

Olga V. Ladyzhenskaya¹
Sergey S. Letunovsky²
Tatiana S. Aniskina¹
Victoria A. Kryuchkova¹
Maxim V. Simakhin¹ ✉

¹ Tsistsin Main Botanical Garden of Russian Academy of Science, Moscow, Russia

² Research and production nursery "Malinovii Rai", Maryino village, Michurinsky district, Tambov region, Russia

✉ Simakhin1439@yandex.ru

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О.В. Ладыженская¹
С.С. Летуновский²
Т.С. Аниськина¹
В.А. Крючкова¹
М.В. Симахин¹ ✉

¹ Главный ботанический сад им. Н.В. Цицина Российской академии наук, Москва, Россия

² Плодово-ягодный питомник «Малиновый рай», Марьино, Мичуринский р-н, Тамбовская обл., Россия

✉ Simakhin1439@yandex.ru

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Comparison of modern raspberry varieties long cane

ABSTRACT

Relevance. Modern raspberry varieties (*Rubus idaeus* L.) have great potential for cultivation using Long Cane technology.

Methods. The study compared raspberry varieties Ovation, Wengi, and Vajolet. Seedlings were obtained from root cuttings, then grown from April 2021 to July 2022 for the summer harvest and from April 2022 to October 2022 for the fall harvest.

Results. It has been established that varietal characteristics and the fruiting period significantly affect the indicators. The largest fruits are in the Wengi variety (length 25.5 mm, diameter 24.3 mm, weight 7.2 g), the smallest are in the Ovation variety (length 22.2 mm, diameter 22.5 mm, weight 4.9 g). When observing varieties at different ripening periods, it was found that the fruit length (27.3 mm) and fruit weight (8.3 mm) during the summer fruiting period are maximum in the Wengi variety, and minimum in the Vajolet variety. The amount of sugar ranges from 11 to 13°Bx, the percentage of ripe fruits from 84.5 to 94.5. The difference between the Wengi and Ovation varieties in terms of vegetative characteristics at different growing periods has been reliably proven. During the summer fruiting period, the yield per shoot for Wengi was 2615 g, for Vajolet — 485 g. The Wengi variety was distinguished by its maximum length (27.3 mm) and fruit weight (8.3 g). Based on all the indicators, the most promising varieties for summer fruiting are Wengi and Vajolet, and for autumn fruiting — Ovation.

Key words: Raspberries, Long Cane, cultivation, remontant varieties, fruits, Wengi, Vajolet, Ovation

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Сравнение современных сортов малины, выращиваемых по системе Long Cane

РЕЗЮМЕ

Актуальность. Современные сорта малины (*Rubus idaeus* L.) имеют большой потенциал для выращивания с помощью технологии Long Cane.

Методы. В исследовании сравнивали сорта малины сортов Ovation, Wengi, Vajolet. Сажены были получены из корневых черенков, затем выращены с апреля 2021 г. по июль 2022-го для летнего урожая и с апреля 2022 г. по октябрь 2022-го — для осеннего.

Результаты. Установлено, что сортовые особенности и период плодоношения существенно влияют на показатели. Самые крупные плоды у сорта Wengi (длина 25,5 мм, диаметр 24,3 мм, масса 7,2 г), самые мелкие — у сорта Ovation (длина 22,2 мм, диаметр 22,5 мм, масса 4,9 г). При наблюдении за сортами в разные сроки созревания установлено, что длина плода (27,3 мм) и масса плода (8,3 мм) в период летнего плодоношения максимальны у сорта Wengi, а минимальны — у сорта Vajolet. Количество сахара колеблется от 11 до 13°Bx, процент спелых плодов — от 84,5 до 94,5. Достоверно доказана разница между сортами Wengi и Ovation по вегетативным характеристикам при разных сроках выращивания, где максимальные значения были получены на второй год. В период летнего плодоношения урожай с одного побега у Wengi составил 2615 г, у Vajolet — 485 г. Сорт Wengi отличался максимальной длиной (27,3 мм) и массой плодов (8,3 г). По совокупности показателей наиболее перспективными сортами для летнего плодоношения являются Wengi и Vajolet, для осеннего — Ovation.

