The Impact of The Cherry Tree Pruning Period on The Production and Quality of Fruit in an Intensive Cultivation System

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Abstract
The study was conducted during the period 2018 to 2020 in the central area of the Republic of Moldova, and was designed to assess the effect of pruning of cherry trees (*Prunus avium L.)* of „Regina" variety, grafted on the Maxima 14 rootstock, during the rest and vegetative phase of plant development. The pruning was done as follows: during the rest period (control group), during the flowering period; after the harvesting (in July) and in early autumn (the first decade of September). The tree pruning influenced the fruit size. From the moment the colour of the cherry skin became pinkish-yellow and the fruit started to ripen and till its maturity, the diameter of the fruit doubled. The pruning carried out in early autumn had a great impact on the reduction of the percentage (1.6-2.9%) of fruit 24 mm and downwards in diameter and the increase of the yield of fruit (18.3-36.1%) 28 mm and upwards in diameter. It is necessary to study the post-harvest and early autumn pruning in order to determine their impact on the fruit quality and size improvement without affecting the crop yield. A long-term study, on the other hand, would be needed to evaluate the impact of pruning on harvest, especially on the weight and the commercial size distribution of the fruit.
Keywords: *Prunus avium L.*, tree pruning, fruit quality, fruit yield

Introduction

Changes in the production of cherries have been observed in the Republic of Moldova. New high-density intensive orchards of new varieties are being planted; low vigour (*Gisela 5, Krymsk 6*), average-vigour (*Maxima Delbard 14, Piku 1, Piku 4*) and average-low vigour (*Gisela 6, P HL-C, Krymsk 6*) rootstocks are being used; new tree formation systems are being applied such as spindle crowns, the Kym Green Bush system, Spanish Bush and naturally improved low-volume crowns.

The utilization of new varieties and rootstocks of different vigour permit to form variety-rootstock combinations which permit to grow desired orchards (Balan, 2009, 2015; Cimpoies, 2018; Miter et al., 2012) and have a particularly significant impact on the vegetative growth, precocity, tree yield, fruit quality and the return on investment (Aglar et al., 2019; Aglar et al., 2016; Bujdosó and Hrotkó, 2012). Therefore, the variety-rootstock combinations used in cherry tree cultivation directly determine the tree formation system, the way and period of branch pruning, the care system, the tillage, the irrigation and fertilization employed in orchards (Calabro et al., 2009; Long, Lynn et al., 2014).

Tree pruning and formation continue to induce new requirements regarding the existing cultivation technologies and pruning period which must correspond to the maximum use of the biological potential of cherry orchards. Modern tree formation systems should provide simplicity both in the process of crown formation and in the way and period of branch pruning (Long, Lynn et al., 2014).

The yield of cherry trees has increased considerably, but in many cases the increase in productivity without a proper management of the crown formation and the number of fruit results in trees that produce large crops but small fruit (Whiting et al., 2005, 2006). The fruit

size is a very important quality parameter and a factor that can determine the future viability of an orchard. Traditionally, the number of cherry fruit is regulated by the pruning of the trees during the period of their vegetative rest (Babuc, 2012). However, this method may be insufficient for the variety-rootstock combinations that produce large crops but small fruit. Alternatively, researches are being carried out on the pruning during the vegetative phase of the tree's development. It is necessary to carry out further research before effective recommendations can be made. Another problem that should be studied is the period of the pruning of different productive structures.

The pruning during the vegetative period has been proposed as a procedure aimed at the improvement of the balance between the vegetative growth and fruit quantity in cherry trees (Long, Lynn et al., 2014). The pruning of trees in early autumn, namely during the first decade of September, has a great impact on the number of fruit and their size compared to the conventional pruning during the dormancy of trees. It has been observed that, the pruning of trees during the vegetative phase of plant development leads to an increase in the size of fruit and a change in their colour, as well as to a decrease in the incidence of brown rot. (Lauri, 2005). In the Republic of Moldova, very few scientific experiments have been carried out on different periods of cherry tree pruning. No works have been found which would compare the pruning of cherry trees during their dormancy and the vegetative phase of their development.

