Yield and berry quality of red raspberry as affected by cultivar and fertilisation regimes

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Abstract

The work presents the results obtained by examining the effects of cultivar and fertilisation with organic, mineral and foliar fertilisers and ground limestone on the number of fruiting laterals per floricane, their length, yielding and main berry quality attributes of 'Willamette' and 'Meeker' red raspberries in western Serbia. Impact of cultivar on the length of the fruiting laterals, yield per hectare, berry width, its shape index, soluble solids content, acidity and ripening index was significant. On the basis these results, 'Meeker' generally had better values than 'Willamette'. The significant impact of fertilisers was manifested in the number and length of fruiting laterals per floricane, yield per floricane and per meter of trellis, berry weight and its dimensions whereas impact on berry shape, soluble solids, acidity and ripening index was not significant. In general, the best values of the tested properties were obtained by the combined application of organic, mineral and foliar fertilisers supported by ground limestone. However, the interaction cultivar × fertiliser has been significant for fruiting laterals properties, yield and physical berry attributes, showing the inconsistent reaction of cultivars to applied fertilisers.

Keywords: berry size, *Rubus idaeus* L., soluble solids, titratable acidity, yielding capacity

Zusammenfassung

Ertrag und Beerenqualität von Himbeeren in Abhängigkeit von Sorte und Düngungssystem. Die Arbeit präsentiert die Ergebnisse einer Untersuchung zu den Auswirkungen von Sorte und Düngung mit organischen, mineralischen und Blattdüngern sowie vermahlenem Kalk auf die Anzahl der Fruchttriebe pro Ruten (Floricane), deren Länge, Ertrag und die wesentlichen Qualitätsmerkmale der Beeren von 'Willamette' und 'Meeker'-Himbeeren im westlichen Serbien. Der Einfluss der Sorte auf die Länge der Fruchttriebe, den Ertrag pro Hektar, die Beerenbreite, den Formindex, den Gehalt an löslichen Feststoffen, die Säure und den Reifeindex war signifikant. Basierend auf diesen Ergebnissen zeigte 'Meeker' generell bessere Werte als 'Willamette'. Der signifikante Einfluss der Düngung zeigte sich in der Anzahl und Länge der Fruchttriebe pro Rute, im Ertrag pro Rute und pro Meter Spalier sowie im Beerengewicht und deren Dimensionen, wohingegen der Einfluss auf die Beerenform, den Gehalt an löslichen Feststoffen, die Säure und den Reifeindex nicht signifikant war. Im Allgemeinen wurden die besten Werte der untersuchten Eigenschaften durch die kombinierte Anwendung von organischen, mineralischen und Blattdüngern in Verbindung mit vermahlenem Kalk erzielt. Allerdings war die Wechselbeziehung Sorte × Dünger für die Eigenschaften der Fruchttriebe, den Ertrag und die äußeren Beerenmerkmale signifikant, was die uneinheitliche Reaktion der Sorten auf die angewandten Dünger verdeutlicht.

Schlagwörter: Beerengröße, *Rubus idaeus* L., lösliche Feststoffe, titrierbare Säure, Ertragsleistung

Introduction

The raspberry belongs to the family Rosaceae and the *Rubus* genus, which includes raspberries and blackberries. Red raspberry (*Rubus idaeus* L.) is a perennial plant that produces a compound fruit i.e. berry. The aerial part of the plant is very pronounced with a large amount of biomass during the growing season, while the root is distributed in the surface layer of the soil. It is characterized by a very intensive metabolism, especially the berries, making them perishable with a very short shelf life (Lo Piccolo et al., 2023). In general, the whole plant is sensitive to stresses such as drought, excessive soil moisture, low air humidity, especially during harvest, nutrient limitation, weediness, infections with diseases and infestations of pests, etc. (Petrović et al., 2020). Its production in the world has increased drastically since the 1960s, i.e. from 134,115 t in 1961 to 947,852.03 in 2022 (FAOSTAT, 2024). It is therefore not surprising that the global raspberry production has increased by 80 % in the last 10 years. In many countries worldwide it is figuratively called a “rising star”. The predominant cultivar in Serbia is ‘Willamette’ (over 90 %), making up 100 % in some regions. In the last few decades, other newly bred cultivars have been introduced in Serbian plantations in small parts such as ‘Meeker’, ‘Tulameen’, ‘Fertödi Zamatos’ etc. as summer-bearing types, and ‘Heritage’, ‘Lyulin’, ‘Autumn Bliss’, ‘Polana’ and ‘Polka’ as fall-bearing types (Milosevic et al., 2009). However, among them, only ‘Meeker’, sporadically ‘Polka’ and ‘Fertödi Zamatos’, have greater importance for Serbian growers and exporters.

