Physiological and biochemical parameters of drought tolerance of some genotypes of garden roses

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Abstract. To identify drought resistance of the studied genotypes of garden roses during the period of maximum probability of drought on the Southern Coast of the Crimea, the water regime, proline concentration, enzyme activity and chlorophyll fluorescence induction parameters under controlled dehydration were studied. Analysis of water regime parameters showed that under conditions of water stress, the best water-holding and recovery capabilities were shown by leaves of cv. 'Borisfen' and R. hugonis species. Species R. indica, R. bracteata, R. rouletti, R. foetida showed instability of water regime under conditions imitating dry weather. Studies of changes in biochemical parameters revealed that under relatively mild wilting conditions after removal of stress, metabolic processes are restored in R. hugonis, R. bracteata, R. indica and cv. 'Borisfen'. Wilting under conditions imitating dry weather does not cause irreversible metabolic disturbances in R. hugonis, R. bracteata, and cv. 'Borisfen'. Under different wilting conditions, cv. 'Borisfen'and R. foetida species had relatively stable functioning of FS II. Simulation of dry weather led to irreversible disturbances in the oxygen-releasing complex and thylakoid destruction in R. gallica during the stressor, and in R. indica and R. bracteata species - after recovery of water availability. The highest drought tolerance is in in cv. 'Borisfen'and R. hugonis sprcies.

1 Introduction

The genus rose (Rosa L.) belongs to the family Rosaceae Juss., counting in the world flora from 400 to 500 wild species [1]. Today, the garden rose is one of the most fertile crops to solve various problems in the landscape design of the Southern Coast of the Crimea (SCC) [2]. In general, the natural and climatic conditions of the SCC are suitable for the cultivation of roses, but the summer atmospheric and soil drought on the background of high air temperatures negatively affect the vital functions and decorativeness of plants [3]. In this regard, the issue of drought tolerance, in which the main role is played by water-holding power of leaf tissues and the ability to quickly restore physiological and biochemical processes after drought exposure, requires special attention. The action of stressors, in particular water deficit, causes activation of non-enzymatic oxidation processes and formation of reactive oxygen species

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(ROS) [4, 5]. To prevent oxidative damage, plants have an antioxidant system including both low molecular weight non-protein antioxidants and specific enzymes [6, 7]. The universal antioxidant in plants is proline, which acts as an osmolyte and a source of carbon, nitrogen and energy under stress [8]. The main antioxidant enzymes with diverse functions in plants are peroxidase and catalase. Peroxidase plays a key role in lignification, cell growth, cell differentiation and development, as well as in plant adaptation to abiotic and biotic stressors [9]. Catalase is an important component of photosynthesis and promotes the rapid utilization of hydrogen peroxide, participating in the protective response of plants to stress [10]. In addition to the enzymes of antioxidant system, polyphenol oxidase forms resistance to stressors in plants. Induction of polyphenol oxidase gene expression in response to stressors is associated with plant resistance [11]. It is known that the development of water-deficit stress is rather quickly reflected in the course of primary photosynthetic processes and manifests itself in changes in chlorophyll fluorescence induction parameters (CFI) [12]. Analysis of literature sources revealed that there is no information on the degree of drought tolerance of the studied genotypes of garden roses. Also, the relationship of drought tolerance of garden roses with proline content, enzyme activity and CFI parameters in leaves under drought conditions has not been studied.

In connection with the above, the aim of these studies was to identify drought-tolerant genotypes by determining changes in a number of physiological and biochemical parameters in the leaves of garden roses under controlled dehydration.

2 Materials and methods

Seven genotypes of garden roses were chosen as objects of research: species Rosa bracteata J.C.Wendl., Rosa chinensis var. minima (Sims) Voss - Rosa rouletii, R. foetida var. persiana (Lem.) Rehder, R. indica L., R. gallica L., R. hugonis Hemsl and variety Borisphen growing in collection of Nikitsky Botanical Garden.

