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Early ripening and marketability of the products in different types of the sweet cherry orchards in the Ukrainian Forest-Steppe

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The considerable vigour of the sweet cherry (*Prunus avium* L.) trees' growth and their late fruit-bearing beginning complicate the industrial highly efficient orchard creation. Besides, the requirements of the global trade networks increased to the fruit marketable quality as well. Therefore, the purpose of our research was the selection of large-fruited cultivars bred in Ukraine as well as clonal rootstocks including Gisela 5, Gisela 6, and Studenykivska as well as cvs Krupnoplidna, Etyka, and Annushka appeared to influence positively the beginning of the orchards fruit-bearing, the acceleration of the early maturity, providing the constantly high fruits productivity and marketable quality. The field, laboratory, and comparative methods of the investigations were applied as well as the statistical ones. The highest productivity was ensured by the semi-vigorous rootstocks (like Gisela 6). Their average yield per tree in the five-year age was 14.4–18.5 kg.tree^{-1} depending on the variety. The maximum number of trees loaded with fruits was provided by Krupnoplidna (28.9 kg.tree^{-1}). On account of the surface unit was 25.7 t.ha^{-1}. It was noted that irrespective of this index the trees at a young age were able to ensure the highest fruits marketable quality. The highest qualitative indices were provided in the orchards where the cultivar of the middle and middle-late ripening terms were used in which products unidimensional job lots were formed (74.8–100%) with the fruit diameter 29.8–35 mm. At the same time more rapid rates of fruits diminution were noted in the orchards on the semi-dwarfing rootstocks 'Gisela 5' and 'Studenykivska' where the average fruit mass in the eight-year age reduced almost by two times as compared to those which were formed in the 5–6 year orchards. Therefore, it is most expedient to create cherry plantations on semi-vigorous rootstock Gisela 6, which provides 1.8–2.1 times higher productivity of trees, as well as the high marketable quality of fruits during the period of productive use of plantations.

Keywords: *Prunus avium*, orchard constructions, clonal rootstocks, marketability, products quality

Introduction

Among the fruit crops sweet cherry (*Prunus avium* L.) is the least favorable for intensive horticulture. The trees of this crop are characterized by great vigour and late fruit-bearing beginning that complicates the creation of early ripening low-holed orchards. One of the optimum methods of solving this problem is utilizing clonal rootstocks (Balmer, 2015; Musacchi et al., 2015; Grandi and Lugli, 2017; Bujdoso and Hrotko, 2019).

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Under modern conditions the requirements of the global trade networks for sweet cherry fruits marketable quality increased considerably the diameter of which should exceed 28 mm that demands the selection of large-fruited cultivars (Kappel et al., 2012; Quero-Garcia et al., 2017; Szpadzik et al., 2019). According to the FAOSTAT data (2021). Ukraine was included among the ten leading sweet cherry fruit producers with a total crop of 61.8 thousand t and a yield of 6 $t.ha^{-1}$.

Today, there are more than 2000 varieties of this culture in the world. Ukraine is the world leader concerning the creation of this crop cultivar. Only in the last 30 years, about 500 new cherry cultivars were created, of which more than 100 were created by Ukrainian breeders (Milatović and Nikolić, 2011).

Nowadays, in the State Register of Varieties of Ukraine suitable for distribution in Ukraine, among the 28 registered cultivars, domestic cultivars predominate and only four (Regina, Summit, Cordia, Bigarreau Burlat) are foreign selected (State Register, 2022). This ensures self-sufficiency according to this indicator and makes it possible to choose adapted varietal composition of plantings for various reasonable and climatic conditions.

Ukrainian breeders have created large-fruited cherry varieties with high taste qualities with an average fruit weight of 10–12 g, which can exceed 18 g under the conditions of irrigation (Turovtsev and Turovtseva, 2002). Therefore, they meet the requirements of global trade networks.

In this connection, it is actually to select inland large-fruited cultivars as well as dwarf rootstocks that would contribute to the decrease of the tree's unproductive period and ensure the products stable high productivity and marketable quality.

Material and methodology

Plant material and setting up the experiment

The experiments were conducted in the orchards of the Institute of Horticulture of the National Academy of Agrarian Sciences (IH NAAS) of Ukraine (Kyiv) in two field experiments.

