Breeding opportunities for increasing the black currant large-fruiting

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Abstract. The results of the study of the black currant varieties collection of FSBSI FRC of Horticulture, located in the Bryansk region, by large-fruiting are presented. Genetic sources have been identified for inclusion in the breeding process to increase the average weight of berries (Lentyai, Titania, Gamayun, Dobry Gin, Podarok Veteranam, Podarok Astakhova, Kudmig, Debryansk, Bryanskiy Agat, Dar Smolyaninovoy, Kudesnik, and others). The most productive families for the output of large-fruited seedlings are given, such as Debryansk × Dar Smolyaninovoy, Orloviya × Nara, Rita × Titania, Strelets × Partizanka Bryanskaya, 10-141-2 (Strelets × Golubichka) × Partizanka Bryanskaya. The result of well-chosen combinations of crosses was the creation of new highly productive varieties of black currant Mif, Favorit, and several selected forms.

1 Introduction

In industrial and amateur gardening, special attention is paid to such a popular berry shrub as black currant (*Ribes nigrum* L.). The growing trend of consumer interest in black currant is largely due to the high content of biologically active substances, macro- and microelements, essential oils, tannins, and coloring substances, etc., potentially useful for human health. The positive effect on the human body of vitamin and mineral complexes contained in fruits, which are natural antioxidants that increase resistance to stress effects, has been confirmed [1-2]. Black currant is considered a multivitamin culture, since its berries contain two independent vitamins in optimal amounts: C (ascorbic acid) and P (P-active [phenolic] substances) [3-4]. In addition, the source of useful phenolic compounds are not only berries, but also leaves, buds, and even seeds [5-6]. Thus, fruits and related products of black currant production are successfully used in the food, pharmaceutical industry, and even in cosmetic production (production of hair dyes) [7]. The seeds contain oil rich in essential polyunsaturated fatty acids, as well as an average of 1143 mg/100 g of tocopherol oil and 6453 mg/100 g of phytosterol oil [8].

In domestic and foreign horticulture, much attention is paid to improving the technology of berry plant cultivation. It remains important that in the commercial production of currants, most issues on the mechanization of the basic elements of agrotechnical cultivation techniques have already been resolved associated with significant capital

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investments, including planting and, which is a key moment in the popularization of culture, mechanized berrying [9-10]. The use of combines of various types during harvesting is possible as early as the 3rd-4th year after the plantation is laid [11].

The yield of black currant varieties is a complex polygenic trait with a wide variability range, which indicates great opportunities for selecting valuable samples to be involved in the breeding process [12]. It is known that the limiting indicators in the commercial evaluation of the variety include yield and average fruit weight, which largely depend on the morphobiological characteristics of the variety, environmental conditions of the region, level of agricultural technology, and protective measures [13-14]. The variety yield is to a certain extent determined by the average weight of its fruits. Biometric indicators (weight and size) of the fruit are a varietal feature, at the same time a decisive and important indicator of commercial and consumer qualities and consumer requirements.

The purpose of our research was to study the initial forms of black currant and hybrid progeny to select the best combinations of crosses for the yield of large-fruited seedlings for their further inclusion in breeding work to improve the black currant assortment.

2 Material and Methods

The research was carried out in the Bryansk region at the breeding and collection sites of the Kokinsky control station of the FSBSI FRC of Horticulture in the period from 2010 to 2020. The object of research is the progeny of 11 crossing combinations in the amount of 561 seedlings. Breeding research and evaluation of the collection material were carried out in accordance with the requirements of the relevant programs [15-16]. The study of varieties was carried out in three-fold repetition, at least 5 plants of each variety in repetition. Plants in hybrid families were studied by shrub, i.e. each individually.

