Assessment of the resistance of raspberry varieties and hybrids to abiotic factors for use in breeding

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Abstract. The purpose of the research was to identify genetic sources of resistance to abiotic environmental factors. The assessment of the raspberry source material was carried out in 2017-2021. The study included 40 varieties and 20 hybrid forms of raspberry. It is established that under simulated conditions, the selected form 1-188-1 has high resistance to temperature -35°C in the middle of winter (II component). Sources of resistance to frost -22°C after the thaw (III component) are varieties Ulybka, Meteor and forms 1-15-1, 1-4-2. The varieties Ivan Kupala, Ulybka and selections 1-188-1, 1-4-2, 6-125-4, 8-10x-1 with freezing up to 1.6-2.1 points were distinguished by the greatest resistance of the buds for the IV component of winter hardiness. The Penguin, Yubileynaya Kulikova varieties and selections 8-189-1, 3-40-14, 44-154-2, 1-180-2 with full ripening of the crop and a relatively short fruiting period (48-55 days) are of interest for further breeding for early ripening of the primocane raspberry. In breeding for high drought and heat resistance, the varieties Gusar, Ulybka, Poklon Kazakovu, Medvezhonok, Gerakl and selected forms 37-143-3, 11-107-1 are promising, combining several indicators of the water regime at the optimal level.

1 Introduction

Thanks to successful breeding work and the development of new cultivation technologies, the area of raspberry cultivation has become much wider than the natural expansion of the species *Rubus idaeus* L. Raspberry is grown not only in temperate latitudes, but also in the regions of the Far North, subtropics, and tropics [1-4]. At the same time, the modern assortment is far from being perfect. The degree of its biological potential realization significantly depends on the resistance to abiotic environmental factors. Depending on the vegetation zone, the limiting factors of effective raspberry cultivation may be low-temperature stress of the winter period, high temperature and low humidity of the soil and air during plant growth and development, short growing season, lack of heat, etc. [5]. In this regard, the direction of breeding for adaptation is one of the priorities for breeding programs.

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Studies of raspberry resistance to negative temperatures include the study of physiological aspects of frost resistance, the search for biochemical markers, new genetic sources, and the creation of new adapted varieties on this basis. Thus, in Finland, work is being carried out to study the possibility of raspberry stems and buds to be re-hardened and to restore winter hardiness, as well as frost resistance of raspberry roots in pot culture [6-8]. Numerous studies on the creation of highly winter-hardy raspberry varieties and the identification of new genetic sources are carried out in the Russian Federation (RF), where the most stable forms have been identified for various natural and climatic conditions [9-12]. To create adapted raspberry varieties to the harsh conditions of northeast China, local forms of the wild species *R. crataegifolius* Bge are actively used in breeding. [13]. The sources of resistance to temperature fluctuations in unstable winter conditions in Latvia have been identified – Liene and Lina varieties [14].

With the help of field and laboratory research methods, work is being carried out to find sources and donors of drought resistance in various humidification zones of the Russian Federation, in the Republic of Belarus, Moldova [15-19]. In Poland and Chile, the physiological response of various raspberry genotypes to stress from moisture deficiency was studied [20, 21]. Research on the creation of highly adapted raspberry varieties has not lost its relevance and continues to develop.

2 Material and Methods

Raspberry samples were assessed in 2017-2021 at the collection site of the FSC of Horticulture in the Bryansk region (Kokino village, 53°15` north latitude, 34°12` east longitude). The study included 40 varieties and 20 hybrid forms of raspberry, both with the traditional type of fruiting (on two-year-old stems) and primocane (fruiting on annual shoots).

Winter hardiness in the field was determined in accordance with the methodology of variety study [22], under controlled conditions – according to the methodology of the FSC of Horticulture [23]. The maximum frost resistance (component II) was studied in mid-January, freezing the stems at -35°C, which had undergone preliminary hardening (at -5 and -10°C for 3 days); to assess the component III of winter hardiness in the first decade of February, the stems were kept for a week at a temperature of 4°C, and then frozen at a temperature of -22°C; the component IV was modeled in the third decade of February, creating thaw conditions (4°C) for 7 days, then hardening was carried out at -5 and -10°C (for 3 days) and freezing at -30°C. The freezing in all variants lasted for 18 hours. Modeling of winter damaging conditions was carried out in the climatic chamber TH-6 JEIO TECH at the FSC of Horticulture.

