PLANTS
IN URBAN AREAS AND LANDSCAPE

WATER DEFICIT IMPACT ON SELECTED PHYSIOLOGICAL PARAMETERS OF THE WOODY PLANT *CORNUS MAS* L.

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Studying resistance of woody plants and herbs to drought has become the subject of various experiments. The paper presents the study of impact of the water scarcity on chlorophyll fluorescence and stomatal conductance of the woody plants *Cornus mas* L. The experiment was carried out on plants in two different water regimes (a control variant was maintained with soil water supply on 60% and a stress variant with soil water supply on 30%). Chlorophyll fluorescence was carried out by chlorophyll fluorometer in a 21 days´ period in two growing seasons of 2013 and 2014. The following chlorophyll fluorescence parameters were recorded: maximum quantum efficiency of PSII (F_v/F_m), effective quantum yield of PSII (Φ_{PSII}) and chlorophyll fluorescence decrease ratio (R_{FD}). Stomatal conductance (g_s) was carried out by leaf porometer in 21 days period in two growing season, 2013 and 2014. By the results the water deficit represented by soil water supply on 30% does not affect the values of F_v/F_m. The values of Φ_{PSII} and Rfd were significantly affected due to water deficit in the soil in a model plant. Limiting of the irrigation on model plants resulted in the reduction in the stomatal conductance (g_s).

Keywords: chlorophyll fluorescence, stomatal conductance, water deficit

1 Introduction

The urban environment is a natural habitat for plants. Only some species are able to survive in these extreme conditions (drought, salinity, high temperature, etc.). The plants were selected with focus on species with adequate properties. Nowadays, the plants with ornamental and useful character are becoming extremely popular, especially fruit species that can be grown also in unfavourable environmental conditions (Hričovský and Vargová, 2007). For these reasons, *Cornus mas* L. was set as a model plant. *Cornus mas* L. belongs to useful – ornamental shrubs that bear tasty fruits. It is used in ornamental horticulture thanks to its early flowering. The fruits of *Cornus mas* L. can be universally used both in a fresh and processed state as well as in the medicine.

Evaluation of the reaction of plants to the physiological level, especially on the status of photosynthesis was chosen. The simple method of measurement of the photosystem II, which could be affected by stress factors, is the use of chlorophyll fluorescence techniques. Chlorophyll fluorescence technique has become popular among breeders, biotechnologists, plant physiologists, farmers, gardeners, foresters, ecophysiologists and environmentalists (Kalaji et al., 2016).

The chlorophyll fluorescence signal is very rich in its content and very sensitive to changes in photosynthesis (Kalaji et al., 2014). Björkman and Demming (1987) consider the maximum quantum efficiency of PSII (F_v/F_m) as a screening indicator of plant response to a particular stress factor. F_v/F_m represents effectiveness of light utilization under the standard conditions of CO_2 fixation and the quantum yield of photochemical processes (Björkman and Demming 1987). Reactions of F_v/F_m to drought by woody plants were recorded by Bauerle and Dudley (2003), Gallé and Feller (2007), Percival and Sheriffs (2002).

The effective quantum yield of PSII (Φ_{PSII}) is a real yield of active PSII reaction centres in the processing of absorbed light energy. Φ_{PSII} represents the light used in photochemistry (Genty et al., 1989; Schreiber, 2004). The impact of water stress caused a decrease of Φ_{PSII} in woody plants (Peguero-Pina et al., 2008, Gallé et al., 2007).

Fluorescence decrease ratio (R_{FD}) is considered to be the vitality index of the photosynthetic apparatus (Lichtenthaler and Babani 2000). Lower values are typical for plants in suboptimal conditions and the higher ones represent a higher photosynthetic activity and also adaptability of woody plants (Lichtenthaler et al., 2005). The decrease of R_{FD} values was observed by Pukacki and Kamińska-Rożek (2005).

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The stomatal conductance (g_s) of the leaves was used to monitor the reactions of stomata through water deficit impact. It is a very important defence mechanism against a loss of water (Tardieu and Davis, 1993, in Živčák, 2006). The impact of water deficit results in the closure of stomata and the decrease in photosynthesis. Lower values of stomatal conductance also represent adaptation of plants in extreme conditions (Živčák, 2006).