Cultivation of black currant in collection plantings and on a hybrid plot was carried out in accordance with the agricultural techniques generally accepted in the Non-Chernozem zone of Russia. The weather conditions of the Bryansk region are typical for the Central region of Russia, the climate is temperate continental. In the research area, climatic conditions are characterized by moderately cold winters, warm summers, and uneven distribution of precipitation (Fig. 1). As can be seen, the weather conditions during the experiment were favorable for the growth and fruiting of black currant plants, nevertheless, in some seasons, fungal diseases actively spread against this background. According to the data of the Bryansk SAU weather station located in the immediate vicinity of the breeding site (coordinates from the zero meridian of the Greenwich Observatory: 53°26'N 34°08'E), in some years there is an increase in soil air temperature to +47°C, in winter at the soil level the absolute minimum corresponds to -41°C. During the growing season, the amount of precipitation averages 270 -330 mm.

The average weight of berries was determined by weighing 100 berries taken in a row in each repetition, and dividing the resulting value by 100, while selectivity was not allowed when sampling in repetitions, samples were taken in racemes, keeping all the berries.

Based on the results obtained, a hybridological analysis was carried out. The degree of dominance in the F_1 population was judged by the inheritance index (Hp), determined by the formula:

$$Hp = \frac{F_1 - MF}{HF - MF} \quad (1)$$

where F_1 is the average value of the trait of the studied seedlings;
MF – the average value of the parental trait;
HF – the average weight of berries of the best initial form.

The segregation frequency of transgressive hybrids in families was calculated by the formula:

$$Tch=(A/B)\times 100 \quad (2)$$

where A is the number of hybrids that exceed the best parental form in average berry weight; B is the number of hybrids studied in the family.

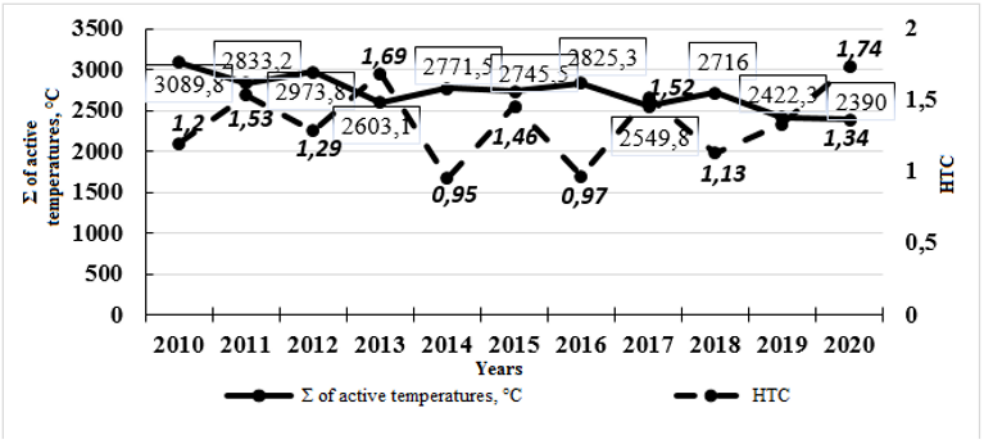

Fig. 1. The level of heat and moisture provision during the research period

The maximum degree of transgression (T_{cmax}) characterizes the hybrid population according to the genetic potential of the trait being determined and is calculated by the formula:

$$T_{CMAX} = \left(\frac{P_g \times 100}{P_r}\right) - 100, \quad (3)$$

where *Pg* – the maximum value of the trait in the best seedling in the population;
Pr – the maximum value of the attribute in the best initial form.

3 Research results

The black currant yield, harvested by mechanized means, namely, this is how fruit is mainly harvested from berry bushes in the countries of the European Union and the USA, in the future it is more often processed and comes to the consumer in the form of frozen berries, various jellies, jam, wine products, etc. [1]. With the expansion of consumer demand for fresh berries, with the increasing appearance of dessert varieties in modern horticulture, when cultivating berry crops, more attention is paid to the large-fruited cultivated assortment. The indicator "berry weight" is one of the defining commercial and consumer qualities of the black currant variety.