In the first experiment (the elaboration of effective sweet cherry (*Prunus avium* L.) orchards types to obtain competitive fruits, planting in 2015) the cultivars Melitopolska Myrna, Krupnoplidna, Etyka, and Annushka were studied in the orchards on the four clonal rootstocks, in particular, vigorous were researched as wells –vigorous Colt (5 × 3 m), semi-vigorous Gisela 6 (4.5 × 2.5 m) and semi-dwarfing Gisela 5 and Studenykivska (4.5 × 2.0 m).

In the second experiment (selection of competitive strains for industrial orchards, planting in 2018) 25 large-fruited inland cultivars of different ripening rates were researched as well as two foreign ones on the semi-vigorous rootstock Gisela 6 (4.5 × 2.5 m). Control cultivars were Valery Chkalov (early), Talisman (middle), and Lyubava (middle and late), which are included in the State register of the cultivars of the plants valuable for the spread in Ukraine for 2022 in accordance with the terms of their maturity (Table 1).

Research methodology

There were 9 estimated trees in each variant with the orbicular crown and lowered fruit-bearing zone. The repetition was three-fold. The soil of the experimental plots (dark-grey, podzol, light loamy, on the carbonate loess) was managed on bare fallow without irrigation.

Conducted a study on early ripening, fruit productivity, and marketable quality. Estimates and observations in conformity with the main indicators of growth and fruit-bearing were carried out by applying the accepted methods (Karpenchuk and Melnyk, 1987; Syedov and Ogoltsova, 1999; Metodica..., 2005), in particular, early fruiting was assessed by counting flowers and fruits on 9 typical trees of each variant. After removing these fruits, the yield from each tree was recorded using the weight method. The average weight of the fruit was determined by weighing 100 fruits from each variant of the experiment. The marketability of the collected products was determined according to GSTU 01.1-37-165:2004 and by dividing them into fractions according to the transverse diameter of the fruit: 19.0–22.9 mm, 23.0–27.9 mm, 28.0–29.7 mm, 29.8–31.3 mm and 31.4 mm and more.

Statistical analysis

For processing the experimental research results statistically and determining the reliability and substantiality of the obtained data the dispersing method of the statistical analysis was used with the application of the computer program AGROSTAT. The value will be presented as the mean value of the standard deviation (SD). The data were analyzed for statistical significance with the help of the Student's *t*-test. *P* values less than 0.05 were considered significant.

Table 1 List of cultivars of cherry (*Prunus avium* L.) that are being studied in experiment 2, rootstock Gisela 6 (4.5 × 2.5 m) (planting in 2018)

Cultivars of the early and middle early ripening term	Cultivars of the middle maturity term	Strains of the middle-late and late ripening term
Valery Chkalov (control)	Talisman (control)	Lyubava (control)
Skazka	Krupnoplidna	Temporion
Dzherelo	Dilema	Zodiak
Valeriya	Vasylisa Prekrasna	Udivityelna
	Elektra	Anonce
	Melitopolska Myrna	Nizhnist
	Yaroslavna	Anshlag
		Novynka Turovtseva
		Etyka
		Annushka
		Donetska Krasunya
		Donchanka
		Bigarreau Hatif Burlat
		Regina

Results and discussion

To ensure rapid fruiting of cherry plantations in the practice of global industrial horticulture, weakly growing clonal rootstocks are used (Santos et al., 2006; Cantin et al., 2010; Long et al., 2017; Vignati et al., 2022).

Our observations of the plant's development in the orchard showed that their early maturity and productivity depended to a considerable degree both on a cultivars and rootstock (Figure 1). For example, in the third year after planting already in the orchards on cultivars Gisela 5, Gisela 6, and Studenykivska nearly all the trees (83–100% of their total amount in these variants) the establishment of fruit bud) was noted while on the rootstock Colt, they were absent altogether. The highest extent of the generative bud establishment on the mentioned rootstocks contributed to their early fruit-bearing beginning. The individual strain peculiarities were established for flower creation on the three-year trees. For instance, cultivars Krupnoplidna, Etyka, and Annushka had 180–250 individuals while cultivar Donchanka had their largest number of 320 which testified to these cultivars' early ripening on the low-holed clonal rootstocks. The trees of the above-mentioned cultivars on Gisela 6 proved the most productive ones at the beginning of the fruit-bearing. Their yield in the fourth year after planting with one-year planting trees was 3.2–4.1 kg.tree^{-1}, whilst in the fifth 12.7–15.5 kg.tree^{-1}, which is 1.6–2.6 times higher than on rootstocks Gisela 5 and Studenykivska. On the rootstock Colt the self-contained fruit-bearing was noted in the fourth year after planting and the next year the yield did not exceed 0.3–0.4 kg.tree^{-1}.