This research intended to evaluate the impact of the period of cherry trees pruning on the yield and the quality of cherry fruit *(Prunus avium L.)* of „Regina" variety (fruit weight and diameter, dry matter, total sugar content, titratable acidity) cultivated in the central area of the Republic of Moldova. The pruning period involved the maintenance and fruiting pruning of the cherry trees both during the rest and the vegetation periods.

Material and Method

Location

The study was conducted during the period 2018 to 2020 in the central area of the Republic of Moldova (at a latitude of 47.2544º, a longitude of 29.1258º and an altitude of 21 meters above the sea level). This area is characterized by rugged topography, fertile soils, strong winds predominantly blowing from the north, early autumn frost, late spring hoarfrost and medium water supply. During the research, the thermal regime was high, and the annual amount of precipitation was within the norm. According to the multiannual data, the average annual temperature reaches +10.9ºC; during the vegetation period it reaches +17.3ºC. If the temperature is above 10ºC, the vegetative period amounts to 2200-2300 hours. The frost-free period amounts to 280-290 days; during 180-185 days of this period the temperature is above +10°C (http://www.meteo.md/). The orchard was planted on a typical medium humus loamy chernozem. Within the horizon of 20 cm the humus content accounts for 2.94%; the soil is moderately humidified. At a lower level, the humus content decreases, namely at a depth of 20-40 cm it accounts for 1.85%, and in the pedogenetic horizon B below the level of 80 cm, it accounts for less than 1%. Carbonates can be found below the level of about 20 cm. The soil is slightly alkaline at a depth of 0-40 cm, medium alkaline at the level of 40-60 cm and strongly alkaline at a depth of 60-80 cm.

The material which has been utilized

The pruning period of the cherry trees of the „Regina" variety grafted on the Maxima 14 rootstock was researched. The trees were planted in the autumn of 2012 at a distance of 5x3 m;

the rows were north-south directed. Naturally ameliorated reduced volume crown shapes were used (Babuc, 2012).

Research methodology

The maintenance and fruiting pruning of the cherry trees was carried out during the rest and the vegetation periods as follows: in G1 - Pruning during the rest period (control); in G2 - Pruning during flowering; in G3 - Post-harvest pruning (in July); in G4 - Pruning in early autumn (the first decade of September). The basic objective of the maintenance and fruiting pruning of the cherry trees, grafted on the Maxima 14 rootstock, was to maintain the crown shape at the designed parameters and the physiological balance between growth and fruiting in order to obtain high quality fruit production. Thinning pruning, the pruning of a part of the branch and branch shortening were performed. Pendent and thin branches that produced small cherries were pruned. The old branches were shortened up to 30-40 cm at the bottom of the tree and up to 8-10 cm at the top of it. The annual pruning of the main branches was performed on 5- or 6-year-old branches, and of the secondary branches – on 3- or 5-year-old branches. The annual branches, depending on their position, were shortened from a third to half of their length or partially to the length of about 20 cm (Long, Lynn et al., 2014). These kinds of pruning were done to balance the vegetation between the base and the top of the crown, the branches in the rows and the branches of the crown.

Cultural management of the plantation

The soil is kept artificially grassed, the orchard is drip irrigated, and Watermark sensors are used to monitor the soil moisture. The water is distributed through mains with drippers fixed at 40 cm from the ground in the direction of the row. The fertigation technology and software are computerized and can be tracked in real time. Thus, the fruit grower knows, without leaving the office, when to irrigate or start a certain component of the fertigation. The strips between the rows, which are 2.5 m wide, are mowed when the grass reaches a height of 25-30 cm; the grass is used as mulch. The soil among the trees is herbicides and milled if needed.

Sampling

The research was conducted both in the field, where biometric measurements were performed to determine the impact of the variety, the crown maintenance pruning and the fruiting pruning on the growth and fruiting of cherry trees, and in the laboratory where physiological and biochemical analyses were performed. During the experiment, 4 randomized groups of 8 trees each were used. The trees were selected on the basis of vigour and uniform development (Dospehov, 1985; Moiseicenco, et al., 1994). Twelve trees were selected in each group taking as a basis the diameter of the trunk 20 cm below the first main branch, using a digital calliper (± 0.01 mm) (*TOLSEN Tools, 35053, China*) and a uniform number of main and secondary branches. The diameter of the cherries during the fruit development and ripening periods was identified with the help of a digital calliper and a template provided with holes of 24, 26, 28, 30, 32 and 34 mm (*VOEN, Germany*). These analyses were performed every 3 days, starting with the time the fruit began to change its skin colour from green to yellow-pink until the full ripening, using the CTIFL (Center Technique Interprofessionneldes Fruit et Legumes, France) colour chart: pink-yellowish, very light red, red, bright ruddy, dark red, dark reddish-brown, dark brown. The fruit was harvested from 32 trees in each group, and the fruit yield was expressed in kg of fruit per tree and per hectare. The number of fruit and their location inside the crown and on various branches was studied during fruit harvesting using 3 typical trees in