A long-term evaluation of the black currant collection allowed to select the best samples on the basis of large-fruiting in the conditions of the south-west of the Non-Chernozem region of Russia. 115 varieties of domestic and foreign breeding were included in the study. When selecting for large-fruiting, genotypes capable of forming berries with an average weight of up to 1.5 g or more are of interest. These are such varieties as Pigmey, Selechenskaya 2, Mif, Kudmig, Litvinovskaya, Etud, Lentyai, Titania (average weight 1.5 g), Gamayun, Dobriy Gin (Xav. = 1.6 g), Barmaley, Podarok Veteranam (Xav. = 1.7 g), Podarok Astakhova (Xav. = 1.9 g), Debryansk, Bryanskiy Agat, Dar Smolyaninovoy, Favorite, Kudesnik, Istok (Xav. = 2.0...2.5 g). In years with favorable weather conditions in

the winter-spring period and during the crop formation, according to the studied indicator, the varieties Yadrenaya, Strelets, Uslada, Kipiana, Partizanka Bryanskaya, Nara, Delicates, Tamerlan approach them. All the varieties presented have clear differences in a number of economically significant indicators and were grouped into a large-fruited group. In this regard, they were involved in breeding work as parental forms to transmit to the progeny the large-fruiting trait and other economically valuable indicators.

It is known that the phenotypic assessment of parental forms in the study of the tr4ait "fetal mass" in most cases does not guarantee the receipt of a significant proportion of large-fruited progeny [17]. As a rule, only hybridological analysis gives an idea of the value of parents as donors which are able to transmit the trait of large-fruiting to hybrid and inbred progeny. A number of researchers note the polygenic nature of large-fruiting inheritance and assume that the patterns of this trait inheritance will be similar for all berry plants [18-20]. This causes a wide range of variation in the hybrid progeny of fruit weight indicators and, as a rule, a significant yield of medium- and small-fruited progeny.

During the research period, we performed about 920 combinations of controlled crosses. Further analysis of the resulting hybrid stock showed that a significant part of the seedlings grown were medium- and small-fruited. As a rule, a high yield of large-fruited hybrids is noted in families with at least one large-fruited parent form. Similar conclusions were also made in different years by V.S. Ilyin [21], T.P. Ogoltsova, E.P. Kuminov [15], who argued that the mass of hybrid berries often does not exceed the size of the fruits of the original genotypes and is often even lower than that of the parents. At the same time, in some populations there is a small proportion of hybrids with fruits larger than those of a larger parent, i.e. positive transgression is observed.

From the abundance of controlled crosses carried out, the most successful combinations are presented here, in the progeny of which it was possible to select forms that surpass the parental genotypes in terms of the studied indicator. Thus, reciprocal crosses of large-fruited varieties Debryansk and Dar Smolyaninovoy are of particular interest in the output of large-fruited progeny. The genetic interaction of both parental genotypes determined the high yield of large-fruited progeny. When using the Debryansk variety as the maternal form, the proportion of seedlings, where the average berry weight was more than 1.5 g, reached 36.7%, in reverse crosses – 31.6% (Fig.2). The further inclusion of these varieties in hybridization, both with large-fruited genotypes and other initial forms of carriers of economically valuable traits did not lead to a similar result, which emphasizes the value of the presented reciprocal combination. Combinations of crosses 10-141-2 (Strelets × Golubichka) × Partizanka Bryanskaya, Debryansk × Litvinovskaya, Tamerlan × Kudesnik, Orloviya × Nara, Strelets × Golubichka, Rita × Titania, turned out to be effective where the proportion of large-fruited progeny (more than 1.5 g) ranged from 12.7% to 17.5%.

Nevertheless, in some families, despite the inclusion of large-fruited parents in the crosses, the yield of promising seedlings turned out to be low. For example, in the Strelets × Partizanka Bryanskaya family, the proportion of large-fruited hybrids was 9.4%. Despite this, two heterotic seedlings were selected in the presented population, the average berry weight of which was 2.4 g, which is 1.7 times higher than that of the best parent form (Strelets variety), and the total number of transgressive hybrids in the family was 29.7% (Table 1).