The beginning of the fruiting phenophase of primocane varieties and forms of raspberry was considered the date of the appearance of the first mature fruits on annual shoots. The degree of crop ripening was considered at the time of the first frost, as the proportion of ripe berries in the structure of generative organs.

The indicators of drought and heat resistance were determined in the laboratory of plant physiology of the Bryansk State Agrarian University, in accordance with the methodological recommendations developed for fruit crops [24]. When assessing the drought resistance of the source material according to the indicators of the water regime, an evaluation scale was used, according to which highly drought- and heat-resistant varieties should have a leaf water content of more than 70.0%, a water deficit of <10%, a water loss after a temperature "shock" of +50°C <10% and the degree of water content restoration of 70.1% and higher [25].

Statistical processing of the research results was carried out by the variance analysis method. The significant difference between the varieties was calculated using a 5% significance level. The results were processed in the Microsoft Excel program.

Raspberry was grown in the open ground without shelter and bending the stems for the winter. The top of the primocane varieties was mown late in autumn to the soil level.

3 Research results

In the natural and climatic conditions of most of the Russian Federation, the yield of raspberry bearing fruit on two-year-old stems depends on the condition of the plants after overwintering [12]. It is possible to give an objective assessment of the winter hardiness of plants in the field only in abnormal winters. Over the past five years of observations, the conditions for raspberry overwintering in the winters of 2016-2017 and 2017-2018 were the most unfavorable. So in the first and third decades of January 2017, there were two waves of a sharp decrease in air temperature to -20...-22°C after thaws with a temperature of 0.9...2.5°C. The third prolonged wave of cold up to -24°C was observed in the first decade of February. Such temperatures were not critical for most of the studied varieties. The main part of the assortment (69.2%) was characterized by minor damage from 0.2 to 1.0 points (Table 1). Varieties Cleopatra and Lazarevskaya did not have winter damage at all. The group of winter-hardy (damage 2.0 points) in these conditions included varieties Pamyat Medvedevoy, Lavina, Cowichan, and selected form 18-11-2 (6-12-2 sv.op.). The Meeker and Izobilnaya varieties received the greatest damage from winter stress (2.5-3.0 points).

Table 1. The subfreezing level of raspberry samples, point.

Variety, form	2016-2017	2017-2018	Xav.
Balsam	0.2	0.0	0.1
Gusar	0.2	0.0	0.1
Phenomen	0.4	0.0	0.2
Maria	0.5	0.0	0.3
Peresvet	0.5	0.0	0.3
Skromnitsa	0.7	0.0	0.4
Ulybka	1.0	0.0	0.5
Lazarevskaya	0.0	0.3	0.2
Vanda	0.5	0.3	0.4
Beglyanka	0.5	0.5	0.5
Meteor	0.3	1.0	0.7
Sputnitsa	0.3	1.0	0.7
2-12-1	0.5	1.0	0.8
Shakhrazada	1.0	1.0	1.0
Volnitsa	0.5	1.2	0.9
6-12-2	1.0	1.5	1.3
Lavina	1.5	1.5	1.5
Cleopatra	0.0	2.0	1.0
Shosha	1.0	2.5	1.8
18-11-2	2.0	2.5	2.3
Cowichan	2.0	2.5	2.3
Izobilnaya	2.5	2.5	2.5
Newburg	0.5	3.0	1.8
Sulamif	1.0	3.0	2.0
Pamyat Medvedevoy	2.0	3.0	2.5
Meeker	3.0	3.0	3.0
LSD_{05}	0.62	0.70	-

In the winter of 2017-2018, December and the first two decades of January were characterized by relatively warm weather with minimum temperatures of -4 ...-6°C, frequent deep thaws up to 4.2 ...6.8°C. In the third decade of February, cold weather was established for two weeks, the air temperature was -23°C, and at the snow level it dropped to -32°C. The varieties Izobilnaya, Shosha, Cowichan and form 18-11-2 were sensitive to such conditions, in which 25-30% of the buds died. Varieties Pamyat Medvedevoy, Newburg, Sulamif, Meeker, which froze to 2/3 of the stem length, suffered an abnormal decrease in temperature in late winter – early spring worse than other varieties. At the same time, the varieties Balsam, Maria, Gusar, Skromnitsa, Ulyka, Phenomen, Peresvet when growing in spring had no visible frost damage. It can be assumed that these varieties have increased resistance of the component III of winter hardiness.