Regarding horticultural practices, the development and adoption of innovative technologies has allowed conventional agricultural systems to pursue increased efficiency, yield, quality, food safety, and production viability with reduced costs (Sunding and Zilberman, 2001). Based on this doctrine of plant production, adequate fertilisation and irrigation plays a pivotal role in increasing crop yield and quality without risks and harmful consequences for the environment and human and animal health.

It has been long known that raspberry is the largest consumer of nutrients among berry types (Unuk et al., 2023). Nutrient requirements depend on several factors such as crop quantity, habitat, plant age, soil type, irrigation (or precipitation) and cultivar. Among the essential macro- and microelements, N has the greatest importance, as it directly affects the intensity of primocane growth, flowering and fruit development (Strik and Bryla, 2015). In the best raspberry plantations in western Serbia, which are usually located in hilly and mountainous areas between 600 and 1,100 m above sea level, mature sheep or cattle manure is traditionally applied to the soil together with compound NPK 15:15:15 at the end of winter (Petrovic and Milosevic, 2005). Fertilisation with N fertilisers, using usually alkaline calcium ammonium nitrate (CAN), is done in three terms: before the beginning of vegetation, at the beginning of flowering and at the beginning of fruit ripening. Urea, as a physiologically acidic fertiliser, known as a great source of N is rarely applied because over 60 % of the soil in Serbia is acidic (Petrović et al., 2020).

Other macro- and microelements are added as needed or *ad hoc*, most often through foliar nutrition (Stojanov et al., 2019).

Around the world, many raspberry fertilisation experiments have been carried out. However, the results of numerous fertiliser trials show some inconsistencies and discrepancies, mainly due to differences in soil fertility, plant age (Gercekcioglu, 2008), applied horticultural practices, geographical site (Stojanov et al., 2019) and also duration of the experiment (Strik, 2008; Unuk et al., 2023). Recently, many researchers have emphasized the great importance of using foliar fertilisers containing macro- and microelements complemented with various biostimulants - mixed or individual (Wojcik, 2005; Ochmian et al., 2008; Krok and Wieniarska, 2008; Ičanović and Handanović, 2022; Unuk et al., 2023).

The main goal of the current study was to define the impacts of cultivar and different fertilisation approaches to raspberry nutrition as well as to clarify the role of organic pelleted chicken manure, ground limestone, N fertiliser, compound NP + Ca + S + Zn mineral fertiliser and five foliar fertilisers containing different macro- and microelements and enriched with growth biostimulants and amino acids on fruiting lateral properties as well as yield and berry physico-chemical attributes of 'Willamette' and 'Meeker' cultivars grown on acidic soil under western Serbian conditions.

Materials and methods

Plant material and field experiment

This study was carried out in a commercial plantation located in Gliječa village near Ivanjica city, western Serbia in 2017. The study area is located at 809 m above sea level, 43°34'52" N latitude and 20°10'56" E longitude. The plantation was established in 2002 with 'Willamette' and 'Meeker' (summer-bearing) red raspberry cultivars. Plants were spaced 0.25 m within rows and 2.0 m apart. Vertical I-trellis (i.e. espalier) consisted of posts (spaced 5 to 6 m apart) and two horizontal wires at 0.8 and 1.7 m above ground level with 2 to 3 cross arms. Floricane training was done from mid-February to end of March. Floricanes were shortened to 2 to 3 buds above the top wire (total floricane height was about 1.9 m on average). Conventional and traditional management practices under Serbian conditions for red raspberry such as pruning, training, floor management, pest, disease and weed control were conducted without irrigation.

