Prospects for obtaining new primocane-fruiting raspberry varieties in the Southern Cisbaikalia

Maxim Rachenko[1*], *Elena* Kiseleva[1], and *Anna* Rachenko[1,2]

[1]Siberian Institute of Plant Physiology and Biochemistry of the Siberian Branch of the Russian Academy of Sciences, 132, Lermontov str., Irkutsk, 664033, Russia
[2]EDP Federal State-Funded Educational Institution of Higher Education 'Irkutsk State Agrarian University named after A.A. Ezhevsky', Molodezhny, Irkutsk district, Irkutsk region, 664038, Russia

Abstract. Studies were carried out in 2019-2022. The varieties successfully adapted to the conditions of the region were selected as parental forms. Over 170 primocane-fruiting raspberry seedlings were obtained from open pollination during the years of research, 105 of which showed primocane-fruiting capacity. The selection was carried out according to the following characteristics: thorniness, early ripening, stampiness, damageability by fungal infections, the weight and size of the fruits. The overwintering of the seedlings obtained from open pollination of such varieties as Gerakl, Oranzhevoye chudo, as well as form 1-220-1 was 100%. The largest number of early ripening samples was noted among the seedlings obtained from open pollination of the Zolotyye kupola variety (26%). The largest number of stamp plants was found in hybrid progenies of the Yevraziya and Pingvin varieties (50 and 53.3%, respectively). More than 50% of the seedlings of such varieties as Gerakl, Rubinovoye ozherel'ye, Pingvin, Yevraziya, and forms 37-15-4 and 32-151-1 had hard thorns on the stems. Slightly more than 19% of the varieties had a smooth stem. As a result of the selection, early and mid-ripening genotypes of primocane-fruiting raspberry that are promising for use in breeding in the Irkutsk region were obtained.

1 Introduction

Over the past decade, human interest in food products rich in biologically active substances has especially increased. Ascorbic acid (vitamin C) and phenolic compounds (vitamin P), which have high antioxidant activity, and therefore can have a significant positive effect on the functioning of the human immune system, play a special role in human metabolism. Therefore, a significant part of the modern person's diet should consist of fresh fruits and berries [1-5].

One of the most economically profitable berry crops is raspberry. According to the FAO data for 2020, global raspberry production amounted to 895,771 tons with a cultivation area of 112,167 hectares. The world's largest raspberry producers are the Russian Federation (151,738 tons), Serbia (92,514 tons), Poland (84,674 tons), and the USA (81,865 tons) (https://www.fao.org/faostat/en/#data/QCL/visualize).

* Corresponding author: bigmks73@rambler.ru

Modern primocane-fruiting raspberry varieties are a huge success among consumers. An important factor for the expansion of primocane-fruiting raspberry to the north is the almost complete elimination of the cold factor pressure on the plant in winter since the above-ground part of the plants is cut off for winter. Primocane-fruiting raspberry is also significantly less susceptible to damage by diseases and pests. Minimizing cultivating makes this crop not only more "economically efficient" but also makes it possible to obtain an environmentally friendly harvest [6].

The main directions of primocane-fruiting raspberry breeding are high marketability of products, adaptability to local natural and climatic conditions, and resistance to diseases and pests [7]. Currently in Siberia, the main assortment of primocane-fruiting raspberry is represented by varieties of European selection. Over the years of research, we have discovered that not all the varieties of European selection have sufficient yield capacity and adaptability to the harsh conditions of Eastern Siberia [8]. When creating a new variety, "... the modifying influence of climatic growing conditions on the manifestation of trait variability is very important..." [9]. This emphasizes the importance of using those varieties in breeding which were tested in specific agrobiological conditions of the region. The modern model of the "ideal" raspberry variety combines optimal levels of more than 20 traits and properties [10, 11]. The primocane-fruiting raspberry variety "model" adapted for the regional conditions must have the following main characteristics: high winter hardiness (-15°C –for the underground part of plants, -30...35°C – for the above-ground part), yield capacity of at least 8.0...10, 0 t/ha, be large-fruited (more than 5 g), stampiness, earliness of ripening, resistance to pathogens of fungal infections and pests, and high nutritional value and commercial quality.

