Drip irrigation impact on cherry fruit quality and biochemical composition

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Abstract. The aim of the study was to investigate the impact of different drip irrigation regimes on the yield and quality of the Volochaevka and Molodezhnaya cherry varieties in the Central Region of Russia's Non-Black Earth Region from 2023 to 2025. After fruit ripening and harvesting, the average fruit weight per tree was determined for each variety and experimental treatment, along with the yield per hectare. Biochemical analysis was also performed using standard methods. The results showed that water availability significantly impacts the biochemical composition of the fruit. With an irrigation regime of 60–80% of MWC, the fruit had the highest concentrations of dry matter and vitamin C, indicating the development of denser, more intensely flavored berries. A 70–90% of MWC irrigation regime provided an optimal balance of productivity and quality: high yields (up to 32.5 t/ha for the Volochaevka variety and 36.6 t/ha for the Molodezhnaya variety in 2025) were combined with increased sugar content and moderate acidity. Under 80–100% of MWC irrigation conditions, an increase in average fruit weight was observed, but the dry matter concentration decreased, resulting in more watery berries. Control variants without irrigation were characterized by the lowest yields (8.3–20.7 t/ha) and increased acidity, which made the berries more watery. The results of the study suggest that the most efficient irrigation regime is achieved by maintaining soil moisture in the range of 70–90% of MWC.

1 Introduction

Cherries are one of the most studied stone fruit crops in Russia due to the combination of nutritional and technological value of their fruits. The biochemical profile determines the organoleptic perception and technological purpose of the harvest, with the key factors being the total sugar content, titratable acidity, soluble solids (SS), ascorbic acid, and mineral elements. Generalized data on domestic varieties reveal a significant varietal and ecological-geographical range in these parameters, which is important to consider when assessing quality and selecting raw materials for various types of processing [1; 2]. The biochemical composition of cherries is largely determined by moisture conditions, which regulate carbohydrate and mineral metabolism processes and also influence the organoleptic characteristics of the harvest.

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Sprinkler irrigation is traditionally used in orchards in southern regions. This method quickly compensates for moisture deficits, but if used inappropriately, it can lead to excessive soil moisture and a decrease in dry matter concentration in the fruit. Guidelines for intensive cherry cultivation emphasize that with sprinkling, fruit develops larger, but their sugar content and dry matter content may be somewhat lower than with drip irrigation.

Surface (furrow) irrigation is used in older orchards and areas with available water resources. Research shows that furrow irrigation achieves high yields. However, biochemical parameters of the fruit (in particular, sugar content and vitamin C concentration) can decrease due to uneven moisture distribution in the soil. Furrow irrigation can also dilute the cell sap and reduce the extractability of the raw material.

Under dryland horticulture conditions, the biochemical characteristics of fruits are strongly influenced by weather factors. Long-term observations of cherry varieties have shown that sugar and dry matter content is, on average, higher than under irrigation; however, yield remains unstable. Varieties grown under insufficient water supply conditions accumulate more dry matter and organic acids, but this reduces fruit weight and marketability [3]. In Dagestan, a wide range of sugar (8–15%) and ascorbic acid (up to 20 mg/100 g) levels was observed in dryland cherry varieties grown without irrigation, which is associated with the adaptability of genotypes to the regional climate [4]. Additional studies on hybrid forms of cherries have confirmed the variability of chemical composition depending on moisture supply conditions [5].

Drip irrigation is recognized as the most effective method of maintaining optimal water conditions in orchards. It ensures the stable accumulation of carbohydrates and organic acids and improves plant biometric parameters. Cherry seedlings with drip irrigation exhibit higher survival rates, growth rates, and improved biochemical characteristics of fruits compared to controls [6]. The combined use of drip irrigation and fertilizers increases the total content of soluble solids and sugars [7]. Optimizing moisture supply regimes allows for the regulation of plant loads and the formation of fruits with a more balanced sugar-acid composition. Modern research also emphasizes the importance of considering heat and moisture availability when developing drip irrigation schedules for fruit crops.

