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SPECIAL CHARACTERISTICS OF WATER REGIME OF HIGH-POTENTIAL DECORATIVE VARIETIES AND FORMS OF THE GENUS *Malus Mill*

A.N. Yushkov [1*], N.N. Saveleva [1], N.V. Borzykh [1], A.S. Zemisov [1], V.V. Chivilev [1], A.V. Vislobokov [1]

[1] *Genetic Selection Center of Michurin Federal Research Center, Michurinsk, RUSSIA.*

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ABSTRACT

One of the criteria determining the suitability of plants for landscaping is their ability to tolerate stress associated with insufficient moisture and high temperatures during the growing season without reducing decorative qualities. In this regard, the goal of this work was to define the influence of water regime on the functionality of apple tree genotypes from the genetic collection of Genetic Selection Center of Michurin Federal Research Center. Simulation of wilting, heat shock, and water content recovery of genotypes based on changes in leaf mass was carried out in laboratory conditions. Drought conditions were created in a Sanyo MLR-350 environmental test chamber with maintaining a constant level of illumination of about 9,000 lux. The studies were carried out in the summer period (July-August) in the conditions of prolonged (at least 2-3 weeks) lack of precipitation. Assessment of the water regime of apple tree genotypes selected by decorative qualities during laboratory simulation of drought conditions was carried out. We selected genotypes with maximum drought tolerance and with high potential for using for landscaping and selection: Uralskoye nalivnoye, 7-I-4, 7-I-13, 7-I-14, 7-I-22, 7-I-42, 7-I -43, 7-I-104, 7-I-108.

Disciplinary: Plant Sciences, Botanical Garden, Biotechnology.

1. INTRODUCTION

Trees and shrubs being the most important components of anthropogenic landscapes play a major role in creating aesthetic modern cities' appearances. High polymorphism and ecological flexibility, decorativeness, ability to neutralize atmospheric pollution and to reduce the psychophysiological load on the human body determine the usefulness of these objects for organizing a comfortable urban environment (Laere et al., 2018).

Using fruit crops in landscaping provides broad options for transforming urban space and

*Corresponding author (A.N. Yushkov) Email: cglm@rambler.ru

decorating garden plots. Currently, their amount among other ornamental plants in our country is undeservedly small; their range is poor and is often formed randomly. World experience speaks for the potential benefits of decorative fruit trees. For example, in the UK, the taxonomic diversity of this group amounts to 279 species and cultivated varieties, with more than 130 taxa of only apple trees being grown (Komar-Tyomnaya, 2015). High resistance of ornamental apple trees to abiotic stressors allows its successful cultivation not only in the European part of Russia but also in harsh conditions of Siberia and the Urals (Makarenko, 2018). Among the representatives of the genus *Malus Mill,* small-fruited apple trees are especially ornamental, i.e. *Malus baccata* and *Sorbomalus sect.* that are native species of Central and East Asia. They are highly immune to the number of fungal diseases and adverse climatic factors (Kozlovskaya, 2015). Wild representatives of this genus and their derivatives are also a valuable source of increasing genetic variation in selection, including that of ornamental apple varieties (Dan et al., 2015).

One of the defining criteria for the suitability of plants for landscaping is their ability to tolerate negative effects associated with insufficient moisture and high temperatures during the growing season without reducing their decorative qualities (Nigmatyanova et al., 2016; Kornilov and Ozherelyeva, 2017; Kornilov et al., 2019). According to climatologists, lack of precipitation, in the long run, will increase the frequency of droughts and desertification processes in southern regions. In a temperate climate, the functional state of plants depends on the amount of precipitation to a greater extent than phenology. Their reduced ecological sustainability is associated both with the negative effect of high temperatures and with increased moisture deficit (Dong, et al., 2016; Gosling and Arnell, 2016). It should be considered that plantings in the urban environment are subject to increased stress loads in comparison with garden agrocenoses: higher daytime temperature maximum, low air humidity, overheating, and soil drying.

