7.88
LSD 5%	-	0.845	0.529	0.82	0.675	0.315	0.783	-

The shape of the crown did not significantly influence the yield in the studied varieties, because the small volume crown shape has a favorable impact on the growth of the sweet cherry trees grafted on the Gisela 6 moderate vigor rootstock in a high density system (Long, 2003; Usenik et al., 2010; Balan et al., 2018). At the „ProdCar" Ltd, the 'Adriana', 'Ferrovia' and 'Skeena' sweet cherry trees, grafted on the 'Gisela 6', also came into fruit in the 4th year after their planting yielding 0.66-1.56 t/ha; in the 5th year they yielded 4.25-5 t/ha (Table 3).

In 2015, as the trees got older, the fruit crop tripled and amounted to 11.87-13 t/ha in the Adriana variety, 13.25-14.12 t/ha in the 'Ferrovia' variety and 16 t/ha in the 'Skeena' variety. In 2016, the sweet cherry harvest doubled compared to the previous year and amounted from 21.87-22.50 t/ha in the 'Adriana' variety to 26.25-28 t/ha the 'Skeena' variety.

Table 3. The yield of the sweet cherry trees according to variety and crown shape, t/ha.
('Gisela 6' rootstock, planting distance - 4 x 2 m, the age of the trees - 4-11, *ProdCar* Ltd)

Variety	Years								Average yield (2013-2020)
	2013	2014	2015	2016	2017	2018	2019	2020	
Naturally improved low volume crown									
Adriana	0.62	4.37	11.87	21.88	10.87	12.96	13.38	9.32	10.66
Ferrovia	1,12	4.87	13.25	4.75*	5.75*	5.22*	10.79	4.28*	12.51
Skeena	0.63	4.25	6.00*	6.25*	6.88*	7.58*	7.04*	6.65*	14.41
Improved slender spindle crown									
Adriana	0.87	4.50	13.00	22.50	10.75	14.82	13.13	10.82	11.29
Ferrovia	1.56	5.00	14.13	4.50*	12.70	15.39	13.54	6.64*	12.93
Skeena	0.38	4.38	6.00*	8.00*	4.00*	7.50*	7.42*	8.99*	14.58
LSD 5%	-	0.435	0.971	1.315	1.429	1.423	2.305	1.314	-

In 2017, the crop decreased remarkably and represented only 10.75-10.88 t/ha in the Adriana variety, 12.70-15.75 t/ha in the 'Ferrovia' variety and 14-16.79 t/ha in the 'Skeena' variety. The average crop was larger when in the Skeena variety the crown of which are of improved slender spindle shape (14.58 t/ha) followed by the 'Ferrovia' variety (12.93 t/ha). The smallest crop was produced by the 'Adriana' variety (10.65 t/ha) in the group in which the trees had naturally improved low volume shaped crowns. It is a medium-sized yield for a sweet cherry orchard

with trees grafted on 'Gisela 6' rootstock (Ivanov & Balan 2017).

The researchers conducted at the „Terra-Vitis" Ltd included the analyses of the structure of the sweet cherry orchard not only from the point of view of the growth vigor of the rootstock and variety, but also of the planting distance. The density of the trees, in the first years of vegetation, did not influence the length and width of the crown. It is a well-known fact that when the distance between the trees in a row, from 1.5 m to 2.5 m, increases, the time to fill the area reserved for the crowns increases too.

The crowns of the 'Bigarreau Burlat' and 'Ferrovia' varieties joined in the direction of the row in the 4th year, and the 'Lapins' variety - in the 5th year of their vegetation, and reached the necessary parameters to capture the maximum solar energy to produce large harvests of qualitative fruits.

