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Evaluation of productivity, berry quality and adaptability of garden strawberry varieties in the conditions of Southeastern Kazakhstan

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ABSTRACT

Garden strawberry (*Fragaria* × *ananassa* Duch.) is one of the most valuable berry crops in modern fruit growing due to its precocity, early ripening, high taste qualities and wide possibilities of using products in fresh form and processing. In the conditions of the Southeast Kazakhstan, the selection of varieties combining high productivity, berry quality and adaptability to the continental climate is of particular relevance. The aim of the study was a comprehensive assessment of garden strawberry varieties of different ripening periods according to phenological, productive, biochemical and commercial indicators in order to identify the most promising varieties for industrial cultivation. The studies were conducted in 2023-2025 at the Talgar experimental plot of the Russian Federation of the Kazakh Scientific Research Institute of Fruit and Vegetable Growing, LLP in the foothill zone of the Trans-Ili Alatau. Twelve varieties were studied: early ripening — Kokinskaya rannyaya (control), Alba, Kleri, Honey; Mid-season varieties included Ducat (control), Asia, Siriya, and Korona; and everbearing varieties included Albion, Elizaveta 2, San Andrias, and Murano. Early-ripening varieties were found to begin ripening in late May, mid-season varieties in early June, and everbearing varieties that bore fruit continuously until September. Everbearing varieties demonstrated the highest productivity, with Murano standing out among them, producing an average of 33.1 berries per bush, with a yield of up to 577.7 g $bush^{-1}$ and a productivity of up to 367.5 c ha^{-1}. Among short-day varieties, the bests were Clery and Asia. Everbearing varieties also surpassed the others in dry matter content, sugars, vitamin C, sugar-acid index, transportability, and tasting score. The obtained results demonstrate the high potential of the Murano, San Andrias, Albion, Clery, and Asia varieties for industrial berry production in Southeastern Kazakhstan.

Key words: Garden strawberry, Variety, Productivity, Yield, Biochemical composition, Commercial qualities, Adaptability

Introduction

Garden strawberries are one of the leading berry crops for commercial cultivation in many countries. Their popularity stems from their advantages: high profitability, dessert flavor, and high nutritional value. Strawberries contain up to 10% sugars, 1.3% organic acids, 120 mg% vitamin C, 750 mg% P-active substances, 5 mg% vitamin

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B_9 (folic acid), as well as potassium, calcium, phosphorus, magnesium, silicon, copper, and iron (Kazakov *et al.* 2009; Guerrero-Molina *et al.* 2014).

According to FAOSTAT (Food and Agriculture Organization of the Nations) for 2018, the top ten largest strawberry producers include China (2.9 million tons), the USA (1.3 million tons), Mexico (0.6 million tons), Turkey (0.4 million tons), Egypt (0.4 million tons), Spain (0.3 million tons), Korea (0.2 million tons), Russia (0.2 million tons), Poland (0.2 million tons), Japan (0.2 million tons), world strawberry production exceeds 9 million tons per year and shows positive dynamics (Pernet & Ribi Forclaz 2019; Canton 2021).

In modern conditions, the development of the crop is determined by a number of factors: changing climate conditions, increasing phytosanitary pressure, and increasing demands on berry quality and the competitiveness of varieties (Eizenga *et al.* 2023, Vondracek *et al.* 2024). In this regard, strawberry breeding is focused on creating varieties with high adaptability, resistance to diseases and stress, and improved berry density and transportability (He *et al.* 2023). Molecular genetic methods (GWAS, QTL mapping, and genomic selection) are being actively implemented, accelerating the development of new competitive genotypes (Zhou *et al.* 2023).

For zones characterized by a small variety of strawberries, despite almost a century of breeding work (since the 1930s), there is an obvious need to develop and use zonal intensive technologies in the industrial production of existing strawberry varieties and to create varieties that respond to intensive technologies. Domestic breeding programs are effective in creating adaptive and productive varieties. At the same time, improving the quality of strawberries to meet market demands is currently a priority for developing a competitive assortment (Marchenko 2020).

In the Republic of Kazakhstan, garden strawberries are cultivated both in open and protected ground. The highest concentration of plantings is found in the southeastern regions of the country—Almaty, Turkestan, and East Kazakhstan Oblasts—where climatic conditions are characterized by a long growing season, high average daily temperatures, and the availability of irrigated land (Statics 2021). In recent years, there has been a steady trend toward expanding cultivated areas and intensifying production, driven by growing domestic demand, the development of greenhouse technologies, and import substitution for berry products (Group 2023). Modern research by Kazakh and international researchers shows that strawberry productivity and adaptability in Kazakhstan's sharply continental climate are largely determined by the variety's resistance to abiotic stress (drought, high temperatures, and spring frosts) and the effectiveness of irrigation technologies. It has been established that stressful summer conditions lead to changes in the physiological and biochemical parameters of plants, including the accumulation of osmoprotectants and free amino acids, reflecting the adaptive potential of varieties (Antipenko *et al.* 2025).

In today's environment, the use of biotechnological propagation methods, including *in vitro* culture, is particularly important. This allows for the production of virus-free planting material and accelerates the introduction of promising varieties into production. Research by Kazakh scientists confirms the high effectiveness of microclonal propagation of strawberries for creating high-quality starting material and increasing crop productivity (Dinanova *et al.* 2025). Furthermore, a current trend is the selection of varieties with increased resistance to diseases and adverse environmental factors, as well as improved fruit quality. The use of molecular genetic methods and DNA markers allows for the accelerated selection of genotypes with desired economically valuable traits, which is particularly important in the face of climate change and increasing phytosanitary pressure (Vondracek *et al.* 2024; Muñoz *et al.* 2024; Jiménez *et al.* 2025). Strawberries possess a number of economically valuable characteristics that ensure their high commercial appeal: precocity (fruiting from the following year after planting), early ripening, high added value, versatility of use (fresh market, processing, and freezing), and high consumer demand.

