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Effect of fertilization with bioproducts on the nutritional and physiological status of Glohaven peach cultivar

Irina Staneva* **and Vanya Akova**

Agricultural Academy, Fruit Growing Institute – Plovdiv, 4004 Plovdiv, Bulgaria
**Corresponding author:* tsarewa@abv.bg

Abstract

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The study was carried out during the period 2020–2022 in a young peach plantation at the territory of the Fruit-Growing Institute of Plovdiv, Bulgaria. Glohaven cultivar, grafted on the vegetative rootstock GF677, was the object of the investigation. The following fertilization treatments were studied: soil application of Agriful at rates of 670 ml/da, 1.0 L/da and 1.3 L/da; foliar application of Humustim at rates of 120 ml/da, 140 ml/da and 180 ml/da; and Lumbreco applied as a foliar treatment (450 ml/da), soil treatment (1.7 L/da) or combined foliar (450 ml/da) and soil (1.7 L/da) treatment, as well as an untreated control. The aim of the present study was to follow the effect of the selected bioproducts on: the concentration of N, P, K, Mg and Fe in the leaves, the content of leaf pigments (chlorophyll a, b, a+b and carotenoids), and the biochemical composition of the fruits. The applied fertilization successfully maintained the nutrient reserves in the peach leaves and favoured the accumulation of larger amounts of N, Ca, Mg and Fe. The variants with Lumbreco 450 ml/da + 1.7 L/da, Agriful 1.0 L/da and Humustim 120 ml/da had the best effect on the formation of photosynthetic pigments. An increase of up to 62% in the content of chlorophyll a+b was reported at the end of the study period compared with the untreated control. All fertilized treatments had higher TSS (°Brix) values than the control. Sucrose concentrations were 1.4–2.0 times higher than those of invert sugars.

Keywords: peach; fertilization; bioproducts; mineral elements; photosynthetic pigments

Introduction

Soils contain natural reserves of nutrients, but to a large extent they are in forms unavailable to plants. Only a small part of them are released by the biological activity of soil microorganisms or through chemical processes. The application of different types of fertilizers (chemical and organic fertilizers, as well as bioproducts) has different effects on nutrient uptake, crop growth and soil fertility (Chen, 2006; Yang et al., 2019). Proper use of fertilizers can effectively increase nutrient concentrations in plant leaves and soil, thereby improving crop yield and quality (Wan et al., 2021). In response to the global trend towards limiting the use of mineral fertilizers in agriculture, a number of studies have been conducted to reduce their rates or replace them with other products that do not pollute the soil or groundwater and do not negatively affect product quality (Frąc et al., 2023).

The use of organic fertilizers has been shown to significantly affect soil chemical properties by increasing organic matter, total nitrogen and available phosphorus (Ji et al., 2021). Biofertilizers can enhance nutrient availability by converting nutrients from unavailable to plant-available forms. In a study carried out over an eight-year period using bioproducts, Staneva and Kornov (2020) found that the long-term application of Biohumus and Agriful bioproducts provided an optimal nutrient supply to the soil (nitrogen, phosphorus and potassium). Several studies have shown that biofertilization has a positive effect on vegetative growth, mineral nutrition and fruit production in various fruit species (Von-Bennewitz and Hlusek, 2006; Fawzi et al., 2010;

El-Gleel Mosa et al., 2014; Kumar et al., 2013; Perazzoli et al., 2020; Alowaiesh et al., 2023; Staneva and Akova, 2022; Akova et al., 2023).

The aim of the present study was to investigate the effects of using three biopreparations (Lumbreco, Agriful and Humusim) in a young peach plantation (cv. Glohaven/GF677) on: 1) The concentration of N, P, K, Ca, Mg and Fe in the leaves; 2) The content of leaf pigments (chlorophyll a, b, a+b and carotenoids); 3) The biochemical composition of the fruits; 4) The yields.