The trees began to bear fruit in the 4th year of vegetation and yielded from 0.32-0.4 t/ha, when planted at the distance of 5 x 2.5 m, to 0.67-1.07 t/ha when planted at the distance of 5 x 1.5 m (Table 4). In the 2nd year of fruiting, the largest statistically proved crop (5.48-6.82 t/ha) was produced by the trees planted at the distance of 5x1.5 m; the smaller crop (3.72-4.2 t/ha ha) - by the trees planted at the distance of 5x2.5 m. In the 3rd year of fruiting, the trees yielded 8.0-12.86 t/ha; in the 4th year - 14.62-20.07 t/ha. During the period of tree growth and fruiting, the sweet cherry crop was higher and statistically proved when the trees were planted at a smaller distance from each other. The trees the crowns of which are of improved slender spindle shape turned out to be the most productive, as compared to the trees the crowns of which are of naturally improved low volume shape, but these values are not statistically proved. During the growth and fruiting period, the 'Bigarreau Burlat', 'Ferrovia' and 'Lapins' cherry trees, grafted on the 'Gisela 6', produced an average yield of 8-10 t/ha.

With regard to the variety productivity, it is worth mentioning that the highest crop was recorded in the 'Ferrovia' variety planted at the distance of 5x1.5 m (18.94-20.07 t/ha), and the lowest crop, with the trees planted at the distance of 5 x 2.5 m (15.63-16.90 t/tree)in the 7th year of vegetation. The phenomenon can be explained by the difference in the number of trees per hectare between the two planting schemes.

It is also worth mentioning that the cherry trees grafted on the 'Gisela 6' rootstock and planted at high density can have a medium-sized crown, stimulate the early fruiting, increase pruning productivity and make it possible to gather fruit from the ground (Cimpoies, 2018; Ivanov & Balan, 2017); planting density is limited by the economic law of diminishing marginal productivity (Sumedrea et al., 2014).

Table 4. The yield of sweet cherry trees depending on the variety, planting distance and crown shape, t/ha.
('Gisela 6' rootstock, the age of the trees - 7, *Terra-Vitis* Ltd)

Variety	Planting distance, m	Naturally improved low volume crown				Improved slender spindle crown			
		Year 2013	Year 2014	Year 2015	Year 2016	Year 2013	Year 2014	Year 2015	Year 2016
Bigarreau Burlat	5 x 1.5	0.79	5.96*	11.41*	17.98*	0.71*	6.34*	12.21*	18.94*
	5 x 2	0.40	4.89	9.15	15.16	0.50	5.12	11.82	16.16
	5 x 2.5	0.32	3.72	8.00	14.62	0.40	4.17	10.20	15.63
Ferrovia	5 x 1.5	0.93	6.39*	12.72*	18.16*	1.07*	6.82*	13.82*	20.07*
	5 x 2	0.70	5.26	12.35	15.92	0.80	5.58	13.13	17.81
	5 x 2.5	0.56	4.45	9.88	15.37	0.64	5.02	12.89	16.90
Lapins	5 x 1.5	0.66	5.48*	12.28*	18.55*	0.67*	5.79*	11.86*	19.38*
	5 x 2	0.50	4.580	9.400	17.240	0.500	5.010	9.900	18.210
	5 x 2.5	0.40	3.720	9.888	16.152	0.400	4.200	9.520	17.536
LSD 5%		0.275	0.647	1.375	1.284	0.275	0.647	1.375	1.284

During the fruiting period, the yield of cherry orchards depends on the variety and the climatic conditions (Figure 1). Thus, in 2018 the 'Ferrovia', 'Kordia', 'Regina', 'Skeena' and 'Stella' sweet cherry trees, grafted on the 'MaxMa 14' rootstock, yielded from 4.18 t/ha in the 'Ferrovia' variety to 15.70 t/ha in the 'Skeena' variety. A significantly higher crop was produced by the 'Kordia' variety (10.94 t/ha), the 'Skeena' variety (15.70 t/ha) and the 'Stella' variety (9.13

t/ha). In 2019, the record harvest of 19.22-19.31 t/ha was produced by the 'Kordia' and 'Regina' varieties, and the lowest harvest - by the 'Ferrovia' (4.11 t/ha) and the 'Stella' varieties (7, 99 t/ha). In the 10th year of vegetation, the 'Regina' variety produced the highest yield (12.05 t/ha) as compared to the 'Ferrovia' (2.73 t/ha) and the 'Kordia' varieties (2.91 t/ha). Over the years, the 'Kordia' (11.06 t/ha), 'Regina' (12.35 t/ha) and 'Skeena' (11.31 t/ha) varieties produced an identical crop, while the 'Ferrovia' (3 .68 t/ha) and 'Stella' (8.81 t/ha) varieties produced a smaller crop.