No less urgent is the problem of variety renewal and creation of domestic varieties of intensive type, corresponding to the world level in the following indicators: productivity (more than 400 g plant^{-1}), commercial quality of fruits (average weight of berries is higher than 12 g, diameter of berries higher than 25 mm, yield of premium and first commercial grades higher than 60%, and density of pulp higher than 380 g), consumer quality (berries are bright red, intensely red, aromatic, shiny, good and excellent taste), high marketability during transportation and after short-term storage (Olbricht *et al.* 2021).

In the context of import dependence during the winter period, expansion of domestic production is of strategic importance for the country's food security.

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The aim of the study is a comprehensive assessment of garden strawberry varieties (*Fragaria* × *ananassa* Duch.) with different ripening periods in the conditions of Southeastern Kazakhstan based on phenological, productive, biochemical and commercial indicators in order to identify the most promising varieties for industrial cultivation. To achieve this goal, the following tasks were defined:

- To study the phenological phases of development of garden strawberry varieties (beginning of vegetation, flowering, ripening and end of fruiting) in the conditions of the region.
- To evaluate the productivity of varieties by the number of berries per bush, average berry weight, yield per bush, and yield per unit area.
- To analyze the biochemical composition of berries, including the content of dry matter, sugars, acidity, sugar-acid index and vitamin C.
- To determine the commercial qualities of berries, including average and maximum weight, proportion of commercial products, transportability and tasting assessment.
- To identify the most promising varieties for the conditions of Southeastern Kazakhstan in terms of yield, product quality and adaptability.

MATERIALS AND METHODS

The research was conducted in 2023–2025 at the experimental plots of the Russian Federation "Talgar" of the Kazakh Scientific Research Institute of Fruit and Vegetable Growing LLC, located in the Talgar district of the Almaty region.

The region's climate is sharply continental, characterized by cold winters and hot summers. Average annual precipitation ranges from 450 to 600 mm, and the sum of active temperatures above 10 °C ranges from 3200 to 3400 °C.

The soils of the experimental plot are light chestnut and meadow chestnut, medium loamy, with a humus content of 2.5–3.2%, characterized by a satisfactory supply of nutrients and good water permeability.

Field experiments were conducted using the methodology for studying fruit and berry crop varieties, adhering to the principles of randomization and replication. Records and observations were conducted in accordance with generally accepted methods (Dospekhov 1985; Sedov & Ogoltsova 1999).

The objects of the study were garden strawberry varieties (*Fragaria* × *ananassa* Duch) of different ripening periods: Early ripening: Kokinskaya rannyaya (control), Alba, Kleri, Honey; Mid-ripening: Dukat (control), Asia, Siriya, Korona. Everbearing varieties: Albion, Elizaveta 2, San Andrias, Murano.

The selected varieties are widely used in industrial berry growing and differ in biological characteristics, productivity, and berry quality, which allows for an objective assessment of their adaptability to the conditions of Southeastern Kazakhstan.

A comprehensive assessment of the economically valuable traits of strawberry varieties bred at the I.V. Michurin Federal Scientific Center and the suitability of the introduced varieties of the crop for various cultivation systems was carried out in accordance with the methodological recommendations (Sedov & Ogoltsova 1999; GOST 2011; Nilova *et al.* 2023; Singh *et al.* 2025). The content of ascorbic acid (vitamin C) in fruits was determined by the iodometric method based on the titration of ascorbic acid with potassium iodate in an acidic medium in the presence of potassium iodide and starch (Fernández-Lara *et al.* 2015); the content of anthocyanins - by the pH-differential spectrophotometry method; antioxidant activity (AOA) of fruits - according to GOST R 54037-2010 (Luk'yanchuk *et al.* 2022) using a chromatograph with an amperometric detector "Tsvet Yauza-01-AA". The experimental data were processed using mathematical statistics methods using the computer programs Excel 2007 and STATISTICA 6.0. Statistical processing of the data was carried out using the method of variance analysis with the calculation of the NSR_{05} according to B.A. Dospekhov (1985).

Planting pattern and growing conditions. Plants were planted using a single-row pattern: 0.8–0.9 m between rows and 0.25–0.30 m between plants within a row, which ensured a planting density of 45,000–55,000 plants per hectare.

The experiment was carried out in triplicate. The agricultural technology for cultivation included: drip irrigation, systematic loosening of the inter-row spaces, application of mineral fertilizers according to the agrochemical analysis of the soil, and protection of plants from pests and diseases using recommended preparations. Care of the plantings was carried out in accordance with zonal recommendations for garden strawberries.

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RESULTS AND DISCUSSION

Research conducted between 2023 and 2025 revealed that the studied strawberry varieties differ significantly in terms of the timing of phenological phases, productivity levels, biochemical composition, and commercial quality of their berries. However, consistent positive trends were observed for most indicators, indicating the varieties' good adaptation to the soil and climatic conditions of Southeastern Kazakhstan.

An analysis of the phenological phases of development of garden strawberry varieties for 2023–2025 showed that the timing of the onset of vegetation, flowering, and mass flowering varied depending on varietal characteristics and weather conditions of the year.

In all groups of varieties, minor fluctuations in the timing of phenological phases were noted across years within 2–3 days.

The earliest start of the growing season was observed in 2025, which is associated with the earlier onset of spring temperatures. In 2024, a slight delay of 1–2 days was observed.

A similar trend is characteristic of the onset and mass flowering: in 2025, the phases began earlier, and in 2024, somewhat later.

The varieties of this group were characterized by the earliest dates of passing through phenological phases.

The beginning of the growing season was noted at the end of March (27–29.03), the beginning of flowering – at the beginning of May (01–04.05), and mass flowering – in the first ten days of May (07–10.05).

The earliest variety was Alba, while the Honey variety was characterized by slightly later dates (by 1–2 days) (Table 1).