Modeling of cold season stressors under controlled conditions, which is successfully used on many fruit crops, allows to assess the level of genotype stability for individual components of winter hardiness [26]. The search for genetic sources of resistance to low negative temperatures for each of winter hardiness components makes it possible to further design varieties that can withstand the complex of unfavorable winter factors. We have previously found that raspberry buds are more sensitive to frost than bark, cambium, and wood [12]. The assessment of a number of varieties and hybrid forms of raspberry for the resistance of buds to low temperatures in the middle of winter (component II of winter hardiness) after preliminary hardening showed large varietal differences (Fig. 1).

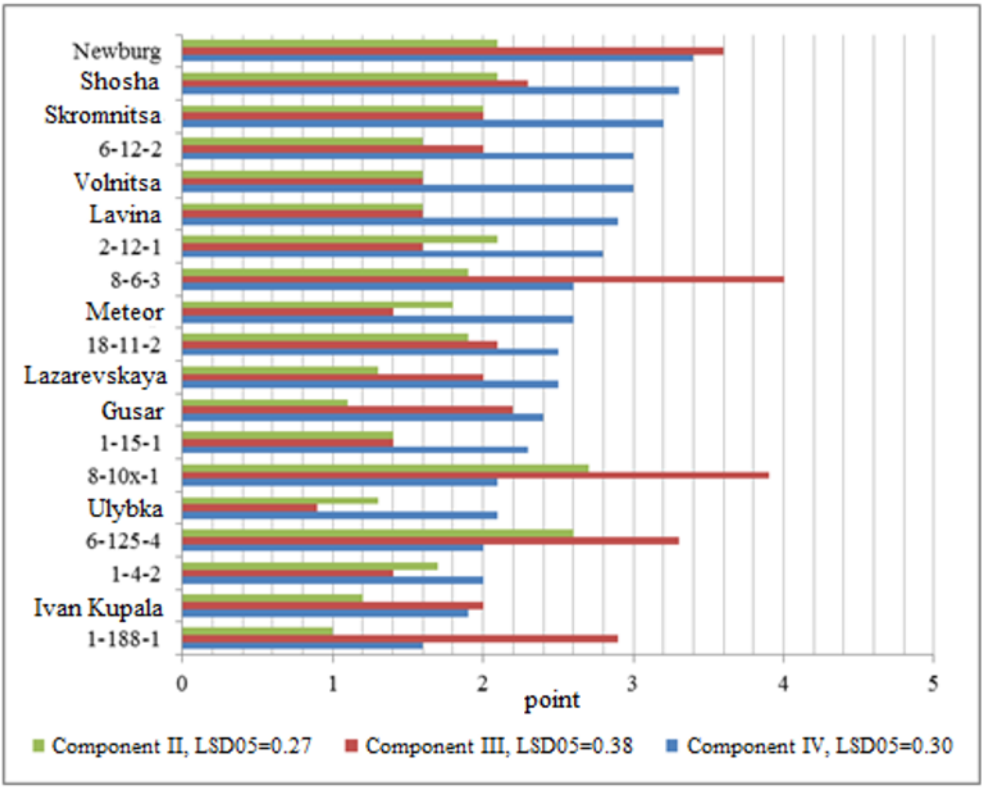

Fig. 1. The degree of damage to raspberry buds when modeling winter damaging factors, point.

Only the selected form 1-188-1 (Malakhovka×Divine) showed high frost resistance of buds at a temperature of -35°C, which freezing did not exceed 1.0 points. In half of the studied genotypes (varieties Gusar, Ivan Kupala, Lazarevskaya, Ulybka, Meteor, Lavina, Volnitsa, Skromnitsa and selected forms 1-4-2 (4-8-1xOP), 1-15-1 (4-7-1xOP), 18-11-2 frost damage was 1.1-2.0 points. The most severe reversible damages (2.6-2.7 points) were noted in selected forms 6-125-4 (Ulybka×Gusar) and 8-10x-1 (RA13049×RA14007). This level of stability allows to preserve plants but does not provide a yield.