each group. 100 fruit were harvested at random from each tree on trial and evaluated at room temperature. Annually, the fruit were analysed to determine their weight and diameter, the dry matter, the total sugar content, and the treatable acidity expressed in % of malic acid. The fruit weight was measured using a digital scale (± 0.01 g) (*AS 82/220.X2*). The soluble dry matter content in the fruit was measured using a digital refractometer (*DR201-95, Germania*). The weight, diameter and firmness of the fruit were determined in 20 cherries using four identical samples (n = 80) from each group.

Statistical analysis

The methods of analysis, synthesis, tabulation, comparison and graphing were used to interpret the scientific results. The processed data are presented in average values per years of research. The differences between the groups were compared at a significant level of 0.05 using the Tukey test (Dospehov, 1985).

Results and Discussions

In modern pomiculture, the shape, structure and dimensions of the crown play a major role in ensuring the conversion of solar energy in fruit, its quality, as well as the productivity of manual pruning and harvesting. These aspects generated the necessity to research a long period of cherry tree pruning (Table 1). The maintenance and fruiting pruning of cherry trees in the first decade of September were carried out during the period 2018 to 2019, and the pruning during the rest, flowering and post-harvesting periods was carried out in the years 2019 to 2020.

Fruit yield

The fruit yield in the first year of the research amounted to 27.5-31.3 kg per tree. The highest yield was obtained when the pruning was performed during the vegetative period (G3, G4), while the pruning performed during the rest period (G1) and during the flowering period (G2) resulted in non-substantial reductions of crop per tree which constituted from 6 to 13 %. The results were confirmed by the previous data (Balan et al., 2017) regarding the extensive cherry orchards of Valerii Cicalov and Record varieties in the sense that the annual pruning of the secondary branches during the tree vegetative period and the maintenance and fruiting pruning during the vegetative period ensures the growth of new vigorous fruit branches of average length on the main branches of the trees. The non-essential reduction of the yield is the result of the identical technology of tree pruning during the rest and vegetative periods (Babuc, 2012).

In 2020, the yield of cherries decreased considerably and constituted only 17.1-19.6 kg per tree, i.e. it was by 36.1-38.3% less compared to 2019. The reduction in fruit yield in 2020 was due to low temperature during the flowering and very high temperature during the growing season.

Table 1. The impact of tree pruning on the production, number, weight and diameter of cherry fruit of „Regina" variety grafted on Maxima 14 rootstock

Pruning period	Yield, kg/tree	Number of fruit on a tree, pc.	Fruit weight, g	Fruit diameter, mm
Year 2019				
Pruning during the rest period (control)	27,7	2479	11,2	28,8
Pruning during the flowering period	27,5	2525	10,9	28,5
Post-harvest pruning	29,4	2800	10,5	28,5
Pruning in early autumn (the first decade of September)	31,1	2678	11,6	29,5
LSD, 5%	1,9	-	0,44	0,66
Year 2020				
Pruning during the rest period (control)	17,1	1571	10,6	27,9
Pruning during the flowering period	19,4	1950	9,6	27,7
Post-harvest pruning	18,7	1911	9,8	27,8
Pruning in early autumn (the first decade of September)	19,6	1795	10,9	28,5
LSD, 5%	2,5	-	0,72	0,51

The impact of pruning on the number of fruits

In 2019, the pruning during the rest and the flowering periods reduced the number of fruits by 19.6 and 11.8%, respectively, compared to the number of fruits harvested after the post-harvest pruning. This reduction in the number of fruits during the vegetative dormancy suggested that there was no significant limitation in the supply of the fruit with carbohydrates depending on the pruning period. The number of fruits, when the pruning was performed during the flowering period (G2) and in early autumn (G4), coincided with the number of fruits in control (2525-2678 pcs/tree). In 2020, the number of fruits varied from 1571 pcs/tree in G1 to 1950 pcs/tree in G2. The number of fruits in the groups in which the pruning during the flowering period (G2) and the post-harvest pruning (G3) was performed was significantly higher compared to the number of fruit when the pruning during the rest period (G1) and the pruning in early autumn (G4) were used.

