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Evaluation of Promising Sweet Cherry Cultivars on the Clonal Rootstock Krymsk 5 in the Forest-Steppe Zone

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ABSTRACT

One of the key factors in establishing commercial sweet cherry (*Prunus avium*) orchards is the selection of cultivars and rootstocks that optimize the yield of marketable fruit capable of commanding premium prices. This study aimed to identify large-fruited, high-yielding sweet cherry cultivars suitable for industrial-scale cultivation in the Forest-Steppe zone of Ukraine. A total of 23 cultivars grafted onto Krymsk 5 rootstock were evaluated at a planting density of 889 trees ha^{-1}, with assessments focusing on growth characteristics, precocity, yield, and fruit marketability. Among the early-bearing cultivars, 'Kazka' was distinguished by its compact crown architecture. In the mid-season group, 'Elektra' emerged as a notable performer, while the late-maturing group included promising cultivars such as 'Krupnoplidna', 'Annushka', 'Etyka', 'Anshlag', 'Anons', and 'Stark Hardy Giant'. By the seventh year, tree height ranged from 3.4 to 3.6 m, with crown volumes between 13.2 and 16.0 m^3. In terms of precocity and productivity, the late-maturing cultivars 'Zodiak', 'Anshlag', 'Anons', 'Donchanka', 'Etyka', and 'Krupnoplidna' were particularly noteworthy, yielding 11.3–16.4 t ha^{-1} in the fifth year after planting and 34.0–46.2 t ha^{-1} in the sixth year. The largest fruits, measuring 31.3–32.7 mm in diameter, were produced by 'Temporion', 'Etyka', and 'Krupnoplidna'. Overall, these cultivars exhibit strong potential for use in industrial orchards, combining high yields with fruit quality that meets the stringent standards of global retail chains.

Introduction

Sweet cherry (*Prunus avium*) is valued for its excellent flavor, consistently strong consumer demand, and high profitability. Although it accounts for only 0.4% of global fruit production, it maintains a stable presence in the fresh produce market. According to FAO data (2022), Ukraine ranks 12th worldwide, producing 58.2 thousand t annually, which represents 2.1% of the global total of 2.8 million t. Despite substantial reductions in cultivated area due to military conflict, Ukrainian sweet cherry orchards achieve an average productivity of 8.3 t ha^{-} which is 1.3 times higher than the global average. In commercial production, the optimal selection of high-yielding cultivars is crucial for ensuring orchard profitability. The primary objective is to maximize the volume of high-quality, marketable fruit capable of commanding premium prices (Balmer, 2015; Bujdosó and Hrotkó, 2016). In response to evolving quality standards in global retail markets, there has been a widespread renewal of industrial sweet cherry assortments. This trend favors large-fruited cultivars (Kappel et al., 2012; Kishchak, 2017; Szpadzik et al., 2019) that offer an extended harvest period, improved resistance to diseases and fruit cracking, and superior transportability (Iurea et al., 2018; Garcia, 2019).

Dark-colored fruits exceeding 28 mm in diameter are increasingly preferred by retailers (Szilágyi et al., 2022; Ayala et al., 2024; Vávra, 2024).

As marketability has declined in orchards planted on dwarf and semi-dwarf rootstocks, traditional approaches to establishing intensive orchards are being reconsidered. Attention is shifting toward medium- and vigorous-growth rootstocks (Sansavini and Lugli, 2014; Kishchak and Bondarenko, 2019; Kishchak, 2021; Stanislav, 2024). Research by Senin and Senin (2005), Kishchak et al. (2020), and Kondratenko et al. (2021) has identified the clonal rootstocks Gisela 6 and Krymsk 5 as among the most effective for establishing high-yielding sweet cherry orchards. Sweet cherry breeding in Ukraine began in 1928 under the leadership of H.S. Pokrovska at the Melitopol Research Station of Horticulture, part of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine. Since then, breeding efforts have expanded across diverse soil and climate zones through six research centers, resulting in the development and registration of more than 280 economically valuable cultivars in the State Register of Plant Cultivars Suitable for Distribution in Ukraine (Kopan', 1999; Omelchenko and Hrynyk, 2012). Genealogical analyses of modern Ukrainian sweet cherry cultivars reveal that most are first- or second-generation descendants of ancient Western European varieties. The predominant maternal lineage traces to the German cultivar 'Drogans Grosse Gelbe' and its Crimean-discovered clone 'Napoleon Bila'. On the paternal side, breeders have most frequently used 'Valerii Chkalov', obtained through open pollination of 'Kavkazka Rozheva' (Tolstolik, 2019).

Given the significant achievements of Ukrainian breeders in producing high-yielding, locally adapted cultivars, the selection of a competitive assortment for establishing modern commercial sweet cherry orchards in the Forest-Steppe zone remains a priority. The Forest-Steppe zone, with its moderate continental climate, fertile soils, and distinct seasonal fluctuations, offers both opportunities and challenges for sweet cherry cultivation. Winter hardiness, tolerance to spring frosts, resistance to prevalent fungal pathogens, and adaptability to episodic droughts are essential prerequisites for cultivar success in this region. Furthermore, the demands of the modern fruit market—favoring large, visually appealing fruits with consistent flavor, extended shelf life, and excellent transport resilience—require that cultivar evaluation goes beyond basic yield metrics. This study aimed to evaluate the biometric traits, productivity, and marketable fruit quality of promising large-fruited sweet cherry cultivars grafted onto the medium-vigorous rootstock Krymsk 5, a combination known for balancing high productivity with robust tree growth and orchard longevity. By identifying cultivars that unite superior horticultural performance with market-preferred fruit characteristics, the research seeks to provide a scientifically grounded basis for the formation of profitable, resilient orchard systems. Ultimately, the findings are intended not only to guide producers in the Forest-Steppe zone but also to contribute to Ukraine's broader strategic goal of maintaining its competitive position in both domestic and international sweet cherry markets, even under conditions of economic and geopolitical uncertainty.

