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Influence of organic fertilization on the growth and productivity of red raspberry (*Rubus idaeus* L.) under combined abiotic stress

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Abstract: *The present study evaluates the impact of organic fertilization on the biometric and productive indicators of the 'Polka' raspberry cultivar under the influence of combined abiotic stress – transplant shock, drought, and extreme high temperatures (2025). The experiment was conducted at the experimental field of the Faculty of Agriculture at Trakia University, using a planting scheme of 2.20 x 0.30 m. The main objective of the research is to determine the potential of organic fertilization to mitigate the negative effects of stress and maintain the productivity of the plantation. Vegetative parameters (number, height, and diameter of shoots) and reproductive indicators (yield and fruit weight) were analyzed. The results show that the extreme conditions in 2025 severely suppressed vegetative growth in the control (unfertilized) plants, where shoot height and thickness decreased by 50.4% and 47.6%, respectively, compared to the previous year. Organic fertilization exhibited a pronounced buffering effect, maintaining a better vegetative habitus and an optimized shoot density (14.3 shoots/m). This led to a 37.16% higher yield in the fertilized variants (1154.9 g/m) and preserved the standard fruit size under drought conditions. The study proves that organic fertilization is a key factor for enhancing resilience and maintaining raspberry productivity under abiotic stress.*

Keywords*:* *Rubus idaeus* L., organic fertilization, abiotic stress, yield

Introduction

Raspberry is a fruit species of great economic importance, due to its high productivity and profitability. It possesses significant ecological plasticity, allowing it to develop in environments unfavorable for other crops. However, this adaptability is severely limited in the presence of extreme abiotic stress. The plants are highly sensitive to water deficit, temperature anomalies, and nutrient imbalance, which, combined with biotic factors, can drastically compromise growth and yield (Petrović et al., 2020).

The productivity of raspberry plants is determined by the shoot density per linear meter, their biometric parameters (height and thickness), as well as the number and weight of fruits per plant. Yield and product quality are directly dependent on the geographical location, the agrometeorological conditions of the region, cultivar characteristics, and the applied agricultural practices (Georgiev, 2006; Leposavić et al., 2013; Pešaković et al., 2013; Zorenc et al., 2017).

Over the past decade, interest in biological technologies that exclude the application of synthetic chemicals has been growing (Krishkova and Tsolova, 2021). Organic farming is establishing itself as a sustainable alternative to conventional production, stimulated by the global demand for clean foods produced without mineral fertilizers and pesticides (Gomiero, 2017; Estrada-Beltran et al., 2020).

Nevertheless, the influence of organic fertilization on fruit quality remains a subject of debate in scientific circles. On one hand, numerous studies demonstrate that organically grown crops, such as raspberries, strawberries, blueberries, and plums, exhibit higher antioxidant potential and a richer content of phenolic compounds (Olsson et al., 2006; Jin et al., 2011, 2012; Crecente-Campo et al., 2012; Cuevas et al., 2015). On the other hand, some authors remain skeptical, highlighting the lack of conclusive evidence for significant advantages in the physicochemical composition of organic food compared to conventional foods (Lairon, 2010; Lima and Vianello, 2011; Oliveira et al., 2013). This drives the growing need for additional research to optimize ecological technologies and ensure the long-term sustainability of organic agriculture under climate change conditions. In this regard, foliar feeding with macro- and microelements, supplemented by various biostimulants, is emerging as a highly effective approach (Wojcik, 2005; Ochmian et al., 2008; Krok and Wieniarska, 2008; Ičanović and Handanović, 2022; Unuk et al., 2023).

Despite the accumulated data, research on the comprehensive effect of organic fertilization on raspberries remains insufficient, and a number of aspects regarding the physiological response of the plants are yet to be fully elucidated. Studies conducted so far have focused mainly on tracking the effects of different fertilization rates on yield and fruit quality under standard conditions. However, in the context of increasingly frequent climate anomalies, the question of how

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organic nutrition influences plant resilience to abiotic stress is becoming more relevant than ever.