For the first time, work on developing decorative forms of apple trees with various crown types that are highly resistant to abiotic stressors and diseases was started in Michurin All-Russian Research Institute for Fruit Crop Selection by academician Saveliev (1998). From crossing high-potential forms, hybrid offspring were obtained that combined in its genotype high decorativeness with resistance to adverse environmental factors. However, the resulting gene pool requires further study of different qualitative parameters.

In this regard, the goal of our work was to assess the water regime of genotypes of apple trees from the genetic collection and hybrid fund of the Genetic Selection Center of Michurin All-Russian Research Institute for Fruit Crop Selection during laboratory simulation of drought conditions.

2. MATERIALS AND METHODS (STUDY MODELS)

The studies were performed in the Genetic Selection Center of Michurin All-Russian Research Institute for Fruit Crop Selection in 2017-2019. Study materials included species, types, varieties and forms of the genus *Malus Mill* distinguished by their decorative features: *M. purpurea* 2392, *M. purpurea v. pendula*, *M. spectabilis* 2415, *M. spectabilis v. rubra plena*, *M. transitoria*, domestic and foreign selection varieties: Antonovka (control), Altayskoye purpurnoye, Altayskoye naryadnoye, Altayskoye bagryanoye, Alye parusa, Surpriz Altaya, Uralskoye nalivnoe, Charah, Jay Darling, columnar forms – derivatives of *M. baccata* F1 and F2: 7-I-4 (18-9 (KV 5 × Yakutskoye 1) × 5-24), 7-I-9 (18-9 (KV 5 × Yakutskoye 1) × 18-3 (KV 5 × Yakutskoye 1), 7-I-13 (18-6 (KV 5 × Yakutskoye 1) × Uspenskoye), 7-I-14 (32-26 (Yakutskoye 1 × KV 25) × 9-24), 7-I-22 (32-26 × 7-22), 7-I-27

(32-26 × 5-24), 7-I-32 (32-26 × 5 -24), 7-I-33 (18-9 × GD (small-size green)), 7-I-36 (18-9 × GD), 7-I-42 (18-9 (KV 5 × Yakutskoye 1) × GD), 7-I-43 (32-26 (KV 25 × Yakutskoye 1) × Uspenskoye), 7-I-83 (32-26 × GD), 7-I-104 (9-24 × 32-26), 7-I-108 (9-24 × 32-26 (Yakutskoye 1 × KV 25)).

Heat and drought tolerance of genotypes was defined in laboratory conditions by weight method based on the assessment of changes in leaf mass when modeling wilting, heat shock, and water content recovery (Kushnirenko et al., 1976; Leonchenko et al., 2007). Drought conditions were created in a Sanyo MLR-350 environmental test chamber while maintaining a constant level of illumination of about 9,000 lux (Budagovsky et al., 2011). Studies were carried out during the summer period (July-August) in the conditions of a prolonged (at least 2-3 weeks) lack of precipitation. The weighing was performed with the help of the A&D GH-200 analytical balance (accuracy 0.1 mg). Absolute dry weight was defined after drying in a thermostat at the temperature of +100°C to constant weight.

Test variants:

- simulation of dehydration and water content recovery – weathering (+ 25°C, 2 hours); recovery (+25°C, 30 min);
- simulation of heat shock and water content recovery – heat shock (+ 50°C, 0.5 hours); weathering (+25°C, 1.5 hours); recovery (+ 25°C, 30 min).

Results were processed and analyzed in Microsoft Office Excel 2010.

3. RESULTS AND DISCUSSION

It was found that in the process of wilting simulation for 2 hours, the loss of water by leaves of the studied varieties and forms ranged from 8.1-25.6% of water, 14.3% on average for the studied varieties. Maximal water-holding ability was registered in selected seedling 7-I-4. Leaves of *M. virginiana, M. niedzwetzkyana* 13279, of 7-I-104, 7-I-43, 7-I-42 forms, small-fruited varieties Surpriz Altaya and Uralskoye nalivnoye have lost relatively little water (8.4-10.9%) (Table 1).