Materials and Methods

Biological materials

The experiments were carried out from 2022 to 2024 in an orchard established in 2018 at the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (IH NAAS), located in Kyiv. The study examined 23 large-fruited sweet cherry cultivars encompassing a wide range of ripening periods, including 21 cultivars of Ukrainian origin and two of foreign origin. The control group consisted of three widely recognized cultivars officially listed in the State Register of Plant Varieties Suitable for Distribution in Ukraine: 'Valerii Chkalov' (early ripening), 'Talisman' (mid-season), and 'Lyubava' (mid-late to late ripening).

All cultivars were grafted onto the semi-vigorous Krymsk 5 rootstock and planted as one-year-old saplings using a linear spacing arrangement of 4.5 × 2.5 m. The experimental design followed a randomized complete block layout with three replications of three trees per cultivar (nine trees per treatment). Trees were trained to a rounded crown form with a lowered fruiting zone, and no support structures or irrigation systems were employed, reflecting rainfed orchard conditions. The orchard floor was maintained under a bare fallow (steam) system throughout the study period.

Biometric assessments, counts of fruit-bearing structures, crop load per tree, and measurements of average fruit weight were conducted according to the methodological guidelines of Karpenchuk and Melnyk (1987) and Kramer (1987), ensuring comparability with previous regional studies.

Tree growth

Trunk diameter was measured 30 cm above the graft union using a precision caliper. Tree height and crown diameter were recorded at the end of the vegetation period with a measuring rod, positioning the instrument at the level of the crown's greatest density. Crown diameter was calculated as the mean of two perpendicular measurements—parallel to and across the planting row. Shoot length was measured after the cessation of active shoot growth using a ruler, with measurements taken from the shoot base to the tip of the terminal bud.

The feeding area of trees is determined by the following formula:

$$s_n = b \cdot c$$

where S_n is the feeding area (m^2), b is the width of the row spacing (m), c is the distance between trees in a row (m).

The usable part of the feeding area is determined by the ratio of the area of the horizontal projection of the crown to the feeding area of the tree:

$$K_s = \frac{B_b \cdot B_c}{s_n} \times 100\%$$

$$K_s = \frac{a^2}{S_n} \times 100\%$$

where K_s is the usable part of the feeding area (%), B_b is the width of the crown across the row (m), B_c is the width of the crown along the row (m), a is the average width of the crown (m^2).

The volume occupied by the tree (V_δ) was calculated by multiplying its height (H) by the feeding area:

$$v_\delta = H \cdot s_n$$

The volume of a tree crown was calculated using the formula of the ellipsoid of rotation:

$$V_k = \frac{H \cdot B_b \cdot B_C}{1{,}91}$$

$$V_k = \frac{H \cdot a^2}{1{,}91}$$

where H is the height of the crown (m), a is its average width (m), $V_к$ is the volume of the crown (m^3).

The use of the crown volume (K_v) in percentage of occupied area by the tree was determined by the ratio of the crown volume ($V_к$) to the volume of the tree (V_δ).

$$k_V = \frac{V_к}{V_\delta} \cdot \times 100\%$$

Specific productivity of trees

To determine specific productivity, the yield per tree (kg $tree^{-1}$) was divided by the horizontal crown projection area (m^2), crown volume (m^3), and the trunk cross-sectional area (cm^2).

Fruit-bearing structures were counted separately on each recorded tree.

Yield assessment

Yield was determined by weighing the total harvest from the recorded trees using a weight-based method, with results expressed as the full yield per treatment variant. Average fruit weight was calculated from a representative sample of 100 fruits collected from all replications of each variant, weighed on a Radwag electronic balance with an accuracy of 0.01 g. Fruit dimensions, specifically the equatorial diameter (D), were measured on 50 fruits in three replications using a Luumytools digital caliper and a sizing ruler. These measurements adhered to the standards defined in the United States Washington Administrative Code (WAC), Chapter 16-414, Section 16-414-011, which specifies minimum size requirements for sweet cherries.

Statistical analysis

The study was conducted using a completely randomized block design with two factors: harvest stage and cultivar. Data were analyzed by analysis of variance (ANOVA), and mean values were compared at a significance level of $P \leq 0.05$ using both Tukey's Honestly Significant Difference (HSD) and Fisher's Least Significant Difference (LSD) tests. All statistical analyses were performed with Minitab software.

Results

The influence of cultivar-specific characteristics on the growth of sweet cherry trees grafted onto the medium-vigorous clonal rootstock Krymsk 5 was evaluated. At seven years of age, tree height varied between 3.4 m ('Kazka', 'Krupnoplidna', and 'Etyka') and 4.1 m ('Regina' and 'Temporion') (Table 1).