A randomized complete block design with 20 m of I-trellis, i.e. espalier, per each cultivar and fertiliser treatment in four replicates (n = 80 m) was used. Each cultivar/fertiliser treatment was repeated in four blocks. Fertilisation treatments were as follows (Tab. 1):

Tab. 1: Treatment scheme of applied fertilisers in the experiment

Treatments	Fetrilizer
T_1	Control (without fertilisation)
T_2	Fertor (65 % organic matter + NPK 4.5-2.7-2.3 + 1.1 % Mg + 9.3 % Ca + microelements: Fe + Mn + Cu + Zn + B + Mo) + Kalk (90 % $CaCO_3$)
T_3	Fertor + Kalk + CAN (calcium ammonium nitrate with 27 % N_{TOT}) + NutriMAP (NP 10-40 + 2 % Ca + 4 % S + 0.1 % Zn)
T_4	Fertor + Kalk + CAN (calcium ammonium nitrate) + NutriMAP + foliar fertilisers [Nutriamino Plus (0.48 % N_{TOT}, 0.48 % organic N + 10 % P_2O_5 + 2 % amino acids) + Nutri Fos-K (15 % P_2O_5 + 10 % K_2O) + Ferticare™ (NPK 14-8-30 + 2 % MgO + 1.8 % S + microelements) + Fitofert Cristal Berry (NPK 14-8-30 + 2 % MgO + microelements) + Fertileader Elite (NK 9-6 + 12 % CaO + 0,1 % B + IPA + GB + AA)]

Fertor (FulviChina Co., Tianjin, China) is an organic fertiliser in the form of pellets. It is produced from 100 % chicken manure, with the addition of other organic substances of plant origin, which increase and improve the nutritional value of the manure. Kalk (ground limestone) (Schaefer Kalk GmbH & Co., Diez, Germany) is solid, powdery fertiliser and soil improver, with declared $CaCO_3$ content (min. 90 %). It is used to reduce soil acidity. NutriMAP (FulviChina Co., Tianjin, China) is a complex mineral fertiliser with a balanced ratio of N, P, Ca, S and Zn. Foliar fertilisers commercially named Fitofert Cristal Berry (Fertico DOO, Inđija, Serbia), Nutriamino Plus (FulviChina, Tianjin, China), Nutri Fos-K (AMC Chemical, Sevilla, Spain), Ferticare™ (Yara Int., Oslo, Norway) and Fertileader Elite (Timac Agro, Novi Sad, Serbia) contained essential macro- and microelements and amino acids in different ratios and concentrations. Fertor, Kalk and NutriMAP were applied to the soil at end of winter (after binding of the canes to the wire) in amounts of 1,500 kg, 3,000 kg and 300 kg per hectare, respectively. CAN as N fertiliser was applied at onset of vegetative cycle (1/3), just before flowering (1/3) and at the beginning of berry ripening (1/3) in amount of 200 kg per hectare. Organic and mineral fertilisers and ground limestone were applied to the soil parallel to the row, 0.5 m from the row center using field rotocultivator.

Foliar fertilisers were applied in the following order: Nutriamino Plus at the end of April in order to prevent abiotic stresses and create optimal conditions for the growth of fruiting laterals and flowering; Nutri Fos-K at mid-May in order to improve quality of flowering and good berry formation (fruit set); Fitofert Cristal Berry, Ferticare™ and Fertileader Elite at the beginning and mid-June, respectively in order to improve the growth, development and ripening of berries and increase their size.

Weather and soil conditions

Average annual temperature, humidity and total precipitation were 9.3 °C, 78.2 % and 920.4 mm, respectively, in the research area in 2017, which is the experimental year. Average temperature during vegetative cycle was 11.9 °C. The soil is brown on Paleozoic shale as a sole. It has a very acidic reaction (soil pH in KCl was 3.68). Soil contained a high amount of organic matter (3.24 %) and total N (0.28 %), 5.59 and 20.16 mg available K_2O and P_2O_5, respectively without $CaCO_3$ in 0-30 cm soil depth. Results revealed that the soil had an unfavourable pH value, a very high and high contents of organic matter and total N, respectively, and moderate levels of available P_2O_5 and K_2O.