Table 1: Grouping of the original forms of apple trees by the water holding capacity of leaves during dehydration simulation

Water loss in dehydration simulation, %			
8.1-11.5	11.6-14.0	14.1-16.5	Over 16.5
Syurpriz Altaya Uralskoye nalivnoye *M .virginiana* *M. niedzwetzkyana 13279* *M. orientalis 41623* 7-I-4 7-I-104 7-I-13 7-I-43 7-I-42	Altayskoye purpurnoye Altayskoye naryadnoye Charah Jay Darling *M. sargentii 2428* *M. prunifolia 2454* *M. florentina* 7-I-14 7-I-108 7-I-9	Altayskoye bagryanoye Alye parusa *M. cerasifera* *M. sachalinensis* *M. sylvestris 41639* *M. zumi* *M. baccata* 7-I-83 7-I-22 7-I-27	Antonovka (control) Krasnaya grozd *M. floribunda* *M. orientalis 29484* *M. spectabilis 2415* *M. purpurea pendula* *M. sieversii 13975* *M. caspiriensis 14943* 7-I-33 7-I-36 7-I-32 7-I-110 7-I-61 7-I-24

M. prunifolia 2454, *M. sargentii* 2428, decorative forms 7-I-14, 7-I-108, 7-I-9, varieties Charah, Jay Darling (*M. niedzwetzkyana* x *M. baccata*), Altayskoye naryadnoye were characterized with somewhat less water-holding capacity (water loss 12.0-13.3%). Leaves of hybrid seedlings 7-I-83, 7-I-22, 7-I-27; *M. cerasifera*, *M. sachalinensis* 25950, *M. sylvestris* 41639, *M. zumi*, *M. baccata*, varieties Alye parusa, Altayskoye bagryanoye lost from 14.1 to 17.4% of water.

More significant water loss (18.1-25.6%), at the level of Antonovka control cultivation variant, was registered for varieties and forms 7-I-32, 7-I-33, 7-I-36, *M. spectabilis* 2415, M. *floribunda*, *M. orientalis* 29484, *M. purpurea pendula*. After water content recovery, a significant part of the studied genotypes completely restored all water amount lost during weathering (Table 2).

Table 2: Grouping of the original forms of apple trees according to the degree of leaf water content recovery during dehydration simulation

Degree of leaf water content recovery, %			
Under 30	31-60	61-90	Over 90
M. sieversii 13975 *M. caspiriensis 14943*	Krasnaya grozd *M. floribunda* 7-I-36	Antonovka (control) Charah *M. orientalis 41623* *M. sargentii 2428* *M. cerasifera* *M. spectabilis 2415* 7-I-110	Altayskoye purpurnoye Altayskoye naryadnoye Alye parusa Altayskoye bagryanoye Jay Darling Syurpriz Altaya Uralskoye nalivnoye *M. purpurea pendula* *M virginiana* *M. niedzwetzkyana13279* *M. prunifolia 2454* *M. florentina* *M. sachalinensis 25950* *M. sylvestris 41639* *M. zumi* *M. orientalis 29484* *M. baccata* 7-I- 42 7-I--27 7-I-32 7-I-14 7-I-108 7-I-33 7-I-4 7-I-104 7-I-13 7-I-43 7-I-9 7-I-83 7-I-22 7-I-61 7-I-24

More than 90% of lost water was restored by the varieties of Ural group: Altayskoye purpurnoye, Altayskoye naryadnoye, Alye parusa, Altayskoye bagryanoye, Surpriz Altaya, Uralskoye nalivnoye, many species and varieties of wild apple trees, among them: M. *purpurea pendula, M. virginiana* and *M. niedzwetzkyana* 13279.