Analysis of trunk diameter growth in sweet cherry trees revealed pronounced variability among cultivars. The smallest trunk diameters, ranging from 12.9 to 13.1 cm, were recorded for 'Kazka' and 'Stark Hardy Giant,' while the largest values were observed in 'Temporion' (16.7 cm), 'Zodiak' (16.5 cm), and 'Annushka' (16.5 cm). The most intensive annual increases in trunk diameter occurred in 'Elektra,' 'Melitopolska Myrna,' 'Udivitelna,' 'Regina,' and 'Nizhnost,' with growth rates between 2.1 ± 0.7 cm and 2.3 ± 0.1 cm. In contrast, the lowest rates of annual trunk thickening were recorded for 'Kazka,' 'Krupnoplidna,' and 'Novynka Turovtseva,' ranging from 0.9 to 1.4 ± 0.4 cm. Crown volume was identified as the most reliable indicator of tree vigor during the fruiting period, as it integrates both tree height and crown width (measured along and across the row), thereby providing a comprehensive representation of the three-dimensional space occupied by a tree of a given cultivar. This parameter not only reflects the potential light interception and canopy photosynthetic capacity but also serves as a valuable metric for precise orchard design and planting density optimization. At seven years of age, 'Regina' trees exhibited the largest crown volume, reaching 19.1 m^3. Slightly lower values—within 10% of this maximum—were recorded for 'Temporion,' 'Donetska Krasunia,' 'Donchanka,' and 'Prostir,' with crown volumes ranging from 17.2 to 17.5 m^3 (Table 2).

Table 1. Biometric characteristics of sweet cherry trees of different cultivars on Krymsk 5 rootstock, 2024. Orchard planted in 2018.

Cultivars	Trunk diameter (cm)	Average annual trunk diameter increment	Tree height (m)	Average shoot length (cm)
Early and mid-early ripening cultivars				
Valerii Chkalov	14.5^{de}	1.9^{ab}	3.7^{abc}	72.2^{de}
Kazka	13.1^{gh}	0.9^{cd}	3.4^{c}	66.2^{g}
Rubinova rannia	15.8^{bc}	1.8^{ab}	3.8^{abc}	78.6^{abc}
Mid-season cultivars				
Talisman	16.3^{ab}	1.7^{abc}	3.5^{bc}	71.7^{de}
Dilema	16.2^{ab}	1.6^{abc}	3.7^{abc}	71.7^{de}
Prostir	16.2^{ab}	1.7^{abc}	4.0^{ab}	66.3^{fg}
Elektra	14.8^{d}	2.1^{ab}	3.6^{abc}	79.1^{ab}
Melitopolska Myrna	15.1^{cd}	2.1^{ab}	3.7^{abc}	60.0^{h}
Medium-late and late ripening cultivars				
Lyubava	16.4^{ab}	2.0^{ab}	4.0^{ab}	68.5^{efg}
Krupnoplidna	13.7^{fg}	1.4^{bcd}	3.4^{c}	65.5^{g}
Temporion	16.7^{a}	2.0^{ab}	4.1^{a}	82.0^{a}
Udivityelna	14.0^{ef}	2.1^{ab}	3.9^{abc}	68.0^{efg}
Anons	15.2^{cd}	1.9^{ab}	3.6^{abc}	74.2^{cd}
Nizhnist	16.4^{ab}	2.3^{a}	4.0^{ab}	77.3^{bc}
Anshlag	14.0^{ef}	1.8^{ab}	3.5^{abc}	65.1^{g}
Novynka Turovtseva	15.2^{cd}	1.4^{ab}	4.0^{ab}	77.8^{abc}
Etyka	14.7^{de}	1.6^{abc}	3.4^{c}	60.4^{h}
Annushka	14.5^{de}	1.9^{d}	3.6^{abc}	71.1^{de}
Donetska Krasunya	16.0^{ab}	1.9^{ab}	4.0^{ab}	66.1^{g}
Donchanka	16.3^{ab}	2.0^{ab}	4.0^{ab}	60.0^{h}
Stark Hardy Giant	12.9^{h}	1.8^{ab}	3.5^{bc}	71.6^{de}
Zodiak	16.5^{ab}	1.5^{abc}	3.9^{abc}	70.9^{def}
Regina	16.0^{ab}	2.2^{ab}	4.1^{a}	68.7^{efg}

Fisher's Least Significant Difference (LSD) test was used to compare mean values. A *P*-value of < 0.05 was considered statistically significant.

A more compact crown habit was observed in the cultivars 'Krupnoplidna,' 'Annushka,' 'Kazka,' 'Rubinova Rannia,' 'Udivitelna,' 'Stark Hardy Giant,' 'Etyka,' 'Anshlag,' and 'Anons,' where crown volume did not exceed 15 m^3 and growth vigor was 21.4–30.8% lower compared with the vigorous standard cultivar 'Regina.' Similarly, compact crowns were also recorded in 'Elektra,' 'Dilema,' 'Melitopolska Myrna,' 'Novynka Turovtseva,' 'Lyubava,' 'Zodiak,' 'Valerii Chkalov,' and 'Nizhnost,' where crown volume did not exceed 17 m³, corresponding to growth vigor 12.7–19.7% lower than that of 'Regina.' Based on crown volume, the studied cultivars were conditionally divided into two groups: a vigorous group comprising 'Prostir,' 'Donchanka,' 'Donetska Krasunya,' 'Temporion,' and 'Regina' (all exceeding 17.1 m^3), and a medium-vigorous group including all remaining cultivars.

Shoot length—an important indicator of vegetative growth influenced by plant age, rootstock, and cultivar-specific traits—varied notably among the tested genotypes. The cultivar 'Novynka Turovtseva' exhibited the highest growth intensity, with an average shoot length of 82.8 cm (Table 2). Medium growth intensity was recorded in 'Donchanka,' 'Anshlag,' and 'Zodiak,' with average shoot lengths between 58.0 and 59.6 cm, while the remaining cultivars were characterized by longer shoots.

