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Influence of Varietal Characteristics and Planting Schemes of Remontant Raspberries on their Productivity

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Abstract: The red raspberry (*Rubus idaeus* L.) is a member of the *Rosaceae* family. The production of raspberries has increased rapidly worldwide. In recent years, about 300 ha of remontant raspberry varieties have been planted in the Almaty region, Kazakhstan. These varieties are technologically easier to grow compared to traditional varieties because they bear fruit on annual shoots and do not require protective measures against winter damage or the installation of expensive trellis. Statistical methods can be used to quantify the impact of various factors on biometric indicators. The research aimed to evaluate the influence of the factors of variety and planting scheme of remontant raspberries on the biometric indicators of leaves and productivity. Observations were conducted in 2020 in the Aidarbayev peasant farm, Enbekshikazak district, Saymasay village, Almaty region, Kazakhstan. The Bryanskoe divo variety was found to be more productive with 40.8 t/ha, while the Polka variety showed more than twice as low yields (15.6 t/ha), due to higher numbers of laterals, the number and weight of berries and the number of leaves and a high leaf area index. The planting scheme of remontant raspberries (2.8×0.4 m) led to the highest yield (54.4 t/ha) due to a higher number of laterals per shoot, the number of berries per shoot and running m and the productivity of 1 shoot per running m as compared to the sparser planting scheme of (2.8×0.15) ×0.4 m, the productivity of which is more than two times lower at 24.6 t/ha. Thus, the variety of Bryanskoe divo cultivated at a lesser density, when compared to Polka and to a higher density planting scheme, displays better results in terms of biometric indicators, productivity, and yield.

Keywords: Red Raspberry, Biometric Indicators, Planting Scheme, Varietal Characteristics, Statistical Methods

Introduction

Red raspberries (*Rubus idaeus* L.) are a member of the *Rosaceae* family and together with blackberries belong to the genus Rubus (Evdokimenko *et al*., 2021). Raspberry production worldwide has increased rapidly from 134,115 t in 1961-812,735 t in 2017 (FAOSTAT, 2019).

In recent years, about 300 ha of plantations of remontant raspberry varieties have been established in the Almaty region, Kazakhstan (Asylbekovna *et al*., 2020). These varieties are technologically easier to grow than traditional ones because they bear fruit on annual shoots and do not require protective measures against winter damage and the installation of expensive trellis.

Recent studies worldwide have focused on the effect of polyethylene biodegradable plastic mulch (Zhang *et al*., 2019), spotted wing drosophila (DiGiacomo *et al*., 2019), phytochemicals (Frias-Moreno *et al*., 2019), reduced nitrogen fertilizer rates (Lu *et al*., 2022), pruning practices (Nehrbas and Pritts, 1988; Gundersheim and Pritts, 1991) and yield components (Hoover *et al*., 1988; Freeman *et al*., 1989; Kantarbayeva *et al*., 2017) on the productivity of crops. Remontant raspberry is a group of raspberry varieties characterized by the ability to bear fruit on annual shoots (Kazakov *et al*., 2007; Pantsyreva *et al*., 2020).

Statistical methods can be used to quantify factors in plant disease incidence indices, disease development (Dutbayev *et al*., 2022), physiological indices (Dutbayev *et al*., 2023; Rakymbekov *et al*., 2023),

mycotoxin composition and yield parameters (Kuldybayev *et al*., 2021). These methods can be widely used to quantify the impact of climatic index changes on observed yield by means of principal component analysis (Kuldybayev *et al*., 2021; Dutbayev *et al*., 2022; 2023).

The aim of the present study is to evaluate the effect factors of variety and planting scheme of remontant raspberries on the biometric indices of leaves and plant productivity using statistical processing. The study consists of five sections, namely introduction, materials and methods, results, discussion, and conclusion.

Materials and Methods

In 2020, we conducted research on the technological features of cultivation of isolated raspberry varieties in the research sites of the Aydarbayev peasant farm, Enbekshikazakh district, Almaty region, Kazakhstan (coordinates: 43.445994, 77.332846). Observations were made according to methods generally accepted in berry-growing (Asylbekovna *et al*., 2020).

