# Some special features of the water regime and the photosynthetic apparatus activity in *Feijoa sellowiana* (O. Berg) O. Berg plants under the water stress

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**Abstract.** When assessing the drought tolerance of *Feijoa sellowiana* cultivars and forms, the total water content in leaf tissues and their water-retaining and regenerative capacity were determined, and the parameters of chlorophyll fluorescence induction were measured at different water content in leaves. Current-year leaves were characterized by a higher sensitivity to drought. According to the complex of water regime parameters and characteristics of the chlorophyll fluorescence induction (CFI), it was found that the cultivar Aromatnaya Fantazia and the form 3/1 are characterized by a relatively high drought tolerance. It has been demonstrated that the common method for assessing plant tolerance by the index of their water-retaining forces, in relation to *Feijoa sellowiana* genotypes, does not allow determining the critical level of water deficit. It has been found that in the cultivars and forms with low water stress tolerance, with the water loss of 20-25% from the leaf tissues complete hydration, irreversible irregularities in the PS II structures occurred. The most sensitive to the lack of water in the leaves were such parameters as variable fluorescence, rate constants of the photochemical and non-photochemical deactivation of the excitation, as well as the processes of $Q_a$ reduction in the reaction centers of PS II.

Feijoa - *Feijoa sellowiana* (O. Berg) O. Berg is an evergreen plastic plant, which is a xeromesophyte. Although, in the areas with annual rainfall less than 700 mm, it can only be cultivated with irrigation. In the last decade, almost every year on the southern coast of Crimea, there has been a tendency to an increase in the frequency and duration of rainless periods, and complex soil and air drought has been observed [1]. An increase in air temperature in the summer months (especially July-August) results in an increase in evaporation, a decrease in precipitation during this period, a significant increase in arid phenomena, which causes temperature and water stress in plants: in plants the leaves lose their turgor during the day, foliage prematurely turns yellow and fall off, significant crop losses were noted [2]. Plant drought tolerance has a great effect on the stability of its

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fruiting. Under the moisture deficit, some feijoa cultivars and forms have a manifest reduction in productivity elements (especially in the first period of rapid fruit growth, which occurs in August), the size of fruits decreases, as well as plant productivity [3]. Among the methods that enable one to obtain objective information about the stress level, before the appearance of its visible features, is the analysis of the chlorophyll fluorescence induction parameters [4].

The aim of the presented studies was to select potentially drought-tolerant cultivars and forms of *Feijoa sellowiana*, as well as to define the characteristics of the plants` water regime parameters and the state of their photosynthetic apparatus under increasing water stress. The research was carried out in 2015-2017 years, on the basis of the Nikita Botanical Gardens - National Scientific Center collection plots. The objects of the research were two feijoa cultivars originated in the Nikita Botanical Gardens: Nikitskaya Aromatnaya and Aromatnaya Fantasia, planted in 1951, and 2 forms - 2/1 and 3/1, planted in 1989. The analysis of the water regime parameters was carried out under conditions of controlled leaf wilting during the summer seasons of the study period. The water retention capacity of leaf tissues was determined by the amount of water lost over a certain period of time. The regenerative capacity of leaf tissues was assessed by the area of damaged sectors after stress removal [5]. The state of the photosynthetic apparatus was assessed by the changes in the chlorophyll fluorescence induction (CFI) parameters using a portable chronofluorimeter "Floratest". The following CFI parameters were used: $F_0$ — baseline fluorescence; $F_m$ - the maximum fluorescence value; $F_{st}$ - the stationary fluorescence level. Calculated indexes: Fv = Fm - $F_0$ - variable fluorescence; (Fv/Fst is the fluorescence decay coefficient (viability index); (Fpl-$F_0$)/Fv - the amount of unrecovered Qa in PS II reaction centers; Fv/$F_0$ - the ratio of the rate constants of the photochemical and non-photochemical deactivation of the excitation in PS II. [6,7]. Data statistical analysis was made with the software MS Excel 2007. The significance of the differences between the variants was assessed by the Student's t-test at the 5% significance level. In the tables and graphs, the means and their standard errors are represented.

