Development of primocane-fruiting raspberry varieties in the conditions of forest-steppe zone of the Irkutsk region

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Abstract. Heightened interest in primocane-fruiting raspberry in the region necessitated a detailed study of this berry crop. The article introduces the research carried out in 2019 on the 0.15 ha collection site of Siberian Institute of Plant Physiology and Biochemistry of the Siberian Branch of the Russian Academy of Sciences (Irkutsk). The research objects were 9 varieties and 3 select forms of primocane-fruiting raspberry of the domestic breeding. Particular attention was paid to the biological and practical features of the research object: early maturity, cropping power, and damage caused by phytopathogenic objects. During the growing season, the varieties bearing fruit in late July – early August and those bearing fruit in the first and second ten-day intervals of September were noted. Large-fruit varieties (fruit mass more than 6 g) and large-fruiting forms (fruit mass more than 7 g) were singled out. In the study season, fruiting continued until early October due to weather conditions. That allowed many plants to give maximum yield. The last harvest was on October 7, 2019. However, there were some plants that were only entering the stage of mass bearing at that moment. As a result, more early-maturing forms and varieties with the highest cropping power and resistance to fruit rot during the rainy season were registered among the range of varieties under study. Observations on the spider mite population on the plants were described. The paper describes the conditions for growing and the difficulties encountered during the planting of primocane-fruiting raspberry. The climatic conditions of the study area are described.

1. Introduction
Rapidly expanding rates of the industrial cultivation of primocane-fruiting raspberry necessitated the need for additional information on the production and biological characteristics, and potencies of this berry crop in the region.

Primocane-fruiting raspberry is a group of varieties able to bear fruit both on biennial and annual shoots. Fruiting begins later than that of red raspberry: it occurs until frosts.

The first primocane-fruiting forms were described more than 200 years ago by John Abercrombie, a Scottish horticulturist, in 1778 and Bernard MacMahon, an American horticulturist, in 1806. In Russia, primocane-fruiting forms were singled out in the works of I.V. Michurin (variety ‘Progress’). Only in the 1970s Soviet scientists began work on the creation of primocane-fruiting forms which continuously bore fruit until late autumn. The greatest work of Professor I.V. Kazakov and Doctor of Sciences (Agriculture) S.N. Evdokimenko in the development of Russian breeding in this field is worth mentioning. In Cisbaikalia, a lot of studies of primocane-fruiting raspberry in the south of the Irkutsk region were carried out by specialists from Siberian Institute of Plant Physiology and Biochemistry

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Siberian Branch of the Russian Academy of Sciences and Irkutsk State Agrarian University named after A.A. Ezhevsky; E.I. Rachenko, N.E. Martynova, M.A. Rachenko, (2010-2013) [7]. M.Yu. Pushchina, M.A. Rachenko, R.A. Sagirova, (2017) [6]. Within the framework of the present research we continue to study the berry crop in order to select adaptive and sustainably productive varieties for the region with the prospect of selecting parental forms with persistently high biological and practical features. After all, “... the choice of parents is based on their phenotypic characteristics” [11].

To date, more than 30 varieties of primocane-fruiting raspberry are known in the country. This crop is one of the most popular of the berry crops. According to the State Register of Breeding Achievements of the Russian Federation, there are no released varieties of primocane-fruiting raspberry in the East Siberian region. However, there are ones recommended for cultivation in all the country regions. The range is represented by 17 varieties: ‘Avgustina’, ‘Atlant’, ‘Bryanskoye divo’, ‘Zhar ptitsa’, ‘Yevraziya’, ‘Zolotaya osen’, ‘Karamel’ka’, ‘Malinovaya gryada’ (2019), ‘Nizhegorodets’, ‘Oranzhevoye chudo’, ‘Pingvin’, ‘Podarok Kashinu’, ‘Poklon Kazakovu’, ‘Pokhvalinka’ (2019), ‘Rubinovoye ozherel’ye’, ‘Samokhval’, ‘Yantarnaya’ [1]. In 2019, three of them (‘Pokhvalinka’, ‘Samokhval’, and ‘Malinovaya gryada’) were recommended for cultivation in all regions of the Russian Federation. The berry plants are winter-hardy and have a constant yield. Not-released varieties ‘Polka’, ‘Nadezhnaya’, ‘Gerakl’, ‘Shapka Monomakha’, ‘Zolotyye kupola’, ‘Apel’sin’, ‘Brilliantovaya’, and others are also popular in the region.