To estimate physiological and biochemical parameters during development of hydrothermal stress in representatives of garden roses, a series of experiments on controlled leaf wilting under different combinations of temperature and air humidity were carried out: variant 1 - air temperature +25ºC, relative humidity 60%; variant 2 - simulation of conditions close to the action of dry weather (air temperature +27ºC, relative humidity 25-30%). The experiments were carried out in a climatic chamber MKFT (Binder). Physiological and biochemical parameters in leaves were determined in the state of complete watering (control), after 3-5 hours of wilting, and after recovery of leaf tissue water availability. Leaf tissue water content was determined by weight method (by drying the samples in thermostat at 105°C to constant weight); water deficit, water-holding capacity and resistance to dehydration were determined according to classical methods [13]. Changes in the chlorophyll fluorescence induction (CFI) parameters were performed using "Floratest" chronofluorimeter. The parameters analyzed were: F_0 - baseline fluorescence level, which depends on the loss of excitation energy during migration along the pigment matrix, as well as on the content of chlorophyll molecules without functional connection with reaction centers (RC), variability fluorescence $Fv = Fm-F_0$ - indicator of photochemical redox processes; (Fm-Fst)/Fm - relative photosynthetic activity; Fv/Fm - efficiency of the light phase of photosynthesis; $(Fpl-F_0)/Fv$ - amount of unreduced Q_a in reaction centers of FS II [14]. Proline content was determined according to the modified Chinard method [15]. Peroxidase activity was determined spectrophotometrically by the benzidine oxidation reaction rate, polyphenol oxidase was determined colorimetrically in the presence of pyrocatechin and *p*-phenylenediamine [16]. Determinations were performed on "Evolution 220 UV/VIS" spectrophotometer by Thermo Scientific. Catalase activity was determined by titrimetric method [17]. The experiments were repeated three times. MS Excel 2007

application was used for statistical processing of the obtained data. The tables show the mean values of the determinations and their standard errors.

3 Results and discussion

In May, water content in rose leaves did not exceed 50% of wet weight. In the process of controlled wilting, the weakest water-holding power and reparative capacity were observed in *R. gallica* leaves (after two hours, the water loss was 24%, and no more than 40% of tissues recovered). Leaves of *R. rouletti* had a comparatively lower water retention capacity. Leaves of other genotypes lost from 11 to 25% of moisture during the complete wilting time (4 hours). This amount did not exceed the level of sublethal water deficit in leaves, due to which turgescence was found high (98-100%). The exception was *R. bracteata*, where a 20% loss was critical for its leaf tissues and only 85% of the leaf surface area could be restored after saturation. The highest water-holding power of leaves along with complete tissue recovery was demonstrated by cv. 'Borisfen'.

In June, leaf water content increased to 58-65%, water deficit varied in the range of 9-18% (the lowest was observed in *R. indica*, the highest - in *R. foetida*). When leaves were completely watered (control), proline concentration ranged from 84.7 to 254.1 μg/g, peroxidase activity was 0.016-0.385 cfu/g-c, polyphenol oxidase was 0.043-0.781 cfu/g-c, and catalase was 54.1-108.9 gO_2 /g-min (Fig. 1).

Under relatively mild wilting conditions (5 h, t 25ºC and Rh 60%), the water loss was 26-30% (Table 1).