The main part of the primocane-fruiting raspberry varieties bred by the Federal State Budgetary Scientific Organization "Federal Horticultural Center for Breeding, Agrotechnology and Nursery" was obtained from open pollination of interspecific elite forms [12]. Kazakov I.V. et al., "considering the role of distant hybridization in the creation of source material and new primocane-fruiting raspberry varieties", noted "the importance of using one of the methods of analytical selection – open pollination of parental forms. With the advent of more advanced parental forms of interspecific origin and their mutual crossing under the conditions of open pollination, the role of this method is continuously increasing. ...Most primocane-fruiting raspberry forms have bisexual flowers. However, under natural conditions, their self-pollination occurs less frequently than cross-pollination. In this regard, seedlings of parental forms obtained from open pollination can be considered, with a small degree of error, as hybrid progeny" [6].

The research purpose was to select the most promising (meaning a complex of economic and biological characteristics) seedlings of red raspberry with a primocane type of fruiting for breeding and cultivation in the Southern Cisbaikalia.

2 Materials and methods

The following varieties were used as parent forms: Oranzhevoye chudo, Gerakl, Rubinovoye ozherel'ye, Pingvin, Zhar ptitsa, Zolotyye kupola, Yevraziya, as well as selected forms 37-15-4, 32-151-1, and 1-220-1. The research took place at the collection site of Siberian Institute of Plant Physiology and Biochemistry of the Siberian Branch of the Russian Academy of Sciences (Irkutsk). The soil type was gray forest, its granulometric texture was medium loamy. The observations were carried out from 2019 to 2022.

The study region is characterized by a sharply continental climate with significant differences in daily temperatures. Winters are cold and long. Average winter temperatures range from -13 to -15°C. January is the coldest month, with average temperatures -19.3°C (absolute minimum – -50°C). On average, the height of snow cover in Cisbaikalia is about

40 cm [13]. The minimum temperature in the winter of 2019...2020 was -34.6°C, the average winter temperature was -14.0°C. The height of the snow cover was 30 cm. In the winter of 2020...2021, the minimum temperature was -30.9°C, the average temperature was -13.0°C. The height of the snow cover was 22.6 cm. For the whole winter period of 2021...2022, the minimum temperature was -30.4°C, the average air temperature was -13°C. The abundance of precipitation was a distinctive feature of that winter. Before the snowmelt began, the height of the snow cover was 30 cm. 2020 was the most favorable year in terms of temperature and precipitation for plant development (during the growing season, the average temperature was +14°C, precipitation – 479 mm). That influenced the earlier start of plant growth. The growing season of 2021 was characterized by the lower average temperature (+12°C), but the higher precipitation amount (496.7 mm).

During the fruiting period, large, ripe and healthy berries were selected from the parent plants. Then, seeds were isolated from those berries. The dried seeds were then stored in a refrigerator at +4...+6°C. After stratification, the main part of the seeds was sown in seed boxes with soil (a 2:1 mixture of peat and sand) from January to March (in artificial climate chambers Fitotron), and some part of the seeds was sown in open ground in autumn. Firm seedlings were picked at the end of spring. At the end of summer – beginning of autumn, they were planted in a separate area to select overwintered plants. In spring, firm, overwintered plants were transferred to the experimental area for observation (planting scheme 2.0 × 0.5 m). The hybrids were grown naturally, without the use of fertilization and plant protection systems. Rejection of plants took place at all the stages of plant observation. Most of the plants were rejected in spring (primarily those that were negatively affected in winter and those with weak growth vigor), and in autumn (those that had not entered the fruiting period).

The objects of the research were 170 seedlings obtained from open pollination of 10 varieties and forms of primocane-fruiting raspberry.

The studies were carried out according to the Program and Methods for Breeding Fruit, Berry, and Nut Crops [14] and Methodological Guidelines for Studying the Resistance of Fruit, Berry, and Ornamental Crops to Diseases [15]. Statistical processing of the results was carried out according to the standard method [16] using Microsoft Office Excel.