One of the crucial factors for plant growth is the accessibility of water in the soil. Plants have more adaptive mechanisms that help them to tolerate adverse environmental conditions. There has been quite a lot of research about the drought response of crops but also more testing of drought tolerant ornamental plant species is needed in the field of landscape architecture. The impact of water scarcity to ornamental and useful woody plant *Cornus mas* L. was tested. The aim of the evaluation was to investigate if there were any differences in the mean values of chlorophyll fluorescence parameters and stomatal conductance of the leaves on the plants in variants during the experiment with different levels of soil water supply.

2 Material and Methods

Within a pot experiment, physiological responses of plants in relation to water scarcity were monitored. The non-destructive methods of monitoring the impact of a lack of water in the soil to plants, measurement of leaf stomatal conductance and modulated chlorophyll fluorescence were chosen.

The one-year old seedlings (in the year 2013) of *Cornus mas* L. come from generative propagation. The two variants with different soil water supply in the 3 litre size pots were established. A half of plants were exposed to 30% of the soil water supply (a variant with reduced water content in the soil – a stress variant) and another part of the plants were further hydrated in 60% of the soil water supply (a control variant). The plants were cultivated into the substrate based on the white peat, enriched with the clay (20 kg/m^3), pH 5.5–6.5, with NPK fertilizer 14 : 10 : 18 (Klasmann TS3, Klasmann-Deilmann GmbH, Germany), under the polypropylene cover with 40% of shading. The experimental plants were grown in the differentiated water regime from June to September, for the total period of 151 days in the year 2013 and 154 days in the year 2014. Ten plants in the control variant and ten plants in the stress variant were used for the measurement. Chlorophyll fluorescence was measured on two leaves of each plant by the chlorophyll fluorometer Hansatech FMS 1 (Hansatech Instruments Ltd, United Kingdom) in the morning hours. The software Modfluor for the data analysis was used and 21 days period of measurements was set in the two years. The following characteristics of measurement protocol of the chlorophyll fluorescence were used: one second light pulses of red light with an intensity of 895 μmol/m^2/s^1, the intensity of actinic light 34 μmol/m^2/s^1 and the saturation light pulse 10 000 μmol/m^2/s^1. These parameters were measured and also used for the statistical analysis: F_v/F_m, Φ_{PSII} and R_{FD}.

When measuring the leaf stomatal conductance, the Delta T leaf porometer AP4 (Delta-T Devices Ltd, United Kingdom) was used. The measurement of a loss of water vapour through the stomata took place before midday (best conditions for measurement were between 8:00–10:00 am because of stomata closure at the midday because of higher temperature and light intensity) on two leaves per plant. The leaf stomatal conductance was determined in mm/s^1, together with the recording the current time, light intensity in μmol/m^2/s^1 and the current temperature in degrees Celsius.

For the mathematical and statistical analysis of the data, the one-way Anova and Kruskal-Wallis Test, $P < 0.05$ were used. The statistical assessment of the data was conducted using the software Statgraphics Centurion XVII (StatPoint Technologies, USA, XV, licence number: 7805000000722). The differences in the monitored parameters in the woody plant *Cornus mas* L. with reference to different water content in the soil were tested.

3 Results and Discussion

F_v/F_m measurements results are presented by non-significant differences between two variants with different water supply in the soil. The mean value of F_v/F_m after 21 days of experiment duration time in the year 2013 was in the stress variant 0.77 and in the control variant 0.80. In the year 2014 after 84 days of treatment the mean value was 0.81 (stress variant) and 0.83 (control variant), (Table 1). It can be possible that 30% of water supply for *Cornus mas* L. was not the critical level of water stress. Cornic and Massacci (1996) define that metabolism processes are not affected in the moderate water stress and also the short period of water deficit does not affect the F_v/F_m (Papageorgiou and Govindjee, 2004). These findings confirm the results of other authors (Bjorkman and Deming 1987; Johnson et al., 1993, Kalaji et al., 2012) that values around 0.83 are optimal for the most of the plant species in non-stressed conditions. Also Roháček

(2002) states the value 0.832 ±0.004 as the constant value which is reached by a lot of different plant species under non-stressed conditions. The results in the woody plants *Spiraea japonica* L. ´Little Princess´ and *Cornus stolonifera* Michx. ´Kelseyi´ (Šajbidorová, 2013) as well as in *Pyrus pyraster* L. and *Sorbus domestica* L. (Šajbidorová et al., 2015) confirm that this parameter is non-sensitive to water deficit.