The biometric indicators of two varieties of remontant raspberries were measured in the year of planting. The parameters measured were the number of shoots (productive and non-productive), the height of shoots, the fruiting zone, and the length of internodes. We assessed 10 shoots at fruit ripeness in three-fold repetitions. The study tested the effect of variety factor (the Polka and Bryanskoe divo remontant raspberries factor levels) on the number of laterals, their number per running m, the number of berries per shoot, average weight of the berry, shoot productivity, and yield. Under evaluation was also the effect of the variety factor on the number of leaves per running m and ha, the average area of one leaf, the number of leaves per 1 m^2, and the leaf area index. Finally, we assessed the effect of varietal characteristics of remontant raspberries on the biometric indicators of leaves. The study focused on the influence of the variety factor on the number of leaves per running m and ha, the average area of one leaf, the number of leaves per 1 m^2, and the leaf area index. Measurements were taken from 10 shoots at fruit ripeness in three-fold replications.

The objects under study were the Bryanskoe divo and Polka remontant raspberry varieties. Polka is a remontant variety marked by long fruiting. Fruiting lasts about 3 months and ends in October once the temperature drops (Asylbekovna *et al*., 2020). Bryanskoe divo is a large-fruited remontant raspberry variety that mainly bears fruit on annual shoots in late summer and early autumn. The berries are very large, with an elongated-conical shape and homogeneous drupes, red in color (Kazakov *et al*., 2007).

Table 1: Remontant raspberry planting schemes

Factor levels	Planting scheme, number of plants
1 (control)	2.8 m ×0.4 m (8,000 plants/ha)
2	(2.8×0.15) m ×0.4 m (17,000 plants/ha)
3	(1.4×0.15) m ×0.4 m (32,000 plants/ha)

Productivity indicators of the two varieties in the year of planting. Economic and biological characteristics are composed of several components. In remontant raspberry, such components are the number of laterals, the number of berries, the average weight of the berry, and productivity.

The study evaluated the effect of remontant raspberry planting schemes (Table 1) on leaf assimilation surface area, the number of laterals, their number per linear m, the number of berries per shoot, average weight of the berry, shoot productivity, and yield. We measured 10 shoots during fruit ripeness in three-fold replications.

Statistical data processing was performed in the R-studio environment by means of variance analysis with student's t-test. The level of significance was determined through p-value<0.05 (Kuldybayev *et al*., 2021; Dutbayev *et al*., 2022; 2023).

Results

The number of productive shoots of remontant raspberry was 10.1 pcs/r.m and the number of non-productive shoots was 2.2 pcs/r.m. (Fig. 1, Table 2).

It was established that Bryanskoe divo variety had higher values of the number of laterals per shoot, the number of berries per shoot, the average weight of the berry, productivity per shoot, and running m and yield (Fig. 2, Table 3). The effect of the factor of variety on the indicators was statistically significant (p-value<0.01). The above-described better indicators resulted in the yield of Bryanskoe divo amounting to 40.8 t/ha, while Polka yielded more than two times less than 15.6 t/ha (Fig. 3, Table 4).

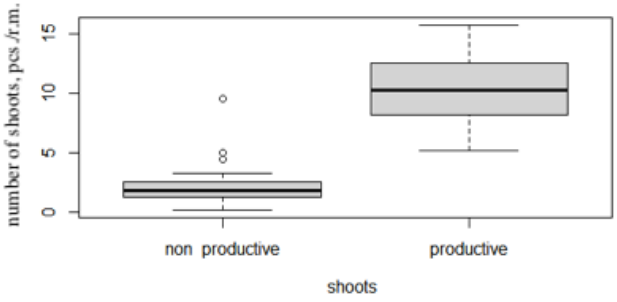


Fig. 1: Graphical analysis of the productivity of remontant raspberry shoots per their number (Saymasay village, Almaty region)

Table 2: Analysis of the productivity of remontant raspberry shoots per their number (Saymasay village, Almaty region)