The horizontal crown projection area of sweet cherry trees ranged from 5.9 to 7.0 m^2, with the largest areas recorded in 'Valerii Chkalov' and 'Regina' (7.8–7.9 m^2). Efficient land use is a key requirement in commercial orchard establishment. According to Hulko (1992), optimal conditions are achieved when, in an intensive orchard, tree crowns occupy approximately 70% of their designated planting area within the first third of the orchard's productive lifespan. By the sixth year after planting, most cultivars had reached this threshold. The highest levels of area utilization were observed in 'Donchanka' and 'Anshlag' (84.5%), 'Etyka' (84.8%), 'Valerii Chkalov' (88.1%), and 'Regina' (89.7%).

Throughout the study period, 'Temporion' consistently displayed the largest trunk cross-sectional area, ranging from 128.7 to 219.0 cm^2, indicating superior vegetative vigor relative to other cultivars. In contrast, by the seventh year after planting, the smallest crown volumes and trunk cross-sectional areas were found in the early-ripening cultivar 'Kazka,' the mid-season cultivar 'Elektra,' and the mid-late cultivars 'Krupnoplidna' and 'Stark Hardy Giant,' confirming their medium vigor status.

The primary criteria for evaluating cultivars for industrial-scale planting are precocity and yield potential. The onset of fruiting varied, with the first isolated fruits appearing between the third and fourth year after planting, depending on the cultivar. Precocity was assessed through the number of spur (bouquet) branches per tree. At the age of five, the highest spur counts—ranging from 316 to 506 per tree—were recorded in 'Anshlag,' 'Dilema,' 'Liubava,' 'Nizhnost,' 'Talisman,' 'Zodiak,' and 'Donchanka' (Fig. 1). Conversely, the lowest spur counts (105–150 per tree) were observed in 'Temporion,' 'Melitopolska Myrna,' 'Elektra,' 'Udivitelna,' 'Prostir,' and 'Rubinova Rannia.'

Table 2. Crown volume, horizontal crown projection area, and trunk cross-sectional area of sweet cherry trees of different cultivars on Krymsk 5 rootstock, 2024. Orchard planted in 2018.

Cultivars	**Crown volume (m^3)**	**Horizontal crown projection area (m^2)**	**Stem cross-sectional area, (cm^2)**	**Feeding area (%)**
Early and mid-early ripening cultivars				
Valerii Chkalov	16.5^{de}	7.8^{ab}	165.3^{l}	88.1^{b}
Kazka	13.9^{kl}	7.1^{bcd}	135.4^{o}	80.4^{ij}
Rubinova rannia	13.9^{kl}	6.3^{e}	196.1^{g}	71.3^{m}
Mid-season cultivars				
Talisman	14.1^{jkl}	7.1^{bcd}	208.7^{d}	8.00^{j}
Dilema	15.6^{fg}	7.2^{abcd}	206.1^{e}	81.8^{fg}
Prostir	17.2^{bc}	7.4^{abc}	206.1^{e}	83.6^{d}
Elektra	15.3^{gh}	7.4^{abc}	172.8^{j}	84.0^{cd}
Melitopolska Myrna	15.8^{fg}	7.4^{abc}	178.3^{i}	84.0^{cd}
Medium-late and late ripening cultivars				
Lyubava	15.9^{f}	6.8^{cde}	211.2^{c}	77.3^{k}
Krupnoplidna	13.2^{m}	6.8^{cde}	147.4^{n}	77.3^{k}
Temporion	17.5^{b}	7.3^{abcd}	219.0^{a}	82.7^{e}
Udivityelna	14.0^{kl}	6.1^{e}	153.9^{m}	69.7^{n}
Anons	15.0^{hi}	7.3^{abcd}	181.5^{h}	82.2^{ef}
Nizhnist	16.7^{cd}	7.1^{bcd}	211.2^{c}	80.9^{hi}
Anshlag	14.9^{hi}	7.5^{abc}	153.9^{m}	84.5^{c}
Novynka Turovtseva	15.9^{f}	6.8^{cde}	181.5^{h}	76.9^{k}
Etyka	14.6^{ij}	7.5^{abc}	169.7^{k}	84.8^{c}
Annushka	13.6^{lm}	6.6^{de}	165.1^{l}	74.7^{l}
Donetska Krasunya	17.5^{b}	7.4^{abc}	201.1^{f}	84.3^{cd}
Donchanka	17.4^{b}	7.5^{abc}	208.7^{d}	84.5^{c}
Stark Hardy Giant	14.2^{jk}	7.2^{abcd}	130.7^{p}	81.3^{gh}
Zodiak	16.0^{ef}	7.1^{bcd}	213.8^{b}	80.0^{j}
Regina	19.1^{a}	7.9^{a}	201.1^{f}	89.7^{a}

Fisher's Least Significant Difference (LSD) test was used to compare mean values. A P-value of < 0.05 was considered statistically significant.