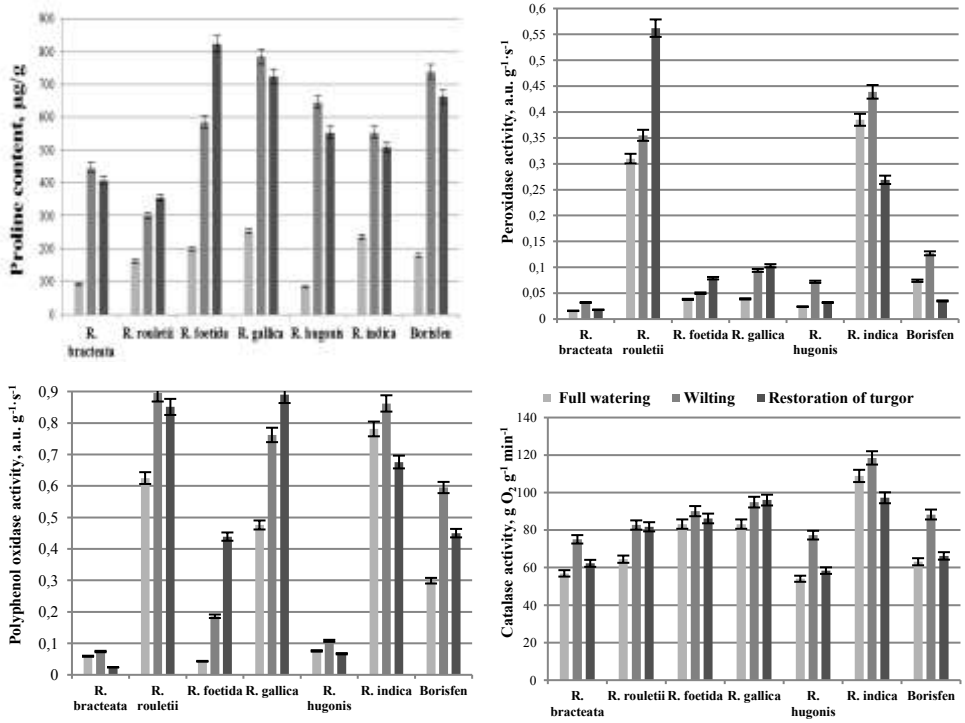

Fig. 1. Proline content and enzyme activity in leaves of garden roses under controlled wilting under the pressure of air temperature 25ºC and relative humidity 60%.

Leaves of cv. 'Borisfen' and *R. hugonis, R. bracteata, R. foetida* species retained moisture for the longest time. Proline concentration and enzyme activity in leaves increased to

different degrees: proline content increased 1.9 (*R. rouletii*) to 7.6 times (*R. hugonis*), peroxidase activity increased 1.1 (*R. indica*) to 3.0 times (*R. hugonis*), polyphenol oxidase activity increased 1.1 (*R. indica*) to 4.3 times (*R. foetida*). Catalase activity increased less intensively by 8.3 (*R. foetida*) to 43.0% (*R. hugonis*). After recovery of leaf water supply, the genotypes *R. hugonis, R. indica*, and cv. 'Borysfen' showed high recovery ability: the turgor recovery rates were 90%, 95%, and 100%, respectively. Leaves of *R. gallica* species lost the greatest amount of moisture (29%) during the first two hours, followed by tissue death. At the same time, the concentration of proline in leaves of most genotypes decreased, continuing to increase in *R. rouletii* and *R. foetida* species. Enzyme activity in leaves of most genotypes also decreased, except for peroxidase activity in *R. rouletii, R. foetida, and R. gallica* species, polyphenol oxidase activity in *R. foetida* and *R. gallica* species, and catalase activity in *R. rouletii, R. foetida*, and *R. gallica* species. The results of the experiment showed that *R. rouletii, R. foetida, and R. gallica* species exhibited severe metabolic disturbances.

Controlled water release by leaves at the beginning of summer season under relatively mild conditions (t +25°C / Rh 60%) revealed that the response to water stress by photosynthetic apparatus is species-specific. Thus, in *R. bracteata* and *R. gallica* genotypes a significant decrease in maximum and variable fluorescence was observed. However, their ratio dropped to a critically low value of 2.76 only in *R. gallica*. The change in the functioning of FS II in *R. indica* manifested itself in a decrease in the number of unrecoveryed Q_a in reaction centers (Table 2).

Table 1. Water retention and reparation capacity of leaves of garden roses (25ºC and Rh 60%, June 2022).

Genotype	Water content in leaves, % of wet weight	Water content in leaves, total watering, % on wet weight	Water deficit in leaves, %	Water loss during wilting, %			Leaves, restored turgor,%
				2 hours	4 hours	5 hours	
Borisfen	60.87	64.94	16.00	12.32	16.59	27.01	90
R. gallica	59.56	62.59	11.96	28.82	*	*	15-20
R. indica	65.82	67.86	8.77	19.81	25.41	29.70	90-95
R. hugonis	60.00	64.29	16.67	11.54	20.51	25.88	95-100
R. rouletti	62.22	65.31	12.50	19.63	29.22	*	65-70
R. bracteata	61.19	63.89	10.87	12.31	21.92	27.03	75-80
R. foetida	58.33	62.96	17.65	12.50	21.25	26.00	60-62

* - no measurements were taken

Table 2. Changes in CFI parameters in garden roses during wilting at t 25°C; Rh 60% (June 2022).