The percentage of viable seeds was determined as a percentage of the number of sown seeds. The number of overwintered plants was determined by the number of vegetating plants at the beginning of June. Damage caused by the influence of low temperatures took the form of delayed development and suppression of plants in the first phases of the growing season. As a result, the percentage of died and damaged to varying degrees plants was identified.

In autumn, primocane-fruiting capacity was assessed by the ability to form a crop on the first year shoots. The assessment of primocane-fruiting capacity was carried out in the third year after the plants entered fruiting. The seedlings that bore fruit on the shoots of the current year were characterized as primocane-fruiting.

Over three years, primocane-fruiting samples were assessed by their ripening time. The early-ripening group included plants that entered the fruiting phase in the first half of August, and the mid-ripening – by the end of August–beginning of September. The samples with later fruit ripening were put at the late-ripening group.

At the beginning of the study, morphological indicators of plants (thorniness and stampiness) were determined according to the principles of qualitative characteristics “YES” – “NO” [17]. The stampiness of raspberry plants was determined by thickened, strong shoots and shortened internodes, which are clearly visible in autumn. The selected stamp plants were scored from 1 to 5; the Pingvin primocane-fruiting raspberry variety was taken as the standard (3 points). The samples exceeding the standard one received 4 and 5 points [14]. Thorniness or thornlessness as well as pubescence were determined visually by the nature of shoot surface (the presence or absence of thorns, their hardness, abundance and number) as a

percentage of the total number of seedlings in the family. The thorniness of raspberry plant shoots was assessed was scored from 1 to 5; the Pingvin primocane-fruiting raspberry variety was taken as the standard (3 points). The samples exceeding the standard one received 4 and 5 points [14]. According to the thorniness degree, the samples, the shoots of which were heavily studded with hard thorns, were classified as highly thorny plants. The samples that had pronounced thorniness in the lower part of shoots with the decreasing number and nature of thorns in the upper part of shoots were defined as medium-thorny plants. The samples that had an average number of thorns in the lower part of shoots and single or absent ones in the upper part were considered weakly thorny [18].

The fruit weight was determined by weighing at least 100 berries, the fruit size – by measuring at least 100 berries, the average data was obtained by the arithmetic mean.

Organoleptic assessment took place on the day of crop harvesting. The tasters were given definite stipulated conditions: to evaluate the berries of each progeny individually, and not to discuss their opinions with the other participants during the tasting. To assess the berries, a 5-point scoring system was used. The taste, aroma, colour, and appearance of the berries were assessed separately and the average score was determined.

The degree of fungal infections was carried out visually by external signs and the degree of damage to plants. Each plant was assessed separately.

3 Results and discussion

The germination capacity of seeds in the boxes was low and ranged from 10 to 44%, in open ground – up to 90%. Seeds sown at the Fitotron artificial climate station germinated unevenly from 45 to 70 days. Spring sowings were more harmonious than winter ones. In open ground, during autumn sowing, seedlings were observed at the end of May; seed germination was higher than that of the Fitotron artificial climate station and ranged from 60 to 95%. Containers with seedlings were placed under additional lighting lamps. The rate of the first overwintering of the plants obtained from open pollination of such varieties as Gerakl, Oranzhevoye chudo, as well as form 1-220-1 was 100%. Seedlings obtained from open pollination of Rubinovoye ozherel'ye, Zolotyye kupola, Yevraziya, Pingvin, and forms 32-151-1 and 37-15- 4 overwintered by 80...93%. A low percentage of surviving plants was observed in ones obtained from open pollination of the Zhar ptitsa variety (less than 17%) (Figure 1).

During the growing season, plant loss was observed for various reasons (stunting, drying out, etc.). The loss varied from 6.7% (among seedlings from open pollination of form 37-15-4) to 40% (among seedlings from open pollination of Oranzhevoye chudo). The overall yield of seedlings averaged 72.4%.