In the summer seasons of 2015-2017 years, the water deficit in young leaves varied from 3.0 to 20.5% and it was 9.7-18.0% in old leaves. The lowest water deficit was noted in the Aromatnaya Fantazia cultivar (3.0-9.7%), as well as in the young leaves of the Nikitskaya Aromatnaya cultivar (7%). It was found that during the periods of maximum probability of dry-hot wind weather (third decade of July - second decade of August), both current-year leaves and ones of the last growing season were characterized by high water deficit, 3/1 form (up to 17.6%) and 2/1 (18.7%). The total water content in all studied cultivars and forms ranged from 42.9 to 48.3% in mature leaves, and from 52.6 to 84.4% in the current-year leaves. The water retention capacity of leaf tissues makes it possible to assess the potential of plants to withstand the pressure of dehydrating factors. Rapid water loss resulted in the damages to the cell structural parts. It was determined that in feijoa, moisture loss after 2 hours was insignificant - from 2.7 to 7.8% in the studied forms, and from 5.4 to 11.1% in the cultivars. After 4 hours, water loss ranged from 6.5 to 12.5%, and only after a day (24 hours), it was from 25.4 to 40.5% (Table 1). The percentage of leaves that recovered turgor above all depends on the age of leaves. The current-year leaves after 24 hours wilting completely recovered turgor. In older leaves, the percentage of damages after 24 hours varied from 2 to 35%. The most complete turgor recovery was noted in the leaf tissues of the 3/1 form (80-96%) and a relatively low level of recovery was in old leaves of the cultivars Aromatnaya Fantaziya (10%) and Nikitskaya Aromatnaya (40%). In the current-year leaves, a high turgor recovery was noted in all cultivars and forms (88-97%), the exception was Nikitskaya Aromatnaya cultivar (65%).

**Table 1.** Water retention and reparation capacity in the leaves of different age in *Feijoa sellowiana* cultivars and forms

| Cultivar, form | Water loss during the wilting, % | | | | | Leaves recovered turgor, % | |
|---|---|---|---|---|---|---|---|
| | after 2 h. | after 4 h. | after 18 h. | after 24 h. | after 35 h. | after 24 h. | after 35 h. |
| Aromatnaya Fantaziya -1* | 11.1±1.1 | 11.7±1.3 | 32.2±1.5 | 38.0±1.8 | 46.8±2.1 | 65 | 10 |
| Aromatnaya Fantaziya -2 | 6.6±0.5 | 7.4±0.2 | 22.9±1.9 | 28.6±1.9 | 40.8±1.9 | 100 | 88 |
| Nikitskaya Aromatnaya -1 | 10.9±0.9 | 12.5±0.9 | 30.9±1.8 | 37.5±1.8 | 48.8±2.4 | 85 | 40 |
| Nikitskaya Aromatnaya -2 | 5.4±0.4 | 8.0±0.8 | 21.8±1.6 | 33.7±1.5 | 56.4±2.5 | 100 | 65 |
| 2/1 -1 | 7.8±0.4 | 11.2±1.3 | 34.5±1.9 | 40.5±1.7 | 47.7±1.8 | 75 | 50 |
| 2/1 -2 | 7.8±0.5 | 10.4±1.2 | 23.6±1.4 | 31.3±1.5 | 37.8±1.7 | 100 | 90 |
| 3/1 -1 | 3.9±0.1 | 7.3±0.6 | 26.4±1.3 | 32.7±1.9 | 42.5±2.2 | 98 | 60 |
| 3/1 -2 | 3.7±0.2 | 6.5±0.3 | 20.1±1.5 | 25.4±1.3 | 38.9±1.5 | 100 | 97 |

*-1 - old leaves, 2 - currant-year leaves

Analysis of CFI parameters in the leaves of feijoa cultivars and forms at full hydration, after 12 hours wilting and subsequent recovery demonstrated that water loss within 20-25% was critical for PS II functioning, despite the absence of visible damages to leaf tissues. In particular, as a result of 12-hour wilting, significant differences in the state of the photosynthetic apparatus were noted in the current-year leaves of the cultivars Nikitskaya Aromatnaya and Aromatnaya Fantaziya (water loss 18 - 22%). Under these conditions, the cultivar Aromatnaya Fantazia demonstrated a decrease in the ratio of the rate constants of the photochemical and non-photochemical deactivation of the excitation and an increase in the amount of unrecovered $Q_a$ by 30% and 40%, respectively. These changes were reversible, as confirmed by the vitality index (Fv/Fst), which remained within the normal range (Table 2).