	F_0	Fm	Fv	Fm/F_0	Fv/Fm	Fv/F_0	(Fm-Fst)/Fm	$(Fpl-F_0)/Fv$
Borisfen								
control	160±8	656±19	496±17	4.1±0.15	0.76±0.04	4.10±0.15	0.71±0.03	0.19±0.01
wilting	128±4	656±22	528±21	5.8±0.13	0.80±0.02	4.12±0.13	0.80±0.03	0.18±0.02
recovery	160±7	720±25	560±23	4.5±0.13	0.78±0.03	3.50±0.13	0.76±0.04	0.09±0.01

Continuation of Table 2.

	F_0	Fm	Fv	Fm/F_0	Fv/Fm	Fv/F_0	(Fm-Fst)/Fm	$(Fpl-F_0)/Fv$
R. bracteata								
control	128±6	1152±35	1024±32	9.0±0.20	0.89±0.04	8.0±0.16	0.76±0.03	0.28±0.02
wilting	112±9	928±28	816±27	8.28±0.19	0.88±0.05	7.29±0.13	0.69±0.02	0.35±0.02
recovery	128±11	992±24	864±24	7.75±0.16	0.87±0.05	6.75±0.11	0.74±0.02	0.31±0.02
R. gallica								
control	208±19	976±24	768±28	4.69±0.16	0.79±0.04	3.69±0.12	0.78±0.03	0.27±0.03
wilting	112±12	416±27	304±22	3.71±0.11	0.73±0.04	2.71±0.11	0.73±0.03	0.22±0.02
recovery	208±18	576±23	368±18	2.76±0.11	0.64±0.02	1.77±0.09	0.64±0.02	0.28±0.03
R. indica								
control	224±21	1040±35	816±23	4.64±0.15	0.78±0.04	3.64±0.13	0.71±0.03	0.22±0.02
wilting	176±18	784±26	608±21	4.45±0.16	0.76±0.04	3.45±0.14	0.69±0.02	0.21±0.01
recovery	224±13	976±24	752±21	4.36±0.16	0.77±0.04	3.36±0.14	0.70±0.02	0.17±0.02
R. Rouletii								
control	176±12	768±21	592±19	4.36±0.16	0.77±0.03	3.36±0.15	0.75±0.03	0.11±0.02
wilting	176±11	560±33	384±15	3.18±0.12	0.69±0.02	2.18±0.12	0.63±0.03	0.29±0.02
recovery	176±11	656±28	480±21	3.72±0.13	0.73±0.03	2.73±0.12	0.69±0.02	0.18±0.02
R. foetida								
control	128±9	688±18	560±28	5.37±0.13	0.81±0.04	4.37±0.13	0.74±0.02	0.14±0.02
wilting	130±11	656±24	526±21	5.05±0.15	0.80±0.02	4.05±0.14	0.66±0.03	0.18±0.02
recovery	128±7	576±26	448±23	4.5±0.10	0.78±0.02	3.50±0.12	0.71±0.04	0.14±0.03
R. hugonis								
control	180±10	1008±38	828±23	5.60±0.15	0.82±0.03	4.60±0.12	0.75±0.03	0.15±0.01
wilting	172±10	736±25	564±29	4.28±0.13	0.77±0.03	3.28±0.13	0.69±0.03	0.15±0602
recovery	135±11	656±21	521±24	4.86±0.14	0.79±0.04	3.86±0.12	0.71±0.02	0.11±0.01

It was found that against the background of reduced water-holding forces, water stress was accompanied in *R. bracteata* by an almost 2-fold increase in the number of unreduced plastoquinones in the reaction centers, which led to destruction of FS II when water availability was restored.