On average during five fruit-bearings on Gisela 6 (the cultivars Krupnoplidna, Annushka, and Etyka) was 10.3–13.1 kg.tree^{-1}, that is by 1.8–2.1 times higher than on the rootstocks Gisela 5 and Studenykivska and on the Colt did not exceed 0.7–5.7 kg.tree^{-1}. The increase in tree productivity by year and their marketability are presented in Figure 1 by the cultivar Krupnoplidna. A similar regularity was observed in the other studied cultivars of Annushka, Etyka, and Melitopolska Myrna.

The analogous results as regards the positive effect of Gisela 6 as well as Egervar on the sweet cherry fruits' productivity and marketability were achieved by Hungarian scientists (Bujdoso and Hrotko, 2016).

During the research years, the marketability of the product depended on strain peculiarities, rootstock, and orchard age. As for as the age rose the fruit size on rootstocks of different vigour reduced gradually. It achieved 19.3–24.3% on the middle rootstocks in the eight-year age. At the same time on the vigorous rootstock Colt, the fruit size decrease was not observed (Report, 2022).

More rapid rates of the physical indexes decrease were noted on cultivars Gisela 5 and Studenykivska. Their fruit's average mass was reduced nearly by two times in the eight-year age as compared to those

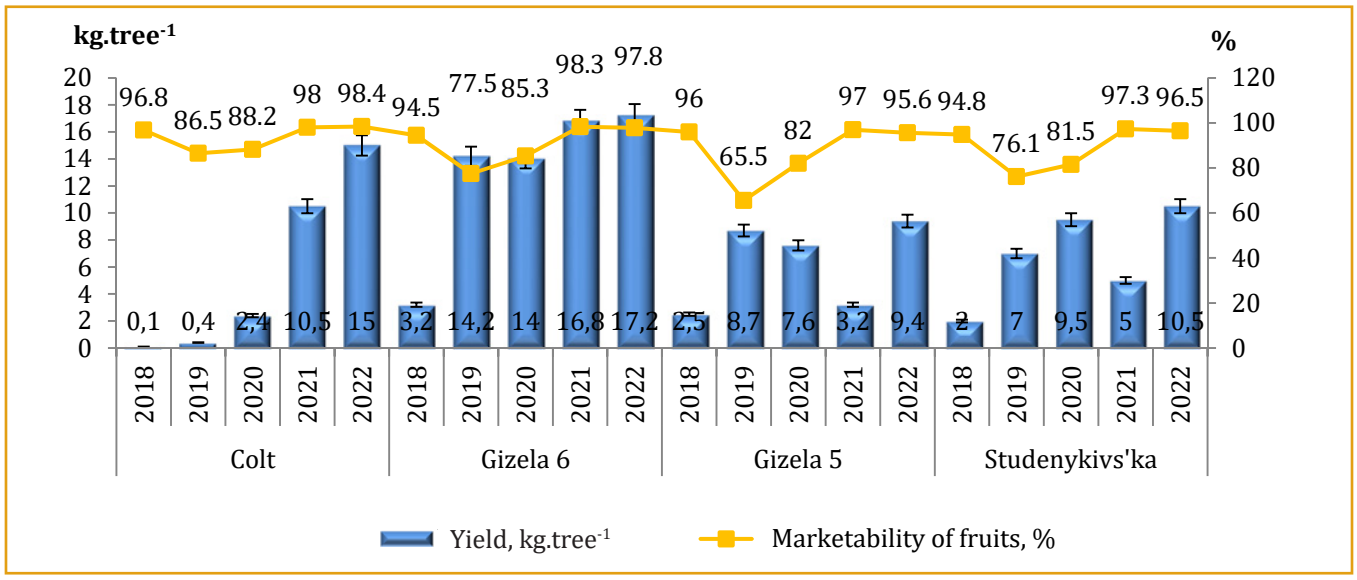

Figure 1 Sweet cherry cultivar Krupnoplidna productivity and marketability of fruits on different rootstocks, 2018–2022

which were formed in 5–6 year orchards (9.1–9.8 g). The description is presented of the sweet cherry large-fruited cultivars bred in Ukraine on the highly productive middle rootstock Gisela 6.