2 Object and methods

Field studies were conducted at the Michurinsky Garden educational and experimental farm of the fruit growing laboratory of the Russian State Agrarian University – Timiryazev Moscow Agricultural Academy from 2023 to 2025. The natural and climatic conditions in the study areas are typical of the Central Non-Black Earth Region of the European part of Russia. Each experimental variant was laid out in triplicate. The first factor was the drip irrigation regimes: control (no irrigation); maintaining moisture in the root zone of the soil in the range of 60-80% of MWC (minimal water-holding capacity of soil); 70-90% of MWC; 80-100% of MWC. The second factor was the Volochaevka and Molodezhnaya cherry varieties.

After fruit ripening and harvesting, the average weight of one fruit was determined for each variety and experimental treatment, the average weight of fruits per tree, and the yield per hectare were calculated. A biochemical analysis was performed using generally accepted methods. The sugar content in cherries was determined according to the method set out in the regulatory document GOST 26176-2019 “Processed fruit and vegetable products. Methods for determining sugars.” The ascorbic acid content in cherries was determined according to the requirements of GOST 34151-2017 “Processed fruit and vegetable products; methods for determining vitamin C.” Titratable acid in cherries was determined according to GOST ISO 750–2013 “Processed fruit and vegetable products. Determination of titratable acidity.” The content of potassium, calcium and magnesium in the fruits was determined

according to the method described in the normative document PND F 16.2.2: 2.3.71-2011 "Methodology for measuring the mass fraction of potassium, calcium, magnesium in food products" (clause 13). The determination of the mass fraction of soluble substances was carried out according to GOST 34128-2017 "Juice products. Refractometric method for determining the mass fraction of soluble dry substances." The moisture content in cherries was determined using a Sartorius MA160 moisture meter (Germany), operating on the principle of gravimetry with infrared heating.

3 Results and discussion

After harvesting and calculating the indicators reflected in Table 1, results were obtained on the dynamics of the average weight of one fruit, the average weight of fruits from one tree, and the yield of cherry trees for each variety from 2023 to 2025 (Table 1).

Table 1 – Characteristics of the yield of cherries Volochaevka and Molodezhnaya

Irrigation mode	Average weight of one fruit, g			Average weight of fruits per tree, kg			Yield per 1 ha, t		
	Volochaevka variety								
	2023	2024	2025	2023	2024	2025	2023	2024	2025
60-80% MWC	3.5	4.0	3.8	2.0	3.2	4.0	13.8	22.1	27.6
70-90% MWC	39	4.4	4.2	2.5	3.8	4.7	17.3	26.3	32.5
80-100% MWC	4.1	4.9	4.5	2.3	3.5	4.3	15.9	24.2	29.7
Control (without irrigation)	3.0	3.3	3.2	1.2	2.0	2.7	8.3	13.8	18.7
	Molodezhnaya variety								
60-80% MWC	4.0	4.5	4.3	2.4	3.6	4.5	16.6	24.9	31.1
70-90% MWC	4.5	5.0	4.8	3.0	4.5	5.3	20.7	31.1	36.6
80-100% MWC	4.7	5.3	5.0	2.7	4.0	5.0	18.7	27.6	34.6
Control (without irrigation)	3.3	3.6	3.5	1.5	2.5	3.0	10.4	17.3	20.7

Analysis of the yield of the Volochaevka and Molodezhnaya varieties in 2023-2025 showed a stable dependence of productivity on the irrigation regime (Table 1). On average, the yield of the Volochaevka variety in 2023 was 13.8-17.3 t/ha with irrigation and 8.3 t/ha without irrigation; in 2024 - 24.2-26.3 t/ha with optimal irrigation and about 13.8 t/ha in the control; in 2025 - up to 32.5 t/ha with a regime of 70-90% of MWC and no more than 18.7 t/ha without irrigation. The Molodezhnaya variety had higher indicators: in 2023, the yield reached 16.6-20.7 t/ha with irrigation and about 10.4 t/ha in the control; in 2024 - 24.9-31.1 t/ha with irrigation and 17.3 t/ha without it; in 2025 - up to 36.6 t/ha at 70-90% of MWC and about 20.7 t/ha without irrigation.