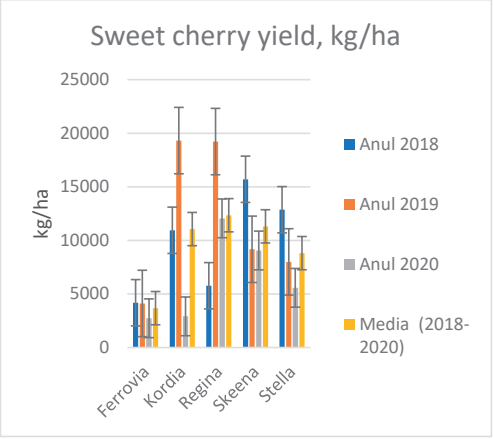

Fig. 1. The yield of sweet cherry trees, kg/ha. ('MaxMa 14' rootstock, planting distance - 5 x 3 m, naturally improved low volume crown, the age of the trees - 8-10, *StarAgroGroop* Ltd)

The 'Early Star' and 'Black Star' varieties, grafted on 'Gisela 6' rootstock, planted at a distance of 4x2 m started to bear fruit (2.9-3.7 t/ha) in the 4th year of vegetation, and the Samba variety - in the 5th year of vegetation (Table 5). In the 2nd year of fruiting, a higher crop was produced by the 'Samba' (16.82 t/ha) and 'Black Star' (10.75 t/ha) varieties; the lowest crop was produced by the 'Early Star' variety (7.01 t/ha). In the 4th year of fruiting, the 'Black Star' variety proved to be more resistant to late spring frosts, thus it yielded 9.87 t/ha. The 'Early Star' and 'Samba' varieties yielded only 3.62 -4.46 t/ha. In 2021, the crop of the 'Early Star' (9.45 t/ha) and 'Samba' (16.26 t/ha) varieties was significantly larger as compared to the 'Black Star' variety (5.50 t/ha). In the 5th year of fruiting, the crop amounted to 9.44-11.01 t/ha, being higher in the 'Early Star' variety. On average over 5 years, the most productive proved to be the 'Samba' variety which yielded 10.07 t/ha.

Table 5. The sweet cherry yield, t/ha. ('Gisela 6' rootstock, planting distance - 4 x 2 m, improved slender spindle crown, the age of the trees - 4-6, StarAgroGroop Ltd)

Variety	Years					Average yield
	2018	2019	2020	2021	2022	
Early Star	2.94	7.01	4.46*	9.45*	11.01	6.97
Samba	3.66	16.82*	3.62	16.26*	9.98	10.07
Black Star	0	10.75	9.87*	5.50	9.44	7.11
LSD 5%	0.992	0.874	1.013	2.372	1.284	-

Choosing the structure and the cultivation system of sweet cherry trees

The effective utilization of natural resources such as soils, light, slopes and land exposure cannot be done without establishing the optimal parameters of the geometric structure of an orchard, which determine the yield and quality of the fruit. In this context, it is appropriate to identify the biotic and abiotic factors that define the cultivation system, which corresponds to the biological production potential of the orchard and the economic interests. (Balan, 2009; Balan et al., 2008).

To establishment of an orchard should be based on the following principles: the geographical conditions and natural soil fertility, the relative vigor of the variety-rootstock association, the planting density, early large harvests, and simple crowns easily adaptable to partial mechanization. At the present, there are a lot of the sweet cherry varieties and rootstocks of different vigor. The crown of this crop can be easily and differently shaped, and it can also be grown on less fertile soils and sloping lands using all cultivation systems.

To describe the relationships between the parameters of the structure of the fruit plantation, the following formula was used

$$L = H \operatorname{tg} \varphi - H \operatorname{tg} \alpha + B$$

The method provides for the determination of the distance between the rows of trees according to the height of the crown (H), the width of the bottom of the crown (B), the angle of inclination of the lateral surface of the crown to the geografical longitude (α) and latitude of the locality (φ). The method described by V. Balan, 1996 can be used to establish the geometric structure according to their variation in different geographical conditions.

