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Features of adaptation of varieties and selected forms of different types of red currants to damaging abiotic factors

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Abstract

Panfilova, O.V., Knyazev, S. D., Golyaeva, O. D., Tsoy M.F. & Kalinina, O. V. (2021). Features of adaptation of varieties and selected forms of different types of red currants to damaging abiotic factors. *Bulg. J. Agric. Sci., 27 (1), 80–87*

The research was carried out at the Russian Research Institute of Fruit Crop Breeding (VNIISPK). Physiological methods of diagnostics of drought resistance and winter hardiness in red currant varieties and selected forms of *Ribes vulgare* Lam. (Jonkheer Van Tets, Roza, Vika), *Ribes petreum* Wulf (Hollandische Rote, Natalie, 1518-37-14) and *Ribes multiflorum* Kit. (Dana, 1426-21-80) of different genetic, ecological and geographical origin were used. Drought resistance and winter hardiness of red currants were determined in the Central region of Russia during the dormancy and vegetation periods. The prospects of using indicators of water regime in the assessment of plant state to adverse environmental factors were confirmed. The weather resistance is determined by the content of the bound water and water-retaining capacity in the plants. According to the water regime indications a high level of winter hardiness and drought resistance was revealed in the progeny of *Ribes petreum* Wulf. and *Ribes multiflorum* Kit. The representatives of *Ribes vulgare* Lam. showed weak adaptability to abiotic factors.

Keywords: subgenus *Ribesia* (Berl.) Jancz.; genotypes; drought resistance; winter hardiness; water regime

Introduction

Currently, global climate change is threatening: frequent warm winters, as well as air and soil droughts in summer in the Central region of Russia, reduce the quality and quantity of horticultural production. Weather anomalies lead to an imbalance in the protective mechanisms of fruit and berry crops and adversely affect such important indicators as winter hardiness and drought resistance (Khaustovich, 2006). That is why the attention of the scientists is paid to the search of express-methods of diagnostics of plant resistance to destructive influence of natural and climatic anomalies (Munné- Bosch & Alegre, 2004; Sękara et al., 2016). The use of physiological and biochemical methods of evaluation is becoming the most promising direction, which allows to significantly optimize the long-term breeding process, minimize crop losses and get new adapted genotypes in growing conditions (Neeru et al., 2016; Panfilova, 2017). An important element of the diagnostics to stress conditions is the feature of water regime in plants, namely, the introduction of new varieties with high water-holding capacity of leaves and annual shoots (Kashtanova, 2013; Kaustovich, 2014). It is known that the questions of berry crop adaptation to abiotic stressors are most poorly studied. Red currant is one of the valuable berry crops due to a high content of vitamins, microelements, sugars and organic acids (Määtä et al., 2001; Pantelidis et al., 2007; Skrede et al., 2011; Tokhtar, 2011). Vitamin and healing properties of berries of this culture are also preserved in the products of processing (Makarkina, 2009). On the data of FAO STAT (2016), the world production of currant berries is 706.91 t/year, and here undisputed leaders are Russia, Poland, France, Austria, Denmark, Great Britain and the Ukraine (www.faostat.fao.org). Plant introduction is an important element in the distribution and production of new red currant varieties. The successful introduction in new conditions is determined by the character of the interaction of hereditary fixed traits and biological features of the plants in specific environment conditions (Miloševi’c, 2018; Tokhtar, 2011; Mikulic-Petkovsek et al., 2013; Jurikova et al., 2014). Red currant belongs to the genus *Ribes* L., subgenus *Ribesia* (Berl.) Jancz. As a culture it was developed on the basis of four species: *Ribes vulgare* Lam., *Ribes petraeum* Wulf., *Ribes multiflorum* Kit., *Ribes rubrum* L. and their hybrids (Fedorovsky, 2001). The world assortment of the *Ribes* L. genus has over 200 varieties, however, the genetic resources of the subgenus *Ribesia* (Berti.) Jancz. are little studied since there is a number of wild species superior to existing varieties for a number of economic and biological characteristics (Golyaeva, 2007).