Material and Methods

The study was carried out during the period 2020–2022 in a young peach plantation established in autumn 2018 at the Fruit Growing Institute – Plovdiv, Bulgaria. The object of the study was the Glohaven cultivar grafted onto the GF677 vegetative rootstock. The plantation was irrigated by gravity during the growing season. The bioproducts Agriful, Humustim and Lumbreco were applied throughout the three-year study period. The following fertilization treatments were studied: soil application of Agriful as an aqueous solution at three rates (670 ml/da, 1.0 L/da and 1.3 L/da); foliar feeding with Humustim at three rates (120 ml/da, 140 ml/da and 180 ml/da); treatment with Lumbreco – foliar (450 ml/da), soil (1.7 L/da), combined – foliar (450 ml/da) + soil (1.7 L/da) and control – untreated. Each treatment was replicated three times. The fertilizer treatments were applied four times during the growing season, at 15–20-day intervals from April through July. Each year, leaf samples were randomly collected from both sides of the tree crown and from the middle part of current-year shoots for each fertilization treatment. The total concentrations were determined as follows: nitrogen (by the Kjeldahl method), phosphorus and iron spectrophotometrically, potassium by flame photometry, and calcium and magnesium complexometrically. The contents of chlorophyll a (Chl a), chlorophyll b (Chl b) and carotenoids were determined spectrophotometrically in a 95% ethanol extract. At the technological maturity stage of the fruits, average samples were collected for each fertilization treatment for the analysis of the biochemical characteristics: dry matter content – by Brix; sugars – by the Schoorl–Regenbogen method; total acidity – titrimetrically; active acidity (pH) – potentiometrically. Initial yield was determined for each fertilization treatment and expressed in kg/da.

The results were statistically analysed using Duncan's multiple range test (Duncan, 1955; Harter, 1960).

Results and Discussion

The main characteristics and total nutrient status of the soil at the beginning of the experiment are presented in Table 1.

The soil in the experimental plot was an alluvial meadow soil, with a slightly alkaline soil reaction (Table 1). Electrical conductivity was relatively low, ranging 1.73–1.88 mS/m^{-1}. The amount of mineral nitrogen in both soil profiles varied from 18.52 mg/kg to 22.92 mg/kg, indicating that the soil was low in nitrogen. For the 0–30 cm layer, the soil was low in phosphorus and potassium. There were differences in soil phosphorus and potassium contents in depth of the soil profile. The soil had a medium phosphorus level (13.2 mg/100 g soil) and a high in potassium (38 mg/100 g soil) at 30–60 cm depth.

The effect of the different types of bioproducts on the concentrations of N, P and K, Ca, Mg and Fe in the leaves of the peach cultivar Glohaven is presented in Table 2.

The biofertilizers increased the nutrient concentrations in the peach leaves. There was a definite tendency to an increase in the content of nitrogen, calcium, magnesium and iron from the first to the third year. The highest value of the element N was reported in the variants with combined treatment with Lumbreco (450 ml/da + 1.7 L/da), Agriful (1.0 L/da) and Humustim (140 ml/da) – 2.99%, 3.0% and 3.01%, respectively, the percentage increase compared with the untreated control ranged from 15% to 32%.

Phosphorus concentrations were within the optimal range, varying from 0.27% to 0.41% among the fertilization treatments. A distinct statistically significant difference was observed only between the variants Lumbreco (450 ml/da + 1.7 L/da) and Humustim (140 ml/da) compared to the unfertilized control in the second and third years.

The K concentration in the leaves was high during the three growing seasons, ranging from 2.45% to 2.99%. The differences among the fertilization treatments were not statistically significant. A statistically significant difference was observed compared with the untreated control. Similar re-

Table 1. Agrochemical characteristics of the soil

Variants	EC	pH (H_2O)	P_2O_5 mg/100 g	K_2O mg/100 g	NH_4^+ mg/kg	NO_3^- mg/kg
	mS/m^{-1}					
0–30 cm	1.88	7.65	5.7	16. 00	22.92	19.72
30–60 cm	1.73	7.42	13.2	38.00	18.52	20.02

Source: Authors' own elaboration

sults were obtained by Eissa et al. (2007), who found that the application of humic acid improved the content of N, P and K in the leaves. According to Hajji and Sanaa (2016) and Al-Hadethi et al. (2017), the application of biofertilizers also led to a significant increase in the content of macronutrients in the leaves.

The calcium content of the leaves increased over the years of the experiment. The lowest values for Ca were reported in 2020 in the trees treated with Lumbreco (foliar and combined application) with values of 2.28% and 2.10%. However, in 2021 the Ca content of those variants increased by 24% and 33% compared to 2020. A significant increase in the content of Ca in the leaves when applying organic fertilizer was also established by Sharaf et al. (2015). No significant differences in calcium concentration were found among the fertilization treatments during the three experimental years. Similar results were reported by Fayed (2005a).