The world's market tendencies testify that today fruits with a diameter of more than 28 mm are considered they have dark coloration and dense flesh. That contributes to their high transportability (Yue et al., 2014; Meland et al., 2017; Blanko et al., 2019). Leading countries-exporters of sweet cherry conduct active searches of large-fruited strains with transportable fruits to ensure high profitableness of this business (Naranjo, 2013; Long et al., 2021).

The main indicator that regulates the commercial quality of cherry fruits is their transverse diameter. In EU countries, the requirements for the quality of fruits of this breed are regulated by the standard of the UN European Economic Commission, where cherry fruits of the highest grade must have a diameter of at least 20 mm, and fruits of the first and second grade at least 17 mm (Standart FFV-13, 2017).

The US State Standard (Washington standards, 2005) has the highest level of requirements for the commercial quality of cherry fruits, by which it is normatively established that the minimum size of fruits in terms of the largest diameter should be at least 21.4 mm. With this in mind, active efforts are being made to breed and select large-fruited varieties in the leading cherry fruit-producing countries (Campoy et al., 2015; Dong et al., 2022; Szilágyi et al., 2022).

In our experiments, the fruits calibration as concerns the largest cross diameter showed that their highest indexes of linear and marketability were provided on middle rootstock in the first years after the tree's fruit-bearing beginning. For example, in experiment 2 in the fifth year after planting among early cultivars unidimensional job lots with a fruit diameter of 23–28 mm were formed by cultivars Valery Chkalov, Kazka, and Dzherelo (83.7–100%).

Among the cultivars of the middle maturation rate, it is Dzherelo that belonged to this group (92%), and such as Talisman and Electra ensured linear job lots at a level of 74.2–93.8% with the diameter of the fruit 28–29.7 mm. This met the global trade network requirements and testified to the high inland strains competing (Table 2).

The highest marketability indices were provided by the cultivars of the middle-late ripening rate. Bigarreau Hatif Burlat (74.8%), Vasylisa Prekrasna (96.8%), and Temporion (99.3%) are among them and formed job lots with the fruit diameter 29.8–31.3 mm and such as Krupnoplidna and Etyka had the highest level (100%) with the fruit diameter 34–35 mm.

Talisman (14.4 kg.tree^{-1}), Etyka (14.8 kg.tree^{-1}), Krupnoplidna (17.3 kg.tree^{-1}), Anonce (18.3 kg.tree^{-1}), Anshlag (18.5 kg.tree^{-1}) and Donchanka (20 kg.tree^{-1}) distinguishing themselves for the highest average yield in the five-year age (Report, 2022). The maximum load of the trees with fruits was ensured by cv Krupnoplidna – 28.9 kg.tree^{-1}. In the account the surface unit was 25.7 t.ha^{-1}. The largest fruits of this variety formed a mass of 18.4 g with the largest cross diameter of 35 mm and the one-dimensionality of the products was 100% which testified that irrespective of

Table 2 Structure of the sweet cherry fruit marketable quality concerning their cross diameter (%)