Table 1. Phenological phases of development of garden strawberry varieties (2023–2025).

variety	The beginning of the growing season				The beginning of flowering				Mass flowering			
	2023	2024	2025	average	2023	2024	2025	average	2023	2024	2025	average
Early ripening												
Kokinskaya early (k)	March 28	30.03	March 27	March 28	02.05	04.05	01.05	02.05	08.05	10.05	07.05	8.05
Alba	March 27	29.03	26.03	March 27	01.05	03.05	April 30	01.05	07.05	09.05	06.05	07.05
Clery	March 28	30.03	March 27	March 28	03.05	05.05	02.05	03.05	09.05	11.05	08.05	09.05
Honey	29.03	31.03	March 28	29.03	04.05	06.05	03.05	04.05	10.05	12.05	09.05	10.05
Average ripening period												
Ducat (k)	30.03	01.04	29.03	30.03	05.05	07.05	04.05	05.05	11.05	13.05	10.05	11.05
Asia	30.03	01.04	29.03	30.03	06.05	08.05	05.05	06.05	12.05	14.05	11.05	12.05.
Siriya	31.03	02.04	30.03	31.03	06.05	08.05	05.05	06.05	13.05	15.05	12.05	13.05
Crown	31.03	02.04	30.03	31.03	07.05	09.05	06.05	07.05	13.05	15.05	12.05	14.05
Everbearing varieties												
Albion	29.03	31.03	March 28	29.03	05.05	07.05	04.05	05.05	12.05	14.05	11.05	12.05
Elizabeth II	29.03	31.03	March 28	29.03	06.05	08.05	05.05	06.05	13.05	15.05	12.05	13.05
San Andrias	29.03	31.03	March 28	29.03	06.05	08.05	05.05	06.05	13.05	15.05	12.05	13.05
Murano	30.03	01.04	29.03	30.03	07.05	09.05	06.05	07.05	14.05	16.05	13.06	24.05

The varieties Kokinskaya rannyaya (k) and Kleri occupied an intermediate position. Mid-season varieties lagged behind early varieties by 2–4 days across all phenological phases. The onset of vegetation occurred between March 30 and April 2, with flowering beginning between May 5 and May 8, and full flowering between May 11 and May 14. The earliest variety in this group was Dukat (k), while Siriya and Korona were distinguished by later flowering periods.

Everbearing varieties were characterized by development periods close to mid-season varieties. The beginning of the growing season was noted at the end of March (29–30.03), the beginning of flowering – in the first ten days of May (05–07.05), mass flowering – in the second ten days of May (12–14.05).

No significant differences were found between the varieties in this group, however, the Murano variety was distinguished by slightly later mass flowering.

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Conclusions. The study found that the timing of phenological phases in garden strawberry varieties in Southeastern Kazakhstan is highly stable and is primarily determined by the genetic characteristics of the varieties. Early ripening varieties are characterized by an earlier start of vegetation and flowering, ahead of mid-season and everbearing varieties by 2–4 days.

A slight variability in terms of maturity was noted across years (within 2–3 days), which indicates good adaptation of the varieties to regional conditions.

Thus, the studied varieties ensure stable passage of phenological phases, which allows for effective planning of technological operations and harvest timing.

Table 2. Phenological phases of development of garden strawberry varieties (2023–2025).

variety	Beginning of ripening				Mass ripening				End of fruiting			
	2023	2024	2025	average	2023	2024	2025	average	2023	2024	2025	average
Early ripening												
Kokinskaya early (k)	27.05	29.05	26.05	27.05	03.06	05.06	02.06	03.06	June 18	June 20	June 17	June 18
Alba	25.05	27.05	24.05	25.05	01.06	03.06	31.05	01.06	June 17	June 19	16.06	June 17
Clery	28.05	30.05	27.05	28.05	04.06	06.06	03.06	04.06	June 19	June 21	June 18	June 19
Honey	29.05	31.05	28.05	29.05	05.06	07.06	04.06	05.06	June 20	22.06	June 19	June 20
Average ripening period												
Ducat (k)	02.06	04.06	01.06	02.06	09.06	11.06	08.06	09.06	June 25	June 27	June 24	June 25
Asia	03.06	05.06	02.06	03.06	10.06	12.06	09.06	10.06	June 26	June 28	June 25	June 26
Siriya	04.06	06.06	03.06	04.06	11.06	13.06	10.06	11.06	June 27	June 29	June 26	March 27
Crown	05.0	07.06	04.06	05.06	12.06	14.06	11.06	12.06	June 28	June 30	June 27	March 28
Everbearing varieties												
Albion	10.06	12.06	09.06	10.06	June 20	22.06	June 19	June 20	20.09	22.09	September 19	20.09
Elizabeth II	12.06	14.06	11.06	12.06	22.06	June 24	June 21	22.06	25.09	September 27	24.09	25.09
San Andrias	11.06	13.06	10.06	11.06	June 21	June 23	June 20	June 21	23.09	25.09	22.09	23.09
Murano	12.06	14.06	11.06	12.06	22.06	June 24	June 21	22.06	25.09	September 27	24.09	24.09

An analysis of the phenological phases of ripening and fruiting of garden strawberry varieties for 2023–2025 showed that the timing of the onset and mass ripening, as well as the end of fruiting, were determined by varietal characteristics and depended to a lesser extent on annual conditions.

In all groups of varieties, minor fluctuations in ripening times were observed across years within 2–3 days.

The earliest dates for the onset of ripening were noted in 2025, while in 2024 there was some shift to a later period (by 1–2 days).

Mass ripening and the end of fruiting also followed a similar pattern: an earlier onset in 2025 and a later onset in 2024. The varieties of this group were characterized by the earliest ripening periods.

The beginning of ripening varied from 25.05 (Alba) to 29.05 (Honey), mass ripening – from 01.06 to 05.06, the end of fruiting – from 17.06 to 20.06. The earliest variety was Alba, while Honey was distinguished by its later ripening period. The Kokinskaya Rannyaya (k) and Kleri occupied an intermediate position: 5–7 days behind early varieties. Ripening began between June 2–June 5, peak ripening between June 9–June 12, and fruiting ended between June 25–June 28. The earliest variety in the group was Dukat (k), while Korona had the latest ripening period.