We used physiological express-methods in the diagnostics of red currant resistance to unfavorable factors of dormancy and vegetation periods. The aim of the work was to study the basic indications of the water regime of the varieties and selected forms of subgenus *Ribesia* (Berl.) Jancz. in conditions of the Central region of Russia and to reveal winter hardy and drought resistant genotypes for introduction into different climate zones.

Materials and Methods

The studies were carried out in 2011-2014 at the Russian Research Institute of Fruit Crop Breeding (VNIISPK, Orel region, Russia). The Orel region is situated in the central part of the Central Russian Upland. The climate is temperate continental; the average monthly temperature in January is -8.9°C while the absolute minimum is -44.0°C (in 1940). Steady frosts come at the end of November and stop in the first half of March. First and last frosts are observed in late September and early May. Summers are moderately warm, sometimes hot, lasting until mid-September; average monthly temperature in July is +18.6°C...+19.0°C, absolute maximum is +38.0°C (Kalutzkova, Goryachko et al., https://bigenc.ru/geography/text/2694070). The meteorological data for the periods of vegetation and dormancy in 2011-2014 are presented in Table 1 (according to the information of the VNIISPK meteorological station).

The weather conditions of the dormancy period not strongly varied by the years of studies. In the Central region of Russia, the average monthly temperature in January did not exceed the average yearly one, however, the third decade of December and the first and second decades of January in 2011-2014 were characterized by a small snow cover at low temperatures. In winter the absolute minimum reached 31.7 and 30.7°C (January, 2014 and 2012, respectively). Quite frequent winter thaws were the reason of the unstable snow cover and led to the unbalance of protective mechanisms in plants. In March the snow melts very quickly and sharp day and night temperature differences lead to plant damages. Sharp temperature fluctuations, drought and some other weather anomalies were observed during the vegetation period. Hot weather was noted in May and July 2013 and July 2014, while in July low air humidity (45% in 2013 and 47% in 2014) and minimal rains were noted against the background of the maximum temperature. The moderate hu-

Table 1. Weather conditions of the central region in 2010-2013 гг. (Orel region, Russia)

Year	Month	Average monthly t°	t °, мах	t°, min	Recepetation, mm
2011	December	-5.9	0.6	-23.6	44.6
2012	January	-8.2	0.5	-30.7	32.8
	March	-5.0	6.5	-29.0	4.4
	May	13.8	20.4	6.0	17.2
	June	18.4	31.5	6.9	61.7
	July	21.4	33.0	14.3	100.0
	December	-1.1	8.5	-23.0	40.8
2013	January	-6.4	6.0	-26.9	18.6
	March	-3.6	11.0	-19.6	37.4
	May	15.3	28.6	1.6	12.2
	June	16.8	29.7	2.5	44.1
	July	19.9	32.2	6.8	23.7
	December	-8.6	11.5	-27.8	44.9
2014	January	-8.9	0.8	-31.7	39.6
	March	-7.4	5.3	-22.0	68.7
	May	16.5	23.2	4.0	37.1
	June	18.5	31.2	6.2	40.0
	July	19.6	31.5	8.5	37.1

midification at elevated temperatures was observed in June for years of research, and in 2012 also in July.

Five red currant genotypes of VNIISPK breeding (Dana, Roza, Vika, 1518-37-14 and 1426-21-80) and three genotypes of foreign breeding (Natalie, Hollandische Rote and Jonkheer Van Tets) were studied. The scheme of planting was 2.8 × 0.5 m. The studied genotypes belong to different genetic and ecological and geographical species: *Ribes vulgare* Lam. (Jonkheer Van Tets, Roza, Vika), *Ribes petraeum* Wulf. (Natalie, Hollandische Rote, 1518-37-14) and *Ribes multiflorum* Kit. (Dana, 1426-21-80). Two of these species, *Ribes vulgare* Lam. and *Ribes multiflorum* Kit. are endemic for Europe; the area of distribution of *Ribes vulgare* Lam. is in the western part of Europe, while *Ribes multiflorum* Kit. is distributed in the southern and south-east parts of Europe. The natural area of distribution of *Ribes petraeum* Wulf. is in the mountainous areas of Europe from the Pyrenees to the Caucasus, Iran and North Asia (Sorokopudov et al., 2005).