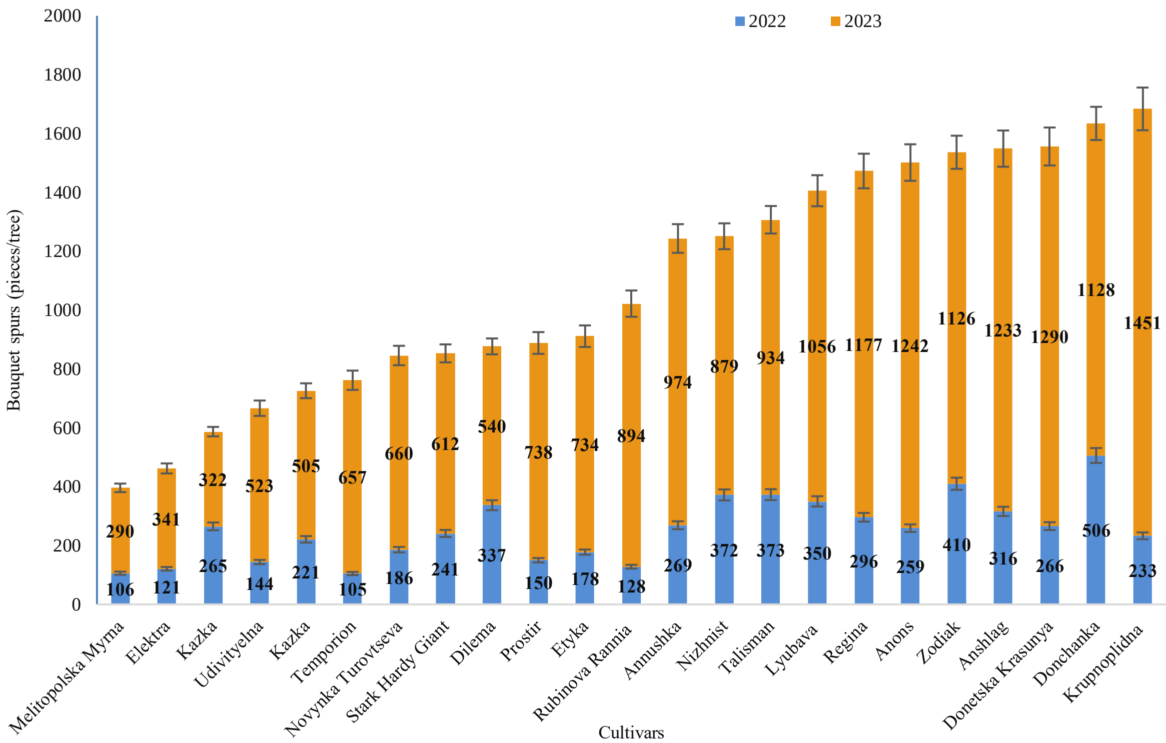

Fig. 1. Number of bouquet spurs in the studied sweet cherry cultivars on Krymsk 5 rootstock. Orchard planted in 2018.

The highest intensity of fruiting structure formation was recorded in cultivars ‘Anons’, ‘Zodiak’, ‘Anshlag’, ‘Donetska Krasunya’, ‘Donchanka’, and ‘Krupnoplidna’, each producing between 1,500 and 1,684 bouquet branches per tree over a two-year period. In contrast, the cultivar ‘Melitopolska Myrna’ produced only 396 bouquet branches per tree during the same timeframe. Tree yield was significantly influenced by weather conditions, the extent of flowering, and pollination efficiency. The growing seasons of 2022–2023 were favorable for the full realization of the biological potential of the studied cultivars. By contrast, in 2024, excessive rainfall during the flowering period adversely affected fruit set, while prolonged precipitation during the harvest period of late-maturing cultivars substantially reduced fruit quality. Among the early-maturing cultivars, the highest productivity was recorded for ‘Kazka’ and ‘Rubinova Rannya’, which yielded an average marketable harvest of 6.5–9.7 kg tree^{-1} (Table 3).

Within the mid-season group, the cultivar ‘Talisman’ distinguished itself by its rapid yield increase, achieving an average productivity of 16.4 kg tree^{-1}. Trees of the mid-late cultivars demonstrated markedly higher productivity compared with those of the early and mid-season groups. In particular, ‘Anons’, ‘Anshlag’, ‘Zodiak’, ‘Krupnoplidna’, ‘Etyka’, and ‘Donchanka’ produced between 12.7 and 20.0 kg tree^{-1} as early as their fifth year, with yields increasing to 38.2–46.0 kg tree^{-1} by the sixth year. In contrast, the lowest yields among mid-season cultivars were observed in ‘Elektra’ and ‘Melitopolska Myrna’, which produced only 4.6–4.9 kg tree^{-1}. Among the late-maturing cultivars, ‘Stark Hardy Giant’ and ‘Regina’ also exhibited low productivity, with yields 4.0 to 6.2 times lower than those of the high-yielding ‘Krupnoplidna’. These results align with findings from the United States, where ‘Regina’ was likewise characterized by inherently low productivity (Long et al., 2021).

To provide a more objective assessment of cultivar performance, specific productivity indices were calculated, relating crop load to crown volume, horizontal crown projection area, and trunk cross-sectional area. The results indicated that, owing to their compact crown architecture and high crop load, the highest specific productivity was achieved by mid-late ripening cultivars—particularly ‘Donchanka’, ‘Etyka’, ‘Anons’, ‘Anshlag’, and ‘Krupnoplidna’. These cultivars recorded average values of 2.03–2.93 kg m^{-3} of crown volume, 4.29–5.40 kg m^{-2} of horizontal crown projection area, and 0.19–0.28 kg cm^{-2} of trunk cross-sectional area (Table 4). In contrast, ‘Melitopolska Myrna’, ‘Regina’, and ‘Elektra’ displayed the lowest specific productivity, with values ranging from 0.37–0.41 kg m^{-3}, 0.77–0.86 kg m^{-2}, and 0.04 kg cm^{-2}, respectively.

Table 3. Yield of different sweet cherry cultivars on Krymsk 5 clonal rootstocks, kg tree^{-1}.