The enumeration of primocane-fruiting raspberry plants began in the first year after the plants were transplanted to the experimental plot (two-year-old plants were planted in spring). The primocane-fruiting capacity was evident in 61.8% of seedlings (105 plants). The largest number of primocane-fruiting raspberry seedlings (more than 70%) was obtained from the Oranzhevoye chudo and Yevraziya varieties as well as forms 32-151-1 and 1-220-1 (Figure 2).

From the second year after the transplantation, an assessment of the ripening time was made. The largest number of early ripening samples was identified among seedlings obtained from open pollination of the Zolotyye kupola variety (more than 33%). Less than 10% of early ripening samples were observed among seedlings obtained from open pollination of the Oranzhevoye chudo and Yevraziya varieties, as well as form 32-151-1.

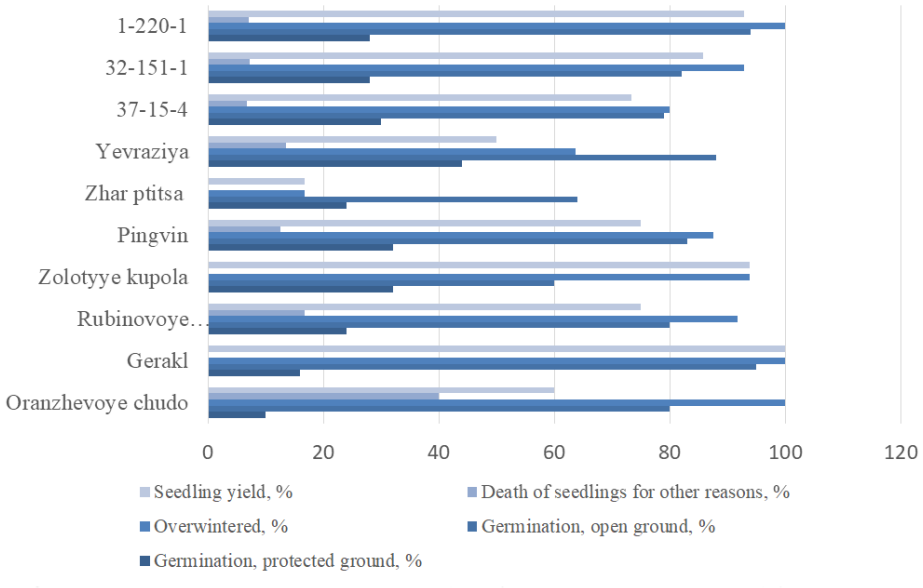

Fig. 1. Enumeration of germinated and overwintered seedlings of primocane-fruiting raspberry obtained from open pollination.

There were no early ripening samples among seedlings obtained from open pollination of the Gerakl and Rubinovoye ozherel'ye varieties, as well as form 1-220-1. The largest number of mid-ripening genotypes was observed in the family of form 37-15-4 (50%). In the other groups, mid- ripening samples ranged from 8 to 19% of the total number of plants.

The absence of thorns on shoots is important for consumers when using manual labor in plant care and harvesting. The inheritance of the raspberry shoot thorniness trait is controlled by the "S" gene and that does not depend on taste and productivity [10, 14]. Thornless and slightly thorny varieties are also the most convenient in breeding [9]. As a result of the observations, the test samples were characterized by the presence of thorns (their qualitative characteristics) on the shoots or by their absence. More than 50% of seedlings obtained from open pollination of Gerakl, Rubinovoye ozherel'ye, Pingvin, Yevraziya, and forms 37-15-4 and 32-151-1 had hard thorns on the stems. The degree of thorniness varied among plants. In seedlings obtained from the Gerakl and Pingvin varieties, thorns were more often located along the entire length of the shoot. There were seedlings in which thorns were concentrated only in the lower part of the shoots, while in the upper part, the hardness and number of thorns decreased. In some seedlings obtained from open pollination of the Oranzhevoye chudo and Rubinovoye ozherel'ye varieties, thorns were single or completely absent. More than 40% of seedlings from the Yevraziya variety family did not have hard thorns on the stem, and 19.16% of all seedlings had a thornless stem.

32.4% of all the analyzed seedlings had thin, hair-like thorns. The samples obtained from open pollination of the Zolotyye kupola, Zhar ptitsa, and Oranzhevoye chudo varieties had pubescent stems (Figure 3).