In response to this scientific necessity, the main objective of the present study is to determine the influence of organic fertilization on the vegetative performance and productivity of red raspberry (cultivar 'Polka ') both under optimal conditions and under the impact of severe, combined abiotic stress.

Since temperature is among the leading factors whose progressive increase exerts a direct impact on yield (Kishor P, 2023; Aguilar, 2025), the lack of detailed research on individual berry crops limits the capacity for response (Pechan et al., 2023). In this context, the present study seeks to fill the existing gap by evaluating the potential of organic fertilization as an effective tool for minimizing the negative consequences of climate stress in red raspberry.

Materials and methods

The experimental work was carried out during the period 2024-2025 at the Educational and Experimental Field of Trakia University, Stara Zagora. The object of the study was the primocane-fruiting (everbearing) red raspberry cultivar 'Polka', investigated under conditions of late-summer to autumn cropping. The plants were established using a planting scheme of 2.20 m inter-row and 0.30 m intra-row spacing. The agrotechnical management of the plantation included maintaining a bare fallow in both the inter-row and intra-row spaces through regular soil cultivation.

The experiment was designed in a randomized block design with two variants, each set up in three replications of one linear meter of the intra-row area:

- Variant I (Control) – Untreated plants.
- Variant II (Treated) – Application of „Proserpina" organic fertilizers.

The products were applied foliarly in three distinct phenological phases: at the onset of the growing season, before flowering, and prior to harvest (Table 1). Their influence on the vegetative and reproductive characteristics of the raspberry plants was investigated. The applied formulations contained macro- and microelements, microorganisms, and amino acids, with the following compositions:

- SlastyK - 12% K_2O, 10% P_2O_5, 0,3% B;
- KheQu - 8% N (7% organic, 1% ammoniacal), 2% P_2O_5, 3% K_2O, 2% amino acids.

The data were statistically processed using analysis of variance (ANOVA). The significance of the differences among mean values was determined using the LSD test at $p \leq 0.05$.

Table 1. Treatment phases, dates, and application rates in 2024 and 2025

Treatment Stage	Date (2024)	Date (2025)	Products Proserpina		Doses (ml/da)
Beginning of vegetation	12.04.2024	25.04.2025	KheQu	SlastyK	250
Before blossoming	29.04.2024	09.05.2025	KheQu	SlastyK	300
Before harvest	31.05.2024	05.06.2025	KheQu	SlastyK	300

In accordance with the methodology for the study of plant resources (Nedev et al., 1979), the following vegetative and reproductive performance indicators of the raspberry plants were recorded:

- average number of shoots per linear meter – the number of shoots per linear meter was counted in each replication
- average height of shoots (cm) – all shoots from each replication were measured
- average thickness of shoots (mm) – measured at 10 cm from the soil surface;
- average fruit weight (g) – samples of 30 fruits were weighed during one of the early harvests and two of the peak harvests;
- average yield per 1 (g/m).

Results and discussion

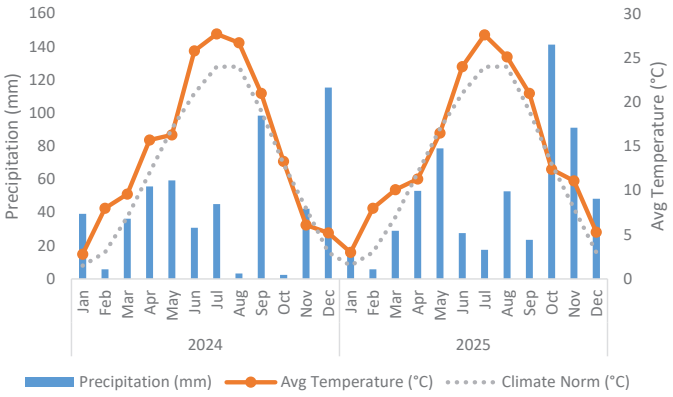

Figure 1. Climatic characteristics for the 2024–2025 period.