Ключевые слова: малина, Long Cane, выращивание, ремонтантные сорта, плоды, Wengi, Vajolet, Ovation

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Introduction/ Введение

Raspberry fruits (*Rubus idaeus* L.) are a unique natural source of a whole balanced in composition complex of nutritious and biologically active substances that attracts the attention of the whole world [1]. Raspberries contain vitamins, minerals (potassium (K), calcium (Ca), iron (Fe), zinc (Zn) and manganese (Mn)), unsaturated fat acids, sugars, proteins and polyphenols [2]. In addition, raspberries have a high antioxidant potential, due to the increased accumulation of ascorbic, ellagic, folic acids and anthocyanins [3]. That is why raspberry fruits have antioxidant, anti-inflammatory, chemo-preventive and antimicrobial properties, which significantly affect the human vital processes [4].

Raspberries varieties (*Rubus idaeus* L.) are divided into summer (biennial-fruiting) and remontant (primocane-fruiting) [5]. Basically, varieties that are used for container growing of long cane in high tunnels are summer (biennial-fruiting), their shoots are formed during one growing season, then plants are removed to frigo-storage [6]. The difference between traditional and remontant varieties is that remontant varieties' blooming and bearing are not related with day length and temperature. In traditional varieties the dormant period begins after the initiation of flowering [7].

According to FAO data for 2020, the area of raspberry plantations in the world was 112 167 hectares, and the yield was 895 771 tons, while in 2019 — 841 351 tons were obtained from an area of 122 195 hectares. That indicates the dynamics of berry producing growth despite the decrease in areas. The leading countries raspberries producing are the Russian Federation (151 738 tons), Serbia (92 514 tons), Poland (84 674 tons) and the USA (81 865 tons)¹. In Russia, to preserve the current industrial area (2412.2 ha), the minimum annual need in raspberry planting material is 2 560 643 seedlings².

Every year the demand for planting material increases, as increases the demand for berry products, however, the modern market needs more stable, high-yielding varieties and more intensive cultivation technologies [10]. Modern breeding programs are focused on the creation of new varieties based on the producers' needs. Subsequently, they become the basis for industrial plantations of red raspberries around the world³. The increased attention is paid to the breeding of universal purpose varieties. They must be suitable both for processing and possess complex resistance or tolerance to diseases [9].

To extend the harvest period, Chinese scientists have developed a technique for simultaneously growing biennial-fruiting and primocane-fruiting in the open field and in tunnel shelters. Thus, the harvest period was more than 220 days [10].

Growing technologies in open and protected ground have their own advantages and disadvantages. For example, growing raspberries in the traditional way in open ground, plants are affected by ectoparasites (for example, needle and dagger nematodes (*Longidorus* and *Xiphinema*), which parasitize both on the roots of perennial shrubs and woody plants, and on annual crops. The danger of phytoparasitic nematodes is that they are carriers of viral diseases that spread locally with the soil and plant material [11].

Another problem growing raspberries in open ground is the infection of plants with a soil bacterium, crown gall disease (*Agrobacterium tumefaciens*), that causes tumor formations on the plants' roots and shoots. The bacterium enters the plant through wound lesions, as a result cell proliferation is occurred, the tumor grows, the flow of water and nutrients is disturbed, the plants become weak, and the yield and quality of fruits are significantly reduced⁴.

Growing late raspberries varieties in open ground in the conditions of the Central and Northern regions of the Russian Federation, 20–30% of the yield does not have time to ripen, however, these regions are the main ones for growing raspberries; also, during prolonged rainfall, fruits are damaged by gray rot (*Botrytis cinerea*), which leads to a significant decrease in yield and loss of fruit quality.

The growth in demand for raspberry products outside the traditional season promoted an increase of protected ground area. For this purpose, the "long cane production system" was developed⁵. However, growing raspberry with long cane system in container technology in tunnels is it necessary to consider varietal characteristics, as well as follow a complex of agrotechnical measures (maintaining of air and soil humidity, normalizing shoots and selecting the optimal container volume).