The levels of drought resistance and winter hardiness were determined according to the indicators of the water regime. The determinations were carried out in dynamics: during dormancy – in December, January and March; during the vegetation period – in May and July. The water content of shoot and leaf tissues was determined by drying them to constant weight in the environmental chamber "Espec" PSL-2KPH (Japan) at temperature of +105°C during 5 hours. The water-retaining capacity was determined by the amount of the lost water after four hours of drying at a temperature of +25°C (Leonchenko et al., 2007). Different water fractions were determined in the 30% solution of sucrose by Okuntzova-Marinchik methodology with refractometer for refractive index of the prepared solution. The exposure time was 2 hours (Voskresenskaya, 2008). The methodology of soil sampling was conducted in accordance with GOST 17.43.01-83. The determination of the absolute humidity was carried out by drying the soil sample in the drying chamber at a temperature of +105°C (Mineyev, 1989).

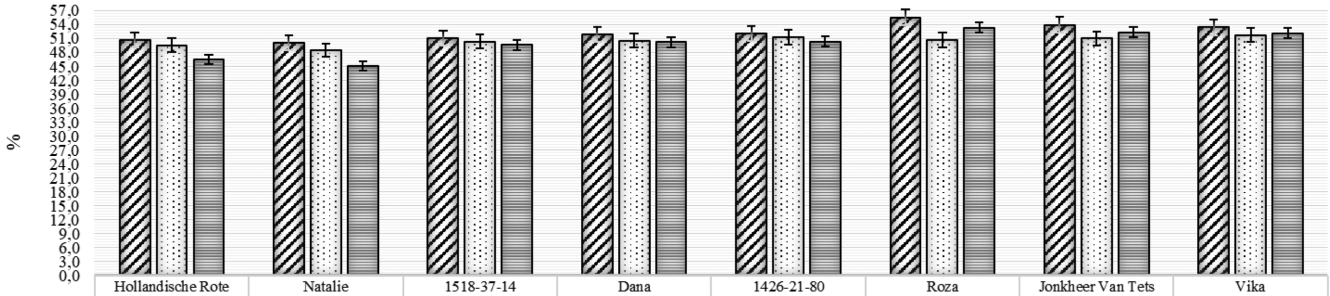
The statistical processing of the results was done by dispersion and correlation methods at 95% confidence level using the software package OriginLab (www.originlab.com) and Microsoft Excel 2010.

Results and Discussions

Red currant is quite winter-hardy culture, but despite this, some of its varieties differ in varying degrees of resistance to low temperatures due to different ecological, geographical and genetic origins (Zatzepina, 2009). The adaptation of plants in winter is determined by the length of the dormancy period and indicators of the water regime of annual shoots (hydration, the ratio of free and bound water and water-retaining capacity) (Krivoruchko, 1998; Preston et al., 2013). Our research has shown that the water content in annual shoots of different red currant species varies depending on the genotype and research period (Figure 1).

Rather sharp temperature changes on the background of a thaw were noted in the early winter, leading to increased imbalance of the power systems of the currant plants. And already at this stage, there was a different degree of preparation of the genotypes of the subgenus *Ribesia* (Berti.) Jancz. to the dormancy period.