Fruit weight and diameter

The weight of the fruit differs depending on the climatic conditions and the management of an orchard. In 2019, the fruit yield was high (27.5-31.1 kg/tree), and the weight of the fruit amounted to 10.5-11.6 g; in 2020, the fruit weight decreased (9, 6-10.9 g), and the yield per tree also decreased (17.1-19.6 kg/tree). The situation was due to the unfavourable climatic conditions, i.e. low temperature and high humidity during the flowering, as well as high temperature during the vegetation period, which decreased not only the yield but also the fruit weight. The pruning performed during the rest period and in early autumn had a good impact on the fruit, i.e. increased their weight in 2019 (11.2-11.6 g) and in 2020 (10.6-10.9 g) as compared with the pruning performed during the flowering period and the after-harvest pruning, but not always the data were statistically proved.

The diameter of the fruit at the time of harvest was in interdependence with its weight, namely in 2019 it amounted to 28.5-29.5 mm and in 2020 it was 27.7-28.5 mm. During the research period, in the groups in which the pruning was performed during the rest period (G1) and in the first decade of September (G4), the diameter of the fruit was larger, but the difference was unessential as compared to the pruning performed during the flowering period (G2) and the post-harvest pruning (G3).

The impact of pruning on the fruit quality parameters

In 2019, the soluble dry matter amounted to 18.12-19.27 °Brix; in 2020, the content of soluble substances in fruit decreased and amounted to 17.29-18.31 °Brix. Thus, the values of soluble dry matter content differed slightly from year to year and almost did not depend on the pruning period used. In 2019 the titratable acidity in fruit amounted to 0.65-0.68 mg of malic acid/100 g-^{1}; in 2020 it amounted to 0.75-0.78 mg malic acid/100 g^{-1}. It should be mentioned that, in 2020, while the soluble dry matter content in fruit decreased, the titratable acidity increased. These results concerning the „Regina" variety grafted on the Maxima 14 rootstock are constant values and slightly differ depending on the period of tree pruning (Table 2).

Table 2. The impact of the tree pruning on the quality parameters of the cherry fruit of „Regina" variety grafted on Maxima 14 rootstock

Pruning period	**Soluble dry matter (°Brix)**		**Titratable acidity, mg of malic acid/ 100 g^{-1}**	
	Year 2019	**Year 2020**	**Year 2019**	**Year 2020**
Pruning during the rest period (control)	18,77	17,84	0,67	0,76
Pruning during the flowering period	18,33	17,52	0,65	0,78
Post-harvest pruning	18,12	17,29	0,66	0,75
Pruning in early autumn (the first decade of September)	19,27	18,31	0,68	0,76
LSD, 5%	0,76	1,08	0,21	0,38

Monitoring the diameter of the cherry fruit during its development

The evolution of fruit growth during the ripening period depends on the variety-rootstock combination and does not depend on the tree pruning period (Ivanov, et al., 2015). When the cherries begin to ripen and the skin colour changes from green to yellowish-pink, the intensity of fruit growth is higher compared to the following maturity periods (fig. 1, 2).