The purpose of our study is to compare modern raspberry varieties of raspberries growing them with the long cane system in container technology using tunnel shelters.

Materials and methods /

Материалы и методы исследования

The studies were carried out in Michurinsk (52°85'86" N, 40°48'97" E, Tambov region, Russia), on the territory of the educational and research greenhouse complex during the growing season of 2021–2022.

In the experiment, 3 varieties of raspberries were used: Wengi, Vajolet and Ovation.

The tunnel (10 m W x 100 m L x 4,7 m H) is covered with a double layer of transparent polyethylene with a density of 150 microns. Inside the tunnel, at a height of 200 cm from the ground, there is a shading net with a density of 50 g/m² (Russia). The ventilation of the tunnel is carried out through the tunnel doors at both ends and four side windows. Humidity was maintained at 50%, the maximum temperature reached inside 36 °C, minimum 7 °C. The optimum temperature at night is 11 °C, during the day 20 °C. The surface in the tunnel is covered with a covering fabric with a density of 130 g/m² (produced in Belarus).

Raspberry seedlings were propagated by root cuttings. In April, rooted cuttings with an aerial part of 15–20 cm were dived and planted into a 1 liter container each. Planting them, it was applied Fertilizer Osmocote Exact Standard 5–6M (15-9-12 + 2MgO + TE) — 2 g/l, Everris (ICL), Netherlands. As a substrate it was used a mixture of peat (75%, Pindstrup, Russia) with agroperlite (25%, Plant of Mineral Fertilizers, Russia). During the growing season, it was carried root fertigation with Master (13-40-13) fertilizer — 2 g/l, Valagro, Italy. The humidity of the substrate was maintained at 65–70% throughout the growing season. In late May — early June, raspberry seedlings were transplanted into foam containers

¹ FAOSTAT Production/Yield quantities of Raspberries in World + (Total) 2000–2020 Retrieved from. <https://www.fao.org/faostat/en/#data/QCL/visualize> (дата обращения: 19.10.2022).

² Расчеты Ягодного союза на основе данных сельскохозяйственной переписи 2016 года. <https://berry-union.ru> (дата обращения: 19.10.2022).

³ Finn C.E., Kempler C., Moore P.P. Raspberry cultivars: what's new? what's succeeding? where are breeding programs headed?. Acta Hort. 2008; 777(1): 33–40. DOI: 10.17660/ActaHortic.2008.777.1

⁴ Pscheidt J.W., O'camb C.M. Blackberry (*Rubus* spp.) Stamen Blight. PNW Plant Disease Management Handbook. 2016. Available at: <https://pnwhandbooks.org/plantdisease/host-disease/blackberry-rubus-spp-stamen-blight>

⁵ Sonstebly A., Stavang J.A., Heide O.M. One technique that has been developed for this purpose is the so-called "long cane production system". Production of high-yielding raspberry long canes: The way to 3 kg of fruit per cane Journal of Horticultural Science & Biotechnology. 2013; 88(5): 591–599.

(55x35x20 cm), volume 40 liters. During the growing season, it was carried 6 times fertilizing out with orthophosphoric acid (OPA), the concentration of 75.2%. Row spacing is 1.5 m, containers are arranged tightly in a row. From 1 to 4 seedlings were planted in each container, depending on the variety. Placement of variants in the experiment is randomized. All varieties are presented in quadruple repetition. Irrigation was carried out using drip tapes 2–3 times a day in hot weather, or once every 2 days in cloudy weather.

The experiment was carried out on a long cane of two types:

- Long canes (floricanes) grown for two years were chosen to study the summer fruiting. In November 2021, the aerial part was shortened to a height of 170 cm; in April 2022, the vegetation resumed. Berries were measured on June 14, 2022.
- Long canes (primocanes) of the first year were grown from one-year-old root cuttings in 2022. Berries were measured on September 14, shoots on October 12, 2022.