Measurements

Measurements were performed at 20 floricanes in four replications per each cultivar/fertiliser treatment and control (n = 80). Number of fruiting laterals per floricanes and their length (cm) were enumerated. Yield per floricane and per m of trellis (both in g) was measured using digital balance OEM (Quebec, Canada) after each harvest. For physical and chemical evaluation, 20 fully mature berries in four replicates (n = 80) per each cultivar/fertiliser treatment were randomly handpicked. Berries were assessed at mid of harvest for berry weight (BW, g) and their linear dimensions (length – L and width – W, both in cm). The BW was measured using digital balance VK-TECH (Daejeon, South Korea) whereas linear dimensions were measured with caliper gauge Starrett 727 (Athol, MA, USA). Length/width ratio (L/W ratio), also called berry elongation index, was calculated.

Soluble solids content (SSC, °Brix) was determined by hand refractometer Milwaukee MR 200 (ATC, Rocky Mount, USA) at 20°C, from juice extracted from the berries. Titratable acidity (TA, % of citric acid) was measured by titration of the same solution with 0.1N sodium hydroxide until reaching pH 8.1 using phenolphthalein as indicator. The ripening or maturity index (RI) was calculated based on the SSC/TA ratio.

Data analysis

The data obtained were analyzed using the Microsoft Office Excel 2003 program (Redmond, WA, USA). A two-way analysis of variance (ANOVA), model 2 × 4, was performed, and differences between means were considered significant at $P < 0.05$ by LSD test. Source of variations were cultivar (A) and fertiliser (B).

Results and discussion

Bearing potential and yielding

Data in Tab. 2 showed that the number of fruiting laterals and their length were significantly affected by fertiliser treatments. Impact of cultivar on number of fruiting laterals was random whereas impact on their length was significant, being higher in 'Meeker' than in 'Willamette'. Our results for both parameters were much lower than those found by Glisic et al. (2009), Bećirspahić et al. (2014) and Stojanov et al. (2019) for both 'Willamette' and 'Meeker', probably due to better weather and soil conditions and cultural management in their locations. Otherwise, 'Meeker' is a genetically more vigorous plant (both primocane and floricane) than 'Willamette' (Finn et al., 2001); the long fruiting laterals of 'Meeker' require additional support in the plantation so that they do not break and/or shrivel under the weight of biomass i.e. leaves and berries, and need more space than other red raspberries in plantations (Petrovic and Milosevic, 2005; Petrović et al., 2020).

Control treatment, T_3 and T_4 induced statistically similar and higher numbers of fruiting laterals per floricane in comparison with T_2. Length of fruiting laterals was the highest under T_4 and the lowest in control (without fertilisation). These data are in agreement with Stojanov et al. (2019) who reported that multi-nutrient compound mineral fertiliser and organo-mineral fertilisers with adequate content of macro- and micronutrients and amino acids improved properties of fruiting laterals in 'Meeker'. Dale and Daubeny (1985) reported that high yield in raspberries was closely related to high numbers of fruiting laterals which confirmed our data.

Tab. 2: Impact of cultivars and fertilisers on numbers of fruiting laterals per floricane and length of fruiting laterals

Parameter		**Number of fruiting laterals**	**Lenght of fruiting laterals**
Cultivar (A)	Willamette	14.89 ± 0.68 a	31.39 ± 1.15 b
	Meeker	13.92 ± 0.82 a	35.03 ± 0.73 a
Fertiliser (B)	T_1	14.35 ± 1.44 ab	28.03 ± 2.50 d
	T_2	12.57 ± 2.13 b	30.62 ± 2.11 c
	T_3	15.11 ± 3.52 a	34.73 ± 3.11 b
	T_4	15.59 ± 1.46 a	39.46 ± 2.97 a
ANOVA (*F* test)			
Cultivar (A)		ns	*
Fertiliser (B)		*	*
A × B		*	*

The different letter(s) in a column indicate significant differences among means within each cultivar and each fertiliser at $P \leq 0.05$ by LSD test.
Asterisks in a column indicate significant differences at $P \leq 0.05$ by *F* test. ns: not significant.