Everbearing varieties were characterized by a later onset of fruiting and a significantly longer fruiting period. Ripening began between June 10 and June 12, with full ripening occurring between June 20 and June 22. A distinctive feature of this group is a prolonged fruiting period, lasting until September, with fruiting ending

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between September 20 and 25. No significant differences were found between the varieties, although the Albion variety began fruiting somewhat earlier. **Conclusions**: As a result of the research, it was established that the ripening and fruiting periods of garden strawberry varieties in the conditions of Southeastern Kazakhstan are characterized by high stability and are mainly determined by the genetic characteristics of the varieties.

Early ripening varieties provide production as early as the end of May, while mid-season varieties do so at the beginning of June. Everbearing varieties are distinguished by a later onset of ripening, but a significantly longer fruiting period, continuing until autumn. Thus, the use of varieties of different maturity groups makes it possible to organize a conveyor belt of berries from the end of May to September, which is important for industrial production and providing the market with fresh produce. During the research (2023–2025), it was established that the productivity indicators of garden strawberry varieties varied significantly depending on the genotype and weather conditions of the growing season. In the group of early-ripening varieties, a positive trend in the increase in the number of berries per bush was noted from 2023 to 2025. For the Kokinskaya rannyaya (k) variety, this indicator increased from 19.2 to 21.2 pcs. bush^{-1}, for the Alba variety - from 19.5 to 22.4 pcs. bush^{-1}, for the Kleri variety - from 21.7 to 24.5 pcs. bush^{-1}, and for the Honey variety - from 18.6 to 21.0 pcs. bush^{-1} (Fig. 1).

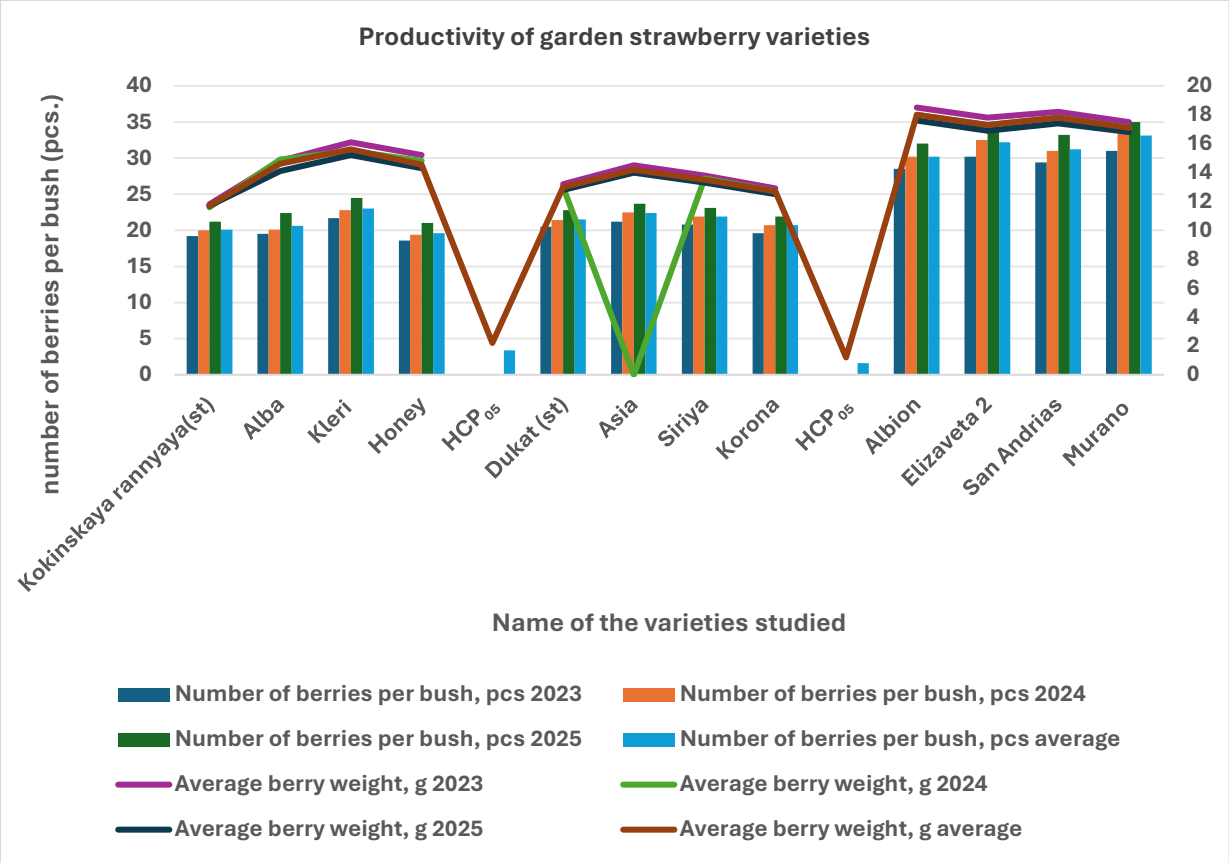

Fig. 1. Productivity of garden strawberry varieties (2023–2025).

The highest level of productivity was noted in the Kleri variety (on average 23.0 pcs. bush^{-1}), which reliably exceeds the control (Kokinskaya rannyaya) by 2.9 pcs., close to the value of HSR_{05} = 3.4.

The average berry weight in this group ranged from 11.7 g (Kokinskaya rannyaya) to 15.6 g (Kleri). The Alba and Honey varieties occupied an intermediate position. Differences in berry weight between varieties were significant (LSD_{05} = 2.2 g).

Mid-season varieties also showed steady growth year after year. The number of berries per bush increased by an average of 1.5–2.0 berries.

The most productive variety was Asia (22.4 pcs bush^{-1}), exceeding the control Dukat (k) by 0.9 pcs. However, this difference was lower than the LSR_{05} (1.6), indicating the statistical insignificance of the differences.

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The average berry weight varied from 12.7 g (Korona) to 14.2 g (Asia). Differences between varieties were minor, falling within the NSR_{05} (1.2 g).

