DROUGHT-INDUCED CHANGES IN CHLOROPHYLL FLUORESCENCE OF YOUNG WHEAT PLANTS

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ABSTRACT
The effects of drought on chlorophyll fluorescence characteristics of photosystem II (PSII) in young winter wheat plants (Triticum aestivum L.) – cv. Sadovo 1 and Katia, were studied. Drought conditions were imposed on 2-week-old plants by withholding water for 10 days. It was found that drought stress increases ground (F₀) fluorescence and decreases maximal (Fₘ), and variable (Fᵥ) fluorescence, as well as Fᵥ/Fₘ parameter in dark adapted leaves. In light adapted leaves a significant decrease in quantum yield (Y), photochemical quenching (qP) and electron transport rate (ETR) of PSII was occurred. In conclusion, it is considered that cv. Katia is more tolerant and cv. Sadovo 1 is more sensitive to drought.

Keywords: chlorophyll fluorescence, drought, wheat

Introduction
In the field plants are often exposed to various environmental stresses. Drought stress is one of the major causes of crop loss worldwide, reducing average yields for most major crop plants by more than 50% (27). Under this stress usually a water deficit in plant tissues develops, thus leading to a significant inhibition of photosynthesis. The ability to maintain the functionality of the photosynthetic machinery under water stress, therefore, is of major importance in drought tolerance. The plant reacts to water deficit with a rapid closure of stomata to avoid further loss of water through transpiration (9, 16). Despite of fact that photosystem II (PSII) is highly drought resistant (28) under conditions of water stress photosynthetic electron transport through PS II is inhibited (6, 7). Several in vivo studies demonstrated that water deficit resulted in damages to the oxygen evolving complex of PSII (18, 24) and to the PSII reaction centers associated with the degradation of D1 protein (9, 13).

In the last years effects of water deficit were studied on different levels: from ecophysiology to cell metabolism (10, 23). The range and importance of these effects depend on the genetically determined plant capacity and sensitivity, as well as on the intensity and duration of the stress, when applied alone or in combination (3).

The aim of this study was to determine the effects of drought stress on chlorophyll fluorescence parameters in leaves of two winter wheat (Triticum aestivum L.) cultivars – cv. Sadovo 1 and cv. Katia.

Materials and methods

Plant material and growth conditions
For this study two cultivars of winter wheat (Triticum aestivum L.) were used: cv. Sadovo 1 and cv. Katia. Plants were grown as soil culture in the plastic pots, according the method described previously for bean plants (29). The measurements were made at the end of stress period on the second leaf, which was fully matured.

Chlorophyll fluorescence
Chlorophyll fluorescence parameters were measured using a pulse amplitude modulation chlorophyll fluorometer MINI-PAM (Walz, Effeltrich, Germany). Minimal fluorescence, F₀, was measured in 60 min dark-adapted leaves using weak modulated light of < 0.15 µmol m⁻² s⁻¹ and maximal fluorescence, Fₘ, was measured after 0.8 s saturating white light pulse (>5500 µmol m⁻² s⁻¹) in the same leaves. Maximal variable fluorescence (Fᵥ=Fₘ-F₀) and the photochemical efficiency of PSII (Fᵥ/Fₘ) for dark adapted leaves were calculated. In light adapted leaves steady state fluorescence yield (Fₛ), maximal fluorescence (Fₘ) after 0.8 s saturating white light pulse (> 5500 µmol m⁻² s⁻¹) and minimal fluorescence (F₀) measured when actinic light was
turned off, were determined. Photochemical (qP) and non-photochemical (qN) quenching parameters were calculated according to Schreiber et al. (21), using the nomenclature of van Kooten and Snel (25). The efficiency of electron transport as a measure of the total photochemical efficiency of PSII (Y) and the rate of electron transport (ETR) were calculated according to Genty et al. (11).

Statistical analysis
Values are the mean ± SE from three consecutive experiments, each including at least five replications of each variant. The Student’s t-test was used to evaluate the differences between control and stressed plants.