Effect of cultivar on yield per floricane and yield per meter of trellis was not significant whereas influence on yield per hectare was significant (Tab. 3). Namely, yield per hectare was higher in 'Willamette' than in 'Meeker'. As known, yield is a complex genetic category and varies widely between cultivars under the same environmental conditions, cultivation management and care treatments as previously reported by Petrovic and Milosevic (2005), Hansen et al. (2021) and Valentinuzzi et al. (2022). Namely, growth potential of plant cultivars, ability to form berry, ripening date or plant structure may affect the yield (Sawicka et al., 2023).

In the present study, the yield performances of raspberry were statistically higher under T_4 treatment in comparison with the unfertilized control variant and the other two treatments (Tab. 3). Similarly to T_4, T_3 also induced higher yield per floricane than control, whereas T_4 induced the highest yield per hectare in comparison with the other treatments and control. These results were expected, because red raspberry, apart from the requirement for organic and mineral fertilisers applied to the soil, especially rich in N (Strik, 2008; Unuk et al., 2023), responds very well to the application of foliar fertilisers (Wojcik, 2005). In addition, Ochmian et al. (2008) and Ičanović and Handanović (2022) have described significant yield increases after the use of biostimulants. However, the interaction cultivar × fertiliser was significant, showing the inconsistent reaction of cultivars to applied fertilisers. For example, yield traits of 'Willamette' were different between T_3 and T_4 applications although the general tendency is that both these treatments had a statistically similar effect. Our range values for yielding were lower, similar and/or higher than those found by different authors. So, Finn et al. (2001) reported similar yield for 'Willamette' under Oregon conditions, whereas Stanisavljević et al. (2002) and Glisic et al. (2009) found much higher yield for both 'Willamette' and 'Meeker' cultivars grown under western Serbian environment. These discrepancies among results can be connected with fact that the yield of raspberry depends to a large extent on the course of the weather (low winter temperatures, drought in spring and early summer), the age of the plantation and cultural practices including fertilization (Sawicka et al., 2023) and irrigation (Petrovic an Milosevic, 2005).

Although 'Willamette' and 'Meeker' are considered very productive raspberries under Serbian conditions (Petrović et al., 2020), yield was poor in the present study. Earlier studies and analyses showed that raspberry yield lower than 10 t ha^{-1} is not profitable and economically justified and viable for Serbian growers (Petrovic and Milosevic, 2005). According to these authors, in the 1980s of the 20th century, not far from Ivanjica city (i.e. in Arilje municipality), the yield of 'Willamette' was 35 t ha^{-1}. Since 'Meeker' and also 'Willamette' are susceptible to drought (Morales et al., 2013), especially under global warming conditions in recent decades, constant irrigation during vegetation is imperative in the dry season in order to obtain higher yields as previously reported by Petrović et al. (2020).

Tab. 3: Average yield per floricane, meter of trellis and unit area influenced by cultivars and fertilisers

Parameter		Yield per floricane (g)	Yield per meter of trellis (g)	Yield per hectare (t)
Cultivar (A)	Willamette	28.32 ± 1.58 a	172.08 ± 10.05 a	10.99 ± 0.67 a
	Meeker	29.36 ± 2.38 a	176.12 ± 13.84 a	9.69 ± 1.32 b
Fertiliser (B)	T_1	23.63 ± 3.91 b	144.40 ± 21.47 c	8.34 ± 1.22 d
	T_2	25.37 ± 6.70 b	153.60 ± 36.64 c	9.27 ± 1.45 c
	T_3	31.11 ± 8.32 a	185.08 ± 54.07 b	11.04 ± 0.16 b
	T_4	35.25 ± 3.58 a	213.31 ± 23.32 a	12.76 ± 0.09 a
ANOVA (*F* test)				
Cultivar (A)		ns	ns	*
Fertiliser (B)		*	*	*
A × B		*	*	*

The different letter(s) in a column indicate significant differences among means within each cultivar and each fertiliser at $P \leq 0.05$ by LSD test.
Asterisks in a column indicate significant differences at $P \leq 0.05$ by *F* test. ns: not significant.

