Formation when using interspecific crossings in the Ribesia subgenus

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Abstract. The aim of the research was to study the offspring from the open pollination of ES 1674-30-30 by the main economically important traits for the crop and to isolate valuable genotypes. During the record, it was revealed that some seedlings inherited from the parent form a trait of apical fruiting. Of the 79 seedlings of such atypical plants, there were 18 seedlings, which was 23.7%. In all years of the observation, the average raceme length for the group of seedlings with apical fruiting exceeded the average for typical seedlings of this family. There were no significant differences in the weight of 100 berries between the groups of seedlings. It was found that plants with apical fruiting aged faster than ordinary seedlings. As a result of the research, it was found that the family 2521 was of breeding value for the yield of long-raceme seedlings resistant to fungal diseases.

1. Introduction

The breeder, creating varieties, improves economically valuable traits by recombination of genes in the process of crossing and formation of new genotypes. Improving the efficiency of the breeding process involves the use of a whole range of methods and approaches that allow influencing recombination variability, one of them is the selection of pairs for crossing. Careful selection of parental forms makes it possible to obtain seedlings with a unique combination of genes forming a peculiar set of selected traits [1].

For further development of breeding work, it is necessary to expand the spectrum of genetic variability of the source material [2, 3]. The probability of obtaining heterotic hybrids increases with increase of the values of genetic distances between parental components [4, 5, 6]. Distant hybridization serves as an impetus that causes a formative process, because of which organisms arise with new properties absent in the parental forms.

Distant interspecific hybridization is the main method of currant breeding [7, 8, 9]. This method made it possible to obtain genetically diverse material and solve many breeding problems on its basis [10, 11].

Currant species included in the same section (Eucoreosma Jancz., Ribesia Berl.) easily interbreed with each other. In the contact zone of the habitats of different red currant species, their spontaneous hybrids are found. The literature sources provide information about the presence of 17 spontaneous interspecific red currant hybrids in nature [12, 13, 14].
The modern red currant assortment is created mainly based on four species of the subgenus *Ribesia* and hybrids between them: *Ribes vulgare* Lam. and its large-fruited variety (*R. vulgare* Lam. var. *macrocarpum* Jancz.), *R. rubrum* L., *R. petreum* Wulf., *R. multiflorum* Kit. [15, 16, 17, 18]. Single varieties are obtained on the basis of *R. palczewskii* (Jancz.) Pojark. (Skorospalaya or Rannyaya Favorskoy), *R. warscewiczii* Jancz. (Varshevicha, Viksne), *R. atropurpureum* C. A. Mey (Obskoy Zakat, Nadezhda) [19]. These varieties as a genetically new source material are used in breeding, and modern varieties have been created with their participation: Premiera [Niva×1097 (Skorospelaya × Jonkheer van Tets) [20], Dzetta, Finish (Chulkovskaya × Rannyaya Favorskoy) [21]; Serpantin (Varshevicha × Gouduin), Nadezhda (see temn-purpurnaya × Varshevicha) [22], Vishnevaya (Jonkheer van Tets × Varshevicha seedling), Ulyublena (Viksne free pollination).

In the red currant breeding program at the Russian Research Institute of Fruit Crop Breeding (VNIISPK), the Viksne variety was widely used in hybridization as a source of high content of phenolic compounds, the amount of P-active substances in it is 1026 mg/100g with an average content of 459.9±18.7 mg/100g according to the Institute's red currant gene collection [23]. In the breeding family 1674 (Niva × Viksne) seedlings were selected, combining economically valuable traits with a high content of phenolic substances from 731.9 to 1190.2 mg/100 g. ELS 1674-30-30 stands out with very long racemes with a long thick leaf stalk. The maximum raceme length on young plants was 18 cm with leaf stalk and 13 cm without leaf stalk. The berries have an attractive cherry color, the weight is average, stable over the years - 0.60-0.65 g. The taste is sweet-sour, pleasant, the acidity (according to the laboratory of biochemical evaluation of VNIISPK varieties) is 1.33-1.97%, lower than that of the parental forms. This seedling is unique in that it has an apical type of fruiting, which is unusual for red currants. The morphological feature of the red currant is that the skeletal and semi-skeletal branches have apical growth buds, which retain strong apical growth for a long period and cause slower aging of plants. In the 1674-30-30 elite seedling, a flower bud is laid on the tops of individual shoots, from which a fruit raceme develops, such a property is not inherent in the original varieties of Niva and Viksne.