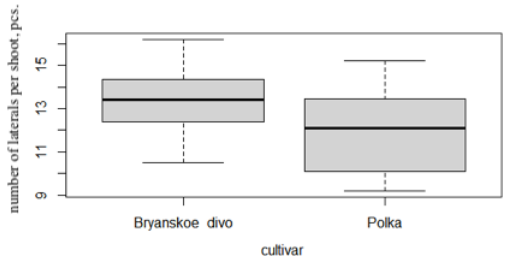
Shoots	Number of shoots**,** pcs. /r.m
Non-productive	2.20
Productive	10.10
p-value	<0.01***

Table 3: Analysis of the influence of varietal characteristics of remontant raspberries on productivity indicators (Saymasay village, Almaty region)

Variety	Number of laterals, pcs.		Number of berries per shoot, pcs	Average weight of the berry, g	Productivity, g		Yield, t/ha
	per shoot	per running m			per shoot	per running m	
Polka	12.00	102.10	48.00	3.30	142.50	1,118.50	15.60
Bryanskoe divo	13.50	88.70	64.90	3.60	229.30	2,048.50	40.80
p-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 4: Analysis of the influence of varietal characteristics of remontant raspberries on the biometric indicators of leaves (Saymasay village, Almaty region)

Variety	Number of leaves on fruit-bearing shoots, pcs		Average area, mm^2		Leaf area index
	per running m	per ha	1 leaf	1 m^2 of leaves	
Polka	310.50	6,162,500.00	5,693.10	1.600	2.40
Bryanskoe divo	366.00	4,500,500.00	7,639.70	2.900	2.60
p-value	<0.01***	<0.01***	<0.01***	<0.01***	0.03*



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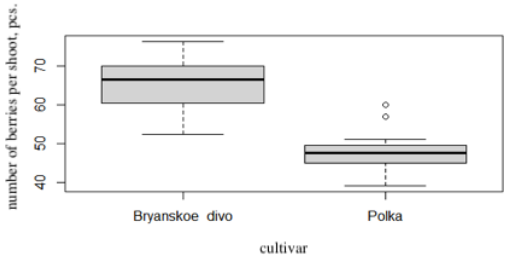

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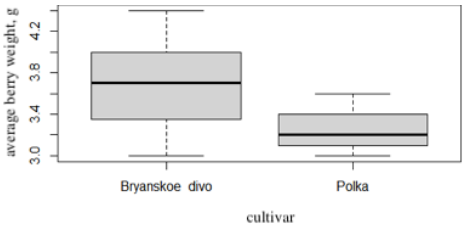

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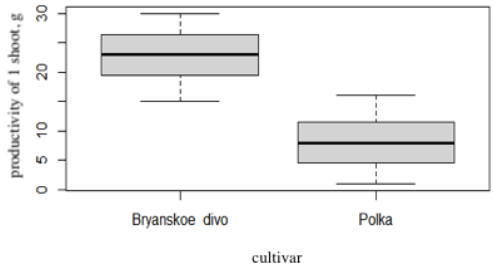

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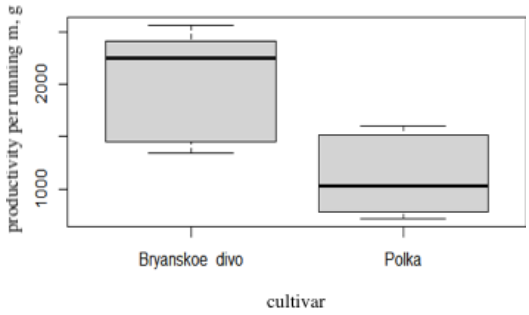

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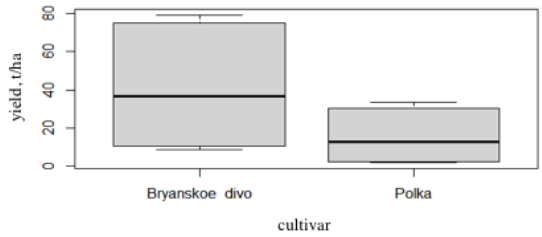