Due to climate change, deep (up to 4...5ºC) prolonged (5-10 days) thaw in January-February have become more frequent, followed by a sharp decrease in temperature, due to which raspberry plantations are severely frozen. Modeling of such conditions has shown that the most vulnerable to frost of -22ºC after the thaw (component III) are the Newburg variety and selected forms 1-188-1, 6-125-4, 8-10x-1, 8-6-3 (TarusaxOP), in which the degree of damage was 2.9-4.0 points, and also allowed to identify sources of high winter hardiness – varieties Ulybka, Meteor and forms 1-15-1, 1-4-2.

Freezing of raspberry stems at -30ºC after the thaw and subsequent hardening showed that the studied genotypes are not able to fully restore the previous level of winter hardiness. The varieties Ivan Kupala, Ulybka and selections 1-188-1, 1-4-2, 6-125-4, 8-10x-1 with freezing up to 1.6-2.1 points had the greatest resistance of the buds for the component IV of winter hardiness. Lazarevskaya, Meteor, Lavina, selections 18-11-2, 8-6-3, 2-12-1 (Patricia×Arbat) had significant but reversible damage (2.5-2.9 points), in which generative rudiments froze, and vegetative ones were able to form leaves. Irreversible bud damage (3.0-3.4 points) was observed in varieties Volnitsa, Skromnitsa, Shosha, Newburg and forms 6-12-2 (Patricia×Arbat).

Among the studied assortment, not a single genotype was found that combines high resistance simultaneously for three components of winter hardiness. At the same time, it was found that the Ulybka variety has a high winter hardiness, combining it in components II and III with an average level in component IV. The Ivan Kupala variety has a high level of winter hardiness for component II in combination with an average level for III and IV, and the selected forms 1-4-2 and 1-15-1 have a high level for component III with an average level of II and IV.

For primocane raspberry bearing fruit on annual shoots, the winter hardiness of the aboveground part of the plants is not a limiting factor of cultivation. For this group of varieties, the most important indicator of adaptation in the middle zone of horticulture of the Russian Federation, determining the possibility of their cultivation in the open ground, is the degree of crop ripening before the onset of autumn frosts. The breeding of primocane forms with a short growing season is carried out by us by combining two traits: an early ripening period and a compressed fruiting period.

The passage of all the development phenophases is closely related to weather conditions. During the research period, the year 2021 was the most unfavorable for the growth and development of primocane raspberry plants. In this season, the dates of the beginning of ripening of the primocane raspberry were shifted 2-3 days later in early varieties and 7-12 days in late varieties. The appearance of the first ripe berries varied greatly - from July 26 to September 18, depending on the variety (Table 2). Usually, the group with an early start of fruiting (before August 5) includes varieties Salyut, Medvezhonok, Penguin, Podarok Kashinu, Eurasia, Yubileynaya Kulikova and selected forms 9-163-1 (13-118-1×1-16-11), 8-189-1 (16-88-1× Medvezhonok), 44-154-2 (Penguin×Bryanskoye Divo), 1-180-2 (9-113-1×Podarok Kashinu), 1-16-11 (1-182-10×Eurasia), 3-40-14 (3-20-1xOP). These cultivars in average weather conditions manage to complete fruiting by the onset of frost. Nevertheless, the growing season of 2021 was characterized by a low temperature regime (the average air temperature is 12.5ºC) and heavy rains (166.3 mm) in September. Freezing up to -3ºC in the first decade of October, the varieties Eurasia, Medvezhonok, and Podarok Kashinu were not allowed to fully mature. The share of immature berries in the structure of generative organs in them was 8.0-19.8%. At the same time, their fruiting period was the longest – 70-73 days.