On the other hand F_v/F_m and Φ_{PSII} are considered by Maxwell and Johnson (2000) as sensitive indicators of plants to stress environmental conditions. Both parameters characterize the function of PSII that significantly reacts to any environmental impact (Swiatek et al., 2001). The values in plants in stressed conditions are rapidly declining, so the parameter is considered as an indicator of photoinhibition or other damage of PSII (Roháček, 2002). Water deficit decreased the F_v/F_m values in *Acer rubrum* L. and *Acer* × *freemanii* E. Murray (Bauerle and Dudley, 2003) and also in *Fagus sylvatica* L. (Gallé and Feller, 2007). Percival and Sheriffs (2002) identified drought tolerant, intermediate, sensitive and very sensitive woody plants based on the F_v/F_m measurement after dehydration.

Φ_{PSII} seems to be the significant parameter of the condition of drought stress in a model plant. Φ_{PSII} is the real yield of active PSII reaction centres in the processing of absorbed light energy and reflects the actual state of the photosynthetic apparatus (Genty et al., 1989; Schreiber, 2004).

The values of Φ_{PSII} of the stress variant were significantly lower in comparison to the control variant (Table 1). In the year 2013, a significant decrease (46%) in the values of Φ_{PSII} in the control variant (0.13) in comparison to the stress variant (0.06) after 41 days of lower water supply in the soil was observed. In the year 2014, a reduction in the values of Φ_{PSII} was more remarkable, a 72% decrease between the variants (the control variant 0.11 and the stress variant 0.08) after longer duration of the differentiated irrigation regime (for 84 days). The similar decline of Φ_{PSII} was observed in *Spiraea japonica* L.,Little Princess´ and *Cornus stolonifera* Michx. ´Kelseyi´ (Šajbidorová 2013). Gallé et al. (2007) found a decrease in the values of Φ_{PSII} in the condition of water deficit in *Quercus pubescens* Willd., as well as Peguero-Pina et al. (2008) in *Quercus coccifera* L. Hillová (2016) considered that the measurement of Φ_{PSII} is a fast and affordable method for sorting of herbaceous perennials into five main groups which not fully correspond with the traditional use of perennials sorting according to Hansen and Stahl (1993).

Within two years, the values of fluorescence decrease ratio (R_{FD}) were significantly lower in the stress variant for most of the period (Table 1). In the year 2013, after 41 days of a lower level of water supply the decrease (62%) from 1.42 in the control variant in comparison to 0.88 in

Table 1 The mean values of the analysed parameters and 95% LSD test for the studied taxa *Cornus mas* L. and for the two variants of the soil water supply (control/stress) in the year 2013. Values with the same letter are not significantly different

Parameter	F_v/F_m		Φ_{PSII}		R_{FD}		g_s	
Duration time of experiment in 2013	control	stress	control	stress	control	stress	control	stress
1st day	0.79a	0.76a	0.11a	0.06b	1.25a	0.89b	0.66a	0.53a
21nd day	0.80a	0.77b	0.13a	0.06b	1.42a	0.88b	1.41a	0.52b

Table 2 The mean values of the analysed parameters and 95% LSD test for the studied taxa *Cornus mas* L. and for the two variants of the soil water supply (control/stress) in the year 2014. Values with the same letter are not significantly different

Parameter	F_v/F_m		Φ_{PSII}		R_{FD}		g_s	
Duration time of experiment in the year 2014	control	stress	control	stress	control	stress	control	stress
1st day	0.83a	0.79b	0.16a	0.07b	1.71a	1.07b	0.45a	0.18b
21st day	0.82a	0.81a	0.10a	0.06b	1.50a	1.07b	0.26a	0.26a
42nd day	0.82a	0.81a	0.13a	0.09b	1.58a	1.79a	0.37a	0.27b
63rd day	0.82a	0.81a	0.11a	0.06b	1.36a	0.95b	0.52a	0.33b
84th day	0.83a	0.81b	0.11a	0.08b	1.42a	0.83b	0.77a	0.27b

the stress variant was recorded. In the year 2014, after 84 days of lower water supply a significant decrease in the values between the two different variants (stress = 0.83 and control = 1.42) was measured, which accounts for the decrease of 58%. Pukacki and Modrzyński (1998) considered the values of R_{FD} ≥2.3 for plants in optimal conditions and the impact of stress factors may result in a decrease in values. Pukacki and Kamińska-Rożek (2005) evaluated the impact of drought in the soil on the plants of *Picea abies* L. After 42 days of water deficit there was observed a decrease in the values Rfd and F_v/F_m by 44% compared to control plants.