Cultivars	2022	2023	2024	average
Early and mid-early ripening cultivars				
Valerii Chkalov	2.5^{ij}	9.0^{n}	4.5^{ij}	5.3^{klm}
Kazka	4.0^{gh}	9.4^{mn}	6.0^{h}	6.5^{jk}
Rubinova rannia	3.5^{hi}	15.3^{k}	10.3^{ef}	9.7^{h}
Mid-season cultivars				
Talisman	14.4^{c}	30.0^{g}	4.8^{i}	16.4^{e}
Dilema	3.5^{hi}	9.7^{mn}	3.5^{jk}	5.6^{klm}
Prostir	5.2^{f}	14.3^{kl}	10.1^{f}	9.9^{h}
Elektra	3.5^{hi}	5.5^{o}	4.8^{i}	4.6^{m}
Melitopolska Myrna	1.5^{j}	6.6^{o}	6.6^{h}	4.9^{lm}
Medium-late and late ripening cultivars				
Lyubava	4.9^{fg}	24.3^{i}	7.8^{g}	12.3^{g}
Krupnoplidna	17.3^{b}	43.5^{c}	25.5^{a}	28.8^{a}
Temporion	5.7^{f}	24.4^{i}	8.2^{g}	12.8^{g}
Udivityelna	5.7^{f}	27.7^{h}	9.4^{f}	14.3^{f}
Anons	18.3^{b}	46.0^{a}	2.4^{lm}	22.2^{d}
Nizhnist	4.8^{fg}	9.3^{n}	11.2^{e}	8.4^{i}
Anshlag	18.4^{b}	52.0^{b}	4.6^{i}	25.0^{b}
Novynka Turovtseva	5.5^{f}	20.0^{j}	1.5^{mn}	9.0^{hi}
Etyka	14.8^{c}	38.2^{e}	16.6^{d}	23.2^{cd}
Annushka	8.3^{e}	24.7^{i}	3.1^{kl}	12.0^{g}
Donetska Krasunya	9.4^{e}	35.0^{f}	1.5^{mn}	15.3^{ef}
Donchanka	20.0^{a}	40.0^{d}	22.9^{b}	27.6^{a}
Stark Hardy Giant	5.6^{f}	13.5^{l}	1.3^{n}	6.8^{j}
Zodiak	12.7^{d}	38.8^{de}	20.4^{c}	24.0^{bc}
Regina	3.9^{gh}	11.0^{m}	3.4^{kl}	6.1^{jkl}

Mean values were compared using Tukey's HSD test. Statistical significance was set at $P < 0.05$.

Table 4. Specific productivity of sweet cherry trees of studied cultivars, 2022-2024.

Cultivars	Per Unit of Crown Volume (kg m^3)	Per Unit of	
		Horizontal Crown Projection Area (kg m^{-2})	Trunk Cross-Sectional Area (kg m^{-2})
Early and mid-early ripening cultivars			
Valerii Chkalov	0.47^{b}	0.98^{b}	0.05^{c}
Kazka	0.63^{b}	1.21^{ab}	0.07^{bc}
Rubinova rannia	0.83^{ab}	1.81^{ab}	0.07^{bc}
Mid-season cultivars			
Talisman	1.51^{ab}	2.64^{ab}	0.10^{abc}
Dilema	0.52^{b}	1.10^{ab}	0.04^{c}
Prostir	0.76^{b}	1.70^{ab}	0.07^{bc}
Elektra	0.41^{b}	0.82^{b}	0.04^{c}
Melitopolska Myrna	0.37^{b}	0.77^{b}	0.04^{c}
Medium-late and late ripening cultivars			
Lyubava	1.00^{ab}	2.22^{ab}	0.08^{abc}
Krupnoplidna	2.93^{a}	5.44^{a}	0.27^{ab}
Temporion	0.94^{ab}	2.14^{ab}	0.08^{abc}
Udivityelna	1.13^{ab}	2.55^{ab}	0.12^{abc}
Anons	2.37^{ab}	4.62^{ab}	0.22^{abc}
Nizhnist	0.63^{b}	1.43^{ab}	0.06^{c}
Anshlag	2.45^{ab}	4.65^{ab}	0.28^{a}
Novynka Turovtseva	0.80^{b}	1.76^{ab}	0.08^{abc}
Etyka	2.28^{ab}	4.29^{ab}	0.19^{abc}

Annushka	1.04^{ab}	2.03^{ab}	0.11^{abc}
Donetska Krasunya	1.13^{ab}	2.41^{ab}	0.11^{abc}
Donchanka	2.03^{ab}	4.43^{ab}	0.19^{abc}
Stark Hardy Giant	0.72^{b}	1.38^{ab}	0.09^{abc}
Zodiak	1.86^{ab}	3.92^{ab}	0.13^{abc}
Regina	0.38^{b}	0.86^{b}	0.04^{c}

Mean values were compared using Tukey's HSD test. Statistical significance was set at $P < 0.05$.

Sweet cherries grafted on the medium-vigorous clonal rootstock Krymsk 5 demonstrated rapid yield increase and high productivity. On average, the highest marketable yield per unit area among the early-maturing group occurred in cultivars 'Kazka' (5.8 t ha^{-1}) and 'Rubinova Rannia' (8.7 t ha^{-1}), while 'Talisman' stood out among mid-season cultivars with 14.6 t ha^{-1} (Table 5).

Table 5. Harvest of different cultivars of sweet cherry trees on Krymsk 5 clonal rootstock (t ha^{-1}).