The most part of genotypes of subgenus *R. petraeum* Wulf. and *R. multiflorum* Kit. (Natalie, Dana, Hollandische Rote, 1518-37-14) was characterized by a significant decrease in the hydration of annual shoots and an increase in the content of bound water in comparison with free water (Table. 2). A high percentage of the transition of free water into the bound water provided a decrease in metabolic active



	Hollandische Rote	Natalie	1518-37-14	Dana	1426-21-80	Roza	Jonkheer Van Tets	Vika
December	50,7	50,1	51,1	51,8	52,0	55,5	53,9	53,4
January	49,6	48,5	50,3	50,5	51,3	50,7	51,0	51,8
March	46,4	45,2	49,6	50,2	50,3	53,3	52,3	52,1

Variety

Fig. 1. Water content in red currant shoots, on average for 2012–2014

water and minimized the cell damage by low temperatures, which should be considered as a specific adaptation of red currant plants to adverse abiotic factors of the dormant period. Gradual lowering of the temperature during the winter led to a further decrease in the water content. Thus, by January, the decrease in the water content of shoots and the increase in the coefficient of bound water to free water were noted in all studied species, due to the presence of the studied genotypes in a state of deep dormancy.

Table 2. The coefficient of bound water to free water, on average for 2012–2014

Variety	December	January	March
Ribes *petraeum* Wulf.			
Natalie	0.7±0.1	1.6±0.1	1.3±0.1
Hollandische Rote	0.5±0.1	1.2±0.1	0.9±0.1
1518-37-14	0.5±0.1	1.7±0.2	1.3±0.1
Ribes *multiflorum* Kit.			
Dana	0.6±0.1	1.4±0.1	1.2±0.1
1426-21-80	0.5±0.1	1.6±0.1	1.0±0.1
Ribes *vulgare* Lam.			
Jonkheer Van Tets	0.3±0.1	0.7±0.1	0.5±0.2
Vika	0.4±0.1	0.7±0.2	0.5±0.1
Roza	0.2±0.1	1.1±0.3	0.7±0.1
$LSDp\geq_{0.05}$	0.2	0.5	0.1

The maximal decrease of the water content and increase of the coefficient of bound water to free water were noted in Hollandische Rote and Natalie (representatives of *R. petraeum* Wulf.). Studies of ecological and biological characteristics of the subgenus *Ribesia* (Berti.) Jancz. in the different ecological zones of Russia, carried out by Sabaraikina (2009) and Tokhtar (2011), and showed, that winter hardy genotypes were characterized by a low water content in shoot tissues and its sharp decrease in winter. A noticeable increase in the average daily air temperature in March contributed to the release of all studied plants from a state of deep dormancy into a state of forced dormancy, which was confirmed by a noticeable increase in the total water content in shoots against the background of a decrease in the coefficient of bound water to free water. At the same time, frequent daytime thaws in March, with fairly low night temperatures, lead to a decrease in plant resistance and, first of all, to the damage of generative buds. And such an indicator as water-holding capacity is very important here, which should be regarded as a specific sign, as defined by the protein of the protoplasm of the cells. The lower the water loss is, the greater the water-holding capacity, and thus higher the resistance of the species to the environmental factors (Klerk & Wijnhoven, 2005; Beliaeva, 2014). In our experiment, the maximum decrease in the ratio of bound water to free water (up to 0.5) and an increase in tissue hydration (up to 53.3%) against the background of high water loss (up to 16.0%) were noted in Jonkheer Van Tets, Vika and Roza due to their earlier release from a state of deep dormancy and the origin of the subgenus *R. vulgare* Lam. The obtained data are consistent with the results of other researchers, who also noted low resistance of the descendants of *R. vulgare* Lam. to negative temperatures (Sorokopudov et al., 2005; Tokhtar, 2011) (Figure 2).