The purpose of the research was to study the offspring from free pollination of ELS 1674-30-30 according to the main economically important traits for crop and the allocation of valuable genotypes.

2. Materials and Methods

Seedlings from free pollination of LS 1674-30-30 (breeding family 2521) were planted in an amount of 79 pcs. in the autumn of 2012, at the VNIISPK breeding site according to the scheme 3.5×0.8 m. The research was carried out in 2017-2020 according to the "Program and methodology of variety study of fruit, berry and nut crops" section "Currant, gooseberry and their hybrids" [24].

To estimate the length of the seedling raceme, the accepted gradation was used:
5 - very long (> 12 cm).
4 - long (10-12 cm);
3 - medium (9-10 cm);
2 - short (6-8 cm);
1 - very short (up to 5 cm);

The berry weight was determined during the ripening period by weighing 100 berries on scales:
5 - very high, >85 g.
4 - high, 66-85 g;
3 - medium, 46-65 g;
2 - low, 26-45 g;
1 – very low, < 25 g;

The condition of the plants was assessed on a five-point scale. The degree of seedling damage by powdery mildew and leaf spots was carried out on a scale where 5 points – high susceptibility, 0 points - no damage.

The growing seasons of 2017-2020 differed in the average daily monthly air temperature and the amount of precipitation for each month (Table 1).
Table 1. Weather conditions of the growing season (2017-2020) (according to the data of the VNIISPK weather station).

| Year | Indicators | Month          |
|------|------------|----------------|
|      |            | April | May | June | July | August | September |
| 2017 | t°C        | 7.1   | 12.3 | 16.0 | 18.6 | 19.2   | 13.0      |
|      | Precipitation, mm | 3.6  | 56.3 | 59.6 | 75.0 | 100.8  | 13.7      |
| 2018 | t°C        | 7.6   | 16.4 | 17.5 | 19.9 | 18.4   | 14.9      |
|      | Precipitation, mm | 20.2 | 31.4 | 18.2 | 119.8| 11.2   | 42.5      |
| 2019 | t°C        | 4.4   | 15.8 | 20.5 | 17.4 | 17.1   | 12.5      |
|      | Precipitation, mm | 27.3 | 85.0 | 20.7 | 49.8 | 54.7   | 50.2      |
| 2020 | t°C        | 5.6   | 11.3 | 19.1 | 19.6 | 18.1   | 15.2      |
|      | Precipitation, mm | 10.0 | 68.4 | 52.3 | 111.6| 26.6   | 23.5      |

The assessment of the significance of difference between the mean values was carried out by comparing aggregates with pairwise related variants [24]. The calculations were performed using the Microsoft Excel 2016 software package.

3. Results and Discussion
In 2017-2020, seedlings of the 2521 family (ELS 1674-30-30 free pollination) were evaluated according to the main selected characteristics. When taking into account the degree of fruiting in 2017 (the period of entry into full fruiting), it was revealed that part of the seedlings inherited an apical fruiting trait from the parental form (Figure 1). Of 79 seedlings of such atypical plants, there were 18 pcs. which is 23.7%. Individual seedlings had a more pronounced terminal fruiting trait compared to the source form, almost all their shoots ended with a raceme. The racemes of atypical seedlings were also slightly modified, they have a very long, thick stalk on which the leaflets could be located (Figure 2).

Figure 1. Caption 2521 family seedling with apical fruiting.
Figure. 2. Terminal raceme.

The measurements carried out showed that the average raceme length for the group of seedlings with apical fruiting in all years of observation exceeded the average for typical seedlings of this family (Table 2).

| Table 2. Seedling raceme biometric characteristics of 2521 family. |
|---------------------------------------------------------------|
| Family 2521 | Quantity, pcs. | Average length of seedlings / min-max, cm | Average, cm |
| Seedlings with apical fruiting | 18 | 11.3 | 12.0 | 13.1 | 10.4 | 11.7 |
| | | 8.0-15.5 | 7.0-15.5 | 5.0-19.0 | 8.0-15.5 |
| Typical seedlings | 61 | 10.3 | 10.3 | 11.6 | 8.4 | 10.2 |
| | | 5.0-15.0 | 6.5-15.0 | 5.5-17.0 | 5.5-11.0 |