The analysis of the meteorological data during the study period (2024-2025) shows significant deviations from the climatic norm, characterized by pronounced temperature and water stress during the vegetation period of the crop (Figure 1). In both years, a trend toward a significant increase in average monthly temperatures compared to the long-term norm was observed during the summer months (June-August). In 2024, a temperature peak was recorded in July, combined with a critical rainfall deficit in August and October, which created conditions for severe combined abiotic stress during the formation and ripening of the fruits of the ‚Polka' cultivar. In July 2025, the average monthly temperature reached 27.6°C (against a norm of 24.0°C), once again accompanied by a critical rainfall deficit (barely 17.6 mm). During the second experimental year, the drought was most pronounced in July, followed by an unusually high rainfall peak in October (141.3 mm), which additionally strained the adaptive mechanisms of the plants. This lack of precipitation, combined with the high temperatures, created conditions for severe atmospheric and soil drought during the most active phases of the crop's development. These climate characteristics allow for an objective evaluation of the potential of organic fertilization as a tool for overcoming stress conditions in plants.

Table 2. Vegetative and reproductive indicators of red raspberry cv. ‚Polka' (2024-2025)

Year	Variant	Average number of canes (shoots/m)	Average cane height (cm)	Average cane diameter (mm)	Average yield (g/m)	Average fruit weight (g)
2024	Control	17.0 a	120.82 a	6.41 a	1435.43 b	2.36 ab
	Treated	22.0 a	132.31 a	6.89 a	1584.11 a	2.50 a
2025	Control	20.0 a	59.95 c	3.36 c	828.00 d	2.04 b
	Treated	14.3 a	82.02 b	5.01 b	1154.90 c	2.52 a

Note: Different letters (a, b, c, d) indicate statistically significant differences according to the least significant difference (LSD) method at $p<0.05$ after two-way analysis of variance

The results of the biometric analysis (Table 2) show the strong dependence of the plants on both agrometeorological conditions and organic fertilization. Under the conditions of 2024, the plants formed vigorous stems (over 120 cm in height and over 6 mm in thickness). These parameters are in agreement with the standard cultivar characteristics for ‚Polka' established by Danek (2002), who described the cultivar as moderately vigorous under optimal conditions.The treated plants produced a higher number of shoots than the control group, but the differences were not statistically significant. The differences in vegetative growth between the control and the fertilized variant in this year were not statistically proven. Nevertheless, organic fertilization had a positive effect on productivity, with the fertilized plants achieving a significant yield of 1584.11 g/m compared to the control (1435.43 g/m). The lower yield in 2024 in the control group can be explained by the extreme drought and high temperatures in August, recorded in Figure 1, while better resistance was observed in the organically fertilized variants.

The drastic difference in plant response became evident in 2025. The combined effect of root damage (resulting from transplant shock) and the subsequent summer drought led to severe growth suppression in the untreated control. In this group, shoot height and thickness decreased by almost half compared to the previous year, reaching 59.95 cm and 3.36 mm, respectively ($p<0.05$). The poor vegetative growth of these shoots resulted in a drastic reduction in yield (828.00 g/m) and a statistically significant reduction in fruit size (2.04 g). Under these extreme conditions, organic fertilization demonstrated a crucial adaptive role. It mitigated the negative impact of abiotic stress, allowing the plants to maintain better vegetative parameters (82.02 cm in height and 5.01 mm in thickness). This mitigation of abiotic stress through organic inputs is consistent with the findings of Frąc and Laszlovszky-Zmarzly (2013), who noted that biostimulants significantly enhance the vegetative stability and stress resilience of primocane-fruiting cultivars. While the stressed control produced a higher number of weak shoots (20 shoots/m), the fertilized plants allocated their resources towards a smaller (14.3 shoots/m), yet optimized number of vigorous stems.

The reproductive performances of the raspberry plants followed the trend observed in vegetative growth. In 2025, the fertilized variants managed to maintain their fruit size (2.52 g) with no statistical difference compared to the previous year, achieving a nearly 40% higher yield (1154.90 g/m) than the untreated plants (828.00 g/m). The positive impact of the applied treatments on stabilizing fruit weight and total yield under stress reinforces the conclusions of Frąc and Laszlovszky-Zmarzly (2013), who demonstrated that biostimulants effectively boost the yielding capacity and physical fruit attributes of primocane-fruiting cultivars, particularly 'Polka'.