To determine the level of genetic interaction of both parental forms, in the populations of seedlings, the degree of dominance (inheritance coefficient) of the "average fetal weight" trait was studied. A series of crosses performed using the initial genotypes differing in large-fruiting, carried out in different years and the analysis of hybrid progeny made it possible to establish the most promising combinations.

The assessment of dominance degree in the presented families indicates the intermediate nature of inheritance by progeny of the large-fruiting trait with deviation more

often towards the worst parent and even depression. Thus, in reciprocal crosses of the varieties Debryansk and Dar Smolyaninovoy, the genetic interaction of both parental genotypes led to depression (Hp= -5.0...-7.0). Despite this, the studied progeny showed a high yield of heterotic seedlings, the average berry weight of which was 2 g or more (Tch = 23.3%...24.6%), which confirms the value of these parents as donors of large-fruiting.

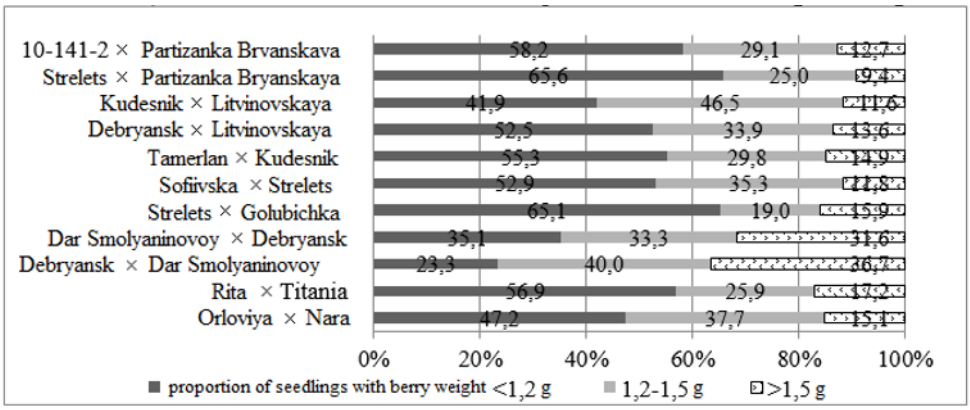

Fig. 2. Segragation of black currant progeny in combinations of crosses by the average weight of fruits.

Table 1. Assessment of black currant populations by the output of transgressive progeny (*Tch, %*) and degree of dominance (*Hp*) in hybrid combinations

Crossing combinations	Year of fruiting beginning	Hybrids studied, pcs.	Average berry weight, g			Tch, %	Ts max., %	Hp
			♀	♂	F_1			
Orloviya × Nara	2010	53	1.0	1.4	1.3	26.4	78.6	+0.5
Rita × Titania	2011	58	1.3	1.5	1.3	17.2	80.0	-1.0
Debryansk × Dar Smolyaninovoy	2014	60	1.9	1.8	1.6	23.3	42.1	-5.0
Dar Smolyaninovoy × Debryansk	2014	57	1.8	1.9	1.5	24.6	36.8	-7.0
Strelets × Golubichka	2015	63	1.5	1.2	1.3	15.9	73.3	-0.33
Sofiivska × Strelets	2016	34	1.2	1.4	1.3	20.6	64.3	0
Tamerlan × Kudesnik	2017	47	1.3	2.0	1.3	8.5	20.0	-1.0
Debryansk × Litvinovskaya	2018	59	1.5	1.4	1.3	13.6	53.3	-3.0
Kudesnik × Litvinovskaya	2019	43	1.8	1.5	1.4	9.3	38.9	-1.7
10-141-2 × Partizanka Bryanskaya	2020	55	1.2	1.3	1.2	30.9	53.8	-1.0
Strelets × Partizanka Bryanskaya	2020	32	1.4	1.3	1.3	29.7	42.9	-1.0

Depression in the inheritance of the studied trait was also noted in the families of Debryansk × Litvinovskaya (Hp= -3.0) and Kudesnik × Litvinovskaya (Hp= -1.7). Such calculations indicate that a sufficiently high level of large-fruited crop has already been achieved, as exemplified by the varieties Debryansk, Dar Smolyaninovoy, Litvinovskaya, Kudesnik, and further overcoming of this threshold is becoming increasingly difficult. With the subsequent differentiation of the seedling population by berry weight, the selection of large-fruited progeny exceeding the best initial form (heterotic seedlings) will be observed much less frequently than in the case of crosses using less large-fruited genotypes. Positive dominance, as well as heterosis, will occur much less frequently, and will manifest more often in combinations involving medium- and small-fruited parents.