Measuring 30 berries were taken into account the following characteristics: length, diameter, weight, proportion of ripened fruits from the total quantity, yield from one shoot⁶.

Fruits weight was measured with Aqua-Lab.RF, YA501 scales. Sugars were measured using an AQ-REF-BRIX4 refractometer (Aqua-LAB, Russian Federation). Fruits diameter and length were measured with a MECHANIK 150 PRO caliper, fruits density was measured with an Ft 327 penetrometer (3–27 Lbs.)⁷

The analysis of experimental data was carried out in the IBM SPSS (IBM, USA) program using the methods of descriptive statistics, one-factor and two-factor analysis of variance using Duncan's post hoc tests (for features whose distribution corresponds to the normal distribution law) and the nonparametric Kruskal-Wallis test for independent samples (for features whose distribution does not correspond to a normal distribution law). Checking the normality of the distribution was performed according to the Kolmogorov-Smirnov and Shapiro-Wilk criteria.

Correlation analysis was performed using Spearman's rank correlation test.

Results and discussion /

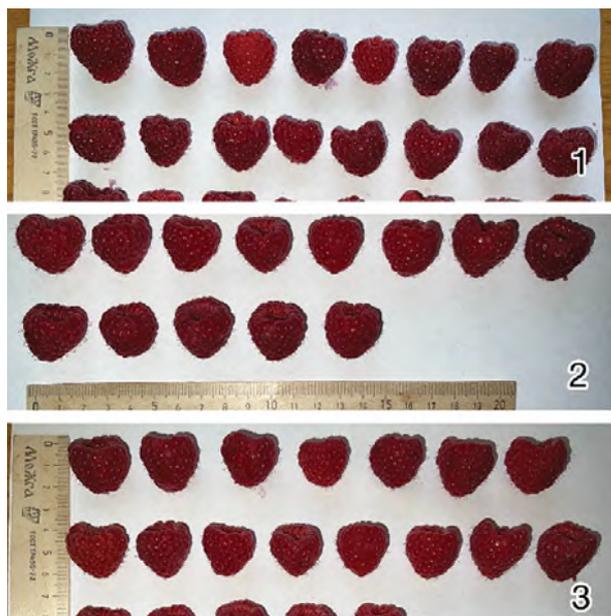
Результаты и обсуждение

Comparison of summer and autumn fruiting of raspberry varieties according to technology Long Cane

According to the results of summer and autumn studies was established a normal distribution of the fruits length, diameter and weight, which makes it possible to use ANOVA to analyze the reliability of differences. For such traits as amount of sugar content in fruits, the percentage of ripened fruits from the total yield and the yield from one shoot, the distribution did not correspond to the normal law, and therefore nonparametric criteria were subsequently used to identify the significance of differences.

It was noted high variability in terms of productivity and proved significant differences between varieties in length, diameter and weight of the fruit (Figure 1). The largest fruits are in Wengi (25.5 mm length, 24.3 mm diameter and 7,2 g weight), and the smallest in Vajolet (22,2 mm length, 21.7 mm diameter and 4.0 g mass).

Fig. 1. Raspberries during autumn fruiting: 1 — Wengi, 2 — Vajolet, 3 — Ovation



Significant differences between fruiting seasons were revealed only on the basis of fruit diameter. On average, for varieties, fruits in autumn fruiting (23.4 mm) are larger than in summer (22.0 mm).

Varietal features in terms of the height and weight of the fruit were revealed in different fruiting periods. Observing the varieties at different ripening periods, it was found that the length (27.3 mm) and fruit weight (8.3 g) during the summer fruiting period are maximum for Wengi and minimum for Vajolet. Ovation showed average values in the summer. It should be noted that during autumn fruiting period, the length and weight of fruits stabilize and take average values (Table 1).