Results and Discussion
Drought stress induces an increase in F_0 accompanied by a decrease in F_m and F_v in the second leaf of the studied cultivars, being cv. Katia less affected (Table 1). An increase in F_0 is characteristic of PSII inactivation, whereas a decline in F_m and F_v may indicate the increase in a non-photochemical quenching process at or close to the reaction center (2).

| Parameters of chlorophyll fluorescence in dark adapted leaves of control and drought stressed wheat plants |
|-----------------|-----------------|-----------------|-----------------|
|                 | F_0             | F_m             | F_v             | F_v/F_m         |
| Sadovo 1        |                 |                 |                 |                 |
| Control         | 436±22          | 2094±92         | 1655±78         | 0.792±0.034     |
| Droughted       | 557±24* (126)   | 1612±74* (77)   | 1063±52** (64)  | 0.659±0.032* (83) |
| Katia           |                 |                 |                 |                 |
| Control         | 462±21          | 2166±97         | 1707±77         | 0.784±0.036     |
| Droughted       | 508±23 (110)    | 1997±92 (92)    | 1488±71* (87)   | 0.743±0.033 (95) |

* P<0.5; ** P<0.1

The F_v/F_m ratio, which characterizes the maximal quantum yield of the primary photochemical reactions in dark adapted leaves, was changed significantly in Sadovo 1 and only showed a slight tendency to a decrease in Katia.

Cv. Sadovo 1 presented a decrease of 43% in the proportion of energy driven to the photosynthetic pathway (qP) in the second leaf, while in cv. Katia qP decreased with 17%. Accordingly, in cv. Sadovo 1 Y decreased strongly with 32%, while in cv. Katia Y was less affected (Table 2).

| Parameters of chlorophyll fluorescence in light adapted leaves of control and drought stressed wheat plants |
|-----------------|-----------------|-----------------|-----------------|
|                 | Y               | qP              | qN              | ETR             |
| Sadovo 1        |                 |                 |                 |                 |
| Control         | 0.526±0.023     | 0.817±0.036     | 0.339±0.014     | 126.2±5.3       |
| Droughted       | 0.358±0.016** (68) | 0.464±0.022** (57) | 0.494±0.023** (146) | 89.4±4.2** (71) |
| Katia           |                 |                 |                 |                 |
| Control         | 0.495±0.024     | 0.838±0.038     | 0.355±0.017     | 140.7±6.6       |
| Droughted       | 0.399±0.017* (81) | 0.695±0.034* (83) | 0.426±0.021* (120) | 112.3±5.2* (80) |

* P<0.5; ** P<0.1

By the end of drought period a significant increase was observed in non-photochemical quenching (qN) in the leaves of studied cultivars, and thus denoting an increase in the energy dissipation through non-photochemical processes.

Concerning electron transport rate (ETR) the plants from studied cultivars were significantly affected and presented reduction of 29% (cv. Sadovo 1) and 20% (cv. Katia).

As Baker and Horton (2) mentioned, two distinct phenomena at least, are involved in producing the changes in the fluorescence parameters under unfavorable environmental conditions. One phenomenon results in an increase in F_0, possibly due to the reduced plastoquinone acceptor (Q_a), being unable to be oxidized completely because of
The absorption of a photon can reach a reaction center. "Open" (expressed by qP), rather than on the efficiency of the proportion of reaction centers which are photochemically under our experimental conditions, Y is mainly dependent on presented a similar behavior to Y (Table 2). This means that photochemical efficiency of PSII under photosynthetic yield of electron transport (Y), which is a measure of the total was further highlighted by the significant decline of quantum also indicated by fluorescence measurements. In conclusion, cv. Katia was more efficiently protected than in the cv. Sadovo 1, as indicated by fluorescence measurements. In conclusion, cv. Katia showed a higher drought tolerance in what concerns stress. However, photoinhibitory damage to PSII may be a secondary effect of drought. Our data are in accordance with the statement of Baker and Horton (2) that the bulk of photodamage to PSII reaction centres or damage to PSII reaction centres. The large drought-induced decreases in qP in cv. Sadovo 1 could be due to a combination of both of these factors.

Conclusion

This study supports the contention that photodamage to PSII reaction centres is not a primary factor in the depression of CO₂ assimilation of the wheat leaves induced by the water stress. However, photoinhibitory damage to PSII may be a secondary effect of drought. Our data are in accordance with the statement of Baker and Horton (2) that the bulk of quenching in the stressed leaves is due to reversible qN processes, since Qₐ was maintained in a highly reduced state throughout the quenching. PSII activity in cv. Katia was more efficiently protected than in the cv. Sadovo 1, as indicated by fluorescence measurements. In conclusion, cv. Katia showed a higher drought tolerance in what concerns photosynthetic activity since Fᵥ/Fₘ was maintained, Y and qP were significantly less affected than in the other cultivar, and it presented a lower increase in qN. Cv. Sadovo 1 can be considered as drought sensitive.

Table 1

Table 2
REFERENCES