Fluorescence parameters of leaves of trees and shrubs during period of adverse weather conditions in Krasnoyarsk

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ABSTRACT

The effect of adverse weather conditions (AWC) on the fluorescence parameters of leaves *Prinsepia sinensis*, *Amelanchier florida*, *Crataegus chlorocarca* is obtained. However, significant changes in the fluorescence of the leaves of *Acer negundo*, *Betula pendula* under AWC were not observed.

Keywords: fluorescence leaves, adverse weather conditions.

INTRODUCTION

Adverse weather conditions are a combination of short-term meteorological factors (calm, light winds, inversion) that contribute to the accumulation of pollutants in the surface layer of atmospheric air. In major industrial cities the deterioration of air quality is observed under appearance of AWC. During this period the concentration of pollutants increases.

Air quality of Krasnoyarsk is determined by such pollutants as benzo(a)pyrene, formaldehyde, nitrogen dioxide and suspended solids. In 2013 the average concentration of these substances amounted to 0,0000042 mg/m^3, 0,0149 mg/m^3, 0,039 mg/m^3, 0,156 mg/m^3, respectively; and the maximum single concentration - 0,0000171 mg/m^3, 0,158 mg/m^3, 0,22 mg/m^3, 3,5 mg/m^3, respectively. In 2013, AWC was observed for 27 days (including three days in August). We were unable to find works devoted to the study of the effect of AWC on the photosynthetic apparatus of plants, which vegetate in conditions of high level of air pollution. In Krasnoyarsk the comprehensive index of the level of air pollution in the second and third quarter of 2013 was 13,3 and 15,2, respectively.

Since, on the one hand, the period AWC shorter than the period of vegetation of plants, and on the other hand, the concentration of suspended solids under AWC increases compared to the annual average concentrations, to identify the reactions of the photosynthetic processes of plants to short-term exposure to high concentrations of the pollutant fluorescence method was used. The research results are presented in this work.

2. MATERIAL AND METHODS

The object of investigation was leaves of hawthorn (*Crataegus chlorocarca* M.), prinsepia (Prinsepia sinensis), shadberry (*Amelanchier florida* Lindl), maple (*Acer negundo*), birch (*Betula pendula*). Trees and shrubs grew on the territory of the arboretum of the Institute of forest SB RAS (Akademgorodok, Krasnoyarsk). Samples were collected in May-September of 2013.

Pigments were extracted with 96% ethanol. Absorption spectra were recorded on a UVICON spectrophotometer 943 (Contron Instruments, Italy). The concentration of chlorophyll was calculated by the formulas [1]:

$$\text{Chl } a \text{ (mg/l)} = 13{,}7\ D_{665} - 5{,}76\ D_{649},$$

$$\text{Chl } b \text{ (mg/l)} = 25{,}8\ D_{649} - 7{,}60\ D_{665},$$

$$\text{Chl } (a + b) \text{ (mg/l)} = 6{,}10\ D_{665} + 20{,}0\ D_{649},$$

where D_{649} and D_{665} - optical density of the extracts of pigments at the wavelength of 649 nm and 665 nm, respectively. Carotenoid content was calculated by the formula [2]:

$$C_{CAR} \text{ (mg/l)} = 4{,}695\ D_{440,5} - 0{,}268\ (\text{Chl}(a+b)),$$

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where $D_{440,5}$ - the optical density of the extracts of pigments at a wavelength λ=440,5 nm.