Table 1. Parameters of summer and autumn fruiting of 3 raspberry varieties

Cultivar	Season	Fruit length, mm	Fruit diameter, mm	Fruit weight, g
Wengi	Summer	27.3 ^c ± 1.7	24.2 ± 1.7	8.3 ^c ± 1.4
Vajolet		20.7 ^a ± 1.4	20.0 ± 2.2	3.2 ^a ± 0.9
Ovation		22.3 ^b ± 1.6	22.0 ± 0.6	4.4 ^{ab} ± 0.7
Wengi	Autumn	23.6 ^b ± 2.1	24.4 ± 2.3	6.0 ^b ± 1.2
Vajolet		23.7 ^b ± 2.3	22.1 ± 1.7	4.8 ^{ab} ± 0.8
Ovation		22.1 ^b ± 1.5	22.9 ± 1.2	5.3 ^b ± 0.5
Average CVS.	Summer	23.4 ± 3.1	22.0 ± 2.1	4.9 ± 1.9
	Autumn	23.2 ± 2.1	23.4 ± 2.1	5.5 ± 1.9
Wengi	Average Seasons	25.5 ^b ± 2.4	24.4 ^c ± 2.2	7.2 ^c ± 1.3
Vajolet		23.1 ^{ab} ± 2.5	21.1 ^a ± 1.9	4.0 ^a ± 1.0
Ovation		22.2 ^a ± 1.5	22.5 ^b ± 1.6	4.9 ^b ± 0.7

Source of variation

Cultivar	*	*	*
Season	n.s.	*	n.s.
Cultivar*Season	*	n.s.	*

The Kruskal — Wallis criteria established the absence of significant differences in the periods of summer and autumn ripening periods in terms of amount of sugar and the proportion of ripened fruits. Yield from one shoot varies depending on the timing of fruiting. In summer, the median productivity is almost 2 times higher (1500 g) than in autumn (820 g) (Table 2).

⁶ Седов Е.Н. и др. Программа и методика сортоизучения плодовых, ягодных и орехоплодных культур. Орел: ВНИИСПК. 1999; 606.

⁷ ГОСТ Р 51938-2002 Соки фруктовые и овощные. Метод определения сахарозы. М.: Госстандарт России. 12 с.

Table 2. Medians of seasonal amount of sugars, proportion of ripened fruits and yield per shoot in raspberry varieties

Season	Amount of sugar, °Bx	Proportion of ripened fruits, %	Yield from one shoot, g
Summer	10	89.0	1500
Autumn	11	89.5	820

Autumn fruiting of raspberry varieties according to Long Cane (Primocane) system

For such parameters as amount of sugar, the proportion of ripened fruits from the total fruits' quantity and the yield per shoot, the distribution was proved to be inconsistent with the normal law. The Kruskal — Wallis test showed that the varieties do not differ significantly in terms of amount of sugar and the proportion of ripened fruits from the total fruits' quantity. In terms of yield from one shoot in the autumn harvest, it was established significant differences between varieties. The median amount of sugar varies from 11 to 13 °Bx, the percentage of ripened fruits is from 84,5 to 89,5%, the yield per shoot is from 705 to 1050 g (Table 3).

Table 3. Medians of autumn amount of sugar, proportion of ripened fruits and yield per one shoot in raspberry varieties

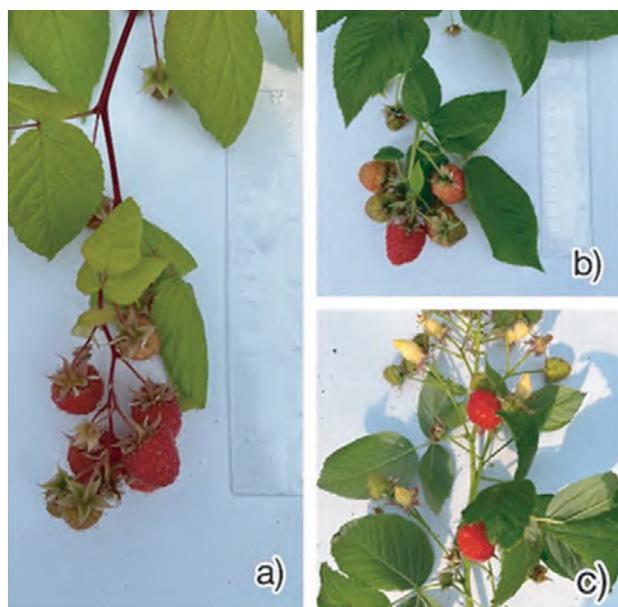
Variety	Amount of sugar, °Bx	Proportion of ripened fruits, %	Yield from one shoot, g
Wengi	11	89.5	705
Vajolet	13	94.5	705
Ovation	11	84.5	1050