The magnesium content in peach leaves varied from year to year. In 2020, the lowest values were reported: from 0.45% for Humustim (140 ml/da) to 0.66% for Agriful (670 ml/da). In 2022, the values were within the range of high reserves (0.70% to 0.88%). The variants treated with Agri-

Table 2. Content of nutrient elements in the leaves of Glohaven cultivar for 2020, 2021 and 2022

2020							
Variants	Rate	% N	% P	% K	% Ca	% Mg	mg/kg Fe
Lumbreco	450 ml/da	2.03 bc	0.30 b	2.69 a	2.28 bc	0.63 a	74.27 e
	450 ml/da + 1.7 L/da	2.58 a	0.34 a	2.54 d	2.10 bc	0.54 ab	77.36 c
	1.7 L/da	2.39 ab	0.27 c	2.61 bc	2.35 b	0.50abc	72.99 f
Humustim	120 ml/da	2.28 abc	0.33 a	2.59 bc	2.92 ab	0.51abc	75.14 de
	140 ml/da	2.28 abc	0.33 a	2.58 c	2.92 ab	0.45 bc	75.49 d
	180 ml/da	2.24 abc	0.31 b	2.58 c	2.87 ab	0.51abc	69.73 g
Agriful	670 ml/da	2.29 abc	0.30 b	2.63 b	2.94 ab	0.66 a	96.09 a
	1.0 L/da	2.01 bc	0.30 b	2.57 c	3.7 a	0.63 a	72.65 f
	1.3 L/da	2.10 bc	0.27 c	2.45 d	3.03 ab	0.50abc	82.08 b
Control		1.95 c	0.21 d	2.25 e	1.44 c	0.36 c	69.36 g
2021							
Variants	Rate	% N	%P	%K	% Ca	%Mg	mg/kg Fe
Lumbreco	450 ml/da	2.73 a	0.36 ab	2.52abc	2.84 de	0.65 e	116.56 a
	450 ml/da + 1.7 L/da	2.71 a	0.38 a	2.58 ab	2.81 e	0.54 f	112.19 ab
	1.7 L/da	2.75 a	0.30 c	2.69 a	3.15 c	0.71 bc	113.85 ab
Humustim	120 ml/da	2.44 b	0.28 c	2.66 ab	3.20 bc	0.72 b	81.65 e
	140 ml/da	2.42 b	0.37 a	2.62 ab	3.75 a	0.55 f	80.05 ef
	180 ml/da	2.34 bc	0.27 c	2.60 ab	2.9 d	0.70 c	78.72 ef
Agriful	670 ml/da	2.27 cd	0.29 c	2.77 a	3.22 b	0.47 g	86.86 de
	1.0 L/da	2.34 bc	0.31 bc	2.68 ab	3.21 b	0.81 a	95.35 cd
	1.3 L/da	2.38 bc	0.31 bc	2.54abc	2.80 e	0.66 d	104.90 bc
Control		2.16 d	0.28 c	2.09 c	2.70 f	0.39 h	70.18 f
2022							
Variants	Rate	% N	%P	%K	% Ca	%Mg	mg/kg Fe
Lumbreco	450 ml/da	2.81 cd	0.39 abc	2.61 cd	3.65 bcd	0.77 ab	142.16 d
	450 ml/da + 1.7 L/da	2.99 ab	0.40 a	2.69bcd	3.69 bc	0.87 a	142.25 d
	1.7 L/da	2.82 cd	0.37 c	2.99 a	3.60 bcd	0.82 a	148.94 cd
Humustim	120 ml/da	2.91 abc	0.38 bc	2.95 a	3.59 bcd	0.78 ab	152.02 bc
	140 ml/da	3.01 a	0.41 a	2.92 a	4.23 a	0.79 ab	157.67 ab
	180 ml/da	2.88 bc	0.38 bc	2.84 ab	4.00 ab	0.70 ab	163.51 a
Agriful	670 ml/da	2.71 d	0.37 c	2.50 de	3.43 cd	0.71 ab	145.68 cd
	1.0 L/da	3.00 a	0.39 abc	2.69 bc	3.98 ab	0.71 ab	149.89 cd
	1.3 L/da	2.96 ab	0.36 d	2.65bcd	3.23 cd	0.88 a	147.89 cd
Control		2.57 e	0.30 e	2.37 e	3.17 d	0.55 b	126.19 e

Source: Authors' own elaboration

ful (1.3 L/da) and Lumbreco (450 ml/da + 1.7 L/da) had the highest values, the differences compared with the control and the other fertilization treatments were statistically significant. These results are consistent with those reported by Melo et al. (2016).