Berry physical properties

The results of berry dimensions (L and W) as well as BW and berry shape index are shown in Tab. 4. Absence of statistically significant differences between cultivars for BW and L was evident, whereas W was higher in 'Meeker' than in 'Willamette'. Results also revealed that 'Willamette' had more elongated berries than 'Meeker'. Hence, berry of 'Willamette' is conical in shape, whereas berry of 'Meeker' is spherical (Stojanov et al., 2019). Bobinaitė et al. (2016) reported that BW in both summer-bearing and fall-bearing raspberries varied from 2.5 to 5-6 g, and, under certain conditions, the berry can exceed 10 g. Differences in berry size can be explained by a very high variability within individual genotypes and is affected by several auxin response factors through modulating the genes transcription (Liu et al., 2015). In addition, main factors affecting berry shape, especially near spherical shape, were sufficient carbohydrates and water, due to mitosis and cell expansion by accumulation of water and secondary metabolites (Tanksley, 2004).

Tab. 4: Average berry weight, berry linear dimensions and berry shape index influenced by cultivars and fertilisers

Parameter		Berry weight (g)	Berry length (cm)	Berry width (cm)	Berry shape index
Cultivar (A)	Willamette	3.70 ± 0.10 a	1.74 ± 0.02 a	1.53 ± 0.02 b	1.14 ± 0.02 a
	Meeker	3.57 ± 0.08 a	1.75 ± 0.03 a	1.59 ± 0.02 a	1.10 ± 0.01 b
Fertiliser (B)	T_1	3.11 ± 0.19 d	1.63 ± 0.04 d	1.45 ± 0.07 c	1.13 ± 0.05 a
	T_2	3.48 ± 0.24 c	1.71 ± 0.07 c	1.55 ± 0.03 bc	1.11 ± 0.04 a
	T_3	3.78 ± 0.32 b	1.78 ± 0.09 b	1.57 ± 0.05 b	1.14 ± 0.05 a
	T_4	4.16 ± 0.25 a	1.85 ± 0.09 a	1.67 ± 0.03 a	1.11 ± 0.04 a
ANOVA (*F* test)					
Cultivar (A)		ns	ns	*	*
Fertiliser (B)		*	*	*	ns
A × B		*	*	*	*

The different letter(s) in a column indicate significant differences among means within each cultivar and each fertiliser at $P \leq 0.05$ by LSD test.
Asterisks in a column indicate significant differences at $P \leq 0.05$ by *F* test. ns: not significant.

Soil application of organic and mineral fertilisers supplemented with ground limestone and foliar fertilisers (T_4) induced the best values of BW and berry dimensions, whereas fertilisation treatments and control variant had no capacity to change berry shape. As expected, the smallest berries were observed in the control variant. For example, T_4 induced more than 25 % higher BW compared to the control, which is in agreement with results of Krok and Wieniarska (2008), Ičanović and Handanović (2022) and Unuk et al. (2023) who reported a higher berry weight treated with fertilisers containing biostimulants – alone or mixed. Also, many local and foreign researchers stated that fertilisation of raspberries, especially with N fertiliser, increases the physical properties of the berries, especially their weight and size (Stojanov et al., 2019; Unuk et al., 2023; Sawicka et al., 2023). However, the results of our study showed that the interaction cultivar × fertiliser had a significant effect on the examined physical berry properties. This indicates a specific reaction of the cultivar to applied fertilisers, i.e. a deviation from the shown tendencies. Hence, genetic background is a key factor that determines the size and shape of the berries as previously reported by Sawicka et al. (2023). In general, our data for BW and berry dimensions were much lower than those found by Stanisavljević et al. (2002, 2003) and Glisic et al. (2009) but much higher than those obtained by Finn et al. (2001), Alibabić et al. (2018), Stojanov et al. (2019) and Yu et al. (2022). Discrepancies in results among authors can be attributed to specific cultural practices, weather and soil conditions, as well as age of plantation.