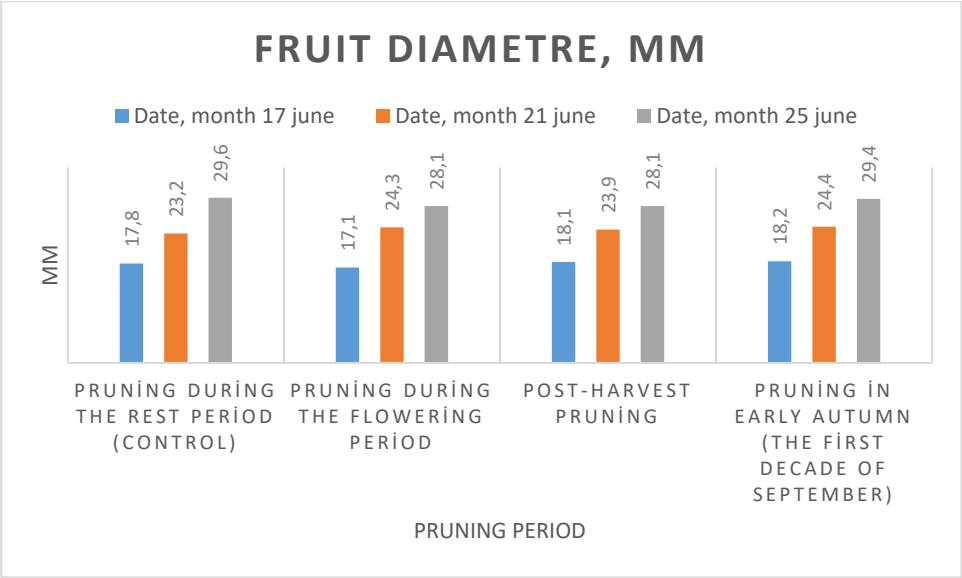

Figure 1. The impact of tree pruning on the diameter of the cherry fruit of „Regina" variety, grafted on Maxima 14 rootstock, during the development process from the moment when the fruit was pink-yellow, year 2019

In 2019, when the skin of the cherries was yellow-pink, their diameter was 17.1-18.2 mm, and when it was light red, it was 23.2-24.4 mm, or by 30.3-42.1% larger. Then, from the stage when it became light red till the stage when it was dark red, the diameter of the fruit increased by only 23.5-26.2%. The same tendency was registered in 2020, i.e. once the cherries had reached the light red colour, the rate of increase of their diameter decreased. Therein, the increase in the diameter during the ripening period continued and constituted 55.2-66.3% in 2019 and 45.5-49.7% in 2020.

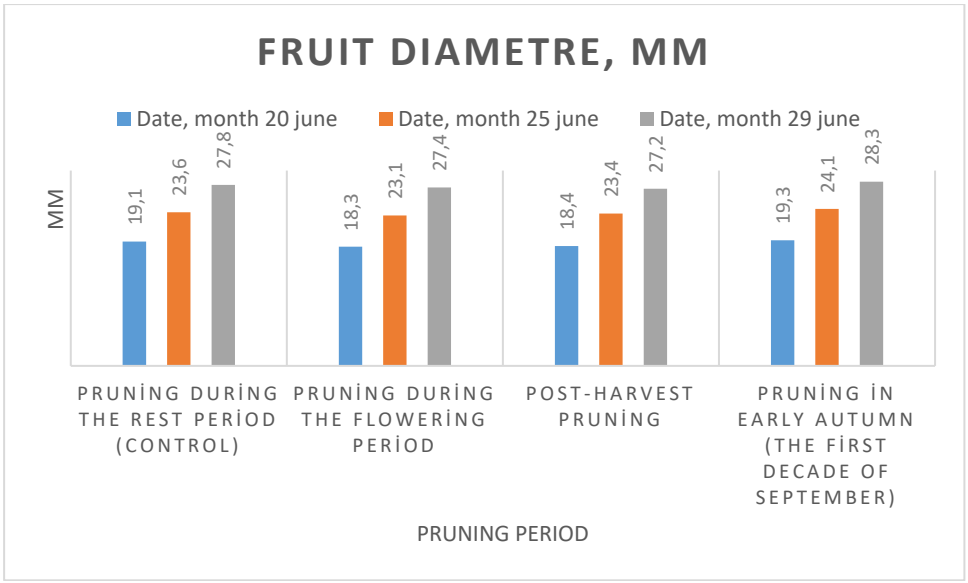

Figure 2. The impact of tree pruning on the diameter of the cherry fruit of „Regina" variety, grafted on Maxima 14 rootstock, during the development process from the moment when the fruit was pink-yellow, year 2020

Thus, from the moment when the cherries entered the ripening period until their maturity, the diameter of the fruit of the „Regina" variety, grafted on the Maxima 14 rootstock, increased considerably, almost doubling in size regardless the variants of tree pruning. The results were

confirmed by the data reported by Balan V. et al. (2017) regarding the „ Ferrovia" and „Regina" varieties, grafted on the Gisela 6 rootstock, in the sense that the weight of the fruit increased by over 40% and their diameter – by over 18%.