Additional parameters of summer fruiting of raspberry varieties according to Long Cane (Florican) system

For raspberry varieties grown in summer fruiting period, it was carried additional studies of the fruiting shoots' structure — lateral's quantity on one shoot and the fruits' quantity on one lateral shoot, on which largely depends the overall yield (Figure 2). It was proved that the distribution corresponded to the normal law and significant differences between varieties for these parameters.

For raspberry varieties grown in summer fruiting period, it was carried additional studies of the fruiting shoots' structure — lateral's quantity on one shoot and the fruit's quantity on one lateral shoot, on which largely depends the overall yield (Figure 2). It was proved that the distribution

Fig. 2. Raspberry laterals during summer fruiting: a) Ovation, b) Vajolet, c) Wengi



corresponded to the normal law and significant differences between varieties for these parameters.

It was noted an inverse relationship between the lateral's quantity and fruit's quantity on the lateral shoot — with a small quantity of laterals on the shoot, cultivar Wengi has the largest quantity of fruits on the lateral, while, with the largest quantity of laterals, cultivar Ovation has much less quantity of fruits on each of them (Table 4).

Table 4. Parameters of the summer fruiting zone of 3 raspberry varieties. Values are averages for 15 shoots, 30 laterals and 30 fruits with standard deviations. The values that have different letters are significantly different according to Fisher's test ($p \leq 0.05$) and Duncan's post hoc tests

Variety	Quantity of laterals on the shoot, pcs	Quantity of fruits on the lateral, pcs
Ovation	18.8 ^b ± 2.8	14.9 ^a ± 1.9
Wengi	11.5 ^a ± 3.0	27.4 ^b ± 5.6
Vajolet	14.7 ^{a, b} ± 4.5	10.3 ^a ± 1.3

There wasn't found any significant differences in amount of sugars and the proportion of ripened fruits between the varieties. It was noted significant differences between the varieties in yield from one shoot, the maximum yield was in the Ovation variety (Table 3).

Table 5. Median summer amount of sugar, proportion of ripened fruits and yield from one shoot for Vajolet, Wengi and Ovation

Variety	Amount of sugar, °Bx	Proportion of ripened fruits, %	Yield from one shoot, g
Ovation	12	86	1233
Wengi	9	89	2615
Vajolet	13	91	485

Growing raspberry using long cane system allows to extend the yield season in many countries of the world [12]. So, for example, Norwegian scientists tested the summer (biennial-fruiting red raspberry) raspberry variety "Tulameen" by growing long cane in 7.5 L containers in the greenhouse and in the open field. The yield in greenhouse conditions was 2700 g per shoot, fruit weight 6.1 g, while the yield in open ground was 2100 g per shoot and fruit weight 6.3 g. Belgian scientists conducted an experiment on growing a remontant raspberry variety "Kwanza". The results of the study showed that growing using long cane system for a summer crop from the end of January to mid-June in greenhouse conditions in a 10 L container and with the formation of 2 shoots per container, the yield was 800 g/m², while under the same conditions it was possible to collect 500 g/m² [13].

In some publications, it was noted that the optimal taste, density, size and color of fruits can be obtained by re-harvesting [15, 16], as it was done in the experiment with raspberry varieties Polesie, Polka, Polana. Our results partially agree; the height, diameter, and weight of the fruit in the Wengi variety are significantly higher during the summer fruiting period, while in the Vajolet and Ovation varieties in the fall.

The long cane technology has been developed to extend the market cycle for fresh raspberries and is regularly amended [16, 17].