An increase in Fe values was observed in the leaves of the treated trees during the different vegetation seasons. The increase in the average value of Fe in 2021 compared to 2020 was by 23% and the values obtained in 2022 were 59% higher than those in 2021.

Leaves are the main organs in which photosynthesis takes place (Drobek et al., 2019). The bioproducts used in the present study had a positive effect on the chlorophyll content in the leaves of the experimental trees, thus increasing the efficiency of the photosynthetic process (Table 3).

A unidirectional trend for higher chlorophyll values in the fertilized plants compared to the untreated control trees was observed. The highest values for chlorophyll a were reported in the variant with Agriful (1.0 L/da) in all three years of the study, followed by the variant with Humustim (120 ml/da) and Lumbreco (450 ml/da + 1.7 L/da). The chlorophyll a concentration in the third year was 47% higher than that in the first year. The content of chlorophyll a was significantly higher than that of chlorophyll b in all the studied variants.

Table 3. Content of chlorophyll (a, b, a+b and carotenoids) when fertilizing with Lumbreco, Agriful and Humustim for 2020, 2021 and 2022

2020					
Variants	Rate	Chl. a mg/g (DW)	Chl. b mg/g (DW)	Chl. a+b mg/g(DW)	Carotenoidi mg/g(DW)
Lumbreco	450 ml/da	3.61 ef	0.96 cde	4.55 e	4.65 e
	450 ml/da + 1.7 L/da	3.99 c	1.25 a	4.90 c	4.97 b
	1.7 L/da	3.69 ef	0.97 cde	4.89 c	4.88 bc
Humustim	120 ml/da	4.36 a	0.98 cd	5.30 a	4.80 cd
	140 ml/da	3.83 d	1.01 bc	4.70 d	4.91 b
	180 ml/da	3.59 f	0.92 de	4.45 e	4.72 de
Agriful	670 ml/da	3.68 ef	0.89 ef	4.49 e	4.64 e
	1.0 L/da	4.13 b	1.03 bc	5.09 b	5.07 a
	1.3 L/da	3.7 e	1.08 b	4.81 cd	4.63 e
Control		2.98 g	0.89 ef	3.79 e	4.21 f
2021					
Lumbreco	450 ml/da	4.98 c	2.07 bcd	7.04 bc	4.72 cd
	450 ml/da + 1.7 L/da	5.65 ab	2.24 ab	7.88 a	5.10 a
	1.7 L/da	5.41 b	2.36 a	7.76 a	5.06 a
Humustim	120 ml/da	4.66 de	2.07 bcd	6.65 cd	4.63 de
	140 ml/da	4.87 cd	2.13 bc	7.11 b	4.98 ab
	180 ml/da	5.41 b	2.35 a	7.70 a	4.98 ab
Agriful	670 ml/da	4.65 de	1.01 cd	6.66 cd	4.64 d
	1.0 L/da	5.74 a	2.37 a	7.95 a	4.89 bc
	1.3 L/da	4.78 cd	1.91 d	6.60 d	4.62 d
Control		4.50 e	1.97 cd	4.46 e	4.13 e
2022					
Lumbreco	450 ml/da	5.63 b	2.68 a	8.24 b	4.58 ef
	450 ml/da + 1.7 L/da	6.10 a	2.58 b	8.67 a	5.15 a
	1.7 L/da	5.40 e	2.19 d	7.57 e	4.71 d
Humustim	120 ml/da	6.10 a	2.52 b	8.55 a	4.98 b
	140 ml/da	5.60 bc	2.31 c	7.88 c	4.83 c
	180 ml/da	5.02 f	2.06 e	7.03 f	4.47 f
Agriful	670 ml/da	5.51 cd	2.26 cd	7.78 cd	4.63 de
	1.0 L/da	6.17 a	2.50 b	8.62 a	5.25 a
	1.3 L/da	5.49 de	2.27 cd	7.70 de	4.63 de
Control		3.04 g	1.21 f	4.26 g	4.29 g