The optimal irrigation regime for both varieties was 70–90% of MWC, which combined the highest yield and stable fruiting. At 80–100% of MWC, yield remained high, but the fruits had a lower dry matter concentration (Tables 2–4). A 60–80% of MWC regime yielded slightly lower yields, but the fruits were denser and more concentrated. In the no-irrigation variants, yield decreased by 30–40%, especially in dry years, confirming the critical role of supplemental irrigation in establishing stable cherry yields in the Central Russian region.

The biochemical characteristics of cherry fruits are presented in Tables 2, 3, and 4 for each year of the study.

Table 2 – Biochemical characteristics of cherry fruits for 2023

Irrigation mode	Absolutely dry matter, %	Soluble solids, %	Titratable acidity, %	Ascorbic acid, mg/100 g	Sugars, %	Potassium, mg/kg	Calcium, mg/kg	Magnesium, mg/kg
Volochaevka variety								
60-80% MWC	23.00	18.5	0.70	17.5	6.00	4550.415	410.531	285.254
70-90% MWC	21.30	16.5	0.68	16.8	7.52	6305.418	330.514	325.576
80-100% MWC	11.00	8.9	0.62	16.0	7.80	7200.041	315.362	310.476
Control (without irrigation)	19.00	15.0	0.82	16.8	5.02	9500.417	310.614	300.067
Molodezhnaya variety								
60-80% MWC	20.00	16.4	0.70	17.0	7.20	6000.335	340.577	345.768
70-90% MWC	20.80	15.5	0.65	16.5	8.40	5900.520	430.723	310.798
80-100% MWC	13.50	10.8	0.62	16.8	8.33	5300.465	520.432	315.936
Control (without irrigation)	17.05	14.0	0.63	15.5	7.84	4234.438	403.390	295.601

The results of the biochemical analysis of the Volochaevka and Molodezhnaya cherry varieties for 2023 are shown in Table 2. In 2023, the best biochemical analysis indicators were achieved under a 60–80% MWC regime: maximum dry matter, vitamin C, and good sweetness. Under an 80–100% MWC regime, the juiciest fruits were found, but with low dry matter content. Due to stressful conditions in the control (without irrigation), higher acid levels, low sugars, but a high potassium concentration were observed. In 2023, varietal characteristics of the cherry were identified: Volochaevka showed a stronger biochemical response to stressful conditions and also had a higher acid content than Molodezhnaya. Molodezhnaya had more stable sugar and calcium levels, producing sweeter and calcium-rich fruits even under high humidity.

Table 3 – Biochemical characteristics of cherry fruits for 2024

Irrigation mode	Absolutely dry matter, %	Soluble solids, %	Titratable acidity, %	Ascorbic acid, mg/100 g	Sugars, %	Potassium, mg/kg	Calcium, mg/kg	Magnesium, mg/kg
Volochaevka variety								
60-80% MWC	25.50	20.5	0.62	18.7	6.71	4950.130	385.231	275.236
70-90% MWC	23.00	18.0	0.61	18.0	8.60	6700.631	310.313	315.261
80-100% MWC	11.50	9.2	0.55	17.2	9.00	7400.030	295.624	295.602
Control (without irrigation)	21.00	16.8	0.70	18.2	5.80	10100.695	290.361	285.705
Molodezhnaya variety								
60-80% MWC	22.50	18.0	0.61	18.5	8.32	6400.312	320.410	335.324
70-90% MWC	23.21	17.5	0.57	18.0	9.50	6350.453	400.513	295.790
80-100% MWC	14.00	11.2	0.55	18.2	8.9	5300.012	490.681	305.376
Control (without irrigation)	19.32	15.8	0.54	17.0	8.20	4550.413	370.721	280.698

The results of the biochemical analysis of the Volochaevka and Molodezhnaya cherry varieties for 2024 are shown in Table 3. In 2024, the best results for both cherry varieties were achieved when grown under a 70–90% MWC regime: high sugar content, a well-balanced acidity and vitamin C. Irrigation at 60–80% MWC resulted in high dry matter levels, especially for Volochaevka. With irrigation at 80–100% MWC, the fruits are more watery, with reduced dry matter and vitamin C content, but with increased sweetness. In the control (without irrigation), plants experience stress: higher acidity, lower sugar content, concentrated potassium, and decreased calcium.