In the period of maximum probability of dry winds on the SCC (July-August) we studied the effect of low air humidity on the water regime and the functional state of the photosynthetic apparatus in garden roses. In July, the range of water content and moisture deficit in leaf tissues remained at the level of the previous month. When leaves were completely watered, proline concentration in leaves ranged from 38.5 to 169.4 μg/g, peroxidase activity 0.010-0.275 conventional units/g-c, polyphenol oxidase activity 0.031-0.229 conventional units/g-c, catalase activity 67.4-114.8 gO_2 /g-min (Fig. 2). Under conditions close to the action of dry weather (t +27ºC and Rh 30%), the process of moisture return was accelerated. Resistant genotypes lost from 20% to 24% of water in 4 hours, unstable genotypes lost the same amount in 3 hours (Table 3). Proline concentration in leaves during wilting increased significantly, 2.2-18.7-fold, maximum in cv. 'Borisfen' and *R. hugonis, R. bracteata* species. Peroxidase activity in leaves changed multidirectionally: it increased 1.2-8.3-fold (*R. foetida*) in most genotypes and decreased in *R. rouletii* and *R. indica* species. Polyphenol oxidase activity in leaves of *R. rouletii, R. foetida, and R. gallica* decreased and increased in other genotypes by 8.5-167.2 %. The catalase activity in the leaves of the studied genotypes increased by 7.5-31.1%, except for *R. rouletii.*

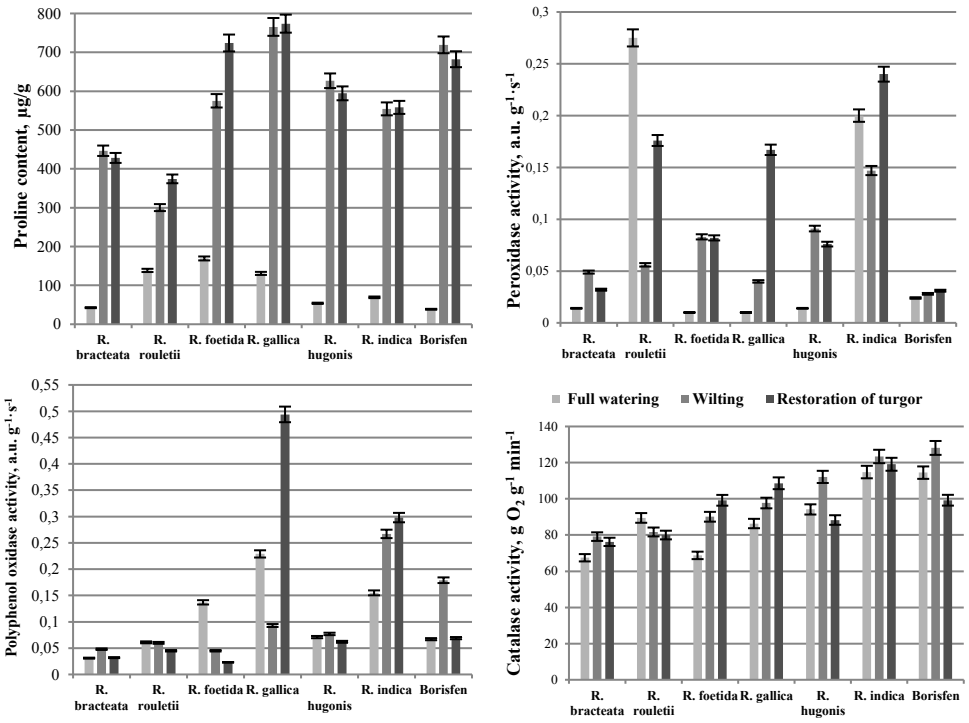

Fig.2. Proline content and enzyme activity in leaves of garden roses under controlled wilting conditions at air temperature 27ºC and relative humidity 30%.

Table 3. Water retention and reparation capacity of garden rose leaves (t 27°C; Rh 30% July 2022).