In his works, I.V. Kazakov indicates that “120–130 frost-free days with the sum of active temperatures of 1800–2000°C are required for berries of primocane-fruiting raspberry to ripe” [5]. The berry plant reacts adversely to high humidity, in case of which fungal diseases spread intensively. “In hot weather, overheating of leaves and shoots is possible, pollination of flowers sharply worsens, the quality of berries decreases, their harvesting is difficult” [4].

Irkutsky District belongs to the south-eastern forest-steppe zone (zone 5) and is characterized by a vegetation period of 120-130 days. The sum of temperatures above 10°C is 1600-1900°C. The frost-free period is on average 95 days. Annual precipitation is 170-450 mm, 160-270 mm of that is from May to September [10].

1.1. The purpose of this research
The purpose of this research is to identify promising primocane-fruited raspberry varieties for cultivation in the south-eastern part of the Irkutsk region.

1.2. Research Objectives:
1. To analyze the conditions for the cultivation of primocane-fruiting raspberry in the region.
2. To give a biological and practical assessment of the available varieties and the select forms of primocane-fruiting raspberry: shoot height, early maturity, cropping power, resistance to diseases and pests.

1.3. Objects and research methods
The object of the study is the varietal diversity (varieties and select forms) of primocane-fruited raspberry from the 0.15 ha collection site of Siberian Institute of Plant Physiology and Biochemistry of the Siberian Branch of the Russian Academy of Sciences (Irkutsk) with perennial plantings of raspberries. The berry plants are arranged in rows at a distance of 0.7 m in a row and 2.0 m in a inter-row spacing (the arrangement recommended for the introduction stage in new regions by the academician of The Russian Academy of Agricultural Sciences Kazakov I.V.). The site is located on the southern slope at an angle of 8-10°. Soil type is gray forest; its granulometric composition is medium loamy.

Biological and practical features of raspberry on the collection site were investigated by the routing method. The territory of the site was divided into uniform routes. While following the routes, phenological descriptions were made. To assess the actual cropping power, the mass of ripened berries...
on one bush before severe frosts was estimated. The studies were carried out according to the program and methodology of variety studies of fruit, berry and nut-bearing crops [8, 9].

Despite covering the inter-row spacing with a black horticultural fleece based on agrofibre with a density of 50-60 g/m², raspberry plantings required constant weeding (during the growing season, four weedicings were performed). Bushes thinning and young shoots removing were performed during the whole summer as and when necessary. Raspberry is responsive to mulching, watering and fertilizing, both root and extra-root (three root fertilizings were carried out with Diammophoska complex fertilizer in standard concentration for berry bushes 80 g/m², and one extra-root fertilizing was carried out with Turmax complex foliar fertilizer in a way of fine spraying with a flow rate of 1 liter of spray material per 10 m²).

2. Research results

On average, two bush tyings to the trellis were carried out during the growing season. Tall-growing canes of ‘Oranzhevoye chudo’ (average cane height is 151.9 cm), ‘Zhar ptitsa’ (156.8 cm) and the 32-151-1 hybrid (169.3 cm) required another third additional tying. In comparison, one tying was enough for low-growing canes of ‘Yevraziya’ (average cane height is 88.9 cm), ‘Pingvin’ (95.8 cm) and the 1-220-1 hybrid (86.4 cm).