When assessing stomatal conductance in the year 2013, lower values in the stress variant after 41 days of a differentiated water regime were observed. In the year 2014, there were lower values in the stress variant for most of the period. A bigger difference was recorded between the two variants after a 42 days period (a decrease by 73%). At the end of the period, after 84 days, the decrease in the values was much lower (35%) (Table 1). The same results emphasize Hillová et al. (2016) on herbaceous perennials when drought stress led to a considerable decline in stomatal conductance. Galmés et al. (2007) observed a decline in stomatal conductance in ten Mediterranean species when water stress intensified. Zweifel et al. (2009) said that stomatal regulation is species-specific. Closed stomata reduce transpiration and also photosynthesis and total tree metabolism (Larcher, 2003).

4 Conclusion

Reliable information about drought tolerant ornamental woody plants and herbs in the field of landscape architecture is needed, with regards to global warming and specific environmental conditions in urban areas. Analysing plants‘ reactions to extreme environmental conditions by research is more effective in case of crops rather than ornamental plants. Testing of drought resistance could be also useful when selecting ornamental plants because of the need for low maintenance of public green spaces in urban areas.

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References

BJÖRKMAN, O. – DEMMING, B. 1987. Photon yield of O_2 evolution and chlorophyll fluorescence characteristics at 77 K among vascular plants of diverse origins. In Planta, 1987, no. 170, pp. 489–504.

CORNIC, G. – MASSACCI, A. 1996. Leaf photosynthesis under drought stress. In Baker N. R. (ed). Photosynthesis and the Environment. Dordrecht : Kluwer Academic Publishers, 1996, pp. 347–366.

GALLÉ, A. – FELLER, U. 2007. Changes of photosynthetic traits in beech saplings (*Fagus sylvatica*) under severe drought stress and during recovery. In Physiologia Plantarum, 2007, no. 131, pp. 412–421.

GALLÉ, A. – HALDIMANN, P. – FELLER, U. 2007. Photosynthetic performance and water realtions in young pubescent oak (*Quercus pubescens*) trees during drought stress and recovery. In New Phytologist, 2007, no. 74, pp. 799–810.

GALMÉS, J. – MEDRANO, H. – FLEXAS, J. 2007. Photosynthetic limitations in response to water stress and recovery in Mediterranean plants with different growth forms. In New Phytologist, 2007, no. 175, pp. 81–93.

GENTY, B. – BRIANTAIS, J.M. – MAKER, N.R. 1989. The relationship between quantum yield of photosynthetic electron transport and quenching of chlorophyll fluorescence. In Biochemica et Biophysica Acta, 1989, no. 990, pp. 87–92.

HANSEN, R. – STAHL, F. 1993. Perennials and their garden habitats. Stuttgart : Ulmer, 1993, 573 p. ISBN 3-8001-6438-8.

HILLOVÁ, D. 2016. Determination of Compositional Principles for Herbaceous Plantings in Dry Conditions. In Drought Stress Tolerance in Plants, vol. 1 [3-319-28897-0; 3-319-28899-7], pp. 499 –511.

HILLOVÁ, D. – LICHTNEROVÁ, H. – MITOŠINKOVÁ, V. – BRTÁŇOVÁ, M. – RAČEK, M. – KUBUS, M. 2016. Effects of drought treatment on three matrix planting perennials. In Acta Scientiarum Polonorum-Hortorum Cultus, vol. 15, 2016, no. 5, pp. 133–144.

HRIČOVSKÝ, I. – VARGOVÁ, H. 2007. Možnosti uplatnenia menej rozšírených okrasno-úžitkových druhov v záhradách. In Enterprise on agricultural land in context of rural development. Conference proceedings with international participation, Račkova dolina, Slovakia, 26–27 April 2007, Slovakia.

JOHNSON, G.N. – YOUNG, A.J. –SCHOLES, J.D. – HORTON, P. 1993. The dissipation of excess excitation energy in British plant species. In Plant, Cell and Environment, 1993, no. 16, pp. 673–679.

KALAJI, M. H. – GOLTSEV, V. – BOSA, K. – ALLAKVERDIEV, S.I. – STRASSER, R.J. – GOVINDJEE. 2012. Experimental in vivo measurements of light emission in plants: a perspective dedicated to David Walker. In Photosynthesis Research, 2012, no. 114, pp. 69–96.