Fruit size distribution effects

The yield and quality of cherries change depending on climatic conditions and the period of tree pruning. The commercial value of the fruit is determined, first of all, by its size and colour, and then by its firmness, taste and aroma. From a commercial point of view, the cherry size is determined by the fruit diameter or weight, which can be further divided into fractions with a diameter smaller than 24 mm; 24-25.9 mm; 26-27.9 mm; 28 mm and larger (fig. 3, 4).

In 2019, the largest distinctly significant crops, by 12.3%, were produced by the trees pruned in early autumn (G4). The trees in control (G1) produced 4.2% of fruit with a diameter of 24 mm and downwards, 11.4% – of 24-25.9 mm, 51.5% – of 26-27.9 mm and 31.9% of the fruits had a diameter of 28 mm and upwards. When the pruning was performed during the vegetation period (G2, G3, G4) the distribution of the fruit according to their diameter was similar to that when the pruning was performed during the rest period (control), namely over 80% of the fruit had a diameter larger than 26 mm, and only 2.9-6.2% of the fruit had a diameter of smaller than 24 mm. The pruning done during the rest period (G1) and the one done in the first decade of September (G4) resulted in a heavier crop of fruit with a diameter of 28 mm and upwards (31.9-36.1%).

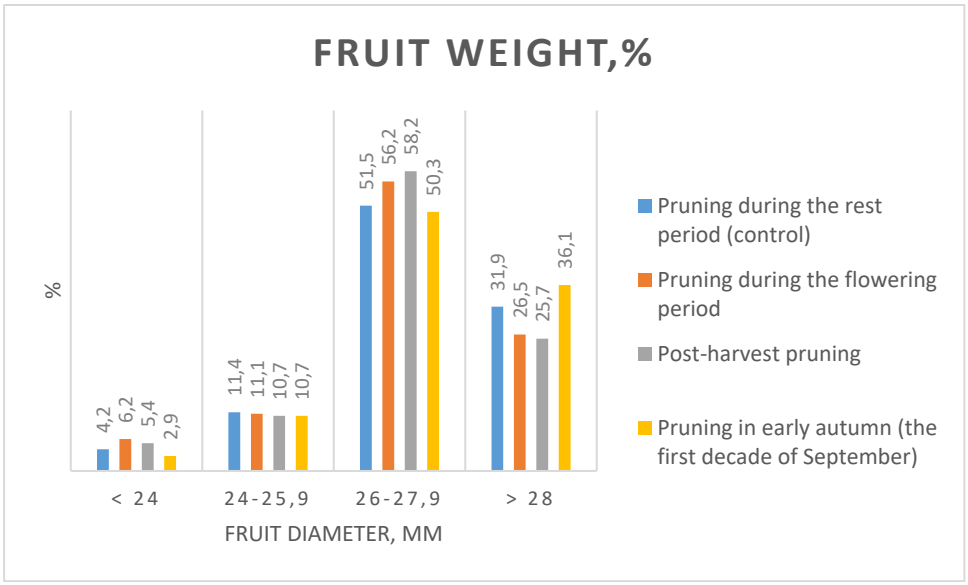

Figure 3. The impact of tree pruning on the distribution of cherry fruit of „Regina" variety, grafted on Maxima 14 rootstock, depending on their diameter, year 2019

In 2020 the fruit harvest was worse (11388-13053 kg/ha) compared to 2019 (18315-20712 kg/ha); the diameter of the fruit also decreased. For example, the trees in G3 produced 12454 kg/ha of fruit, of which 33.1% had a diameter smaller than 26 mm and only 11.2% had a diameter of 28 mm and upward. The same tendency was registered in the groups (G1, G2, G4) in which other periods of tree pruning were used, namely a large amount of fruit (24.4-27.6%) had a diameter smaller than 26 mm and only 11.2-18.3% of the fruit exceeded the diameter of 28 mm.

To sum up, it is necessary to mention that the pruning in early autumn (G4) had a great impact on the reduction of the percentage (1.6-2.9%) of fruit with a diameter of 24 mm and downward and increased the crop of fruit (18.3-36, 1%) the diameter of which amounted to 28

mm and upward, without affecting the total yield.