The calculated criterion of the significance of difference between the average values of $t_f$ is greater than $t_{0.05}$, which confirms the presence of significant differences in raceme length in seedlings of these groups. The range of variability of this indicator in atypical seedlings ranged from 5.0 to 19.0 cm, in standard ones it is slightly smaller - from 5.0 to 17.0 cm. Family 2521 (ELS 1674-30-30 free pollination) is generally characterized by long-raceme, the average raceme length of seedlings in all years exceeded 10 cm (except from typical seedlings in 2020). Nevertheless, the yield of long-raceme forms in seedlings with apical fruiting was higher compared to typical ones (Table 3). The percentage of very long-raceme seedlings (raceme length more than 12 cm) was also higher in the group with apical fruiting, it varied from 22.2% (2020) to 66.7% (2019) over the years, whereas in the group of ordinary seedlings in 2020, very long-raceme forms were not noted, and in 2019 44.4% were allocated.

| Table 2. Yield of long-raceme seedlings in 2521 family (ES 1674-30-30, open pollination) |
|-----------------------------------------------|
| Family 2521 | Quantity, pcs. | Seedlings with raceme length of more than 10 cm, % |
| | | 2017 | 2018 | 2019 | 2020 |
| Seedlings with apical fruiting | 18 | 68.8 | 77.8 | 72.2 | 33.3 |
| Typical seedlings | 61 | 50.0 | 40.4 | 68.5 | 9.1 |
An assessment of the important commodity and consumer quality of products - the weight of berries showed that there are no significant differences between groups of seedlings on this basis (Figure 3). The criterion of the significance of difference between the average values of tf (1.06) is less than t 05 (3.18), which confirms the absence of significant differences in the weight of berries in typical and atypical seedlings. The range of trait variability over the years ranged from 17 (2017, 2019) to 110 g (2018), and the yield of large-fruited seedlings was minimal in 2020 – 21.9% and maximum in 2018 - 69.5%. The manifestation of quantitative traits in seedlings, the raceme length and the weight of berries strongly depends on the weather conditions of the environment.

![Figure 3. Weight of 100 berries of seedlings from open pollination of ES 1674-30-30.](image)

The offspring of ELS 1674-30-30 showed high resistance to leaf spotting, and the splitting of seedlings into groups is observed after the powdery mildew damage. Over the years of research, in 2019 the most favorable conditions for this pathogen have developed. High temperatures and a large amount of precipitation in May (see Table. 1) provoked the active development of the causative agent of powdery mildew; the first signs of damage were noted already on May 17. The conducted calculations showed that the main part of seedlings on a natural infectious background was characterized by high resistance to powdery mildew (the degree of lesion did not exceed 1.0 points), and only 4.0% of seedlings had a lesion above 3.0 points (Figure 4).

![Figure 4. Distribution of seedlings of 2521 family by resistance to powdery mildew.](image)

Observations of the offspring of ELS 1674-30-30 for four years showed that seedlings with the apical type of fruiting in 2020 had a weaker condition than typical seedlings (Table 4). If in 2017 the
average score for groups of seedlings was the same and the percentage of seedlings with good condition practically did not differ, then in 2020 the condition of plants with apical fruiting was estimated no higher than 3.0 points. In these forms, extension shoots were formed not from the apical, but from the lower buds (Figure 5), which gave a weaker increase compared to the terminal bud. This led to a deterioration of their condition.

Table 4. Condition of seedlings from the open pollination of ES 1674-30-30

| Breeding family 2521 | 2017 | 2020 |
|----------------------|------|------|
|                      | average score | % of seedlings with a condition of 4-5 p. | average score | % of seedlings with a condition of 4-5 p. |
| Seedlings with apical fruiting | 3.6 | 44.4 | 2.8 | 0 |
| Typical seedlings     | 3.6 | 47.5 | 3.0 | 24.6 |

Figure 5. Shoots of prolongation in the seedling with apical fruiting.

4. Conclusions
Cleavage in offspring from free pollination ELS 1674-30-30 (Niva × Viksne) atypical for red currant seedlings with apical fruiting confirms the genetic fixity of this trait. It is planned to conduct further studies to identify the nature of the new trait, it appeared because of recombination of genetically divergent parental forms or mutational variability.

As a result of the research, it was found that the family 2521 (ELS 1674-30-30 free pollination) is of breeding value for the yield of long-raceme seedlings resistant to fungal diseases (10 genotypes were selected, including those with apical fruiting).

The study of seedlings with apical fruiting will continue to search for ways to slow down plant aging, agrotechnical techniques will be also considered.

Acknowledgments
This research was funded by the Russian Ministry of Education and Science (Research No. FZUS-2019-0011)
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