Cultivars	General marketability of fruits (100%)				
	including share of the fruits by fractions with the diameter (%)				
	19.0–22.9 mm	23.0–27.9 mm	28.0–29.7 mm	29.8–31.3 mm	31.4 mm and >
Cultivars of the early and middle early ripening term					
Valery Chkalov (control)	3.6 ±0.9	96.4 ±0.9	0	0	0
Skazka	0	100	0	0	0
Dzherelo	16.3 ±0.6	83.7 ±0.6	0	0	0
Valeriya	5.6 ±0.6	94.4 ±0.6	0	0	0
Cultivars of the middle maturity term					
Talisman (control)	6.8 ±0.9	19.0 ±1.3	74.2 ±1.3	0	0
Krupnoplidna	0	0	0	0	100
Dilema	8.0 ±1.5	92.0 ±1.5	0	0	0
Vasylisa Prekrasna	0	0	3.2 ±0.5	96.8 ±0.5	0
Elektra	0	6.2 ±0.6	93.8 ±0.6	0	0
Melitopolska Myrna	5.8 ±0.4	35.3 ±2.2	58.9 ±2.3	0	0
Yaroslavna	7.8 ±1.3	92.2 ±1.3	0	0	0
Strains of the middle-late and late-ripening term					
Lyubava (control)	0	8.5 ±0.6	91.5 ±0.6	0	0
Temporion	0	0.72 ±0.7	0	99.3 ±0.7	0
Zodiak	2.6 ±0.6	2.7 ±0.8	94.7 ±1.4	0	0
Udivityelna	0	14.4 ±1.2	85.6 ±1.2	0	0
Anonce	0	11.9 ±0.4	88.1 ±0.4	0	0
Nizhnist	0	85.3 ±0.6	14.7 ±0.6	0	0
Anshlag	0.4 ±0.3	22.6 ±2.0	77 ±1.7	0	0
Novynka Turovtseva	9.3 ±0.7	90.7 ±0.7	0	0	0
Etyka	0	0	0	0	100
Annushka	0	5.9 ±0.6	94.1 ±0.6	0	0
Donetska Krasunya	0	5.7 ±0.6	94.3 ±0.6	0	0
Donchanka	4.2 ±0.9	95.1 ±0.9	0	0	0
Bigarreau Hatif Burlat	0	0	25.2 ±0.9	74.8 ±0.9	0
Regina	0	4.3 ±1.1	95.7 ±1.1	0	0

within rows, means differ ($p < 0.05$)

the load degree the trees in the young age were able to provide the highest indicators of the fruit marketable quality.

It should be noted that Valeriy Chkalov and Krupnoplidna varieties are donors of high fertility and are widely used in industrial plantations of various countries and breeding programs (Turovtsev and Turovtseva, 2002; Kishchak and Kishchak, 2015; Kishchak, 2017). Today, China has the world's largest fresh cherry fruit market, and Hongdeng and Krupnoplidna are the most popular varieties in industrial orchards in this country (Zhang et al., 2019). In Latvia, which is located between 55–56° north latitude, the basis of the industrial assortment is the Ukrainian varieties Krupnoplidna and Valery Chkalov and the Canadian variety Lapins (Ruisa, 2008). In the Research and Breeding Institute of Pomology Holovousy (Czech Republic) sweet cherry cultivar Tamara with fruits is rather large bred from crossing cherry varieties Krupnoplidna × Van. This variety has become widespread in Europe, is being studied in the USA, and is even successfully exported from Australia to Hong Kong at high prices (Vávra et al., 2021).

The description is presented of the sweet cherry large-fruited cultivars bred in Ukraine on the highly productive middle rootstock Gisela 6. These cultivars stood out during our research.

Krupnoplidna

A middle ripening cultivar that ripens at the beginning of the third decade of June created a the Melitopol Research Station of Horticulture as a result of the pollination of the cultivar Napoleon Bila with the mixture of the pollen of the strains Valery Chkalov + Elton + Jabule (Figure 2).

The tree is vigorous, the crown is orbicular with middle density and begins fruit-bearing in the third year after planting ensuring a yield of 17.3 kg.tree^{-1} (maximum 28.9 kg.tree^{-1}) on the middle clonal rootstock in the five-year age and the fruit-bearing age 45–50 kg.tree^{-1} (Report, 2022). The fruits are very large, linear, and wide-orbicular, with a diameter of 28–29 mm, and an average mass of 10.0 g (maximum 18.4 g with a diameter of 34–35 mm). The colour is dark-red. The skin is thin, dense, and shining, and the tear-off from the fruit is dry. The flesh is dark-red, cartilaginous, and juicy. The taste is sour-sweet. The degustation valuation is 8.8 points (in accordance with the 9-point scale). The fruits contain 14.6% of dry soluble substances, 12.1% of sugars, and 0.7% of acids. The stone is large and round, it separates from the flesh not completely (Report, 2022).