KALAJI, M.H. – SCHANSKER, G. – LADLE, R.J. 2014. Frequently asked questions about in vivo chlorophyll fluorescence: practical issues. In Photosynthesis research, 2014, no. 122, pp. 121–158.

KALAJI, M.H. – JAJOO, A. – OUKARROUM, A. 2016. Chlorophyll a fluorescence as a tool to monitor physiological status of plants under abiotic stress conditions. In Acta Physilogiae Plantarum, 2016, no. 38, p. 102. DOI: 10.1007/s11738-016-2113-y.

LARCHER, W. 2003. Physiological plant ecology – ecophysiology and stress physiology of functional groups. Berlin : Springer Science and Business Media, 2003.

LICHTENTHALER, H.K. – BABANI, F. 2000. Detection of photosynthetic activity and water stress by imaging the red chlorophyll fluorescence. In Plant Physiology and Biochemistry, 2000, no. 38, pp. 889–895.

LICHTENTHLALER, H.K. – BUSCHMANN, C. – KNAPP, M. 2005. How to correctly determine the different chlorophyll fluorescence parameters and the chlorophyll fluorescence decrease ratio R_{FD} of leaves with the PAM fluorometer. In Photosynthetica, 2005, no. 43, pp. 379–393.

MAXWELL, K. – JOHNSON, G.N. 2000. Chlorophyll fluorescence – a practical guide. In Journal of Experimental Botany, 2000, no. 51, pp. 659–668.

PEGUERO-PINA, J.J. – MORALES, F. – FLEXAS, J. – GIL-PELEGRÍN, E. – MOYA, I. 2008. Photochemistry, remotely sensed physiological reflectance index and de-epoxidation state of the xanthophyll cycle in *Quercus coccifera* under intense drought. In Oecologia, 2008, no. 156, pp. 1–11.

PERCIVAL, G.C. – SHERIFFS, C.N. 2002. Identification of drought-tolerant woody perennials using chlorophyll fluorescence. In Journal of Arboriculture, vol. 28, 2002, no. 5, pp. 215–223.

PUKACKI, P.M. – MODRZYŃSKI, J. 1998. The influence of ultraviolet-B radiaton on the growth, pigment production and chlorophyll fluorescence of Norway spruce seedlings. In Acta Physiologiae Plantarum, 1998, no. 20, pp. 245–250.

PUKACKI, P.M. – KAMIŃSKA-ROŻEK, E. 2005. Effect of drought stress on chlorophyll *a* fluorescence and electrical admittance of shoots in Norway spruce seedlings. In Trees, 2005, no. 19, pp. 539–544.

ROHÁČEK, K. 2002. Chlorophyll fluorescence parameters: The definitions, photosynthetic meaning and mutual relationships. In Photosynthetica, 2002, no. 40, pp. 13–39.

SCHREIBER, U. 2004. Pulse-Amplitude-Modulation (PAM) fluorometry and saturation pulse method: An overview. In Papageorgiou GCH, Govindjee, editors. Chlorophyll *a* Fluorescence. A Signature of Photosynthesis: Springer, 2004, pp. 279–319.

SWIATEK, M. – KURAS, R. – SOKOLENKO, A. 2001. The chloroplast gene ycf9 encodes a photosystem II (*PSII*) core subunit, PsbZ, that participates in *PSII* supramolecular architecture. In Plant Cell, 2001, no. 13, pp. 1347–1367.

ŠAJBIDOROVÁ, V. 2013. Adaptácie *Cornus stolonifera* Michx. "KELSEYI" a *Spiraea japonica* L.´LITTLE PRINCESS´ na zmenené podmienky prostredia. PhD, Nitra : SUA, 2013.

ŠAJBIDOROVÁ, V. – LICHTNEROVÁ, H. –PAGANOVÁ, V. 2015. The impact of different water regime on chlorophyll fluorescence of *Pyrus pyraster* L. *Sorbus domestica* L. In Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, vol. 63, 2015, no. 5, pp. 1575–1579. DOI: 10.11118/actaun201563051575

TARDIEU, F. – DAVIES, W.J. 1993. Integration of hydraulic and chemical signalling in the control of stomatal conductanse and water status of droughted plants. In Plant, Cell and Environment, 1993, no. 16, pp. 341–349.

ŽIVČÁK, M. 2006. Využitie diverzity fyziologických reakcií pre skríning genotypov pšenice tolerantných na sucho. PhD, Nitra : SUA, 2006.