In most of the families studied by us, an intermediate character of trait inheritance was noted, either a deviation towards a small-fruited parent or its complete dominance. Thus, the deviation towards the best initial form was noted only in the family of Orloviya × Nara (Hp = +0.5). The berry weight of the progeny and the initial forms of the Sofiivska × Strelets family coincided, there was no deviation towards one of the parents (Hp = 0). In the combinations Rita × Titania, Tamerlan × Kudesnik, Strelets × Partizanka Bryanskaya, and 10-141-2 (Strelets × Golubichka) × Partizanka Bryanskaya marked the complete dominance of the worst of the parents (Hp = -1.0).

Transgressive seedlings were isolated in different proportions in the progeny of all the studied families. The occurrence frequency in hybrids with a berry weight higher than that of a larger-fruited parent (Tch) varied from 8.5% in the Tamerlan × Kudesnik family up to 30.9% in the family 10-141-2 (Strelets × Golubichka) × Partizanka Bryanskaya. A high proportion of transgressive seedlings was also noted in the families Strelets × Partizanka Bryanskaya (Tch = 29.7%), Orloviya × Nara (Tch = 26.4%).

The highest level of manifestation of the maximum degree of transgression was distinguished in the progeny of the Strelets × Golubichka (T_{cmax}= 73.3%), Orloviya × Nara (T_{cmax} = 78.6%), and Rita × Titania (T_{cmax}= 80.0%) families. In the same families, hybrids were selected that combine large-fruiting with other valuable traits. Thus, in a population from complex interspecific hybridization using derivatives of currant species *R. dikuscha* Fisch. (Rita) and *R. ussuriensis* (Titania), a promising variety Mif was isolated, with an average berry weight of 2.1 g, maximum – 4.0 g. In 2016, the Mif variety was included in the State Register of Breeding Achievements.

In the family of Orloviya × Nara, a large-fruited variety Favorit was selected, in 2019 it was transferred to the State Variety Testing in the Central Region of Russia. The average berry weight is 2.0 g, the maximum is 5.8 g, the average yield is 11.7 t/ha. The tasting score of the berries is 5.0 points (on a five-point scale), the nature of the taste is dessert. The maturation period is average, self-fertility is high (>50%).

In the Strelets × Golubichka family, a promising selected form 4-63-4 has been identified, the average berry weight is 1.6 g, the maximum is 4.5 g, the average yield is 11.4 t/ha.

4 Conclusions

1. For further use in breeding work, genetic sources of large-fruited varieties have been identified, these are Pygmey, Selechenskaya 2, Mif, Kudmig, Litvinovskaya, Etud, Lentyai, Titania, Gamayun, Dobry Gin, Barmaley, Podarok Veteranam, Podarok Astakhova, Debryansk, Bryanskiy Agat, Dar Smolyaninovoy, Favorit, Kudesnik.

2. Promising combinations of crosses have been identified, in the progeny of which a significant proportion of large-fruited progeny has been noted. These are such families as Orloviya × Nara, Rita × Titania, Debryansk × Dar Smolyaninovoy, Strelets × Partizanka Bryanskaya, Dar Smolyaninovoy × Debryansk, 10-141-2 (Strelets × Golubichka) × Partizanka Bryanskaya, et al.

3. The result of well-chosen combinations of crosses was the creation of highly productive, large-fruited new varieties of black currant Mif, Favorit, and a number of selected forms.

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breeding methods for the design of new genetic modifications of fruit, berry, vegetable, and field crops that meet modern requirements of agricultural production.

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