During three years, the enumeration and assessment of stamp plants were carried out in autumn. This trait was identified in 26.6% of the genotypes. The largest number of stamp plants was found in the samples obtained from open pollination of the Yevraziya and Pingvin varieties (50 and 53.3%, respectively), and the smallest number (4.76%) was found in the family of the Oranzhevoye chudo variety (Figure 3).

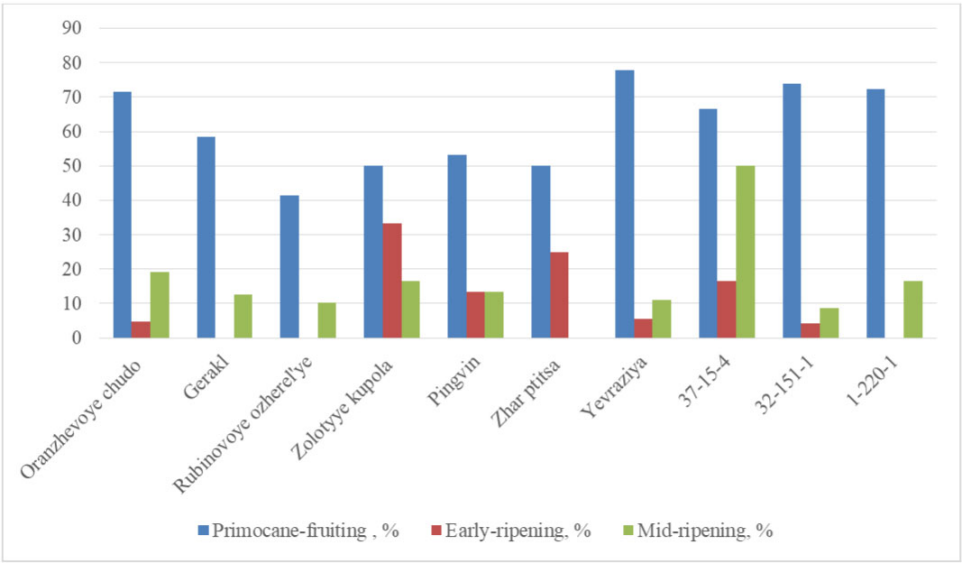

Fig. 2. Yield of raspberry seedlings by primocane-fruiting capacity and ripening time.

Since the primocane-fruiting variety Pingvin, which is successfully cultivated in the region, realizes its potential by more than 80% [8], and shows stampiness signs, was taken as the standard sample, the comparison of the selected seedlings was carried out using this variety.