Table 2. Duration and degree of maturation of primocane raspberry varieties in 2021

Variety	Date of berry ripening beginning	Duration of fruiting, day	Ripe yield, %
8-189-1	July 26	48	100
Salyut	July 26	61	100
Medvezhonok	July 28	73	92.0
Penguin	July 28	50	100
3-40-14	July 28	55	100
9-163-1	July 28	63	100
Podarok Kashinu	July 31	70	80.2
Eurasia	July 31	70	87.2
Yubileynaya Kulikova	July 31	48	100
44-154-2	August 01	48	100
1-180-2	August 02	53	100
1-16-11	August 03	60	100
Oranzhevoye Chudo	August 05	65	77.8
Poklon Kazakovu	August 07	63	86.2
Atlant	August 12	58	72.2
Karamelka	August 15	55	70.5
Zhar-Ptitsa	August 19	51	67.5
Joan J	August 24	46	48.6
Babye Leto	August 26	44	40.3
Poranna Rosa	September 13	26	36.2
Carolina	September 15	24	34.2
Erika	September 18	21	22.8

Among the assortment with full ripening of the crop and a relatively short fruiting period (48-55 days), the varieties Penguin, Yubileynaya Kulikova and selections 8-189-1, 3-40-14, 44-154-2, 1-180-2 were selected, which are of interest for further breeding for early maturity.

Varieties of Zhar-Ptitsa, Oranzhevoye Chudo, Atlant, Poklon Kazakovu, Karamelka, which are widespread in the middle zone of the Russian Federation, were characterized by an average period of fruiting and by the onset of frost were able to realize their productivity potential by 67.5-86.2%. The late onset of fruiting (in late August – mid-September) and the low degree of crop ripening (22.8-48.6%) were distinguished by the Russian variety Babye Leto and foreign varieties Erika, Carolina, Poranna Rosa, Joan J, which is why their cultivation in the Central region of the Russian Federation may be risky.

Raspberry plants are sensitive to moisture deficiency, hyperthermia and, against this background, to excessive solar insolation, which is manifested in turgor loss, decrease in the weight and completeness of fruits, decrease in yield, and appearance of sunburn on berries. The creation of varieties resistant to these adverse factors will reduce crop losses in hot, dry seasons, reduce the cost of additional agrotechnical techniques, and promote raspberry culture in more southern regions.

The study of raspberry varieties and hybrid forms did not reveal highly drought- and heat-resistant genotypes. Only Gusar, Ulybka varieties and selected forms 4-122-2 (4-8-1×Brigantina), 19-15-6 (4-7-1xOP), bearing fruit on two-year-old stems, as well as repair genotypes - Poklon Kazakovu, Medvezhonok, Gerakl, 37-143-3 (Zhar-Ptitsa×Bryanskoye Divo), 11-107-1 (Penguin×1-16-11) approached the optimal level in terms of heat and drought resistance (Fig. 2, 3).

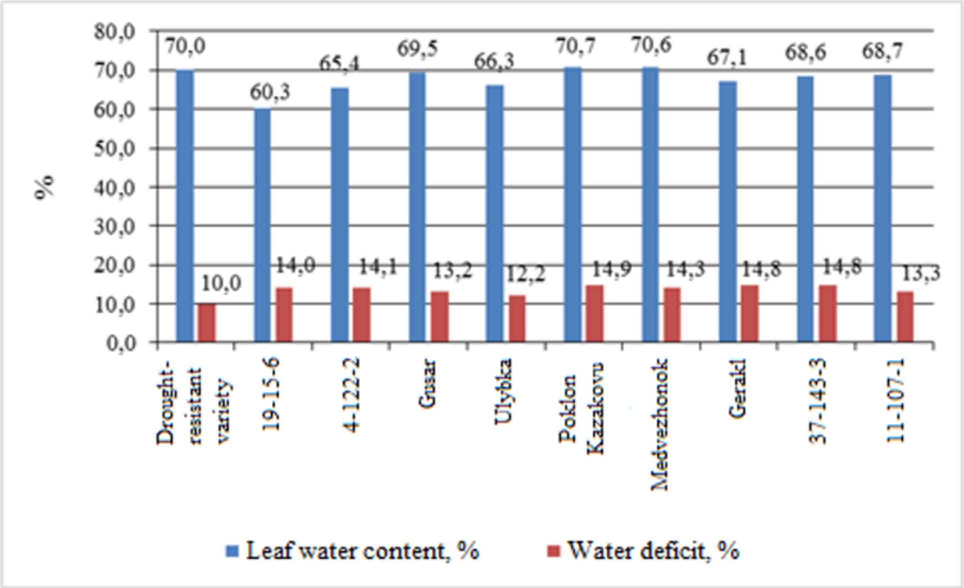

Fig. 2. Drought resistance indicators of the best raspberry genotypes (2018-2020).