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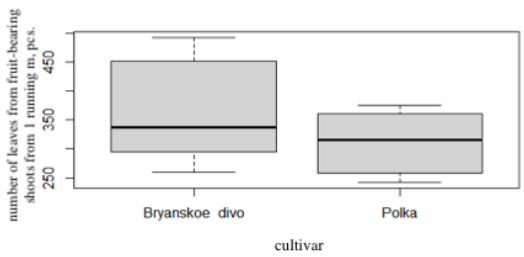
Fig. 2: Graphical analysis of the influence of varietal characteristics of remontant raspberries on productivity indicators (Saymasay village, Almaty region); Note: Influence of the factor remontant raspberry variety on the variable; A-number of laterals per shoot; B-number of berries per shoot; C-average berry weight; D-productivity of 1 shoot; E- productivity per running m; F-yield



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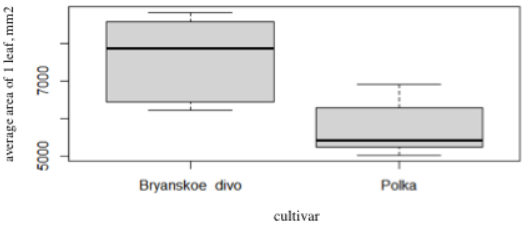

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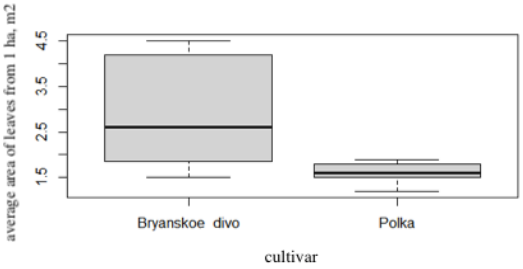

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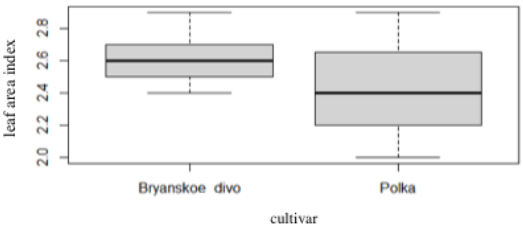

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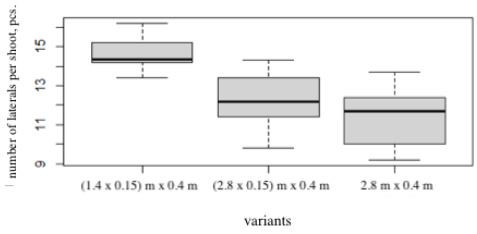
Fig. 3: Graphical analysis of the influence of varietal characteristics of remontant raspberries on the biometric indicators of leaves (Saymasay village, Almaty region); Note: Influence of the factor of remontant raspberry variety on the variable; A-number of leaves from fruit-bearing shoots from 1 running m; B-average area of 1 leaf, mm^2; C-average area of leaves from 1 ha, m^2; D-leaf area index

The factor of variety was found to statistically significantly affect the number of leaves per running m and ha, the average area of one leaf, the number of leaves per 1 m^2, and the leaf area index (p-value<0.01). In Bryanskoe divo, the number of leaves per running m, the average area of one leaf, the number of leaves per 1 m^2, and leaf area index (p-value<0.01) were higher than in Polka (Fig. 2). Bryanskoe divo also had higher shoots, 1,058 mm on average, while the shoots of Polka plants reached only 892 mm (Table 5).

The planting scheme of raspberries significantly affected the number of laterals, their amount per running m, the number of berries per shoot, the average weight of the berry, shoot productivity, and yield (p-value<0.01). The planting scheme 2.8×0.4 m was found to provide the highest yield because of better indicators of the number of laterals per shoot, the number of berries per shoot and running m, and productivity per shoot and running m (Fig. 4, Table 6). The raspberry planting scheme had an impact on the number of leaves per running m and per ha and the average area of one leaf and 1 m^2 of leaves (p-value<0.01). The study has found that with the scheme of planting 2.8×0.4 m, the indicators of the number of leaves per ha and the average area of one leaf were the highest. With the scheme of planting (2.8×0.15) ×0.4 m, the indicators of the number of leaves per running m and the average area of 1 m^2 of leaves, were the highest (Fig. 5, Table 7). With the scheme of planting (1.4×0.15) ×0.4 m, the length of the fruiting zone of shoots was the highest (Table 8).