The cultivar is resistant to monilia (*Monilia cinerea*) and affectioned weakly with cocomycosis (*Cocomyces hiemalis*), high winter-hardy. Plants of this cultivar are partially self-fertile. The best pollinators are Surprise, Franz Josef, Donchanka, and Bigarreau Hatif Burlat. Since 1983 cultivars is spread in the Ukrainian Forest-Steppe and Steppe.

Figure 2 Fruit-bearing of the cultivar Krupnoplidna

Etyka

Middle-late cultivar ripes the third decade of June created at the Donetsk Branch of IH NAAN of Ukraine as a result of crossing the cultivar Donchanka × Valery Chkalov (Figure 3).

Figure 3 Fruit-bearing of the cultivar Etyka

The tree is middle-growing with the orbicular branchy ramified well crown, and begins fruit-bearing in the third-four years after planting providing an average yield of 14.8 kg.tree^{-1} (maximum 21.7 kg.tree^{-1}) and in the fruit-bearing age of 45–60 kg.tree^{-1}(Report, 2022). The fruits are rather large, unidimensional, and wide-orbicular, with an average mass of 10–11 g and a diameter of 29–30 mm (maximum 18.1 g with a diameter of 34–35 mm). The skin is thin, dense, and shining, and the tear-off from the fruit is dry. The flesh is dark-red, juicy, cartilaginous, its taste is pleasant sour-sweet. The degustation valuation is 8.7 points. The fruits contain 18.6% of dry soluble substances, 13.6% of sugars, and 0.6% of acids. The stone is small, it separates easily from the flesh (Report, 2022). Etyka is resistant to major diseases, and high winter-hardy. The plants of this cultivar are self-fertile. The best pollinators are Donetskyi Ugolyok, Donchanka, Yaroslavna, and Annushka. The cultivar has been recommended for growing in the Forest-Steppe and Steppe of Ukraine.

Temporion

Middle-late cultivar ripens at the end of the third decade of June created at the Melitopol Research Station of Horticulture as a result of the pollinating Drogana

Zhovta with the mixture of the pollen of cultivar Valery Chkalov + Sonyachna Kulya (Figure 4).

Figure 4 Fruit-bearing of the cultivar Temporion

The tree is vigorous with the branchy crown of the middle density, and begins fruit-bearing in the third-fourth year after planting ensuring a yield of 5.7–7.0 kg.tree^{-1} in the fifth-year age and 40–50 kg.tree^{-1} in the fruit-bearing one (Report, 2022). The fruits are fairly large, linear, and wide-orbicular, with an average mass of 11.0 g and diameter of 29 mm (maximum 13.5 g and diameter 30–31 mm). The tear-off from the fruit stem is dry. The fruit's colour is dark-red. The skin is of middle thickness dense shining, and the tear-off from the fruit is dry. The flesh is dark-red, cartilaginous, and juicy. The taste is perfectly pleasant sour-sweet. The degustation valuation is 8.8–9.0 points. The fruits contain 16.4% of dry soluble substances, 13.0% of sugars, and 0.7% of acids. The stone is small orbicular and separates easily from the flesh (Report, 2022). The cultivar is resistant to monilia (*Monilia cinerea*), cocomycosis (*Cocomyces hiemalis*), and high winter-hardy. Plants of this cultivar are self-sterile. The best pollinators are Donchanka and Bigarreau Hatif Burlat. The cultivar has been recommended for cultivation in the Ukrainian Forest-Steppe and Steppe.

Conclusions

Thus, the investigation showed that semi-vigorous rootstock Gisela 6, in contrast to vigorous rootstock Colt and semi-dwarf ones (Gisela 5 and Studenykivska), contributes to stable high productivity of plantings and the formation of high marketable fruit quality during the period of operation of the garden (conclusion by of experiment 1). Middle, middle-late, and late-ripening term cherry varieties, in particular Krupnoplidna, Etyka, and Temporion, provide early fruiting and obtain 99.3–100% of fruits with a diameter of more than 29.8 mm, which meets the modern requirements of global trade networks (conclusion of experiment 2).

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