Cultivars	2022	2023	2024	average
Early and mid-early ripening cultivars				
Valerii Chkalov	2.2^{ij}	8.0^{n}	4.0^{ij}	4.7^{klm}
Kazka	3.6^{gh}	8.4^{mn}	5.3^{h}	5.8^{jk}
Rubinova rannia	3.1^{hi}	13.6^{k}	9.2^{ef}	8.7^{h}
Mid-season cultivars				
Talisman	12.8^{c}	26.7^{g}	4.3^{i}	14.6^{e}
Dilema	3.1^{hi}	8.6^{mn}	3.1^{jk}	4.9^{klm}
Prostir	4.6^{f}	12.7^{kl}	9.0^{f}	8.8^{h}
Elektra	3.1^{hi}	4.9^{o}	4.3^{i}	4.1^{m}
Melitopolska Myrna	1.3^{j}	5.9^{o}	5.9^{h}	4.4^{lm}
Medium-late and late ripening cultivars				
Lyubava	4.4^{fg}	21.6^{i}	6.9^{g}	11.0^{g}
Krupnoplidna	15.4^{b}	38.7^{c}	22.7^{a}	25.6^{a}
Temporion	5.1^{f}	21.7^{i}	7.3^{g}	11.4^{g}
Udivityelna	5.1^{f}	24.6^{h}	8.4^{f}	12.7^{f}
Anons	16.3^{b}	40.9^{a}	2.1^{lm}	19.8^{d}
Nizhnist	4.3^{fg}	8.3^{n}	10.0^{e}	7.5^{i}
Anshlag	16.4^{b}	46.2^{b}	4.1^{i}	22.2^{b}
Novynka Turovtseva	4.9^{f}	17.8^{j}	1.3^{mn}	8.0^{hi}
Etyka	13.2^{c}	34.0^{e}	14.8^{d}	20.7^{cd}
Annushka	7.4^{e}	22.0^{i}	2.8^{kl}	10.7^{g}
Donetska Krasunya	8.4^{e}	31.1^{f}	1.3^{mn}	13.6^{ef}
Donchanka	17.8^{a}	35.6^{d}	20.4^{b}	24.6^{a}
Stark Hardy Giant	5.0^{f}	12.0^{l}	1.2^{n}	6.1^{j}
Zodiak	11.3^{d}	34.5^{de}	18.1^{c}	21.3^{bc}
Regina	3.5^{gh}	9.8^{m}	3.0^{kl}	5.4^{jkl}

Mean values were compared using Tukey's HSD test. Statistical significance was set at $P < 0.05$.

The highest yields were recorded in the mid-late maturing cultivars 'Zodiak', 'Krupnoplidna', 'Anons', 'Donchanka', 'Etyka', and 'Anshlag', which produced 11.3–17.8 t ha^{-1} in the fifth year, increasing to 34.0–46.2 t ha^{-1} by the sixth year. Across the study period, these cultivars achieved average yields ranging from 19.8 to 25.6 t ha^{-1}. In contrast, the cultivars 'Novynka Turovtseva', 'Nizhnost', 'Stark Hardy Giant', and 'Regina' produced yields that were, on average, 3.2–4.7 times lower than those of 'Krupnoplidna'.

At present, a key parameter determining the market quality of sweet cherry fruit is equatorial diameter. The United States Department of Agriculture (USDA) defines the most stringent size standards, which are widely adopted as benchmarks in international retail markets. According to these standards, fruit with a diameter exceeding 28 mm is classified as highly marketable, while fruit exceeding 29.8 mm qualifies as premium quality. Uniform batches of fruit with diameters above 28 mm and average weights of 9.3–14.2 g were produced by the early-maturing cultivar 'Kazka'; the mid-season cultivars ‘Elektra’ and ‘Talisman’; and the mid-late cultivars ‘Temporion’, ‘Krupnoplidna’, ‘Zodiak’, ‘Anons’, ‘Anshlag’, ‘Novynka Turovtseva’, ‘Regina’, and ‘Stark Hardy Giant’ (Fig. 2).