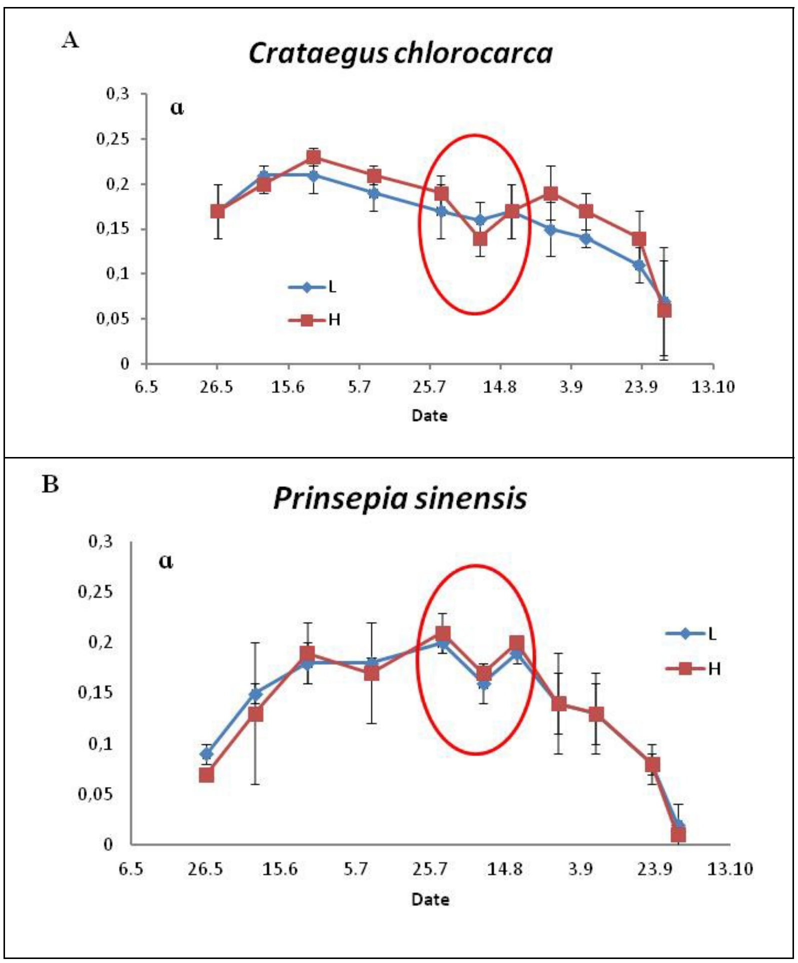
To obtain fluorescence parameters of leaves of trees the modulating pulse PAM fluorimeter (Junior PAM, “Heinz Walz GmbH, Germany) is used. The measurement was performed after 15 minute of dark adaptation of the leaves. The registration of the "rapid light curve" [3] was carried out in two ranges of luminous flux 0-420 (L-range) and 125-1500 (H- range) µmol photons $m^{-2} \cdot s^{-1}$, the light exposure time at a given intensity level was 20 c. Induction curves were recorded at intensities of light, equal 125 and 820 µmol photons $m^{-2} \cdot s^{-1}$. Designation and determination of photosynthetic parameters is given in accordance with conventional nomenclature [4].

Adverse weather conditions were recorded in Krasnoyarsk in August 6-8, 2013. Measurement of the concentration of pollutants was performed in eight posts of the Central Siberian Department of hydrometeorology and environmental monitoring (Federal service) and on the five positions of the Center for implementation of activities on natural resources and environment of the Krasnoyarsk region (Regional service).

3. RESULTS AND DISCUSSION

The program attached to the RAM fluorimeter is allowed to calculate the maximum coefficient of utilization of light energy (the parameter α). Its value is calculated as the coefficient of linear regression built from points lying on light limited plot of "rapid light curve. The course of this curve depends on the environmental conditions [5], and the parameter α characterizes the photosynthetic potential of the leaves of plants.

The variation of the parameter α in the process of vegetation is showed in figures 1 and 2. Reduction of the average value of α on the third day of the effects of AWC (8 August) is observed on the leaves of hawthorn, prinsepia and shadberry (Fig. 1).