Genotype	Water content in leaves, % of wet weight	Water content in leaves, total watering, % on wet weight	Water deficit in leaves, %	Water lost during wilting, %					Leaves, restored turgor,%
				1 hour	2 hours	3 hours	4 hours	5 hours	
Borisfen	67.40	71.05	15.75	*	13.27	17.99	20.94	*	100
R. gallica	60.34	62.21	7.85	25.35	*	*	*	*	60
R. indica	63.74	65.55	7.64	*	15.65	19.13	21.45	22.32	80-85
R. hugonis	60.45	64.72	16.33	*	15.50	20.36	24.01	*	95
R. rouletti	58.43	61.26	11.11	*	25.51	*	*	*	65-70
R. bracteata	57.92	61.18	12.64	*	20.95	23.86	*	*	85-92
R. foetida	62.75	65.12	18.07	*	14.23	21.00	23.50	*	70-75

* - no measurements were taken

Against the background of increased moisture loss, the general trend in water retention capacity was maintained, only in *R. indica* water retention was slower than under more sparing wilting conditions. The amount of leaf surface area that restored normal turgor varied (in ascending order) from 60% to 75% in *R. gallica, R. rouletti, R. foetida*; from 80% to 100% in *R. indica, R. bracteata, R. hugonis*, and cv. 'Borisfen'. After recovery of leaf water supply, proline content continued to increase in *R. rouletii* and *R. foetida* species, remaining without

significant changes in other genotypes. Peroxidase activity decreased in leaves of *R. bracteata* and *R. hugonis* species, polyphenol oxidase activity - in *R. bracteata, R. hugonis* species and cv. 'Borisfen'. Catalase activity in leaves decreased in *R. hugonis* species and cv. 'Borisfen'. The results revealed that in *R. rouletii, R. indica, R. foetida,* and *R. gallica* species metabolic processes were not restored, and in *R. bracteata* species they were severely impaired.

It was shown that in cv. 'Borisfen', characterized by stable FS II performance, and the *R. bracteata* species under conditions of moisture deficiency in this case there was a decrease in Fv/F_0 by 43% and 37%, respectively, which is probably due to an increase in non-photochemical losses and a decrease in the efficiency of water splitting in FS II (Table 4).

Table 4. Changes in CFI parameters in garden roses during wilting at t 27°C; Rh 30% (2nd decade of July, 2022).

	F_0	**Fm**	**Fv**	**Fm/F_0**	**Fv/Fm**	**Fv/F_0**	**(Fm-Fst)/Fm**	**$(Fpl-F_0)/Fv$**
Borisfen								
control	160±10	854±14	694±22	5.33±0.14	0.81±0.03	4.34±0.12	0.77±0.02	0.16±0.01
wilting	160±11	560±28	400±25	3.5±0.13	0.71±0.03	2.50±0.12	0.70±0.03	0.28±0.02
recovery	100±8	384±14	284±21	3.84±0.13	0.74±0.02	2.84±0.09	0.58±0.02	0.32±0.02
R. bracteata								
control	208±9	976±22	768±26	4.69±0.12	0.79±0.04	3.69±0.11	0.69±0.03	0.48±0.02
wilting	192±7	640±29	448±21	3.33±0.11	0.70±0.02	2.33±0.12	0.62±0.02	0.38±0.02
recovery	180±9	656±27	476±23	3.64±0.13	0.73±0.02	2.64±0.09	0.58±0.03	0.39±0.02
R. gallica								
control	240±13	944±24	704±25	3.93±0.12	0.74±0.03	2.93±0.11	0.73±0.04	0.27±0.02
wilting	208±10	688±25	480±25	3.31±0.13	0.70±0.02	2.31±0.12	0.70±0.03	0.23±0.02
recovery	160±11	496±23	336±21	3.1±0.12	0.67±0.03	2.10±0.11	0.64±0.03	0.19±0.01
R. indica								
control	256±13	1024±38	768±23	4.0±0.13	0.75±0.03	3.00±0.13	0.75±0.04	0.23±0.02
wilting	192±9	544±23	352±21	2.83±0.11	0.65±0.03	1.83±0.10	0.62±0.03	0.36±0.02
recovery	176±10	720±24	544±22	4.09±0.12	0.76±0.03	3.09±0.11	0.73±0.04	0.27±0.03
R. Rouletii								
control	208±10	736±28	528±23	3.54±0.13	0.72±0.03	2.54±0.12	0.67±0.03	0.33±0.02
wilting	152±11	504±24	352±21	3.31±0.12	0.69±0.02	2.31±0.11	0.65±0.04	0.22±0.02
recovery	240±18	832±27	592±19	3.46±0.12	0.71±0.04	2.45±0.13	0.69±0.02	0.32±0.04
R. foetida								
control	184±9	848±17	664±26	4.61±0.12	0.76±0.02	3.61±0.12	0.79±0.02	0.20±0.02
wilting	181±8	848±21	632±25	4.68±0.12	0.74±0.03	3.49±0.12	0.74±0.04	0.32±0.02
recovery	128±9	640±20	512±25	5.0±0.12	0.80±0.03	4.00±0.12	0.62±0.03	0.22±0.02
R. hugonis								
control	192±11	724±18	516±22	3.77±0.13	0.71±0.03	2.69±0.09	0.72±0.02	0.15±0.02
wilting	112±10	416±20	304±27	3.71±0.11	0.73±0.03	2.71±0.10	0.73±0.02	0.15±0.02
recovery	95±6	320±16	224±21	3.36±0.12	0.71±0.03	2.35±0.11	0.70±0.03	0.21±0.03