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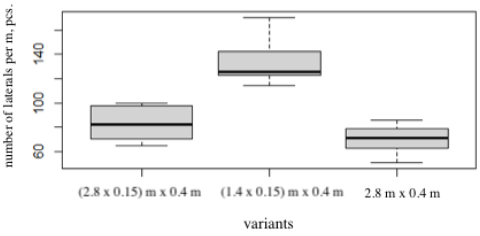

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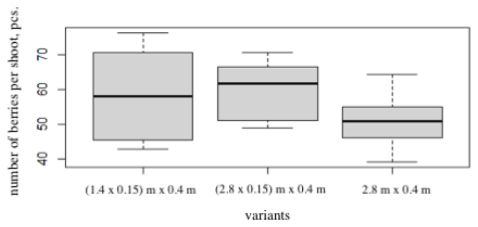

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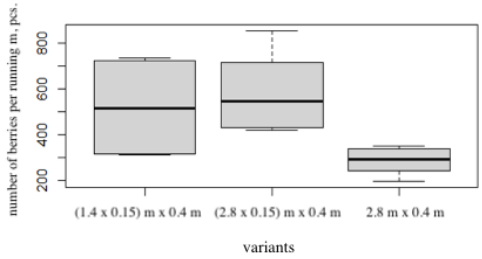

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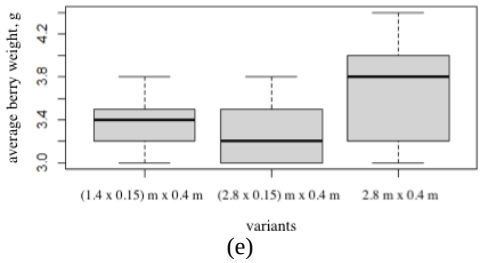

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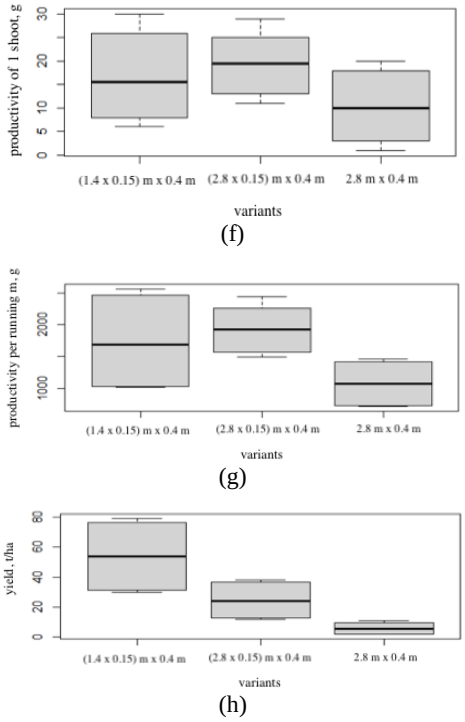
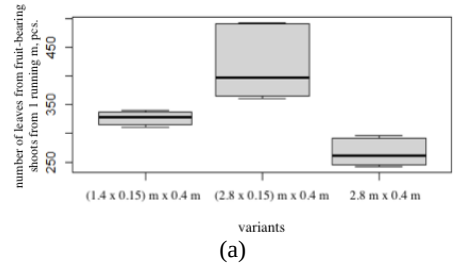


Fig. 4: Graphical analysis of the influence of the planting scheme of remontant raspberries on its productivity indicators (Saymasay village, Almaty region); Note: Influence of the factor of the variety-planting scheme of remontant raspberries on the variable A-number of laterals per shoot; B-number of laterals per m; C-number of berries per shoot; D-number of berries per running m; E-average berry weight; F-productivity of 1 shoot; G-productivity per running m; H-yield