When determining the optimal productive potential of the sweet cherry orchard, the data related to the 'Ferrovia' sweet cherry trees, grafted on 'Gisela 6' rootstock, and the 'Valerii Cikalov' sweet cherry trees, grafted on the 'Mahaleb', in different positioning combinations during the fruiting period were used (Table 6).

Table 6. The optimal productive potential of the cherry orchard depending on the crown structure (geographical latitude 47°, the angle of crown inclination 12°)

Distance between the rows, m	Width of the bottom of the crown, m	Hight of the crown, m	Level of soil covarage, %	Real volume of the crown, thousand m^3/ha	Crown surface, thousand m^2/ha	Production potential, %
'Ferrovia' variety, grafted on the 'Gisela 6' vegetative rootstock						
4	1.5	2.9	37.5	6.5	16.4	71.7
4	2.0	2.3	50.0	8.8	14.4	68.3
5	2.0	3.5	40.0	8.6	15.3	65.5
5	2.4	3.0	48.0	10.6	14.5	67.0
'Valerii Cikalov' variety, grafted on the 'Mahaleb' generative rootstock						
6	2.5	4	41.6	11.1	15.0	65.7
6	3.0	3.5	50.0	13.2	14.4	67.6

In order to determine the parameters of the orchard structure, the relationship between the height of the crown, the angle of inclination of the crown and the free area between the crowns in the neighboring rows were applied. In the 'Ferrovia' variety, in the tees 2.9 m in hight, the level of the soil coverage was 37.5%, and in the trees 2.3 m in hight, the level of soil coverage was 50%. At the distance of 5 m between the rows, the level of soil coverage was 40.0-48.0%. In the 'Valerii Cikalov' variety grafted on the 'Mahaleb' rootstock, the level of soil coverage was practically the same - 41.6-50.0%. The level of ground coverage increases with the decrease in the tree height.

In the 'Ferrovia' variety, the actual volume of the crown, at a distance of 4 m between the rows, was 6.5-8.8 thousand m^3/ha, and at a distance of 5 m between the rows, the volume was 8.6-10.6 thousand m^3/ha. In the 'Valerii Cikalov' variety grafted on the 'Mahaleb' rootstock, the volume increased significantly and amounted to 11.1-13.2 thousand m^3/ha. Thus, the crown volume gradually decreases with the increase in the density of the trees. The obtained data demonstrate that in high-density orchards, the actual crown volume reaches optimal values depending on the structure of the orchard during the first 3-4 years. The lateral surface of the crown was 14.4-16.4 thousand m^2/ha. The area of crowns in the orchard decreases with a decrease in the height of trees.

The value of the production potential of the orchard was calculated according to the efficiency coefficient of the orchard and the volumetric density coefficient of the lateral surface of the crown (Агафонов, 1983). The obtained calculations show that the value of the production potential of the orchard is higher in the orchards with a crown width of 1.5 m and constitutes 71.7%. The height of the trees is the basic element in the development of the cultivation system, because it modifies the technologies of crown pruning and shaping, determines the consumption of manual labor when pruning the trees and harvesting the fruit (Balan, 2009).

Comparing the data on the production potential of sweet cherry orchards with the data presented by other authors, it can be said that they are almost equal to those considered optimal, without changing the angle of inclination of the lateral surface of the crown to the vertical one. At the same time, when reducing of the height of the trees, a better

lighting regime is created, which lead to the development of the fruit and the production of a large and qualitative harvests.
In conclusion, it has to be mentioned that the cultivation system for the sweet cherry trees is chosen depending on the variety-rootstock association, the ecological and technological conditions, which determine the productivity, the yield and the quality of the fruit.
It is also necessary to specify that crowns in a vertical plane up to 2.5-3 m high and 1.5-2 m wide make it possible to organize the orchard care, pruning and fruit picking at lower cost.