In 2019 (the study year), early fruiting began in late July (form 1-220-1) and the first half of August: ‘Pingvin’, ‘Zolotyye kupola’ (August 7) and ‘Gerakl, ‘Yevraziya’ (August 14). During this period, the first fruits were noted, mass fruiting occurred after August 25. ‘Apel'sin’ was the latest to enter the fruiting stage (September 13) (table 1). Fruit formation continued after the frosts on September 15 (-1°C), September 28 (-2°C), and September 30 (0°C) at an average daily temperature of +11°C during that period. Fruit maturation lasted until October temperature drops (on 2.10-5.10.19 from -3°C to -4°C at an average daily temperature of +16°C). The last berrying was carried out on October 07, 2019. After that date, there were no ripened berries.

| No | Variety                     | Start of fruiting |
|----|-----------------------------|-------------------|
| 1  | 1-220-1                     | July 31           |
| 2  | 32-151-1                    | August 28         |
| 3  | 37-15-4                     | August 28         |
| 4  | ‘Yevraziya’                 | August 14         |
| 5  | ‘Pingvin’                   | August 07         |
| 6  | ‘Gerakl’                    | August 14         |
| 7  | ‘Zolotyye kupola’           | August 07         |
| 8  | ‘Oranzhevoye chudo’         | August 28         |
| 9  | ‘Rubinovoye ozherel'ye’     | August 28         |
| 10 | ‘Zhar ptitsa’               | September 02      |
| 11 | ‘Apel'sin’                  | September 13      |
| 12 | ‘Brilliantovaya’            | Fruit stage did not occur |

It is believed that “the most striking and significant indicator of high adaptation of a variety is its cropping power” [2]. We learned from the works of S.N. Evdokimenko that “One of the determining components of cropping power is the mass of fruits” [3]. For the entire fruiting period, the highest cropping power was shown by the 1-220-1 hybrid (1185 g/bush) (figure 1). Despite the later start of fruiting, ‘Zhar ptitsa’ showed high rates of cropping power (354 g/bush). A large number of berries from one bush (on average 282 pcs.) did not affect the cropping power of ‘Yevraziya’ and amounted to only 218 g/bush. This was due to the fact that the maximum weight of one berry fruit averaged 3.7 g. Large
berry fruits of more than 6 g were observed in ‘Gerakl’ (6.1 g), ‘Rubinovoe ozherel’ye’ (6.6 g) (figure 2), and ‘Apel'sin’ (6.3 g).

Figure 1. Fruits of the 1-220-1 primocane-fruited raspberry form, September 2, 2019.

Figure 2. Fruits of the primocane-fruited raspberry variety ‘Rubinovoye ozherel'ye’, September 2, 2019.

The 37-15-4 and 32-151-1 hybrids were the most large-fruited (7.1 and 7 g, respectively) (figure 3) (table 2).

Figure 3. Fruits of the 32-151-1 primocane-fruited raspberry form, September 2, 2019.

According to M.A. Rachenko and M.Yu. Pushchina (2017), ‘Brilliantovaya’ and ‘Gerakl’ showed high cropping power among the studied primocane-fruited raspberry varieties in the region [6]. In 2019, these varieties failed to realize their potential. ‘Brilliantovaya’ did not even enter the bud stage. That may be due to a complex of reasons for the clarification of which some complement observations are required.
Table 2. Average and maximum weight and cropping power of primocane-fruiting raspberry berries grown in the southeastern part of the Irkutsk region in 2019.