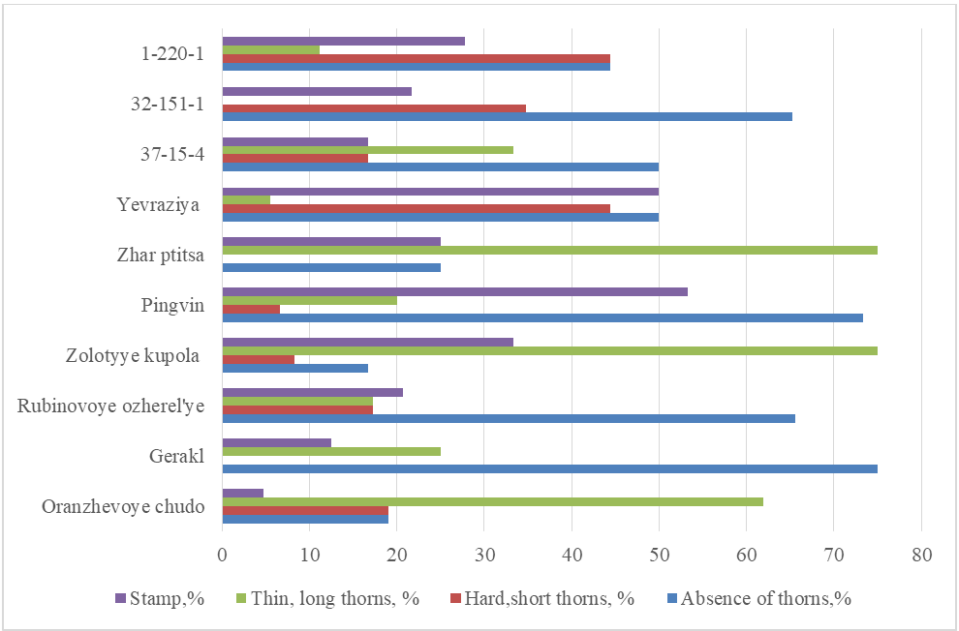

Fig. 3. Assessment of primocane-fruiting raspberry hybrid generation for primocane-fruiting capacity, early ripening, thorniness and stampiness.

Since the primocane-fruiting variety Pingvin, which is successfully cultivated in the region, realizes its potential by more than 80% [8], and shows stampiness signs, was taken as the standard sample, the comparison of the selected seedlings was carried out using this

variety. As a result, only 5 plants showed a point higher than that of the standard, and 21 seedlings from open pollination corresponded to the characteristics of stampiness. Such plants had shoots up to 120 cm, shortened internodes up to 1.0...1.5 cm, and evenly thickened stems (Table 1).

In terms of the number, nature, and location of thorns, a comparison was also made with the primocane-fruiting variety Pingvin. A total of 9 plants were rated a point higher than the standard. These were plants from open pollination of the following varieties: Rubinovoye ozherel'ye (2 pcs.), form 1-220-1 (3 pcs.), Pingvin, Yevraziya, and form 37-15-4 (1 pc. each).

During the observation period, no signs of fungal infection were detected on shoots and leaves of seedlings obtained from open pollination.

Over four years, as the selection result, seven promising genotypes were identified. They showed early ripening, stampiness, large-fruiting capacity, and medium and weak thorniness.

Table 1. Assessment of the primocane-fruiting raspberry progeny for thorniness and stampiness in comparison with the standard variety Pingvin.

Open pollinated seedlings	Number of thorny seedlings, pcs.	Of these marked out by points, pcs.					
		Stampiness			Thorniness		
		1-2	3	4-5	1-2	3	4-5
Oranzhevoye chudo	17	0	1	0	11	6	0
Gerakl	24	0	3	0	24	0	0
Rubinovoye ozherel'ye	24	6	0	0	12	10	2
Zolotyye kupola	11	0	4	0	5	6	0
Pingvin	14	0	6	2	10	3	1
Zhar ptitsa	8	1	0	0	4	4	0
Yevraziya	10	4	3	2	5	4	1
37-15-4	5	1	0	0	3	1	1
32-151-1	15	4	1	0	12	3	0
1-220-1	10	1	3	1	8	0	2
Average	13.8	1.89	2.10	0.50	9.20	3.7	0.90
Amount	138	17	21	5	94	44	7
HCP_{05}		4.38			8.14		

1-1-1 was obtained from the open pollination of the Gerakl variety. The bush is semi-spreading, up to 180 cm high, mid-ripening. The shoots are covered with hard thorns in the lower part. The fruits are elongated trapezoidal, bright red. The fruit weight is up to 10 g.

1-1-4 was obtained from open pollination of the Oranzhevoye chudo variety. The bush is low and spreading. The shoots are medium thorny. Early-ripening. Harmonious ripening of fruits. The berries are bright yellow, large, blunt-conical in shape. The maximum berry weight was 7.86 g, and the maximum size was 3.7 cm.

1-2-10 was obtained from open pollination of the selected form 32-151-1. The bush is stamp. The shoots are pubescent and medium thorny in the lower part of the shoot. The seedling is early-ripening. The berries are bright red, large, blunt-conical in shape. The maximum berry weight was 11.12 g, and the maximum size was 5.8 cm.

1-5-6 was obtained from open pollination of the Pingvin variety. The bush is stamp, branchy, up to 100 cm high, mid-ripening. The maximum berry weight was 5 g. The fruits are roundish, red, and dense.