Everbearing varieties significantly outperformed short-day varieties across all parameters. The number of berries per bush increased from 28.5–31.0 in 2023 to 32.0–35.0 in 2025.

The highest indicator was noted for the Murano variety - 33.1 pcs. $bush^{-1}$, which exceeds the Albion variety by 2.9 pcs. and is at the level of the NSR_{05} (2.8), indicating the reliability of the differences.

The average berry weight of remontant varieties was higher than that of other groups and amounted to 17.1–18.0 g. No significant differences were found between varieties for this indicator (LCR_{05} = 1.0 g).

CONCLUSION

As a result of the conducted research, it was established that the most productive varieties of garden strawberries are remontant ones, among which Murano stands out, providing the maximum number of berries per bush. Among the early-ripening varieties, the best indicators were obtained for Kleri, and in the mid-ripening group, for Asia, however, the differences in the latter group were statistically insignificant.

A consistent trend of increasing productivity was noted across the years of study, which is associated with plant adaptation and favorable agroclimatic conditions. The average berry weight of everbearing varieties was higher than that of short-day varieties, indicating their high economic value and potential for commercial cultivation in Southeastern Kazakhstan.

Analysis of data for 2023–2025 showed that yield per bush and yield per hectare varied significantly depending on the variety and year of research.

In the group of early-ripening varieties, a steady trend of increasing yield per bush was observed across the years. For example, the Kokinskaya rannyaya (k) productivity increased from 226.6 g in 2023 to 245.3 g in 2025: for Alba, from 288.6 to 315.7 g, for Kleri, from 349.4 to 372.8 g, and for Honey, from 283.0 to 301.2 g.

The highest yields were recorded for Kleri, averaging 358.7 g $plant^{-1}$ and 224.2 c ha^{-1}, significantly exceeding the control (Kokinskaya rannyaya – 234.3 g $plant^{-1}$ and 146.4 c ha^{-1}). Alba and Honey occupied an intermediate position.

The yield per 1 ha also increased over the years, which indicates favorable weather conditions and good adaptation of varieties (Fig. 2).

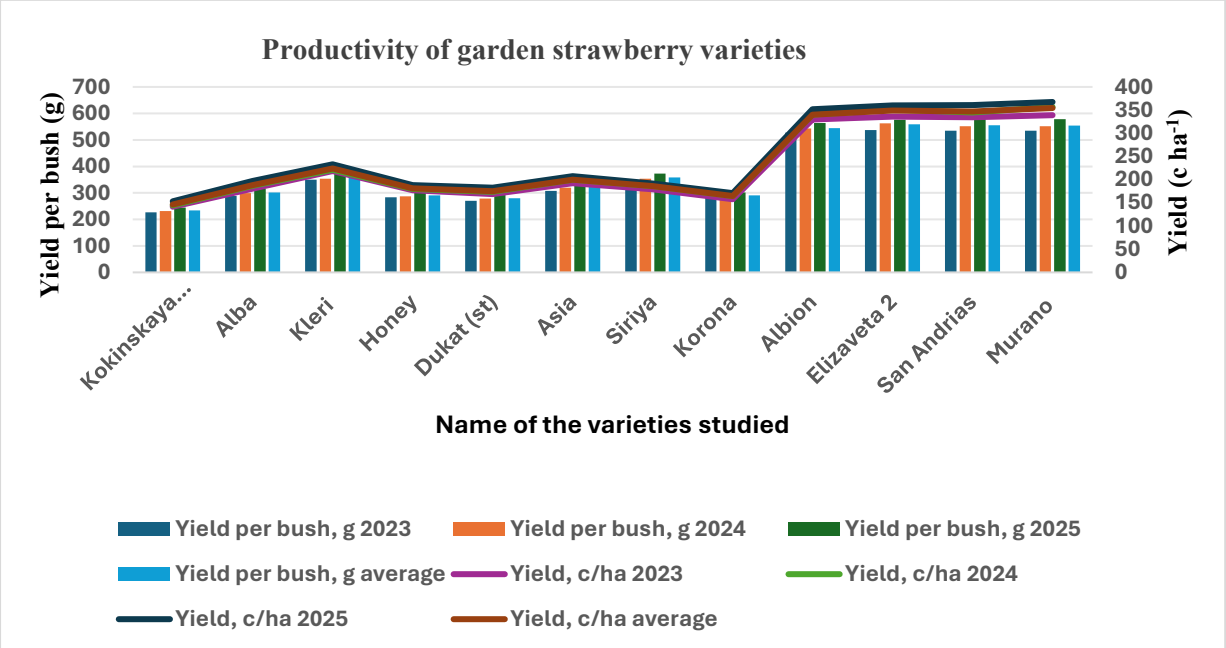

Fig. 2. Yield of garden strawberry varieties (2023–2025).

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Mid-season varieties showed more consistent yields. Yield per bush increased from 270.6–307.4 g in 2023 to 291.8–331.8 g in 2025.

The most productive variety was 'Asia,' delivering the highest yield—325.6 g plant^{-1} and 199.7 c ha^{-1}. 'Siriya' also delivered high yields (358.7 g plant^{-1}), but yielded less than the 'Asia,' which may be due to the specifics of commercial production.

The minimum indicators were noted for Korona (290.5 g bush^{-1} and 164.5 c ha^{-1}), which confirms its lower productivity compared to other varieties in the group.

Everbearing varieties significantly outperformed short-day ones across all parameters. Yield per bush in this group ranged from 527.3 to 577.7 g, which is 1.5 to 2 times higher than those of early and mid-season varieties.

The highest yields were obtained for Elizaveta 2 (558.7 g bush^{-1}; 349.2 c ha^{-1}) and Murano (approximately 554–577 g bush^{-1}; 354.5 c ha^{-1}). San Andrias also demonstrated a high level of productivity (up to 577.7 g bush^{-1} and 361.1 c ha^{-1}).

Notably, the indicators of remontant varieties are stable over the years, indicating their high adaptability and a long fruiting period. As a result of the research, it was found that the most productive varieties of garden strawberries are remontant ones, providing the maximum yield per bush and per unit area.