The experiments showed the dependence of the water regime on the weather factors of the winter period. A positive correlation was found between the hydration of shoots and the minimum temperature of the air in the varieties of *R. petraeum* Wulf. (+0.8), *R. multiflorum* Kit. (+0.8) and *R. vulgare* Lam. (+0.7). A negative correlation was found between the average daily temperature and ratio of bound water to free water in the representatives of *R. petraeum* Wulf. (-0.8) and *R. multiflorum* Kit. (-0.8). A positive correlation was found between the maximal air temperature and ratio of bound wa-

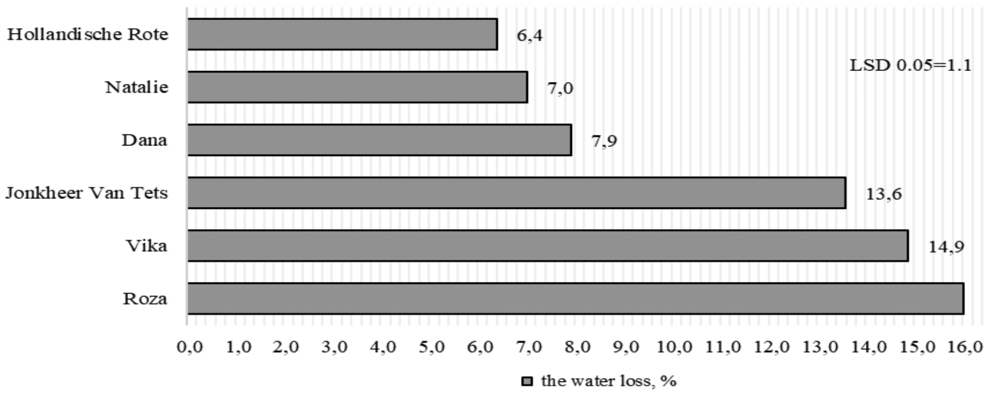


Fig.2. Water loss by annual increments, % of raw weight (March, 2012–2014)

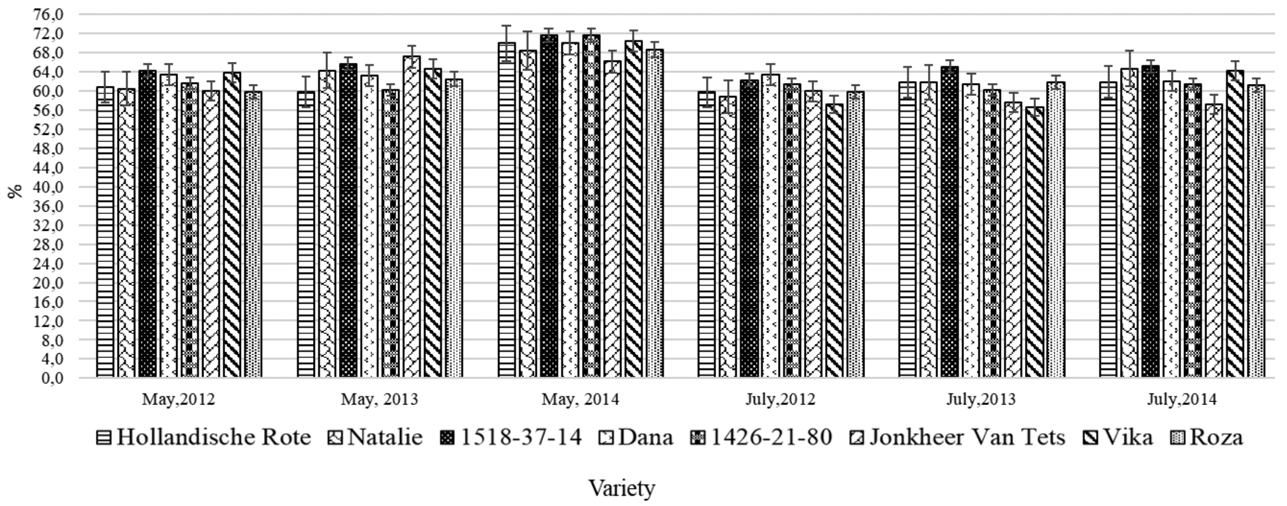


Fig. 3. Water content in leaves of red currant varieties and selected forms during vegetation

ter to free water in the genotypes of *R. vulgare* Lam. (+0.8). The degree of drought resistance in *Ribesia* (Berti.) Jancz. representatives were studied during the vegetation period by the indicators of water regime. The level of water content in leaves significantly varied by years and by periods of plant development (Figure 3).