In *R. indica* species, such changes in the ratio of photochemical and non-photochemical rate constants of excitation deactivation were observed only during wilting, and were restored to control values after 24 hours. In *R. gallica* at a water deficit level of 25% during wilting under conditions of 30% humidity, no disturbances in photosynthetic processes were

detected.

In August, leaf water content decreased to 55-62% in all objects of study, due to which the water deficit in tissues increased by 1.5-5.5%. Imitation of dry weather (t 27ºC and Rh 25%) resulted in rapid and lethal loss of moisture in *R. indica, R. gallica and R. bracteata*, as their leaves lost from 34% to 36% in the first hours of wilting (Table 5).

Table 5. Water retention and reparation capacity of leaves of garden roses (t 27ºC and Rh 25%, August 2022).

Genotype	Water content in leaves, % of wet weight	Water content in leaves, total watering, % on wet weight	Water deficit in leaves, %	Water lost during wilting, %					Leaves, restored turgor,%
				1 hour	2 hours	3 hours	4 hours	5 hours	
Borisfen	61.85	66.21	17.28	*	21.45	*	26.46	29.53	86
R. gallica	55.20	58.58	12.86	35.02	*	*	*	*	25
R. indica	59.72	61.98	9.07	*	35.55	*	*	*	0
R. hugonis	59.04	63.75	18.12	*	20.00	*	25.37	29.55	77
R. rouletti	60.65	64.26	14.29	21.48	26.67	*	*	*	95
R. bracteata	56.98	60.81	11.56	*	33.51	*	*	*	15
R. foetida	61.15	67.23	21.47	15.21	22.30	26.69	*	*	70

* - no measurements were taken

Sublethal water deficit in tissues of leaves of *R. hugonis* species and cv. 'Borisfen' revealed a loss of 20-25% moisture, giving up 26-30% - a critical degree of dehydration. Leaves of *R. gallica* showed the lowest water retention capacity, and weak reparation capacity. Obviously, the acceptable level of moisture loss for leaves of this species should not be more than 10-15%.

In experiments with more severe wilting conditions (t +27°C; Rh 25%), the trend was generally maintained (Table 6). High level of water-holding power was preserved in *R. hugonis* and cv. 'Borisfen', which ensured normal course of photosynthetic processes.

Table 6. Changes CFI parameters in garden roses during wilting at t 27°C; Rh 25% (August, 2022).

	F_0	Fm	Fv	Fm/F_0	Fv/Fm	Fv/F_0	(Fm-Fst)/Fm	(Fpl-F_0)/Fv
Borisfen								
control	105±5	512±10	407±17	4.87±0.14	0.79±0.03	3.88±0.12	0.73±0.03	0.17±0.02
wilting	103±6	400±19	297±18	3.88±0.11	0.74±0.04	2.88±0.12	0.69±0.03	0.19±0.01
recovery	100±5	384±17	284±15	3.84±0.11	0.74±0.04	2.84±0.13	0.58±0.03	0.38±0.03
R. bracteata								
control	208±12	848±8	640±23	4.07±0.11	0.75±0.03	3.08±0.12	0.74±0.02	0.30±0.03
wilting	80±9	304±21	224±18	3.8±0.12	0.74±0.03	2.80±0.10	0.68±0.03	0.57±0.02
recovery	*	*	*	*	*	*	*	*
R. gallica								
control	160±7	624±23	464±29	3.9±0.13	0.74±0.04	2.90±0.02	0.72±0.02	0.17±0.02
wilting	*	*	*	*	*	*	*	*
recovery	*	*	*	*	*	*	*	*

Continuation of Table 6.