Analysing the values of the yield and fruit diameter in the cherry variety „Regina", grafted on the rootstock Maxima 14, depending on the period of tree pruning, and comparing them with the data presented by other authors (Ivanov I., et al. 2015; Bennewitz, E., et al. 2016), the efficiency of tree pruning in early autumn, especially the impact of pruning during the vegetative period on the fruit upsizing, can be reconfirmed.

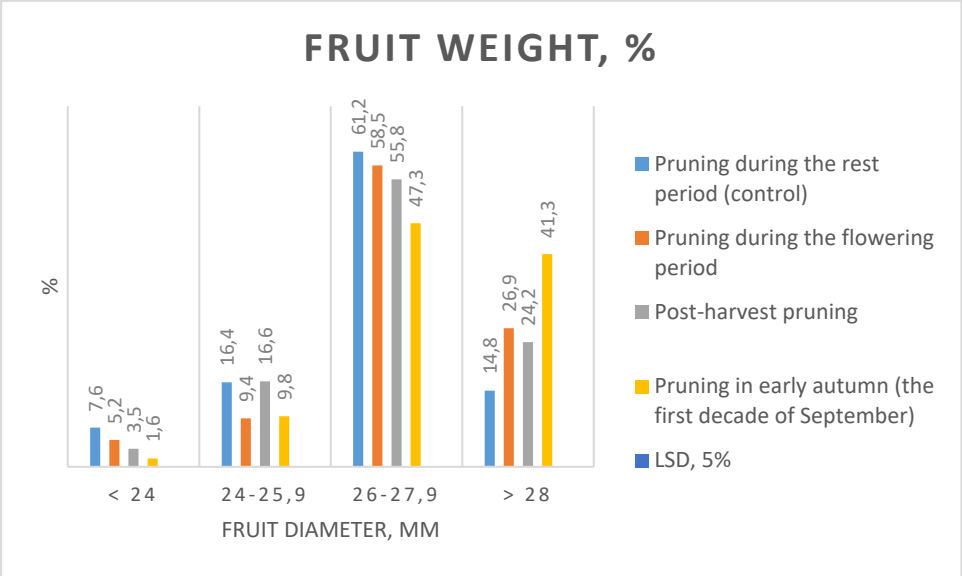

Figure 4. The impact of tree pruning on the distribution of cherry fruit of „Regina" variety, grafted on Maxima 14 rootstock, depending on their diameter, year 2020

Conclusions

Fruit yield varied greatly depending on climatic conditions characterized by late spring hoarfrost during the blossom of the cherry trees and high temperature during the vegetative stage. The periods of tree pruning significantly affected the yield and quality of the fruit in the „Regina" cherry variety grafted on Maxima 14 rootstock. In 2019, the highest values (31 kg/tree), by 13% higher, were observed in the trees in the group in which the pruning was performed in the first decade of September (G4). In 2020, the harvest in G4 decreased substantially, and amounted to only 19.6 kg/tree.

The fruit were uniform and had an average diameter of 27.7-29.8 mm. From the moment, when the cherries became yellow-pink and until their maturity, their diameter increased considerably, almost doubling in all the groups in which pruning was performed. The values of the soluble dry matter content (17,29-19,27 °Brix) and the titratable acidity in fruit (0,65-0,78 mg malic acid/100 g^{-1}) were constant and almost did not depend on the tree pruning period.

It was determined that the pruning during the rest period, when it was used as a strategy to maintain the physiological balance between growth and fruiting and to manage the number of fruit of „Regina" variety grafted on the Maxima 14 rootstock number, had a sufficient impact on the fruit yield and quality. The pruning during the flowering period can to be performed when the buds have overwintered well and the climatic conditions are favourable for fruit binding, especially in self-fertile varieties. The post-harvest pruning can reduce the assimilation of the organic substances necessary for fruit bud formation in the following year. Therefore, long-term studies should be carried out to assess the impact of pruning on yield and, especially, on the diameter, weight and distribution of fruit of commercial size.

The pruning performed in early autumn contributed positively to the increase of the fruit average weight and the fruit distribution depending on their diameter, at the same time reducing

the number of fruit per tree. It also had a great impact on the reduction of the percentage (1.6-2.9%) of fruit with a diameter of 24 mm and downwards and the increase of the number of fruit (18.3-36.1%) with a diameter of 28 mm and upwards without affecting the total yield.

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