According to the research, the optimal high water content in the leaf tissues was observed in 2012 in all studied genotypes, while a natural decrease in water content from May to July during 2012-2014 should be noted. This is due to the consumption of water for the formation of berries and the age of the leaf blade, the older the leaf, the amount of water in it is significantly reduced (Golyaeva &, Petrov, 2007). High temperature in 2013 (Table 1) and low air humidity (up to 45%), aggravated by soil drought, contributed to the weakening of the general condition of red currant plants. Field soil moisture in the soil horizon 0-20 cm was 11.4±3.4 –13.52±6.8% (May) and 14.4±2.4 – 14.6±1.3% (July). According to the reports, absolute humidity of at least 17.3% is considered to be the most optimal for currants (Goode & Hyrycz, 1970; Royeva & Motyleva, 2013). Such climatic anomalies contributed to the decrease of red currant leaf hydration, increase of water-retaining capacity and coefficient of bound water to free water (Figures 3 and 4; Table.3) in comparison with 2012, resulting in delayed functioning of a number of physiological processes (photosynthesis, respiration, metabolism).

The maximal ratio increase at minimal water loss during the active shoot growth (May) till the moment of berry for-

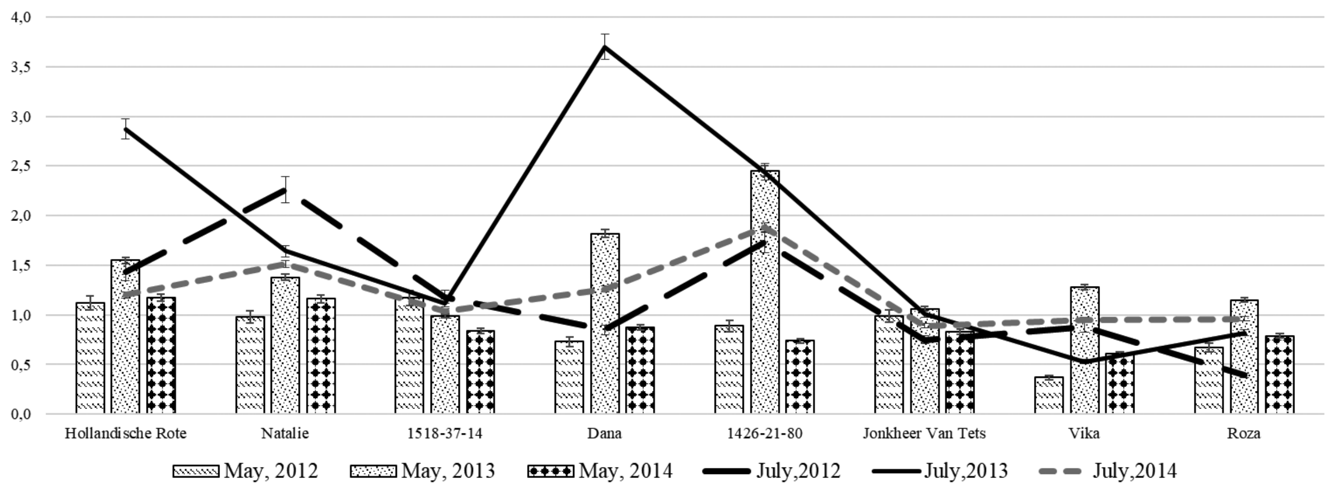


Fig. 4. Ratios of bound water to free water in *Ribesia* (Berti.) Jancz.