CONCLUSIONS

In order to achieve sustainable fruit production, it is necessary to identify the biotic and abiotic factors that define the orchard system of tomorrow. For the cultivation of sweet cherries, all sustainable integrated cultivation systems are successfully used, which are based on geographical conditions, the degree of natural soil fertility, the relative strength of the rootstock-varietal relationship, planting density, simple crowns, early and high yields in order to achieve high economic efficiency.
High vigor rootstock-varietal associations (Seedlings of *Prunus avium;* 'Colt'*,* 'SL 64') are used on non-irrigated soils in association with self-fertile varieties at optimal planting distances that ensure high yields. Sweet cherry trees, grafted on the semi vigorous rootstocks ('Gisela 6', 'P-HL-C', 'Krymsk 6') and moderate vigor rootstocks ('Krymsk 5', 'MaxMa 14', 'Piku 1', 'Piku 4'), are used on fertile soils and irrigated at high densities, provides simple crown shapes, medium-sized trees, which can be managed from the ground level, early harvests, medium yield, reduced costs of tree pruning and fruit harvesting by increasing labor productivity.
The cultivation system for the sweet cherry crop is chosen according to the rootstock-varietal association, the ecological and technological conditions, which determine the productivity, the yield and the quality of the fruit.
The crowns in the vertical plane up to 2.5-3 m high and 1.5-2 m wide make it possible to organize the orchard care, pruning and fruit picking at lower cost.

ACKNOWLEDGEMENTS

This study was supported by the National Agency for Research and Development, project 20.8000.5107.04 *Adaptation of sustainable and ecological fruit production technologies in terms of quantity and quality in accordance with the integrity of the crop system and climate change.*

REFERENCES

Aglar, E., Saracoglu, O., Karakaya, O., Ozturk, B., Gun. S. (2019). The relationship between fruit color and fruit quality of sweet cherry (*Prunus avium* L. cv. '0900 Ziraat'). *Turk J. Food Agric. Sci. 1 (1):* 1-5. ISSN: 2687-3818.

Aglar, E., Yildizand, K., Long, LE. (2016). The effects of rootstocks and training systems on the early performance of '0900 Ziraat' sweet cherry. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca 44(2)*: 573-578.

Babuc, V. (2012). Pomicultura. *Chişinău.* 662 p. ISBN 978-9975-53-067-5.

Balan, V. (1996). Metoda de stabilire a distanţei dintre rândurile de pomi fructiferi // Brevet de invenţie, RM nr. 36: Data publicării hotărârii de acordare a brevetului: 31.01., *BOPI nr.1*/96.

Balan, V., Șarban, V., Ivanov, I. (2022). Optimizarea conceptului de conducere și tăiere a plantațiilor de cireș prin ameliorarea relației intre creștere și fructificare. *Revistă de Știință, Inovare, Cultură și Artă Nr. 2 (65)***,** 99-108. ISSN 1857-0461, E-SSN 2587-3687.

Balan, V. (2009). Sisteme de cultură în pomicultură. Randamentul producţiei de fructe. In: *Akademos, nr. 4(15)*, 82-90. ISSN 1857-0461.

Balan, V. (2015). Tehnologii în intensificarea culturii mărului și cireșului. *Academos 2*, 74-79

Balan, V., Babuc, V., Barbaroş, M. et. al. (2008). Renovation of fruit growing in the Republic of Moldova in base of scientific resultants. In: *Bulletin of UASVM Cluj-Napoca., vol. 65(1): Horticulture*, 503. ISSN 1843-5254.)

Balan, V., Ivanov, I., Balan, P (2018). Influence of the crown shape on the input of the fruit and the productive potential of cherry trees in a high-density system. In: *Bulletin of UASVM Cluj-Napoca. Series Horticulture. vol. 75(2)*, 118-122. ISSN 1843-5262.