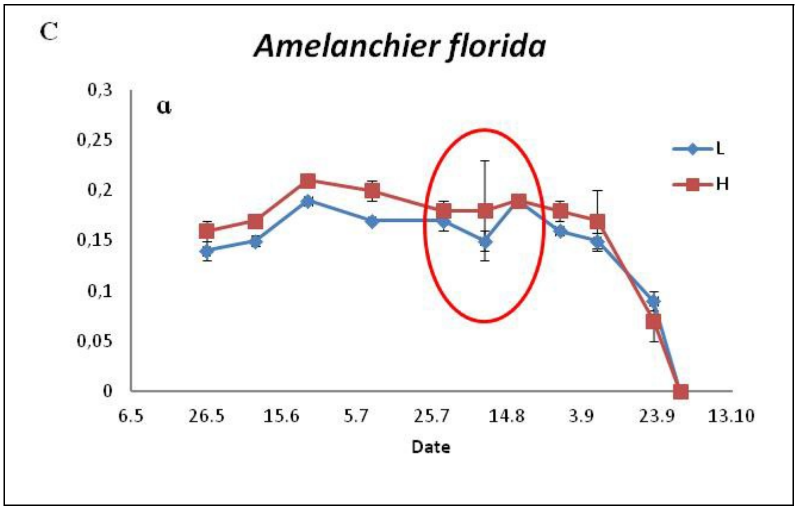


Figure 1. The change of the coefficient of maximum utilization of light energy (the parameter α) in the process of vegetation of hawthorn (A), prinsepia (B) and shadberry (C). The values of the parameter α prior to AWC, while AWC and after AWC are selected in the oval. Measurements of light curves of photosynthesis carried out in two ranges of luminous flux 0-420 (L) and 125-1500 (H) μmol photons $m^{-2}\cdot s^{-1}$

The effect of AWC on the leaves of hawthorn was manifested in the decrease of the parameter α measured in light range H (Fig. 1, A), on a leaf of shadberry - light range L (Fig. 1, C), and on leaves of prinsepia - in two ranges (Fig. 1, B).

The effect of AWC on the leaves of maple and birch is not detected (Fig. 2).

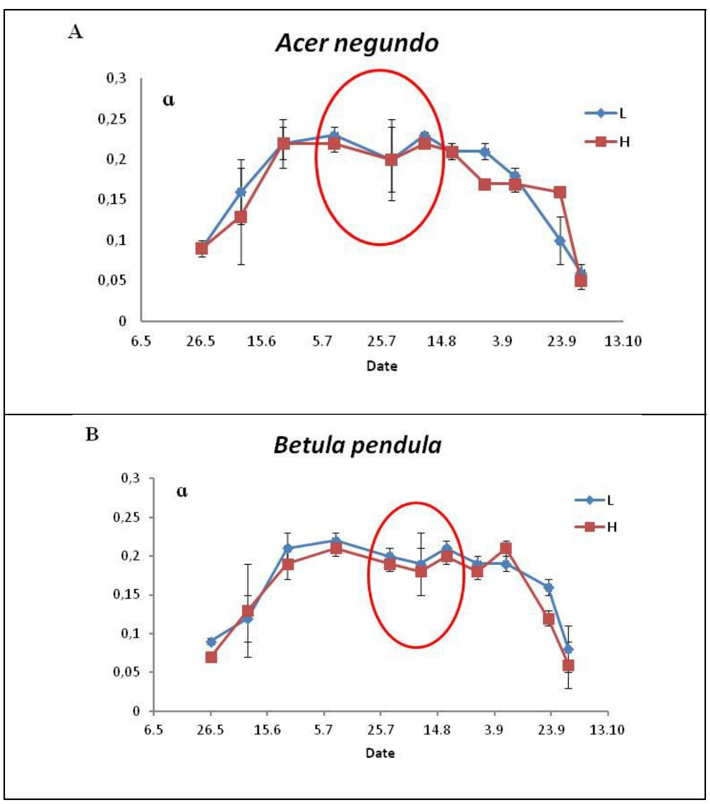


Figure 2. The change in the coefficient of maximum utilization of light energy (the parameter α) in the process of vegetation of maple (A) and birch (B)

Thus, the leaves of three of the five plants were sensitive to AWC.

Other important parameters characterizing the effect of environmental conditions on the photosynthetic apparatus of plants are quantum yield of photosystem (Y(II)). This parameter was determined by induction curves measured at two different light regimes. Quantum yield in leaves of hawthorn decreased under AWC (Fig. 3). The decrease in the value of Y(II) was only defined in the range of the luminous flux 125-1500 μmol photons m^{-2} s^{-1}.