Table 3. The dynamics of water loss by red currant leaves, % of raw weight

Variety	2012	2013	2014
Hollandische Rote	35.8±1.8	26.1±0.6	29.2±0.8
Natalie	33.7±1.1	25.9±0.3	27.4±1.9
1518-37-14	40.9±0.4	27.0±0.7	32.7±0.7
Dana	40.9±0.5	24.1±1.8	29.5±0.4
1426-21-80	36.2±1.0	23.8±0.9	26.5±1.9
Jonkheer Van Tets	38.1±0.4	29.9±0.2	31.8±0.3
Vika	35.5±0.5	31.2±0.5	35.3±0.2
Roza	39.7±0.2	28.7±0.3	28.8±0.5

mation (July) was noted in the varieties and selected forms of two species: *R. petraeum* Wulf. (Natalie, Hollandische Rote) and *R. multiflorum* Kit. (Dana, 1426-21-80). Such changes allowed these genotypes to use water more efficiently and to acclimatize better during the period of thermal stress, which is explained by the ecological and genetic origin of these species.

It should be noted that during the studies there was a high percentage of water loss in Roza and Vika (descendants of *R. vulgare* Lam.) on the background of a low ratio of bound water to free water, and in the field it stimulated early yellowing of leaves and the appearance of necrotic spots, as

a)

b)

Fig. 5. *a*) Red currants variety 'Dana' (*R. multiflorum* Kit.) *b*) Red currants genotype '1426-21-80' (*R. multiflorum* Kit.)

a)

b)

Fig. 6. *a*) Red currants variety 'Jonkheer Van Tets' (*R. vulgare* Lam.) *b*) Shoots of the red currants variety 'Roza' (*R. vulgare* Lam.)

well as early crumbling of berries and their wrinkling. This is consistent with the reports of Munné-Bosch & Alegre (2004) and Mencuccini & Munné-Bosch (2017), who noted significant changes in the water balance of weakly resistant plants during drought, increased water yield, yellowing, leaf fall, as well as the possible death of the whole plant. In 2014, a slight weakening of drought, both air drought (up to 47%) and soil drought (field humidity in the soil horizon of 0-20 cm in May was 12.9±2.3 – 18.6±0.7%, and 13.2±1.1 – 16.7±1.1% in July) contributed to an increase in the total water content in leaves, a decrease in the coefficient of bound water to free water and water-retaining capacity of leaves in all studied genotypes. However, July 2014 was also abnormally hot and the genotypes showed their lability in extreme conditions by adjusting the water regime: increasing the coefficient of bound water to free water and reducing water loss, which allowed them to maintain the resistance to temperature stress and optimum yield under these conditions. The dependence of water content on meteorological conditions of the vegetation period was confirmed by the pair correlation coefficients between maximum air temperature and water loss in all studied species of *R. petraeum* Wulf. (-0.9), *R. multiflorum* Kit. (-0.9) and *R. vulgare* Lam. (-0.9). The obtained laboratory data were fully confirmed by the field observations on the adaptability of the varieties and selected forms of different red currant species to low temperatures during dormancy and high temperatures as well as moisture deficiency during the growing season. Hollandische Rote, Natalie, Dana and 1426-21-80 were characterized by mighty bushes, a large number of annual increments with well-developed leaf blades, and as a consequence, were productive and highly profitable in comparison with the representatives of the *R. vulgare* Lam. (Figures 5 and 6).

Conclusions

The conducted researches have confirmed the prospects of using water regime parameters as an important factor in assessing the physiological state of plants to destructive environmental factors. The resistance of red currant plants to weather conditions is determined by the content of bound water and water-retaining capacity. The representatives of the species of the subgenus *Ribesia* (Berti.) Jancz. showed different ecological plasticity to abiotic factors due to genetic and ecological-geographical origin. High degrees of winter hardiness and drought resistance in terms of water regime were revealed in the descendants of species of *R. petraeum* Wulf. (Natalie, Hollandische Rote) and *R. multiflorum* Kit. (Dana, 1426-21-80). These genotypes are able to regulate their water regime in extreme conditions due to the increase of water-retaining capacity and a coefficient of bound water to free water. These red currant genotypes are important for introduction to natural areas with insufficient water supply and low temperatures. The representatives of *R. vulgare* Lam. showed weak adaptability to negative abiotic factors of the environment.

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