Table 4 – Biochemical characteristics of cherry fruits for 2025

Irrigation mode	Absolutely dry matter, %	Soluble solids, %	Titratable acidity, %	Ascorbic acid, mg/100 g	Sugars, %	Potassium, mg/kg	Calcium, mg/kg	Magnesium, mg/kg
Volochaevka variety								
60-80% MWC	24.53	19.6	0.67	18.1	6.39	4698.230	399.128	277.65
70-90% MWC	22.30	17.6	0.67	17.3	8.10	6525.154	320.413	320.14
80-100% MWC	12.05	9.7	0.60	16.7	8.59	7593.080	304.718	300.89
Control (without irrigation)	20.11	16.1	0.78	17.4	5.45	9898.357	301.135	291.46
Molodezhnaya variety								
60-80% MWC	21.70	17.4	0.66	17.9	7.94	6236.692	330.671	339.17
70-90% MWC	22.35	16.9	0.61	17.3	9.00	6178.850	412.150	300.19
80-100% MWC	14.68	11.8	0.59	17.6	9.01	5506.416	503.143	302.34
Control (without irrigation)	18.62	15.2	0.58	16.1	8.45	4381.200	381.12	288.18

Table 4 presents the results of the biochemical analysis of the Volochaevka and Molodezhnaya cherry varieties for 2025. This year, the fruit of both cherry varieties showed a consistent relationship between their biochemical composition and water availability. At 60–80% MWC, the most concentrated fruit with high dry matter and vitamin C content was formed. A regime of 70–90% MWC provided an optimal balance of quality: increased sugar content, moderate acidity, and stable biologically active substances. At 80–100% MWC, the fruit was sweet and high in calcium, but watery due to a decrease in dry matter. In the control without irrigation, a decrease in sugar and vitamin C content was observed with an increase in acidity and potassium concentration, which is associated with the stressful nature of the water regime. A regime of 70–90% MWC was the most preferable for producing high-quality fruit in 2025.

Research conducted to study the impact of different irrigation regimes on the biochemical composition of Volochaevka and Molodezhnaya cherry fruits in the Moscow region from 2023 to 2025 demonstrated a consistent relationship between fruit quality and water availability and weather conditions during the growing season.

On average, over three years, the highest accumulation of absolute dry matter (ADM) and soluble dry matter (SDM) was observed under an irrigation regime of 60–80% MWC, where fruits had higher dry matter concentrations, ascorbic acid content, and a balanced titratable acidity level. However, under this regime, sugar content was somewhat lower than under more intensive regimes.

The optimal balance of quality indicators was achieved with a 70–90% MWC regime. Under these conditions, the fruits were characterized by increased sugar content, adequate dry matter levels, reduced acidity, and stable vitamin C accumulation. For both varieties, this

regime ensured a combination of good flavor characteristics and high levels of biologically active substances.

Under 80–100% MWC conditions, dry matter concentrations decreased due to dilution of cell sap, but sugar and calcium contents increased (especially in the Molodezhnaya variety). Thus, this treatment resulted in sweeter but more watery fruits.

Under no irrigation conditions, fruits were formed with reduced sugar and vitamin C content and increased acidity. Potassium concentrations also increased due to reduced fruit weight and stress caused by the lack of irrigation.

Summarizing the results of the biochemical analysis of cherry fruits, it can be said that the best quality indicators of the Volochaevka and Molodezhnaya cherry fruits are achieved with irrigation within 70–90% MWC, which ensures both high taste value and an optimal level of biologically active substances.

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