Charah variety, *M. purpurea pendula*, *M. spectabilis* 2415, *M. sargentii* 2428, and *M. cerasifera* were characterized by recovery ability from 61 to 90%. The lower limit of this parameter (recovery of less than 65.4% of water lost by evaporation) was registered for Antonovka variety (control), 7-I-36 form, *M. floribunda*, *M. sachalinensis* 25950. Genotypes of ornamental apple trees developed during selection that involved Yakutskaya 1, for the most part, showed a high degree of water content recovery (over 90%) what indicates their high ecological flexibility.

Simulation of heat shock led to a more significant loss (11.4-37.7%; 22.4% on average for studied varieties) of water by the leaves of the studied varieties and forms. Minimum value of this parameter (11.4%) was observed for 7-I-4 form. High water holding capacity (water loss 13.2-20.4%) was typical for Uralskoye nalivnoye, Altayskoye naryadnoye and Charah varieties, 7-I-104, 7-I-43, 7-I-42, 7-I -13, 7-I-22, 7-I-14, 7-I-108, 7-I-83, 7-I-32 and 7-I-9 selected seedlings. More water (20.8-25.7%) was lost by the leaves of Jay Darling, Alye parusa, Surpriz Altaya, Altayskoye bagryanoye varieties, *M. sargentii* 2428, *M. cerasifera*, *M. prunifolia* 2454, *M. virginiana* and *M sachalinensis* 25950 species and types, 7-I-33, 7-I-27 seedlings.

Antonovka control variety, *M. orientalis* 29484, *M. purpurea pendula*, *M. zumi*, *M. spectabilis* 2415, *M. niedzwetzkyana* 13279, *M. sylvestris* 41639, *M. floribunda*, 7-I-36 form were included in the group with lower water holding capacity and water loss of more than 26.0%.

Taking into account the ability to restore water lost after heat shock, most of the studied genotypes were included in the group with 100% recovery ability. Altayskoye bagryanoye, Jay Darling, *M. purpurea pendula*, *M. prunifolia* 2454, *M. zumi*, *M. cerasifera* forms had slightly lower value of this parameter (80.0-92.5%). Charah, Surpriz Altaya, Antonovka (control) varieties, *M. virginiana*, *M. baccata*, *M. floribunda*, *M. sylvestris* 41639, *M. niedzwetzkyana* 13279, *M. sargentii*, *M. sachalinensis* 25950 species, and selected form 7-I-36 were less able to restore leaf turgor.

Figure 1: Selected form 7-I-13.

Figure 2: Selected form 7-I-14.

The information on water regime parameters was obtained for each studied from water holding capacity of leaves during drought simulation, degree of water content recovery during drought simulation, water holding capacity of leaves during heat shock simulation, degree of water content recovery after heat shock. Differentiation of original varieties taking into account all studied parameters is difficult since the distribution according to the degree of stability was different in each variation series. According to previously obtained data, the values of these parameters correlate with the overall drought tolerance of genotypes (Yushkov, 2019). In this regard, a ranking technique was used for summarizing all parameters – serial number of the object being in each ordered series. The first rank in each variation series was assigned to an object with a preferred degree of quality, i.e. the minimal percentage of water loss, the maximal water content in tissues, and degree of water content recovery. The sum of the ranks was calculated for each object and they were finally ranked on this basis in decreasing order of drought tolerance (Table 3).

Table 3: Ranking of the original forms of apple trees by the parameters of the water regime