Source: Authors' own elaboration

The lowest values of chlorophyll b were found during the first vegetation season, ranging from 0.89 to 1.25 mg/g DW. During the third vegetation, chlorophyll b reached 2.68 mg/g DW in the variant with Lumbreco (450 ml/da), 2.58 mg/g DW in the variant with Lumbreco (450 ml/da + 1.7 L/da) and 2.50 mg/g DW in the variant with Agriful (1.0 L/da), the differences compared with the other treatments and the untreated control were statistically significant. The results for the total chlorophyll a+b monitored within the three-year period showed high values, suggesting good adaptation of the plants to the growing conditions. The control untreated plants had the lowest values (3.79–4.46 mg/g DW). In all the other variants, the values for the content of chlorophyll a+b were significantly higher, with an increase of up to 62% compared with the control. The highest values were reported for the variants with Lumbreco 450 ml/da + 1.7 L/da (8.67 mg/g DW), Agriful 1.0 L/da (8.62 mg/g DW) and Humustim 120 ml/da (8.55 mg/g DW). During the study period, carotenoid concentrations varied within a narrower range than chlorophyll concentrations (from 4.64 to 5.25 mg/g DW), the variants with Agriful 1.0 L/da (5.25 mg/g DW), Lumbreco 450 ml/da + 1.7 L/da (5.15 mg/g DW) and Humustim 120 ml/da (4.98 mg/g DW) standing out.

Peach fruit has a rich and varied chemical composition. Total soluble solids (TSS) are an indicator of sugar concentration in fruits and are one of the fundamental parameters used to assess fruit quality (Shah et al., 2024). According to Grajkowski and Ochmian (2007), fruits with TSS content above 12 °Brix are characterized by excellent taste. Dumitru (2009) indicated a variation in the dry matter content ranging from 9.20 °Brix to 14 °Brix. In the present study, TSS values were positively affected by the application of the selected bioproducts (Table 4).

All fertilized treatments had higher values for TSS (°Brix) compared to the control. In the first year (2021), the average values of TSS in peach fruits were from 11.0°Brix to 13.5°Brix. In the second year (2022), the TSS content reached the following values: 15.20°Brix; 14.90°Brix and 13.80°Brix in the variants treated with Humustim (180 ml/da), Agriful (670 ml/da), Lumbreco (1.7 L/da) and Agriful (1.3 L/da), respectively. The reported increase compared with the control was 17%.

The perceived sweetness of peach fruit depends on its total sugar content (Nowicka et al., 2019). It has been proven that the amount of sugars is greatly influenced by the growing conditions. The application of bioproducts had a favourable effect on the accumulation of sugars in the fruits. The content of total sugars in the different treated variants varied from 10.24% to 12.28% in 2021 and from 11.3% to 14.20% in 2022. Sucrose is the predominant sugar in peach fruits. Sucrose values averaged 1.4–2.0 times higher than inverted sugar values. In the second year, the sucrose content increased by 13% compared to the first. The increase in sucrose compared to the untreated control was 35%. The vari-

Table 4. Biochemical composition of peach fruits of Glohaven cultivar at different fertilization levels of organic products for the period 2021–2022

Variants / Rate	Lumbreco			Humustim			Agrifull			Control
	450 ml/da	450 ml/da + 1.7L/da	1.7 L/da	120 ml/da	140 ml/da	180 ml/da	670 ml/da	1.0 L/da	1.3 L/da	0
2021										
Brix, %	12.70	12.60	13.50	12.90	12.20	11.00	13.40	13.50	13.00	9.30
Total sugars, %	10.38	11.52	11.24	10.38	11.68	12.28	11.30	10.24	11.76	9.82
Inverted sugar, %	4.16	4.34	4.78	4.58	4.16	4.02	4.58	4.70	3.96	4.64
Sucrose, %	5.91	6.90	6.14	5.51	7.14	7.85	6.38	5.26	7.41	4.92
Total acids, %	0.85	0.89	1.32	0.86	1.09	1.14	1.09	0.92	0.89	0.85
pH	3.90	3.86	3.89	3.83	3.98	3.72	3.88	3.99	3.82	3.84
Acidimetritic coefficient	12.25	12.97	8.52	12.05	10.68	10.76	10.40	11.18	13.24	11.59
2022										
Brix, %	13.50	13.40	13.80	13.40	14.00		14.90	12.60	13.80	11.80
Total sugars, %	12.66	11.90	13.56	13.72	14.34	11.30	14.20	13.56	13.56	11.82
Inverted sugar, %	5.72	4.64	5.52	5.12	6.48	5.52	6.26	5.66	5.86	6.06
Sucrose, %	6.59	8.72	7.64	8.17	7.47	5.49	7.54	7.51	7.32	5.47
Total acids, %	0.65	0.60	0.80	0.70	0.64	0.61	0.89	0.68	0.79	0.50
pH	3.95	3.95	4.02	4.04	3.92	4.16	4.32	3.97	3.93	4.17
Acidimetritic coefficient	19.50	19.79	16.96	19.68	22.32	18.58	16.05	19.94	17.25	23.69