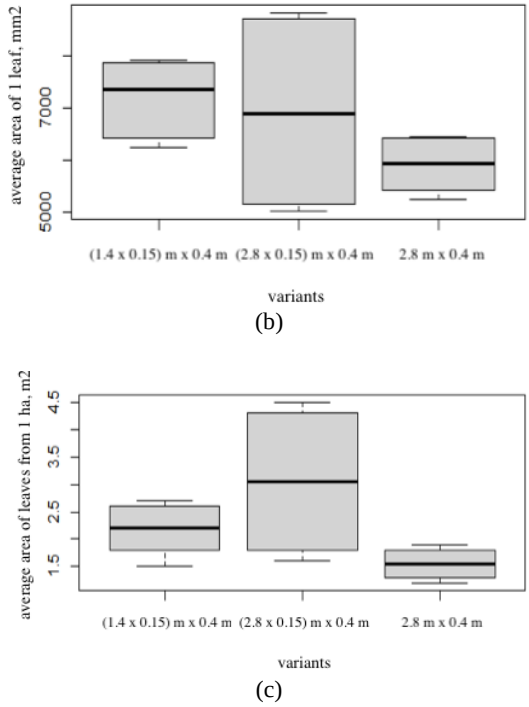


Fig. 5: Graphical analysis of the influence of the planting scheme of remontant raspberry on the biometric indicators of leaves (Saymasay village, Almaty region); Note: Influence of the factor planting scheme of remontant raspberries on the variable; A-number of leaves from fruit-bearing shoots from 1 running m; B-average area of 1 leaf, mm^2; C-average area of leaves from 1 ha, m^2

Table 5: Influence of the factor of variety of remontant raspberries on the height of shoots (Saymasay village, Almaty region)

Variety	Height of shoots, mm
Bryanskoe divo	1,058.730
Polka	892.270
p-value	<0.01***

Table 6: Analysis of the influence of the planting scheme of remontant raspberry on its productivity indicators (Saymasay village, Almaty region)

Planting scheme, m^2	Number of laterals, pcs.		Number of berries, pcs.		Average weight of the berry, g	Productivity, g		Yield, t/ha
	Per shoot	Per running m	Per shoot	Per running m		Per shoot	Per running m	
2.8×0.4 m (C)	14.60	83.20	58.60	517.80	3.40	196.60	1,738.10	54.4
(2.8×0.15) ×0.4 m	12.20	132.70	59.90	572.80	3.30	201.60	1,935.00	24.6
(1.4×0.15) ×0.4 m	11.40	70.26	50.80	285.60	3.70	151.80	1,077.40	6.0
p-value	<0.01***	<0.01**	<0.01***	<0.01***	<0.01**	<0.01***	<0.01***	<0.01***

Table 7: Analysis of the influence of the planting scheme of remontant raspberry on the biometric indicators of leaves (Saymasay village, Almaty region)

	Number of leaves on fruiting shoots, pcs		Average area, mm^2	
Planting scheme, m^2	Per running m	Per ha	1 leaf	1 m^2 of leaves
2.8×0.4 m (C)	326.53	10,144,720	7,173.00	2.16
(2.8×0.15) m ×0.4 m	421.26	7,311,350	6,922.40	3.04
(1.4×0.15) m ×0.4 m	267.04	2,520,650	5,903.80	1.56
p-value	<0.01***	<0.01***	<0.01***	<0.01***

Table 8: Influence of the planting scheme of remontant raspberries on the length of the fruiting zone of shoots, in mm (Saymasay village, Almaty region)

Planting scheme, m^2	Length of the fruiting zone of shoots mm
2.8×0.4 m (C)	408.00
(2.8×0.15) m ×0.4 m	371.10
(1.4×0.15) m ×0.4 m	421.10
p-value	<0.01***

Discussion

Cultivation of remontant raspberry varieties by type of annual crop alleviates the problem of stem winter hardiness and eliminates major diseases and pests without the use of pesticides (Asylbekovna *et al*., 2020). On the other hand, when leaving annual shoots for the second year, gardeners get very extended fruit-bearing periods, which turns out to be attractive for amateur horticulture, especially in the south of European Russia (Rachenko *et al*., 2022).