Variety, form	Water loss after drying, rank	Degree of leaf water content recovery after drying, rank	Water loss after heat shock, rank	Degree of leaf water content recovery after heat shock, rank	Overall drought tolerance, rank
7-13	1	1	1	1	4
7-4	1	1	1	1	4
7-104	1	1	1	1	4
7-43	1	2	1	1	5
7-14	2	1	1	1	5
7- 42	1	2	1	2	6
7-22	3	1	1	1	6
Uralskoye nalivnoye	1	2	1	2	6
7-108	2	1	2	2	7
Altayskoye naryadnoye	2	3	1	1	7
7-9	2	1	2	3	8
7-83	3	1	2	2	8
M .virginiana	1	1	3	3	8
Jay Darling	2	2	2	3	9
7-32	4	2	2	2	10
7-33	4	2	2	2	10
M. prunifolia 2454	2	2	3	3	10
Alye parusa	3	3	3	2	11
7-27	3	3	3	2	11
M. niedzwetzkyana 13279	1	2	4	4	11
Syurpriz Altaya	1	3	3	4	11
Charah	2	4	2	3	11
Altayskoye bagryanoye	3	3	3	3	12
M. cerasifera	3	4	2	3	12
M. orientalis 29484	4	3	4	1	12
M. sargentii 2428	2	4	2	4	12
M. spectabilis 2415	4	4	4	1	13
M. zumi	3	3	4	3	13
M. sachalinensis 25950	3	4	3	4	14
M. sylvestris 41639	3	3	4	4	14
Antonovka (control)	4	4	3	4	15
M. purpurea pendula	4	4	4	3	15
M. baccata	4	3	4	4	15
7- 36	4	4	4	4	16
M. floribunda Siebold.	4	4	4	4	16

For each data series, genotypes were ranked according to the degree of analyzed trait and were divided into four groups. Summarizing of ranks made it possible to arrange original forms in accordance with their assumed stability taking into account the complex of studied water regimen parameters of leaves. This method made it possible to arrange original forms in accordance with their expected drought tolerance. Minimal overall stability rank was registered for 7-13, 7-4, 7-104, 7-43, 7-14, 7-42, 7-22, and 7-108 forms and Altayskoye naryadnoye and Uralskoye nalivnoye varieties that are expected to have maximal drought tolerance among the studied genotypes.

4. CONCLUSION

Studying the influence of water regime made it possible to register a different reaction of genotypes to the conditions of drought and heat shock what is of crucial importance for selection and gives new knowledge in the field of using decorative apple trees for urban landscaping. Laboratory data are consistent with field studies. Thus, based on data obtained, Uralskoye nalivnoye variety and 7-I-13, 7-I-4, 7-I-104, 7-I-43, 7-I-14, 7-I-42, 7-I-22, and 7-I-108 selected seedlings were included in the group of the most drought-tolerant plants. Small-fruited varieties Altayskoye naryadnoye, Alye parusa, Jay Darling, *M. virginiana*, *M. sargentii* 2428 and 7-I-9, 7-I-83 seedlings had little lower sustainability.

5. AVAILABILITY OF DATA AND MATERIAL

Information about this study can be made available by contacting the corresponding author.

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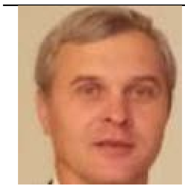
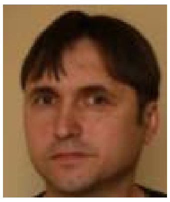
Dr.Andrey N. Yushkov is Head of Genetic Selection Center of Michurin Federal Research Center. He holds a Doctor of Agricultural Sciences. His research is in the field of Physiology and Selection of Fruit Plants.

Dr.Nataliya N. Saveleva is a Senior Research Scientist at Genetic Selection Center of Michurin Federal Research Center. She earned her doctorate in Biological Sciences. Her research interests are related to the Variety and Selection of Fruit Crops.

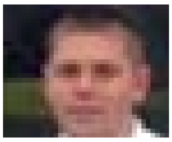
Nadezhda V. Borzykh is a Senior Research Scientist, Genetic Selection Center of Michurin Federal Research Center. She is a Candidate of Biological Sciences. Her research includes the Physiology of Fruit Plants.



Alexander S. Zemisov is Head of the Laboratory of Special Genetics and Selection, Michurin Federal Research Center. He is a Candidate of Agricultural Sciences. He is interested in the field of Selection of Fruit Crops.



Vladislav V. Chivilev is Head of the Gene Pool Laboratory of Michurin Federal Research Center. He is a Candidate of Agricultural Sciences. His research pertains to Gene Pool and Selection of Fruit Plants.



Alexander V. Vislobokov is a post-graduate student at Michurin Federal Research Center.

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