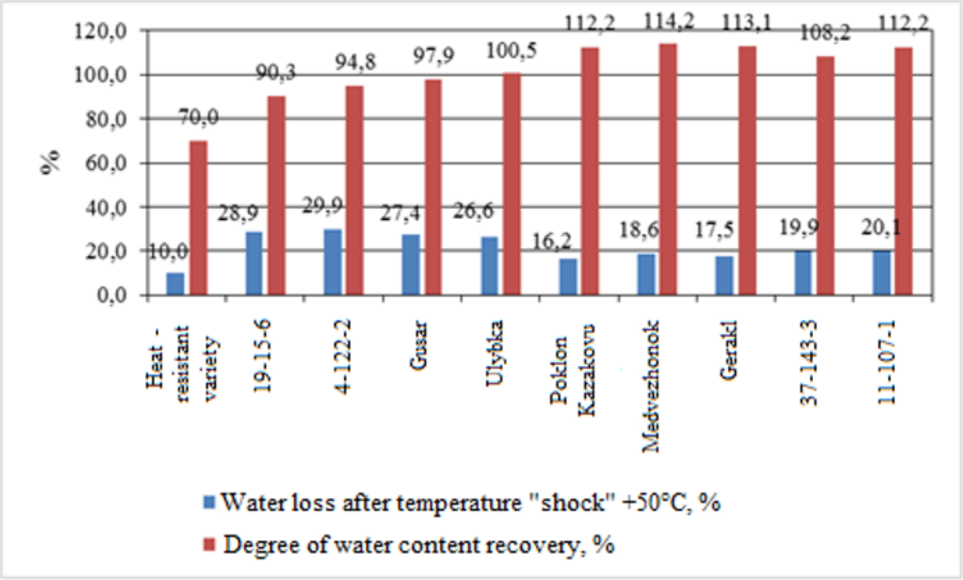

Fig. 3. Heat resistance indicators of the best raspberry genotypes (2018-2020).

Previously, we found that leaf hydration and water deficiency depend on the phenophases of raspberry development and hydrothermal conditions of the growing season. As a rule, the water content in the leaves decreased during the fruiting phase, and the water deficit, on the contrary, increased [27]. These studies revealed that in the critical phenophases of water consumption in most of the selected cultivars, leaf hydration was close to the lower limit of this indicator of highly drought-resistant varieties, and in the varieties Medvezhonok and Poklon Kazakovu corresponded to it. The average water deficit in varieties and forms was 14%, which corresponded to the average level of drought resistance. The lowest value of this indicator was noted in the Ulybka variety (12.2%).

The assessment of the heat resistance criteria revealed their significant difference between the primocane genotypes and the traditional ones. In varieties and forms bearing fruit on two-year-old stems, water loss after a temperature "shock" of +50ºC was 26.6-29.9%, which corresponds to a low level of heat resistance. In primocane varieties, the value of this indicator was lower and ranged from 16.2 to 19.9%, therefore, they had average heat resistance. The exception was the selection 11-107-1, which has a low level of heat resistance. At the same time, the degree of hydration restoration after temperature shock in all isolated forms was very high – 90.3-114.2%, which makes it possible to neutralize the hyperthermia effects.

Thus, the Gusar and Ulybka varieties, which are the best in terms of water regime, combine average levels of leaf hydration and water deficiency with a low level of water loss and a high degree of hydration recovery after overheating. The varieties Poklon Kazakovu and Medvezhonok combine high levels of water content in the leaves and hydration restoration with an average level of moisture deficiency and water loss after heat shock.

The assessment of the stability of the initial forms of raspberry to abiotic environmental factors made it possible to identify genetic sources for further breeding for winter hardiness (Ivan Kupala, Ulybka, 1-188-1, 1-4-2), early fruiting on annual shoots (Penguin, Yubileynaya Kulikova, 8-189-1, 3-40-14, 44-154-2, 1-180-2), and drought resistance (Gusar, Ulybka, Poklon Kazakovu, Medvezhonok, Gerakl, 37-143-3, 11-107-1).

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