Source: Authors' own elaboration

Table 5. Yield (kg/da) from Glohaven' cultivar in different variants with application of Lumbreco, Humustim and Agriful during the period 2021–2022

Variants / Rate	Lumbreco			Humustim			Agrifull			Control
	450 ml/da	450ml/da +1.7L/da	1.7 L/da	120 ml/da	140 ml/da	180 ml/da	670 ml/da	1.0 L/da	1.3 L/da	0
	2021									
Yeild (kg/da)	530	821	1104	802	485	1313	414	634	571	285
	2022									
Yeild (kg/da)	303	389	300	198	416	419	191	212	383	151

Source: Authors' own elaboration

ants treated with Lumbreco (450 ml/da + 1.7 L/da) – 8.72% and Humustim (120 ml/da) – 8.17% stood out with the highest reported values.

Malic acid is the principal organic acid found in ripe fruit and it serves as a measure of the total acidity of peach fruits (Zhang et al., 2010). The total acid content in the present study varied from 0.60% to 1.32%. The values obtained in 2021 were higher than those obtained in 2022.

Data on the active acidity (pH) for the different variants of fertilization varied within a narrow range from 3.72 to 4.16.

The sugar-acid ratio is one of the main quality indicators characterizing the taste of peach fruits. The good combination between acids and sugars enables the sugar-acid ratio to be within favourable limits (from 10 to 20). In all the treated variants, the sugar-acid ratio in 2022 was at optimal values (from 16.05 to 19.96) (Table 4).

The initial yield was also reported by variants during the study period (Table 5). The yield of the Glohaven peach cultivar increased following the application of organic fertilizers. The yield obtained in 2021 (third vegetation) showed a large variation between the variants, and it was from 414 kg/da with the application of Agriful (670 ml/da) to 1313 kg/da with Humustim (180 ml/da). Similar results were reported by Massai and Loreti (2004) for Flavorcrest cultivar grafted on GF677 rootstock. In 2022 (the fourth growing season), recurrent spring frosts hit the trees during flowering, which led to a reduction in yields. The recorded yields were significantly lower (216–418 kg/da) and were therefore not representative. In both growing seasons, the untreated control trees had lower yields than the fertilized treatments. Increased yields after applying organic fertilizers were also obtained in apple (Milošević et al., 2022), pear (Wang et al., 2022), pear-jujube (Ye et al., 2022) and kiwi (Liu et al., 2020).

Conclusions

Fertilization with the bioproducts Lumbreco, Agriful and Humustim successfully maintained the nutrient reserves in the peach leaves and favoured the accumulation of larger amounts of nitrogen, calcium, magnesium and iron.

The variants treated with Lumbreco (450 ml/da + 1.7 L/da), Agriful (1.0 L/da) and Humustim (120 ml/da) had the best effect on the formation of photosynthetic pigments.

The application of Lumbreco, Agriful and Humustim positively affected the biochemical characteristics of peach fruits. A 17% increase in the dry matter content of the fruits of the Glohaven cultivar was reported compared to the control.

Sucrose is the dominant sugar in peach fruit. Sucrose values averaged 1.4–2.0 times higher compared to inverted sugar values. Sucrose concentration was 35% higher than in the untreated control.

In all fertilized treatments, the sugar–acid ratio was within the optimal range, which is indicative of the good taste qualities of the peach fruits.

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