To establish the quantitative dependencies between the vegetative and reproductive traits of the raspberry plants, a correlation analysis was conducted (Table 3).

Table 3. Correlation dependences between vegetative and reproductive indicators of ‚Polka' (2024-2025)

Indicators	Average number of shoots per 1m	Average height of shoots (cm)	Average shoot thickness (mm)	Average yield (g/m)	Average fruit weight (g)
Average number of shoots per 1m	1				
Average height of shoots (cm)	0.29	1			
Average shoot thickness (mm)	0.15	0.97	1		
Average yield (g/m)	0.11	0.95	0.98	1	
Average fruit weight (g)	0.06	0.55	0.52	0.50	1

The results demonstrate the presence of a very strong positive correlation between shoot thickness and average yield (r=0.98), as well as between plant height and yield (r=0.95). A very strong correlation was also established between the vegetative parameters themselves – shoot height and thickness (r=0.97). On the other hand, the average fruit weight showed a moderate positive relationship with height (r=0.55), thickness (r=0.52) and yield (r=0.50). There was no significant correlation between the number of shoots formed, yield (r=0.11) and fruit weight (r=0.06). This lack of statistical correlation mathematically proves the observed physiological response in the untreated control plants under conditions of severe abiotic stress in 2025.

Figures 2, 3, 4 and 5 present the linear regression analysis between the average shoot height and diameter, average height and average total yield, as well as the regression relationship between the average diameter and average yield.

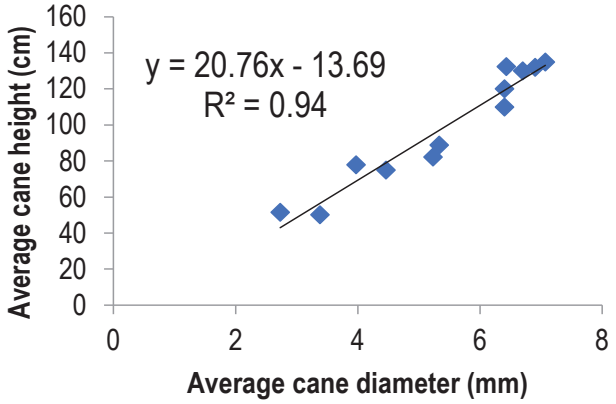

Figure 2. Linear regression analysis between shoot diameter (mm) and height (cm) in ‚Polka' red raspberry (2024-2025)

The analysis of the biometric parameters of the shoots showed the presence of a strong positive linear relationship between their diameter and height (Figure 2). The derived regression model is described by the equation (y=20.762x-13.685). The results demonstrate a high coefficient of determination (R^2=0.94), indicating that 94% of the variation in plant height can be explained by changes in their diameter.

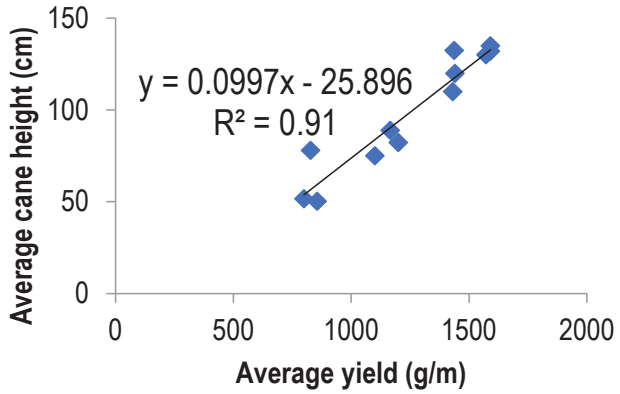

Figure 3. Linear regression analysis between shoot height (cm) and yield (g/m) in ‚Polka' red raspberry (2024-2025)

The results from Figure 2 show a strong positive linear regression between height and yield. The mathematical model is described by the regression equation (y=0.0997x-25.896). The coefficient of determination (R^2=0.91) indicates that 91% of the variation in yield is directly due to the height of the vegetative shoots.