Soluble solids content, acidity and ripening index

Results from Tab. 5 show that SSC, TA and RI were not affected by fertiliser treatment, but values significantly varied between cultivars. 'Meeker' had statistically higher values than 'Willamette'. The absence of significant interaction cultivar × fertiliser on the above traits indicates a very strong influence of the cultivar *per se*.

Tab. 5: Soluble solids, acidity and ripening index of berries influenced by cultivars and fertlisers

Parameter		Soluble solids content (°Brix)	Titratable acidity (%)	Ripening index
Cultivar (A)	Willamette	10.55 ± 0.27 b	1.83 ± 0.03 b	5.77 ± 0.06 b
	Meeker	11.53 ± 0.18 a	1.97 ± 0.04 a	5.85 ± 0.05 a
Fertiliser (B)	T_1	10.89 ± 0.99 a	1.86 ± 0.02 a	5.85 ± 0.04 a
	T_2	10.93 ± 0.41 a	1.88 ± 0.04 a	5.81 ± 0.06 a
	T_3	11.28 ± 0.71 a	1.91 ± 0.02 a	5.91 ± 0.05 a
	T_4	11.07 ± 0.48 a	1.96 ± 0.03 a	5.65 ± 0.06 a
ANOVA (*F* test)				
Cultivar (A)		*	*	*
Fertiliser (B)		ns	ns	ns
A × B		ns	ns	ns

The different letter(s) in a column indicate significant differences among means within each cultivar and each fertiliser at $P \leq 0.05$ by LSD test.
Asterisks in a column indicate significant differences at $P \leq 0.05$ by *F* test. ns: not significant.

In the available literature, contradictory data can be found regarding the impact of fertilisation management, especially N rates, on SSC and TA in berries (Prange and Del, 1998). The most common claims were that higher N rates reduce the SSC (Strik, 2008) and increase the acidity (Stojanov et al., 2019) which is not the case in our study. In general, our results showed that soluble solids, acidity and RI were within data previously reported by other authors for the same cultivars (Alibabić et al., 2018; Milinković et al., 2021; Murtić et al., 2022). However, Stanisavljević et al. (2002), Milivojević et al. (2011) and Yu et al. (2022) reported lower TA values than ours, whereas Stanisavljević et al. (2002), Milivojević et al. (2012) and Stojanov et al. (2019) noted higher TA and SSC, respectively for both 'Willamette' and 'Meeker' raspberries. On the basis of these discrepancies, it can be said that geographic region i.e. site with specific pedoclimatic conditions also play an important role in the biosynthesis of above compounds. The specific nature of the response of different berry species and their cultivars to fertilisation management in different sites and soil types has been previously reported (Hargreaves et al., 2008). However, according to the many different interpretations that can be found in literature, the most important factor determining the raspberry quality is the genetic background of cultivar (Dale and Daubeny, 1985; Valentinuzzi et al., 2018), which was confirmed by our results.

Conclusions

Most of evaluated yielding and fruit parameters were affected by cultivar, fertilisation treatments and their interactions. The best results of these traits were modest from a practical point of view. Namely, short floricane laterals produced small berries. Small berries on a small number of fruiting laterals induced low yield of both 'Willamette' and 'Meeker' that were at the minimum level of cultivation profitability and economic viability of raspberry production under Serbian conditions. Another important issue is the price of fertilisers and supplements and their relationship to the price of the final product. However, when evaluating the results of our findings and observations, it should be taken into account that a certain time must pass after the application of organic, compound mineral fertilisers and ground limestone to fulfill their functions and that they have long-term effects. Also, a more intensive orchard management program, especially irrigation, may be required for these red raspberry cultivars grown under similar weather and soil conditions.

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