1-5-7 was obtained from open pollination of the Pingvin variety. The bush is dwarf, up to 60 cm high, compact, abundantly fruiting, mid-ripening. The fruits are roundish, red. The maximum berry weight was up to 5 g. The fruits are dense (Figure 4).

Fig. 4. Hybrid seedling 1-5-7.

1-1-5 is obtained from open pollination of form 1-220-1. The bush is semi-spreading, up to 160 cm high, mid-ripening. The shoots are pubescent, covered with thin hair-like thorns up to ½ length. The fruits are roundish, bright yellow (Figure 5). The maximum berry weight was 6.8 g.

Fig. 5. Hybrid seedling 1-1-5.

Fig. 6. Hybrid seedling 1-5-8.

1-5-8 was obtained from open pollination of form 1-220-1. The bush is stamp. The shoots are medium thorny. The thorns are not hard; mainly located in the lower part of the shoots. The seedling is early-ripening with harmonious fruit ripening. The berries are bright yellow, large, blunt-conical in shape. The maximum berry weight was 8.10 g, and the maximum size was 3.8 cm (Figure 6).

When comparing the selected seedlings with the parental forms, the fruits of the seedlings obtained from open pollination of the following varieties had a greater average weight: Gerakl (seedling 1-1-1, the maximum fruit weight is 4.6 g more than one of the parental form), and Oranzhevoye chudo (seedling 1-1-4 – by 2.23 g) (Table 2).

Table 2. Comparative assessment of raspberry seedlings with the parental form by weight and size of fruits.

Parent	Seedling	Analyzed sample				Parental form			
		weight, g			Average fruit size, cm	weight, g			Average fruit size, cm
		max	min	med		max	min	med	
32-151-1	1-2-10	11.1	3.5	7.9± 2.75	3.6±0.24	7.1	5.3	6.3± 0.68	3.2±0.22
1-220-1	1-5-8	8.1	3.5	5.0± 1.15	2.6±0.23	5.1	2.9	3.5± 0.77	2.6±0.20
1-220-1	1-1-5	6.8	3.4	5.2± 0.95	3.0±0.20	5.1	2.9	3.5± 0.77	2.6±0.20
Oranzhevoye chudo	1-1-4	7.9	4.0	6.2± 0.21	3.0±0.22	7.4	4.1	4.9± 0.67	3.9±0.20
Pingvin	1-5-7	5.0	3.1	4.3± 0.92	3.0±0.12	6.4	3.6	4.2± 0.47	2.8±0.20
Pingvin	1-5-6	5.0	3.2	3.9± 0.22	2.9±0.22	6.4	3.6	4.2± 0.47	2.8±0.20
Gerakl	1-1-1	10.6	9.4	9.7± 0.16	3.8±0.12	6.9	4.5	5.1± 0.53	2.9±0.25

Medium-fruited samples (less than 5 g) are found among seedlings obtained from open pollination of the Pingvin and Yevraziya varieties. The difference in fruit size between the

parental forms and most samples of the hybrid generation is on average no more than 0.1 cm, which is within the error.

According to the results of the organoleptic assessment of the fruits of the selected seedlings, more than 4 points were obtained for the hybrids: 1-1-1 (obtained from free pollination of the Gerakl variety), 1-1-4 (obtained from free pollination of the Oranzhevoye chudo variety), 1-2-10 (obtained from open pollination of form 32-151-1), 1-5-6 and 1-5-7 (obtained from open pollination of the Pingvin variety), 1-5-8 (obtained from open pollination of form 1-220-1). The fruits from the other hybrid seedlings had a point below 4. The standard deviation for the assessment ranged from 0.4 to 0.8.

4 Conclusion

Based on the main biological and economic indicators, 105 raspberry seedlings with signs of primocane-fruiting capacity were identified during the study of seedlings from open pollination. 11 of those were early-ripening, and 24 – mid-ripening plants. The assessment for thorniness showed that 80.8% of the plants inherited this trait and 19.1% (36 pcs.) of the plants had thornless stems. Some of the resulting seedlings were distinguished by larger fruits compared to the parental forms (1-1-1 and 1-1-4). During the observation period, no plants with signs of infection on stems and leaves were identified.