Balan, V., Sarban, V (2021). The impact of the cherry tree pruning period on the production and quality of fruit in an intensive cultivation system. In: *International Agriculture Congress: conf. şt. intern.*, 16-17 dec. 2021, ed. a 4-a, Turcia, 107-117. ISBN 978-605-80128-6-8

Bennewitz, E., Sanhueza, S., Elorriaga, A. (2010). Effect of different crop load management strategies on fruit production and quality of sweet cherries (*Prunus avium* L.) 'Lapins' in Central Chile. *Jurnal of fruit and Ornamental Plant Research. Vol.18(1)*, 51-57

Bujdosó, G, Hrotkó, K. (2012). Preliminary results on growth, yield and fruit size of some new precocious sweet cherry cultivars on Hungarian bred mahaleb rootstocks. *Acta Horticulturae 1058*: 559-564.

Calabro, J. M, Spotts, R.A. and Grove, G.G. (2009). Effect of Training System, Rootstock, and Cultivar on Sweet Cherry Powdery Mildew Foliar Infections. *HortSciense, vol, 44*: 481-482.

Cimpoieș, Gh. (2018). Pomicultura specială. Chișinău: *Print Caro*, 65-94. ISBN 978-9975-56-572-1.

Gjamovski, V., Kiptijanovski, M., Arsov, T. (2016). Evaluation of some cherry varieties grafted onGisela 5 rootstock. Tu*rkish Journal of Agriculture and Forestry 40(5)*: 737-745.

Gyeviki, M., Bujdosó, G. and Hrotkó, K. (2008). Results of cherry rootstock evaluations in Hungary. *International Journal of Horticultural Science 14(4)*: 11-14.

Ivanov, I., Balan, V. (2017). Efectul sistemului de formare a coroanei la cireș asupra intrării pomilor pe rod, productivității și calității fructelor. In: *Ştiinţa agricolă. nr.1,* 28-32. ISSN 1857-0003.

Ivanov, I., Șarban, V., Balan, P., Vămășescu, S., Balan, V. (2019). Conducerea pomilor de cireș după sistemul cupă. In: *Ştiinţa agricolă. nr. 2*, 45-51. ISSN 1857-0003. DOI: 10.5281/zenodo.3611171

Long, L.E. (2003). Cherry Training Systems: Selection and Development. *PNW 543. Oregon State University, Corvallis, OR*. 26 pp.

Long Lynn, E., Long, M., Pește anu, A, Gudumac, E. (2014). Producerea cireșelor. *Manual tehnologic. Chișinău*, 119-126

Milošević, T., Milošević, N., Glišić, I., Nikolić, R., Milivojević, J. (2014). Early tree growth, productivity, fruit quality and leaf nutrients content of sweet cherry grown in a high density planting system. *Hort. Sci. (Prague), 42*: 1–12.

Musacchi, S., Gagliardi, F., Serra, S. (2015). New training systems for highdensity planting of sweet cherry. *HortScience 50(1):* 59-67.

Sumedrea, D., Isac, Il., Iancu, M. (2014). Pomi, arbuști fructiferi, căpșun. Ghid tehnic și economic. Otopeni : *Invel Multimedia,* ISBN 978-973-1886-82-4, 546 p.

Șarban, V., Balan, V. (2021). Influența portaltoiului asupra productivității și calității fructelor de cireș în sistem superintensiv. In*: Ştiinţa agricolă. Chişinău, nr. 2*, 11-17. ISSN 1857-0003.

Usenik, V., Fajt, N., Mikulic-Petkovsek, M., Slatnar, A., Stampar, F., Veberic, R. (2010). Sweet cherry pomological and biochemical characteristics influenced by rootstock. *Journal of Agricultural and Food Chemistry 58(8)*: 4928-4933.

Vercammen, J. (2002). Dwarfing rootstocks for sweet cherries. *Acta Horticulturae 658*: 307-311.

Агафонов, Н.В. (1983). Научные основы размещения и формирования плодовых деревьев. - *Москва*, - 173 с.

Доспехов, Б. А. **(1985).** Методика полевого опыта (с основами статистической обработки результатов исследования). Москва: *Агропромиздат*. 351 с.

МойсейченкоВ. Ф., Заверюха, А. Х., Трифанова, М. Ф. (1994). Основы научных исследований в плодоводстве, овощеводстве и виноградарстве. Колос, *Москва*, 365 р