	F_0	Fm	Fv	Fm/F_0	Fv/Fm	Fv/F_0	(Fm-Fst)/Fm	$(Fpl-F_0)/Fv$
R. indica								
control	128±10	576±29	448±26	4.5±0.11	0.78±0.02	3.50±0.11	0.78±0.08	0.21±0.02
wilting	112±11	432±31	320±21	3.86±0.12	0.74±0.02	2.86±0.12	0.74±0.10	0.45±0.03
recovery	*	*	*	*	*	*	*	*
R. rouletii								
control	176±13	528±21	352±20	3.0±0.09	0.67±0.02	2.00±0.12	0.66±0.03	0.32±0.02
wilting	100±11	384±14	284±19	3.84±0.12	0.74±0.04	2.84±0.13	0.74±0.02	0.21±0.02
recovery	144±15	400±24	256±19	2.77±0.10	0.64±0.03	1.78±0.11	0.64±0.02	0.25±0.02
R. foetida								
control	176±10	640±19	464±26	3.64±0.11	0.72±0.02	2.64±0.10	0.70±0.03	0.24±0.02
wilting	85±5	304±21	219±11	3.57±0.11	0.72±0.04	2.58±0.10	0.59±0.02	0.19±0.02
recovery	85±5	352±25	267±12	4.14±0.12	0.76±0.04	3.14±0.11	0.54±0.02	0.28±0.03
R. hugonis								
control	112±8	496±22	384±28	4.42±0.12	0.77±0.03	3.43±0.12	0.74±0.02	0.21±0.02
wilting	64±6	304±17	240±25	3.75±0.11	0.79±0.03	4.75±0.13	0.67±0.03	0.33±0.02
recovery	112±9	576±26	464±26	5.14±0.13	0.80±0.03	4.14±0.12	0.75±0.02	0.34±0.03

It was found that air humidity of 25% reduced the number of chlorophyll molecules functionally bound to the reaction centers of FS II in *R. foetida* and *R. hugonis*. Simulation of dry weather led to irreversible disturbances in the oxygen-releasing complex and destruction of thylakoids in *R. gallica* during the stressor, and in *R. indica* and *R. bracteata* species - after recovery of water availability.

4 Conclusion

Analysis of water regime indicators revealed that the best water retention and reparation characteristics under water stress were possessed by leaves of cv. 'Borisfen' and *R. hugonis* species. Species of *R. indica. R. bracteata. R. rouletti. R. foetida* showed instability of water regime under deep drought conditions. The species of *R. gallica* showed the least drought tolerance.

Studies of changes in proline content and enzymatic activity in leaves of garden roses under controlled conditions have revealed that development of hydrothermal stress under different wilting conditions causes different reactions. Under relatively mild wilting conditions. metabolic processes recovered in *R. hugonis. R. bracteata. R. indica* and cv. 'Borisfen' after removal of stress. Wilting under low humidity conditions causes metabolic disorders in *R. rouletii, R. indica R. foetida* and *R. gallica* species. According to biochemical parameters. species *R. hugonis, R. bracteata* and cv. 'Borisfen' are able to adapt to conditions imitating dry weather.

The reaction of the photosynthetic apparatus of garden roses to simulation of conditions close to dry conditions was species-specific. Relatively stable functioning of FS II under different modes of moisture combination was characteristic of cv. 'Borisfen' and *R. foetida*. The most sensitive to the development of water stress in FS II were the maximum fluorescence, the ratio of rate constants of photochemical and non-photochemical excitation deactivation reaction and the degree of Q_a reduction in reaction centers. Simulation of dry weather resulted in irreversible disturbances in the oxygen-releasing complex and destruction

of thylakoids in *R. gallica* during the stressor and in *R. indica* and *R. bracteata* species - after recovery of water availability.

Thus based on the determination of changes in physiological and biochemical parameters. cv. 'Borisfen' and *R. hugonis* species are distinguished by maximum drought tolerance.

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