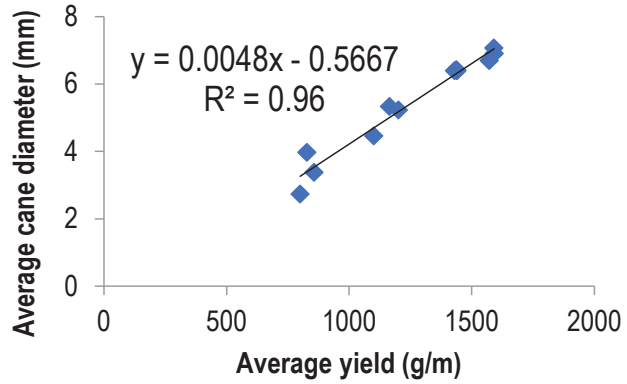

Figure 4. Linear regression analysis between shoot diameter (mm) and yield (g/m) in ‚Polka' red raspberry (2024-2025)

The regression analysis establishes an exceptionally strong and directly proportional relationship between shoot diameter and productivity (R^2=0.96), proving that the thickness of raspberry shoots is a determining factor for their yield.

These strong regression relationships (Figures 2, 3, and 4) underscore the primary importance of the vegetative parameters of raspberry plants in yield formation. Thicker and taller shoots exhibit higher productivity. In this context, the application of organic fertilization emerges as a key factor not merely for nutrition, but for inducing structural resilience in plants against adverse climatic stressors.

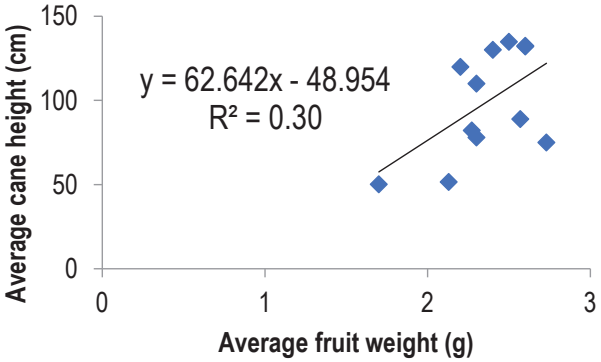

Figure 5. Linear regression analysis between fruit weight (g) and cane height (cm) in ‚Polka' red raspberry (2024-2025)

Figure 5 presents the linear regression between the average fruit weight and the average shoot height for the 'Polka' cultivar. The results show a moderate positive relationship (R^2=0.30). The resulting model (y=62.642x-48.954) demonstrates that stem height determines only about 30% of the variation in fruit weight. This indicates that fruit size in this cultivar is influenced to a much greater extent by other biological and agrotechnical factors (e.g., nutrition, water regime, number of fruits per fruiting lateral) than by the linear growth of the shoots.

Conclusions

Under conditions of combined abiotic stress (drought and high temperatures), the untreated plants respond by forming a high number of weak shoots. The application of organic fertilization exhibits a distinct buffering effect, unlocking an adaptive mechanism – the plants reduce the number of shoots (by approximately 28% compared to the control) but form significantly more vigorous, taller, and thicker stems, optimizing resource allocation. Organic fertilization is a key factor in maintaining productivity under extreme conditions. While stress causes a collapse in yield and a reduction in fruit size in untreated plants, the fertilized variants achieve a nearly 40% higher yield and maintain standard fruit weight (2.52 g), comparable to that under optimal climatic conditions. In the absence of supplementary nutrition during stress periods, raspberry plants exhibit a protective survival response, manifested by the production of a higher number of shoots (20 shoots/m), which are, however, very weak and thin. In conclusion, organic fertilization can be recommended as an effective technological practice for mitigating climatic risks and stabilizing production in the 'Polka' cultivar.

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