Among the short-day varieties, the best performance was shown by Kleri (early ripening period) and Asia (medium ripening period).

A steady positive trend in yield growth has been noted year after year, driven by favorable agroclimatic conditions and the well-adapted varieties. Overall, everbearing varieties are the most promising for intensive strawberry production in Southeastern Kazakhstan.

An analysis of the biochemical composition of garden strawberries for 2023–2025 showed a clear dependence of the indicators on varietal characteristics and growing season conditions, as well as a stable dynamic of their change over the years. It was noted in all variety groups from 2023 to 2025. Dry matter content increased by an average of 0.2–0.4%, while sugar content increased by 0.3–0.4%.

A decrease in the acidity of the berries by 0.03–0.05% was observed, indicating an improvement in the taste of the product and the formation of a more harmonious sugar-acid balance.

The most pronounced changes were observed in 2025, which is probably due to more favorable agroclimatic conditions during the growing season. In this group, the dry matter content varied from 8.5 to 10.2%, sugars – from 5.6 to 7.2% (Fig. 3).

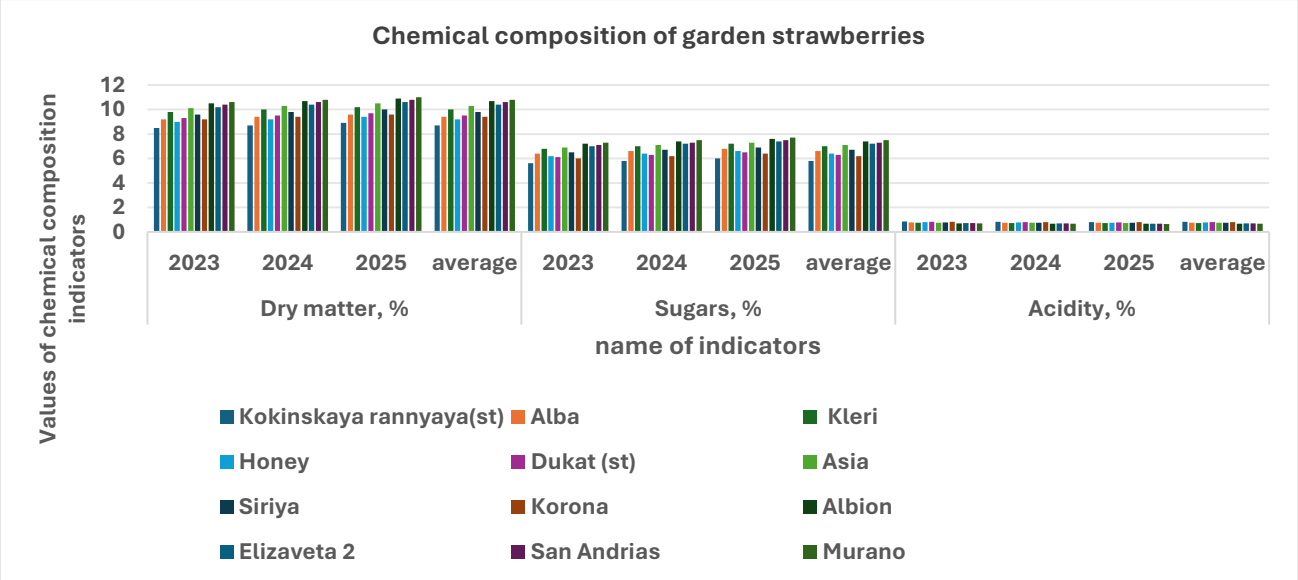

Fig. 3. Chemical composition of garden strawberries (2023–2025).

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The highest indicators were shown by Kleri (on average 10.0% dry matter and 7.0% sugars), while the minimum values were noted for Kokinskaya rannyaya (k).

A decrease in acidity over the years (from 0.85 to 0.81%) indicates an improvement in the taste of the berries.

The varieties of this group were distinguished by higher biochemical indicators compared to early ones.

Asia held the leading position, with dry matter content reaching 10.5% in 2025 (an average of 10.3%) and sugar content reaching 7.3%.

Siriya and Ducat (k) exhibited slightly lower values, but maintained a similar trend of increasing indicators over the years. Acidity decreased from 0.82–0.83% to 0.72–0.78%, also indicating an improvement in taste. Remontant varieties were characterized by the highest values of all biochemical indicators. The dry matter content reached 10.9–11.0%, sugars – 7.6–7.7%, with minimal acidity (0.65–0.70%).

The best indicators were noted for Murano, exhibiting its high nutritional and commercial value. This group was distinguished not only by high values, but also by the stability of indicators over the years, indicating the high adaptability of the varieties.

Conclusions: The research revealed that in 2023–2025, there was a steady trend towards an increase in dry matter and sugar content, while the acidity of garden strawberries decreased, indicating an improvement in their taste.

The highest biochemical indicators are characteristic of remontant varieties, among which Murano stands out, providing maximum accumulation of dry matter and sugars with minimal acidity.

Among short-day varieties, the best indicators were found in Kleri (early ripening period) and Asia (medium ripening period).

Thus, remontant varieties are the most promising in terms of quality and biological value of berries, while Clery and Asia represent the greatest value among traditional varieties for obtaining high-quality products. On average, the index increased by 0.8–1.2 units, which is associated with an increase in sugar content and a simultaneous decrease in acidity.

A similar trend was observed for vitamin C content, which increased by 2–4 mg/% annually. The highest values were observed in 2025, indicating more favorable conditions for berry quality development.

In the group of early ripening varieties, the sugar-acid index varied from 6.6 to 10.0. The highest values were recorded for Kleri (an average of 9.5), indicating a balanced sugar-to-acid ratio. Alba and Honey occupied an intermediate position, while Kokinskaya rannyaya (k) possessed the lowest values (an average of 7.0). The vitamin C content in this group was 58–69 mg/%, with the highest values in Kleri (on average 67 mg/%).

Mid-season varieties were characterized by higher indicators compared to early varieties (Table 3).