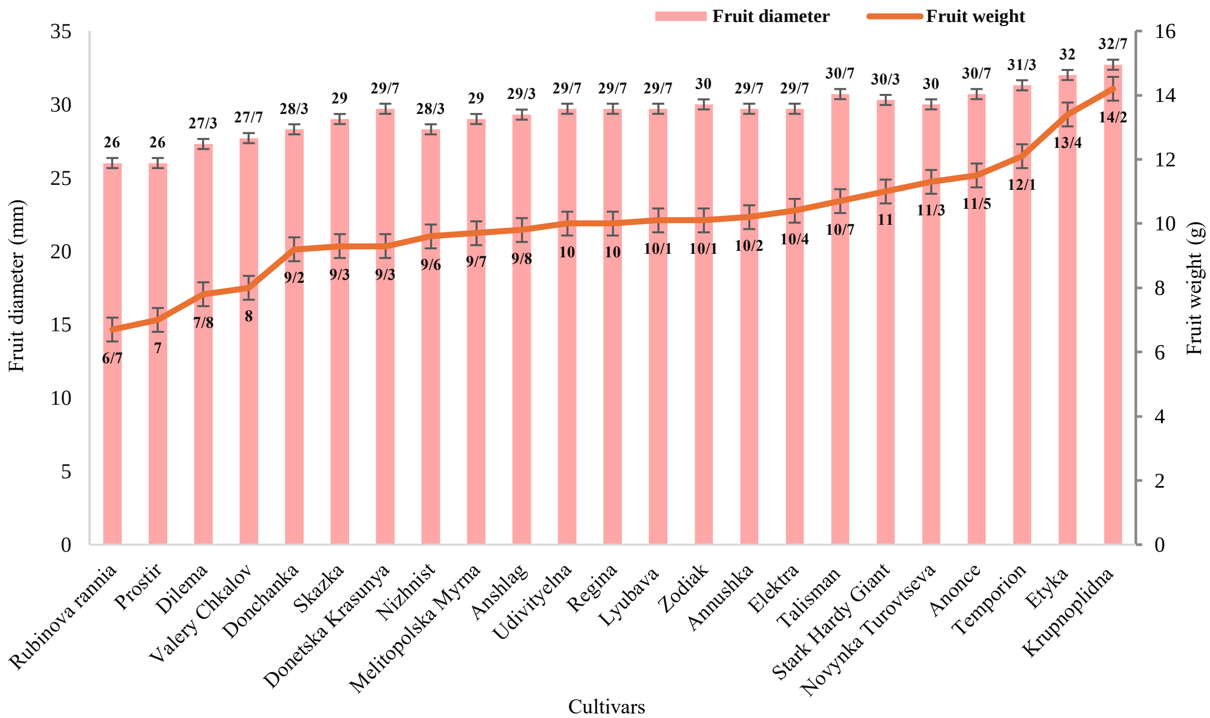

Fig. 2. Average fruit weight and diameter in different sweet cherry cultivars on Krymsk 5, 2022–2024.

It should be emphasized that the largest fruits were produced by the mid-late cultivars ‘Temporion’, ‘Krupnoplidna’, and ‘Etyka’, with an average fruit weight of 12.1-14.2 g, with diameters ranging from 31.3 to 32.7 mm, thus corresponding to premium-quality standards.

Discussion

Sweet cherry cultivation is emerging as a highly promising sector in modern horticulture. The favorable market environment—characterized by premium prices and increasing global export volumes—underscores the crop’s substantial commercial potential. Research indicates that the use of clonal rootstocks yields the best results in temperate climates (Shahini et al., 2023). Although high-density cherry orchards require approximately twice the initial capital investment compared to conventional systems, they provide earlier returns and higher overall profitability (Manolova & Kolev, 2013).

Globally, large-fruited sweet cherry cultivars with excellent flavor characteristics have been developed, typically achieving average fruit weights of 10–12 g, and, under irrigation, frequently exceeding 14–15 g. These cultivars meet the stringent quality standards of major retail chains and remain highly competitive in international markets (Kishchak, 2017). Consequently, many growers now prioritize maximizing fruit size, even at the expense of total tree productivity (Lauri & Claverie, 2005; Spornberger et al., 2013; Rutkowski & Łysiak, 2022). Current research confirms a strong correlation between fruit size and tree load (r = 0.71–0.83) for most varieties, along with a moderate positive linear relationship between crown volume and productivity (r = 0.58–0.65).

In leading cherry-producing countries, breeding programs focus not only on large fruit size but also on achieving stable orchard productivity while maintaining high marketable quality throughout the productive lifespan of trees (Kishchak, 2017; Ganji Moghadam et al., 2022). Ukrainian-bred sweet cherry cultivars are increasingly prominent in this context, attracting interest from research institutions and commercial growers worldwide. For instance, ‘Kazka’ and ‘Prestizhna’ have been identified as the most promising cultivars for central Poland (Głowacka & Rozpara, 2017), while ‘Annushka’ is recommended for cultivation in CIS countries (Palubiatka, 2021). In Romania, ‘Skorospilka’ and ‘Yuvileina’ are advocated for commercial orchard use (Caplan et al., 2019). The cultivar ‘Krupnoplidna’ has gained notable attention in China

(Zhang et al., 2019) and, along with 'Valerii Chkalov,' is widely grown in the Baltic states and Bulgaria due to its high winter hardiness, large fruit size, and high yield (Ruisa & Rubauskis, 2004; Christov et al., 2008; Ruisa, 2008; Rubauskis et al., 2013; Rubauskis et al., 2014).
Ukrainian cultivars are also extensively used in European breeding programs, where selected clones are being developed (Szikriszt et al., 2011; Hegedűs et al., 2013). According to Polish researchers Lisek et al. (2015), the alleles S5 and S9—both associated with large fruit size—are most frequently found in Ukrainian cultivars, distinguishing them significantly from varieties originating elsewhere in Europe (Eremina et al., 2020). In South Korea, where sweet cherry breeding remains relatively limited, most cultivars adapted to spring frost conditions also trace their origins to Ukraine (Nam et al., 2017). As in other leading cherry-producing regions, breeding efforts increasingly emphasize not only large fruit size but also long-term orchard productivity and consistently high fruit quality (Kishchak, 2017; Ganji Moghadam et al., 2022).

Conclusion
In the Forest-Steppe zone of Ukraine, the large-fruited cultivars 'Kazka,' 'Talisman,' 'Krupnoplidna,' 'Temporion,' 'Donchanka,' 'Anons,' 'Zodiak,' and 'Etyka' have been identified as particularly promising. When grafted onto the medium-vigorous clonal rootstock 'Krymsk 5', these cultivars demonstrate moderate vegetative growth, high productivity, and suitability for establishing commercial-scale orchards. Furthermore, their fruit quality meets the stringent standards required by major global retail chains.

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Conceptualization, OK and AS; methodology, OK and YK; software, MM and OM; validation, OM and OK; formal analysis, OK.; investigation, OK and AS; resources, YK; data curation, AS and YK; writing—original draft preparation, MM and YK; writing—review and editing, YK and OK; visualization, AS and OM; supervision, OK; project administration, OK. All authors have read and agreed to the published version of the manuscript.

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The authors indicate no conflict of interest in this work.

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