| No | Variety          | Average weight of a berry, g | Average maximum weight of a berry, g | Average number of berries from 1 bush, pcs. | Average cropping power from 1 bush, g |
|----|------------------|------------------------------|-------------------------------------|---------------------------------------------|--------------------------------------|
| 1  | 1-220-1          | 3.1±1.0                      | 4.6±1.09                            | 398±23.6                                    | 1185±61.4                            |
| 2  | 32-151-1         | 2.8±0.75                     | 7±1.56                              | 78±141.6                                    | 220±166.2                            |
| 3  | 37-15-4          | 3.4±1.15                     | 7.1±1.29                            | 81±30.8                                     | 248±83.4                             |
| 4  | ‘Yevraziya’      | 2.2±0.74                     | 3.7±1.06                            | 282±64.2                                    | 218±214.8                            |
| 5  | ‘Pingvin’        | 2.3±0.50                     | 4.6±0.52                            | 103±32.0                                    | 236±80.4                             |
| 6  | ‘Gerakl’         | 3.3±0.57                     | 6.1±0.74                            | 72±14.35                                    | 235±51.2                             |
| 7  | ‘Zolotye kupola’ | 1.9±1.0                      | 2.7±0.48                            | 79±5.1                                      | 183±19.5                             |
| 8  | ‘Oranzhevoye chudo’ | 3.6±0.98                  | 5.5±0.53                            | 71±7.31                                     | 171±19.5                             |
| 9  | ‘Rubinovoye ozherel'ye’ | 3.2±0.95                  | 6.6±0.84                            | 73±38.18                                    | 238±181.6                            |
| 10 | ‘Zhar ptitsa’    | 2.9±0.98                     | 4.5±0.97                            | 128±17.96                                   | 354±88.9                             |
| 11 | ‘Apel'sin’       | 3.6±0.59                     | 6.3±0.58                            | 23±4.2                                      | 78±12.4                              |
| 12 | ‘Brilliantovaya’ | 0                            | 0                                   | 0                                           | 0                                    |

Berries were harvested 1-2 times a week. In dry and clear weather, berries of all the varieties remained well on the canes for a week. In the rainy season, it was necessary to harvest berries more often since they became watery and began to be affected by gray rot (*Botrytis cinerea*) in ‘Apel’sin’, ‘Zolotye kupola’, 1-220-1, and ‘Rubinovoye ozherel’ye’ (figure 4).

![Figure 4](image1.png)  
(a) Fruits of ‘Zolotye kupola’: (a) and fruits of the 1-220-1; (b) primocane-fruiting raspberry damaged by gray rot, 2019.

In mid-August, berry plants slightly affected by spider mites (*Tetranychus* sp.) were noted (‘Pingvin’, ‘Gerakl’, ‘Apel’sin’, ‘Zolotye kupola’). By the end of the month, spider mites were not observed. No mite treatments were performed.

In the study period, such varieties as ‘Pingvin’ and ‘Yevraziya’ proved to be early-maturing and able to give maximum yield for the growing season. By October, the plants almost finished bearing fruits. The leaves and generative shoots dried up, the fruits were small and single, and the plants were preparing...
for dormancy. Despite the early start of fruiting, the 1-220-1 hybrid almost did not seem to have changed by October: the vegetative part remained untouched by frosts, buds and flowers however became smaller, and the berries became smaller and less fragrant. While the rest of the studied varieties had many buds, flowers, and unripe fruits by the end of the growing season. By October 7, ripe fruits were not large (less than 1 g) and less flavorful.

3. Conclusion
The conditions for growing primocane-fruiting raspberry in the region are harsh. The lack of moisture can possibly be compensated by frequent watering. In hot weather, overhead irrigation is required.

In view of the peculiarities of climatic conditions, it is important to plant early-maturing and highly productive varieties in the region in order to get the greatest harvest. Planting is desirable in the warmest and most lighted spots, excluding ones with stagnant water.

Tall shoots were observed in ‘Oranzhevoye chudo’, ‘Zhar ptitsa’, and the 32-151-1 hybrid. Short shoots were observed in ‘Yevraziya’, ‘Pingvin’, and the 1-220-1 hybrid.

‘Yevraziya’ and ‘Pingvin’ can be pointed out among the early-maturing varieties. The maximum cropping power was observed in 1-220-1 and ‘Zhar ptitsa’.

The 1-220-1 hybrid and ‘Zhar ptitsa’ showed the highest cropping power for the studied fruiting period. The 37-15-4 and 32-151-1 hybrids, as well as ‘Gerakl’, ‘Rubinovoye ozherel'ye’, and ‘Apel'si’ were large-fruiting.

Plants of ‘Pingvin’, ‘Gerakl’, ‘Apel'si’, and ‘Zolotyye kupolava’ were damage by spider mites.

Berries of ‘Apel'si’, ‘Zolotyye kupola’, ‘Rubinovoye ozherel'ye’, and the 1-220-1 form tend to be damaged by rot.

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