Table 3. Indicators of quality and biological value of berries of garden strawberry varieties (2023–2025).

Variety	Sugar-acid index				Vitamin C (mg/%)			
	2023	2024	2025	Average	2023	2024	2025	average
Early ripening								
Kokinskaya early (k)	6.6	7.0	7.4	7.0	58	60	62	60
Alba	8.2	8.7	9.2	8.7	62	64	66	64
Clery	9.1	9.6	10.0	9.5	65	67	69	67
Honey	7.8	8.2	8.7	8.2	60	62	64	62
Average ripening period								
Ducat (k)	7.4	7.9	8.3	7.8	61	63	65	63
Asia	9.1	9.6	10.1	9.6	66	68	70	68
Siriya	8.3	8.8	9.3	8.8	64	66	68	66
Crown	7.2	7.7	8.1	7.6	60	62	64	62
Everbearing varieties								
Albion	10.3	10.9	11.5	10.9	70	72	74	72
Elizabeth II	9.7	10.3	10.9	10.3	68	70	72	70
San Andrias	10.0	10.6	11.2	10.6	69	71	73	71
Murano	10.6	11.2	11.8	11.2	71	73	75	73

The highest sugar-acid index values were noted in Asia (on average 9.6), exhibiting the high taste qualities of the berries.

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The vitamin C content varied from 60 to 70 mg/%, with the maximum values also recorded in Asia (on average 68 mg/%). Siriya and Dukat (k) occupied an intermediate position, while Korona was characterized by lower values.

Everbearing varieties were distinguished by the highest indicators of quality and biological value. The sugar-acid index reached 10.3–11.8, significantly exceeding the values of short-day varieties. The highest value was observed in Murano (an average of 11.2). The vitamin C content was also maximum and varied from 70 to 75 mg/%. The leading position was occupied by Murano (on average 73 mg/%), as well as Albion and San Andrias. High stability of indicators over the years was noted, which indicates good adaptation of remontant varieties to growing conditions.

The research found that in 2023–2025, there was a steady trend towards an increase in the sugar-acid index and vitamin C content in all studied varieties of garden strawberries. The highest quality and biological value indicators are characteristic of remontant varieties, among which Murano stands out, providing maximum values of the sugar-acid index and vitamin C content.

Among the short-day varieties, the best results were obtained with Kleri (early ripening period) and Asia (medium ripening period).

Thus, remontant varieties have the highest nutritional value and taste, which makes them highly promising for industrial cultivation and sale of fresh produce.

An analysis of the commercial qualities of garden strawberries for 2023–2025 showed that the average and maximum berry weights, as well as the share of commercial products, varied significantly depending on varietal characteristics and annual conditions, while a stable trend in their change was noted.

All variety groups showed an increase in maximum berry weight and the share of marketable berries from 2023 to 2025. Maximum berry weight increased by an average of 2–4 g, while the share of marketable berries increased by 2–4%.

At the same time, the average berry weight for most varieties remained relatively stable, with a slight downward trend for certain varieties (especially remontant ones), which is associated with an increased load on the plants and the formation of a larger number of fruits.

Early ripening varieties were characterized by an average berry weight of 11.6–15.5 g. The largest-fruited variety was Kleri (on average 15.5 g), which reliably exceeds the control Kokinskaya rannyaya (k; 11.6 g) with an LSR_{05} = 2.6 g. Alba and Honey occupied an intermediate position.

The maximum berry weight reached 36 g for Kleri, while for the control variety it was 23 g.

The share of commercial berries increased over the years and amounted to 87–94%, with the highest values for Kleri (on average 94%). Varieties in this group exhibited more consistent performance. Average berry weight ranged from 12.5 to 14.2 g (Table 4).

The largest-fruited variety was Asia (14.2 g), however, the differences with other varieties were within the limits of the LSD_{05}, which indicates their statistical insignificance. The maximum berry weight reached 33.6 g for Asia, while the minimum values were noted for Korona (26 g). The share of commercial berries increased from 86–91% in 2023 to 90–95% in 2025, with the best performance observed in Asia and Siriya.

Everbearing varieties were characterized by the highest commercial indicators. The average weight of berries was 17.1–18.0 g, which significantly exceeds the values of short-day varieties and is reliably higher than the LSD_{05}.

The maximum weight of berries reached 42–45 g, with the highest values noted in Albion. The share of marketable berries was the highest and amounted to 94–97%, with the maximum values for Murano (95.6%).

Notably, the indicators in this group are stable over the years, despite a slight decrease in the average weight of berries. The research has shown that the commercial qualities of garden strawberries depend on varietal characteristics and annual conditions, with a tendency for the maximum berry weight and the share of commercial products to increase over the years.

The highest commercial qualities are characteristic of remontant varieties, among which Albion, San Andrias and Murano stand out, ensuring the formation of large-fruited and highly commercial products.

Among the short-day varieties, the best performance was shown by Kleri (early ripening period) and Asia (medium ripening period).

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Table 4. Commercial qualities of berries of garden strawberry varieties (2023–2025).

Variety	Average berry weight (g)				Maximum weight (g)				Share of commercial berries (%)			
	2023	2024	2025	average	2023	2024	2025	average	2023	2024	2025	average
Early ripening												
Kokinskaya early (k)	11.5	11.6	11.7	11.6	22	23	24	23	85	87	89	87
Alba	14.5	14.9	14.1	14.5	30	32	33	31.6	90	92	94	92
Clery	15.8	15.5	15.2	15.5	34	36	38	36	92	94	96	94
Honey	15.0	14.8	14.3	14.7	28	30	31	29.6	88	90	92	90
Average ripening period												
Ducat (k)	13.0	13.2	12.8	13	26	27	28	27.0	87	89	91	89
Asia	14.2	14.5	14.0	14.2	32	34	35	33.6	91	93	95	93
Siriya	13.5	13.6	13.3	13.4	30	32	33	31.6	89	91	93	91
Crown	12.5	12.7	12.5	12.5	25	26	27	26	86	88	90	88
Everbearing varieties												
Albion	18.5	18.0	17.6	18.0	40	42	45	42.3	93	95	97	95
Elizabeth II	17.8	17.3	16.9	17.3	38	40	42	40	92	94	96	94
San Andrias	18.2	17.8	17.4	17.8	39	41	43	41	93	95	96	94.6
Murano	17.5	17.1	16.8	17.1	38	40	42	40	94	96	97	95.6
NSR$_{05}$				2.6				7.0				

Thus, remontant varieties are the most promising for obtaining high-quality commercial products, while short-day ones are advisable to use for early and stable harvesting.