Current varieties of remontant raspberries are distinguished by their large fruit size, so in this respect, they easily compete with the summer raspberry assortment. Their fruits have a berry mass of 3.1-4.5 g and the large-fruited varieties -7,011.5 g (Rachenko *et al*., 2022). For most varieties with average soil fertility, the distance between the rows is 1.5-2.0 m, and between plants in a row is 0.7-0.9 m (Kenzhekhojayev, 2019). Under favorable soil and weather conditions, remontant raspberry varieties can yield more than 20 t/ha (Rachenko *et al*., 2022). The productivity of a variety depends on the number of fruiting shoots on a bush and the number of berries on one shoot, as well as the average berry weight. In the Leningrad region, Russian Federation, high productivity was demonstrated by the Bryanskoe divo, Gerakl, and Evraziya varieties (1,300-1,600 g per bush). The lowest productivity was observed in varieties Babje Leto with 900 g per bush and Brilliantovaya with 1,050 g per bush (Evdokimenko, 2021).

Morales *et al*. (2013) evaluated the effects of drought on the phenological phases, physiological parameters, and yield of two raspberry varieties: Heritage (remontant variety) and Meeker (non-remontant variety). Heritage shows earlier flowering and a shorter period of fruit production in relation to irrigated plants under drought conditions. Meeker increases the length and branching of stems and the plants age earlier under drought conditions.

The findings of Pantsyreva *et al*. (2020) indicate that the yield of raspberry varieties is promoted by soil mulching with straw and sawdust. In this case, the onset of phenological phases of raspberry plants occurs later compared to growing without mulching. A different study (Zejak *et al*., 2021) suggests that raspberry yields can positively correlate with the length and width of stems, while the size and number of berries per side have a negative relationship with stem length. According to our results, Bryanskoe divo is more productive owing to higher values of the number of laterals per shoot and running m, the number of berries per shoot, the average weight of the berry, productivity per stem and running m, the number of leaves per running m and ha, the average area of one leaf, the number of leaves per 1 m^2 and leaf area index.

In Uzbekistan, the productivity of the Redwing remontant raspberry variety based on the development and productivity of plants in the first and second years of vegetation has been assessed by Nurmukhamedova (2022). The study gives evidence of the advantage of dense planting of plants by the scheme 2.0×0.3 m over sparse planting under the scheme 2.5×0.5 m. With dense planting, the average yield over two years of plantation was 63.1 c/ha, 1.9 times higher than with sparse planting (2.5×0.5 m). According to our data, the sparse planting pattern of 2.8×0.4 m gave the highest yield of 54.4 t/ha due to the higher number of laterals per shoot, the number of berries per shoot, and running m and productivity per shoot and running m compared to the denser one ((1.4×0.15) m ×0.4 m).

Conclusion

As a result of the study, it was found that the variety Bryanskoe divo was found to be the most productive with 40.8 t/ha, while the variety Polka had more than twice as low yields -15.6 t/ha. The advantage of Bryanskoe divo owes to higher indicators of the number of laterals, the number and weight of berries, the number of leaves, and the leaf area index. The most productive planting scheme of remontant raspberries was found to be (2.8×0.4 m), which showed a yield of 54.4 t/ha owing to higher number of laterals per shoot, the number of barriers per shoot and running m and productivity per shoot and running m as compared to the sparser planting scheme of (2.8×0.15) m ×0.4 m, the productivity of which was more than two times lower-24.6 t/ha.

Thus, the variety of Bryanskoe divo cultivated at a lesser density, when compared to Polka and to a higher density planting scheme, displays better results in terms of biometric indicators, productivity, and yield. The study was limited to two repair varieties of raspberries-Bryanskoe divo and Polka. In further studies, it is necessary to continue studying the influence of various planting schemes on the productivity of other repair varieties of raspberries.

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Author's Contributions

All authors equally contributed to this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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