We suggest improving the technology with choosing summer and autumn varieties. In autumn fruiting, remontant raspberry varieties gain more sugars, the percentage of ripened fruits is also higher, but the yield is much lower. However, it is worth noting that the variety "Ovation" has a slightly higher productivity in summer than in autumn, while the amount sugars and the proportion of ripened fruits are higher.

Conclusions/Выводы

The largest fruits are in the Wengi variety (length 25.5 mm, diameter 24.3 mm, weight 7.2 g), the smallest are in the Vajolet variety (length 22.2 mm, diameter 21.1 mm, weight 4.0 g). When observing varieties at different ripening periods, it was found that the fruit length (27.3 mm) and fruit weight (8.3 mm) during the summer fruiting period are maximum in the Wengi variety, and minimum in the Vajolet variety.

The amount of sugar ranges from 11 to 13 °Bx, the percentage of ripe fruits from 84.5 to 94.5%, the yield per

shoot from 505 to 1250. During the summer fruiting period, the yield per shoot for Wengi was 2615 g, for Vajolet — 485 g. The Wengi variety was distinguished by its maximum length (27.3 mm) and fruit weight (8.3 g).

The studied varieties are recommended to be used for industrial production. Variety “Ovation” is recommended for both summer and autumn fruiting. Varieties “Vajolet” and “Wengi” are recommended for summer fruiting. Relevance. Modern raspberry varieties (*Rubus idaeus* L.) have great potential for cultivation using Long Cane technology.

All authors bear responsibility for the work and presented data. All authors made an equal contribution to the work. The authors were equally involved in writing the manuscript and bear the equal responsibility for plagiarism. The authors declare no conflict of interest.

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ОБ АВТОРАХ

Ольга Викторовна Ладзыженская¹

научный сотрудник
o.ladyzhenskaya91@mail.ru
<https://orcid.org/0000-0002-8086-8891>

Сергей Сергеевич Летуновский²

директор
Malinovii-raiOO@mail.ru

Татьяна Сергеевна Аниськина¹

научный сотрудник лаборатории культурных растений
tatianiskina@gmail.com
<https://orcid.org/0000-0002-0933-1020>

Виктория Александровна Крючкова¹

кандидат биологических наук; доцент, ведущий научный сотрудник
vkruchkova@mail.ru
<https://orcid.org/0000-0003-1066-3978>

Максим Вячеславович Симахин¹

кандидат сельскохозяйственных наук, научный сотрудник
Simakhin1439@yandex.ru
<https://orcid.org/0000-0003-0680-941X>

¹ Главный ботанический сад им. Н.В. Цицина РАН, Ботаническая ул., 4, Москва, 127276, Россия

² Плодово-ягодный питомник «Малиновый рай», ул. Лесная, 7, дер. Марьино, Мичуринский р-н, Тамбовская обл., 393754, Россия

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ABOUT THE AUTHORS

Olga Victorovna Ladyzhenskaya¹

Researcher Laboratory of Cultivated Plants
o.ladyzhenskaya91@mail.ru
<https://orcid.org/0000-0002-8086-8891>

Sergey Sergeevich Letunovskiy²

Director
Malinovii-raiOO@mail.ru

Tatyana Sergeevna Aniskina¹

Researcher at the Laboratory of Cultivated Plants
tatianiskina@gmail.com
<https://orcid.org/0000-0002-0933-1020>

Victoria Alexandrovna Kryuchkova¹

Candidate of Biological Sciences; Assistant Professor, Leading Researcher
vkruchkova@mail.ru
<https://orcid.org/0000-0003-1066-3978>

Maxim Vyacheslavovich Simakhin¹

Candidate of Agricultural Sciences, Researcher
Simakhin1439@yandex.ru
<https://orcid.org/0000-0003-0680-941X>

¹ Tsitsin Main Botanical Garden of Russian Academy of Science, 4 Botanicheskaya Str., Moscow, 127276, Russia

² Research and production nursery "Malinovii Rai", 7 Lesnaya Str., Maryino village, Michurinsky district, Tambov region, 393754, Russia



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