As the result of the selection, seven promising genotypes were identified. They showed early ripening, stampiness, medium and weak thorniness, and had large fruits of good taste.

The research was carried out using the equipment of the Center for Collective Use ‘Bioanalytics’ and the collection material of the Center for Collective Use ‘Bioresource Center’ of Siberian Institute of Plant Physiology and Biochemistry of the Siberian Branch of the Russian Academy of Sciences (Irkutsk).

References

1. M.A. Makarkina, O.A. Vetrova, Bulletin of Russian Agricultural Science **4**, 40-44 (2022). https://www.doi.org/10.31857/2500-2082/2022/4/40-44
2. D. Ameni, S. Djidel, M. Djarmouni, S. Khennouf, L. Arrar, A. Baghiani, Plant cell biotechnology and molecular biology **23(29-30)**, 10-19 2022. https://www.doi.org/10.56557/pcbmb/2022/v23i29-307768
3. L. Lavefve, L.R. Howard, F. Carbonero, Food & function **11(1)**, 45-65 (2020). https://doi.org/10.1016/j.cofs.2021.06.003
4. O. Golovinskaia, C.K. Wang, Molecules **26(13)**, 3904 (2021). https://doi.org/10.3390/molecules26133904
5. F. Cosme, et al., Foods **11(5)**, 644 (2022). https://doi.org/10.3390/foods11050644
6. I.V. Kazakov, S.N. Evdokimenko, *Primocane-fruiting raspberry* (State Scientific Institution VTISP of the Russian Agricultural Academy, Moscow, Russia, 2007)
7. T.M. Foster, N.V. Bassil, M. Dossett, M.L. Worthington, J. Graham, Horticulture Research **6**, 116 (2019). https://doi.org/10.1038/s41438-019-0199-2
8. M.A. Rachenko, et al., IOP Conference Series: Earth and Environmental Science, IOP Publishing **1112(1)**, 012100 (2022)
9. V.N. Podorozhny, N.A. Piyanina, Biotechnology and plant breeding **4(1)**, 13-24 (2021). https://doi.org/10.30901/2658-6266-2021-1-o2

10. S. N. Evdokimenko, M. A. Podgaetsky, Fruit growing and berry growing in Russia **59**, 294-300 (2020). https://www.doi.org/10.31676/2073-4948-2019-59-294-300
11. E.I. Sharafutdinova, A.A. Danilova, English abstract **22(2)**, 377-380 (2009)
12. V. Pomology, *5. Strawberries. Raspberries. Nut and rare crops* (VNIISPK, Orel, Russia 2014)
13. L.L. Ubugunov, I.A. Belozertseva, V.I. Ubugunova, A.A. Sorokova, Nature of Inner Asia **2**, 40-59 (2019) https://doi.org/10.18101/2542-0623-2019-2-40-59.
14. V.V. Kichina, I.V. Kazakov, L.A. Gruner, *Breeding raspberries and blackberries*, *Program and methodology for breeding fruit, berry and nut crops,* (VNIISPK, Orel, Russia, 1995)
15. L. Treyvas, O. Kashtanova, *Diseases and pests of fruit plants* (Litres, Moscow, Russia, 2020)
16. E.E. Blinova, T.P. Ogoltsova, *Dispersion analysis*, *Program and methodology for the study of fruit, berry and nut crops*, (VNIISPK, Orel, Russia ,1999)
17. S.N. Evdokimenko, M.A. Podgaetsky, Horticulture and viticulture **2**, 5-11 (2023). https://www.doi.org/10.31676/0235-2591-2023-2-5-11
18. E.V. Pavlova, V.A. Motorina, E.V. Krasilnikova, S.V. Kokovkina, T.V. Tarabukina, News of the Komi Scientific Center of the Ural Branch of the Russian Academy of Sciences **1**, 29-36 (2021)
19. V.V. Kichina, *Principles of improving garden plants* (State Scientific Institution VTISP of the Russian Agricultural Academy, Moscow, Russia, 2011) https://doi.org/10.19110/1994-5655-2021-1-29-36