We also marked a change in the quantum yield of fluorescence under adverse weather conditions in the leaves of prinsepiai and shadberry.

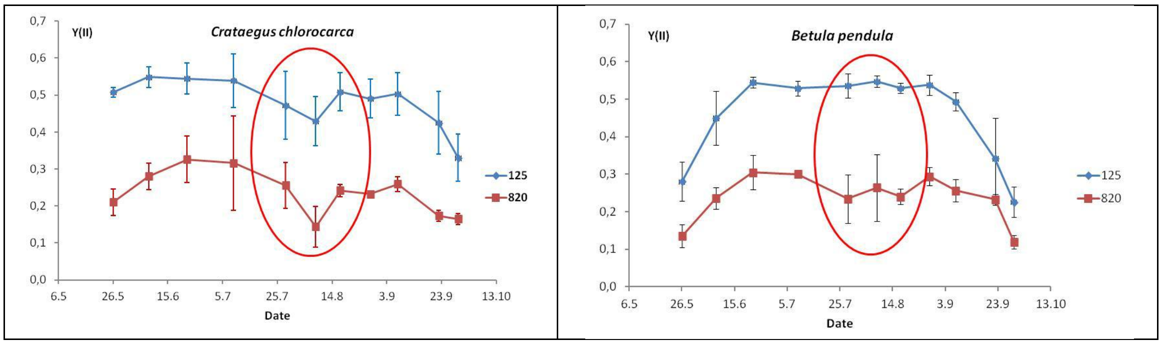


Figure 3. The dynamics of the quantum yield of fluorescence of the leaves of hawthorn (left) and birch (right). The values of Y(II) prior to AWC, while AWC and after AWC are selected in the oval

Quantum yield of birch leaves remained unchanged under the effect of AWC (Fig. 3). The stability of Y(II) to AWC was also observed in maple leaves.

Thus, quantum yield of fluorescence was decreased in the leaves of prinsepia, hawthorn and shadberry in the period of AWC. At the same time, this was not observed in the leaves of birch and maple.

Other important parameters that characterize the photosynthetic apparatus of plants are the speed of electrons through the electron transport chain (ETR), the coefficients of photochemical (qP) and non-photochemical (qN) fluorescence quenching. These parameters were determined by induction curves measured at two different light regimes. For hawthorn leaves are shown (fig. 4) that the parameter ETR (measured in the range of H) was significantly lower in 8 August than in the days of measurements in 28 June and 17 August (no AWC). Change the value of the parameter ETR at AWC was not detected for birch leaves.

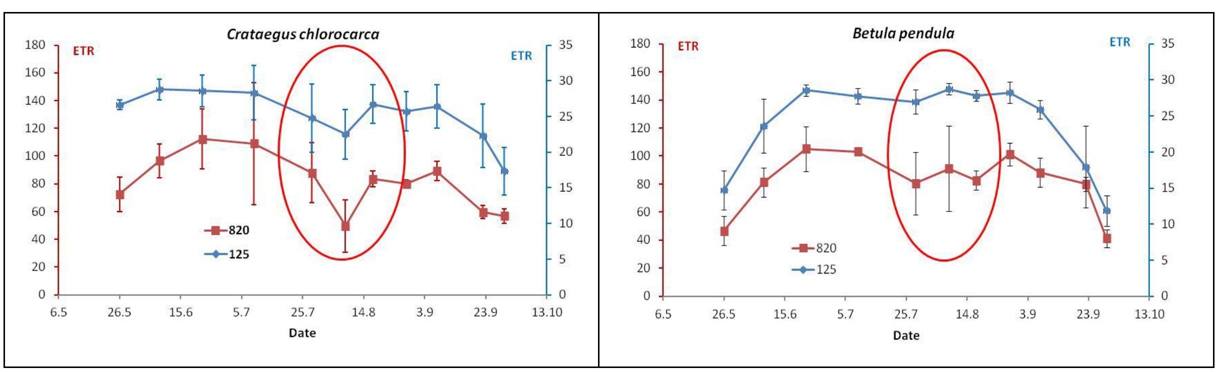


Figure 4. The dynamics of the quantum yield of fluorescence of the leaves of hawthorn (left) and birch (right). The values of ETR (μmol electrons/(m^2•s) prior to AWC, while AWC and after AWC are selected in the oval.