**Table 2.** CFI parameters in leaves of *Feijoa sellowiana* cultivars and forms at different levels of water availability

| CFI parameters | $F_0$ | Fm | Fst | Fv | Fv/Fst | $Fv/F_0$ | $(Fpl-F_0)/Fv$ |
|---|---|---|---|---|---|---|---|
| *Aromatnaya Fantazia* | | | | | | | |
| control | 549±9 | 1216±23 | 543±14 | 667 | 1.23 | 1.21 | 0.46 |
| 12 hours wilting | 656±5 | 1217±31 | 560±17 | 561 | 1.0 | 0.86 | 0.61 |
| recovery | 816±11 | 1424±25 | 608±15 | 608 | 1 | 0.75 | 0.66 |
| | | *Nikitskaya Aromatnaya* | | | | | |
| control | 416±13 | 1808±24 | 448±18 | 1392 | 3.11 | 3.34 | 0.37 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 12 hours wilting | 656±16 | 1424±26 | 720±12 | 768 | 1.07 | 1.17 | 0.73 |
| recovery | 352±3 | 864±8 | 672±7 | 512 | 0.76 | 1.45 | 0.62 |
| 3/1 | | | | | | | |
| control | 432±15 | 1824±21 | 464±6 | 1392 | 3 | 3.22 | 0.33 |
| 12 hours wilting | 434±7 | 1456±24 | 480±13 | 1022 | 2.13 | 2.35 | 0.42 |
| recovery | 512±11 | 1158±29 | 464±9 | 649 | 1.39 | 1.28 | 0.42 |
| | | 2/1 | | | | | |
| control | 480±16 | 1328±27 | 464±10 | 848 | 1.83 | 1.77 | 0.43 |
| 12 hours wilting | 640±12 | 1152±31 | 448±11 | 512 | 1.14 | 1.8 | 0.3 |
| recovery | 480±8 | 816±12 | 416±9 | 336 | 0.81 | 0.7 | 0.45 |

However, when the water supply was recovered, this cultivar retained a fairly high level of stress, which resulted in a further increase in the amount of unrecovered $Q_a$ [8,9]. Despite the high level of water-retaining forces and the absence of visible damages to leaf tissues after water supply recovery, in the cultivar Nikitskaya Aromatnaya we observed irreversible abnormalities in the work of PS II - a decrease in the ratio of the rate constants of the photochemical and non-photochemical deactivation of the excitation by 70%, inactivation of $Q_a$ recovery processes in reaction centers, and also a decrease in the vitality index below 1. Studies of PS II state in feijoa forms showed that at 12 hour wilting, the forms 3/1 and 2/1 lost almost the same water amount (20-23%). Changes in CFI parameters under water deficit were similar in both forms. However, after removing the stress effect in the form 3/1, the main indexes of PS II differed slightly from the control. At the same time, in the form 2/1, inactivation of photosynthetic processes was recorded in the process of water supply recovery in leaf tissues.

The presented studies let us to conclude that the common method for assessing potential drought tolerance by the level of water-retaining forces allows to get a comparative characteristic of drought tolerance in *Feijoa sellowiana* genotypes, but it does not show a real picture of the leaf viability [10]. It has been found that the water loss 20-25% in leaves can cause the destruction of PS II, in the absence of visible damages to the leaf tissue. It has been demonstrated that the current-year leaves had a lower level of water-retaining forces. Among the studied cultivars and forms, by a set of parameters, the cultivar Aromatnaya Fantasy and the form 3/1 are characterized by higher drought tolerance.

## References

1. S. P. Korsakova, Collection of scientific works of GNBS, **139** (2014)
2. E. L. Shishkina, *Features of feijoa fruiting*, Modern scientific researches in horticulture, Materials of the VIII International Gardening Conferences, 11-13 Sept. (Yalta, 2000)
3. E. L. Shishkina, Collection of scientific works of GNBS, **110** (2014)
4. M.Yu. Pimkin, Fruit and berry growing in Russia, **28 (2)** (2011)

5. A. I. Lishchuk, Physiological and biophysical methods in fruit crops breeding *(*Moscow, 1991)
6. V. A. Romanov, I. B., Galelyuka, Ie. V. Sarakhan, Sensor Electronics and Microsystem Technol., **1 (7)** (2010)
7. V. N. Goltsev, Kh. M. Kaladzhi, M. Paunov, V. Baba, T. Horacek, J. Moyski, H. Kotsel, S.I. Allahverdiev, Russian Journal of Plant Physiology, **6** (2016)
8. A. Stirbet, J. Govindjee, Journal of Photochemistry and Photobiology, Biology, **104** (2011)
9. T. Gubanova, R. Pilkevich, I. Paliy, O. Grebennikova, E. Melkozeorova, *Features of physiological and biochemical processes of Prunus armeniaca and Ficus carica in water stress conditions*, International Scientific and Practical Conference "Fundamental and Applied Research in Biology and Agriculture: Current Issues, Achievements and Innovations" (FARBA), 5 May, 2021, Russian Federation (2021)
10. E. Rosenqvist, O. V. Kooten, Practical applications of chlorophyll fluorescence in plant biology (Kluwer Academic Publishers, 2003)