An analysis of the quality indicators of garden strawberries for 2023–2025 showed that transportability and tasting scores varied depending on the variety, with a steady positive trend observed over the years.

In all variety groups, a gradual increase in transportability and tasting assessment was noted from 2023 to 2025. Transportability increased by an average of 0.2–0.3 points, which indicates an elevation in the density and resistance of berries to mechanical damage.

The tasting score also increased by 0.2–0.3 points, which is associated with an improvement in taste qualities due to an increase in sugar content and a decrease in acidity.

In the group of early-ripening varieties, transportability varied from 3.9 to 4.7 points (on average), and tasting scores ranged from 4.3 to 4.8 points. Kleri exhibited the highest scores (4.7 points for transportability and 4.8 points for tasting score), which indicates its high consumer qualities. Kokinskaya rannyaya (k) displayed the lowest values (3.9 and 4.3 points, respectively), inferior to other varieties in the group (Fig. 4).

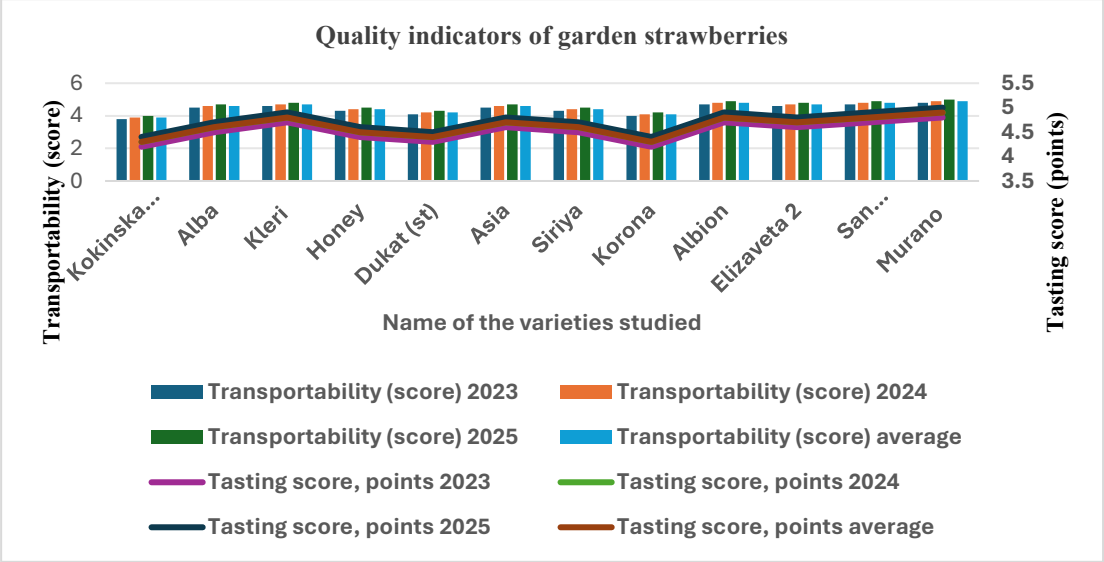

Fig. 4. Quality indicators of garden strawberries (2023–2025).

Mid-season varieties had more consistent performance. The highest values of transportability and tasting score were noted for Asia (on average 4.6 and 4.7 points, respectively), indicating its high commercial and taste value. Siriya and Dukat (k) occupied an intermediate position, while Korona was characterized by slightly lower indicators (4.1 and 4.3 points). Remontant varieties were characterized by the highest quality indicators.

Transportability varied from 4.7 to 4.9 points, and tasting scores ranged from 4.7 to 5.0 points. The leading position was occupied by Murano, whose indicators reached maximum values (4.9–5.0 points), indicating the high consumer properties of the berries. The Albion and San Andrias varieties were also characterized by high and stable quality indicators.

The research showed that in 2023–2025 there will be a steady trend towards increasing transportability and tasting evaluation of garden strawberries.

The highest quality indicators are characteristic of remontant varieties, among which Murano stands out, ensuring maximum transportability and a high taste rating.

Among the short-day varieties, the best indicators were found in Kleri (early ripening period) and Asia (medium ripening period). Thus, remontant varieties are the most promising for the production of high-quality and transportable products, while short-day varieties are suitable for obtaining an early harvest with good taste characteristics.

Research has shown that strawberry varieties grown in Southeastern Kazakhstan differ in the timing of phenological phases, productivity, biochemical composition, and commercial quality of their berries. Early-ripening varieties were characterized by the earliest entry into the flowering and ripening phases, allowing for the first harvest as early as late May. Mid-season varieties ensure harvesting in the first half of June, while everbearing ones provide the longest fruiting period—until September—which is essential for ensuring a continuous supply of fresh berries.

In terms of the totality of economically valuable traits, the best results were shown by remontant varieties, especially Murano**,** San Andrias**,** and Albion. In addition, Elizabeth II, distinguished by high yields, large fruits, increased dry matter and sugar content, a high sugar-acid index, good transportability, and excellent tasting qualities. Among the short-day varieties, Clery was recognized as the most promising, as well as Asia, which combined relatively high productivity and good quality characteristics of berries.

The positive dynamics observed for most indicators in 2023–2025 demonstrate the well-adapted nature of the studied varieties to the region's soil and climate conditions. The practical significance of this study lies in the potential use of the obtained results in developing a range of varieties for industrial berry production aimed at increasing yields, product quality, and extending the time it takes for berries to reach the market.

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