The effect of AWC on the coefficients of photochemical and non-photochemical quenching of fluorescence of the leaves is shown in table 1.

Table 1. The coefficients of photochemical (qP) and photochemical (qN) fluorescence quenching defined by induction curves under the intensity of light is 125 (L) and 820 (H) μmol photons m^{-2} s^{-1}

Plant	Date of measurement	qP		qN	
		L	H	L	H
Crataegus chlorocarca	28.07	0,68 ± 0,09	0,45 ± 0,11	0,51 ± 0,10	0,52 ± 0,03
	08.08	0,63 ± 0,07	**0,24 ± 0,07**	0,53 ± 0,08	0,56 ± 0,10
	17.08	0,70 ± 0,05	0,44 ± 0,01	0,42 ± 0,07	0,54 ± 0,09
Prinsepia sinensis	28.07	0,69 ± 0,07	0,59 ± 0,04	0,43 ± 0,05	0,61 ± 0,06
	08.08	0,71 ± 0,02	**0,47 ± 0,03**	0,44 ± 0,04	0,65 ± 0,02
	17.08	0,72 ± 0,01	0,54 ± 0,01	0,41 ± 0,03	0,66 ± 0,01
Betula pendula	28.07	0,74 ± 0,09	0,44 ± 0,10	0,50 ± 0,09	0,60 ± 0,03
	08.08	0,76 ± 0,01	0,48 ± 0,15	0,43 ± 0,05	0,64 ± 0,02
	17.08	0,73 ± 0,09	0,45 ± 0,02	0,45 ± 0,02	0,67 ± 0,05

From table 1 it is seen that only the value of the coefficient of photochemical fluorescence quenching of leaves of hawthorn and prinsepia (under measured on the intensity of 820 μmol photons m^{-2} s^{-1}) significantly decreased in the period AWC. Under AWC change qP was not in birch leaves.

The data show that AWC influenced on all investigated fluorescence parameters of leaves of hawthorn, prinsepia and shadberry.

Suspended solids are one of the major pollutants of the atmosphere of Krasnoyarsk. Based on the analysis of data monitoring of Federal and regional services we concluded that the size of suspended particles in the period of AWC (August 6-8, 2013) was less than 10 μm. Therefore, one of the main pollutants in the period of AWC was PM_{10} particles.

As mentioned in the introduction the main pollutants of atmospheric air in Krasnoyarsk are benzo(a)pyrene, formaldehyde, nitrogen dioxide and suspended particles (their size may be less than 10 microns). Found that only two of the four substances affect on the fluorescence characteristics of the leaves of plants. There are nitrogen dioxide [6, 7] and PM_{10} [8-10].

Average daily maximum permissible concentration (MPC_{ad}) of nitrogen dioxide in ambient air is equal to 0,04 mg/dm^3, and PM_{10} – 0,06 mg/dm^3. In the period AWC (6-8 August) the concentration of NO_2 increased by 1,7-2,0 times as compared with than the MPC_{ad} and PM_{10} - 6,0 - 6,3 times.

It is established that in the case of a permanent presence (for four months) of particulates less than 10 microns in a concentration of 0,04-0,06 mg/m^3 in air the decrease of the fluorescence parameters of leaves of plants is observed [11]. This concentration is comparable with MPC_{ad} than for PM_{10}. In the period of AWC of August 6-8 PM_{10} concentration was 0,36-0,39 mg/m^3. The high content of suspended particles in the air could cause a decrease in the values of fluorescence parameters of leaves of hawthorn, prinsepia and shadberry.

However, we cannot exclude the influence of nitrogen dioxide or its combined effects of particulate matter on the photosynthesis of plants and shrubs.

4. CONCLUSIONS

Using the pulse modulation fluorimetry it is established that photosynthetic processes of leaves of hawthorn, prinsepia and shadberry are inhibited in the period of AWC. The maple and birch are resistant to high concentrations of pollutants.

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