



DROUGHT-INDUCED CHANGES IN CHLOROPHYLL FLUORESCENCE OF VIGNA PLANTS

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Abstract

The effects of drought on chlorophyll fluorescence characteristics of photosystem II (PSII) in young vigna plants (*Vigna unguiculata* L.) – cv. *Lagoa* and cv. *1183*, 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 (F_0) fluorescence and decreases maximal (F_m), and variable (F_v) fluorescence, as well as F_v/F_m 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. *Lagoa* is more tolerant and cv. *1183* is more sensitive to drought.

Key words: soil drought, vigna, chlorophyll fluorescence, photosystem II, electron transport rate

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% (Wang et al., 2003). 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. Despite of fact that photosystem II (PSII) is highly drought resistant under conditions of water stress photosynthetic electron transport through PS II is inhibited (Chakir and Jensen, 1999). Several *in vivo* studies demonstrated that water deficit resulted in damages to the oxygen evolving complex of PSII and to the PSII reaction centers associated with the degradation of D1 protein (Skotnica et al., 2000).

In the last years effects of water deficit were studied on different levels: from ecophysiology to cell metabolism. 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.

The aim of this study was to determine the effects of drought stress on chlorophyll fluorescence parameters in leaves of young vigna plants (*Vigna unguiculata* L.).

MATERIALS AND METHODS

Plant material and growth conditions

For this study young vigna plants (*Vigna unguiculata* L.) - cv. Lagoa and cv. 1183 were used. Plants were grown as soil culture in the plastic pots, according the method described previously (Zlatev and Yordanov, 2005). The measurements were made at the end of stress period on the first trifoliolate 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, F_0 , was measured in 60 min dark-adapted leaves using weak modulated light of $< 0.15 \mu\text{mol m}^{-2} \text{s}^{-1}$ and maximal fluorescence, F_m , was measured after 0.8 s saturating white light pulse ($> 5500 \mu\text{mol m}^{-2} \text{s}^{-1}$) in the same leaves. Maximal variable fluorescence ($F_v = F_m - F_0$) and the photochemical efficiency of PSII (F_v/F_m) for dark adapted leaves were calculated. In light adapted leaves steady state fluorescence yield (F_s), maximal fluorescence (F'_m) after 0.8 s saturating white light pulse ($> 5500 \mu\text{mol m}^{-2} \text{s}^{-1}$) and minimal fluorescence (F'_0) measured when actinic light was turned off, were determined. Photochemical (qP) and non-photochemical (qN) quenching parameters were calculated according to Schreiber et al. (1986). 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. (1989).

Statistical analysis

Values are the mean \pm 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 first trifoliolate leaf of the studied cultivars, being cv. Lagoa 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.

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 1183 and only showed a slight tendency to a decrease in Lagoa.

Cv. 1183 presented a decrease of 43% in the proportion of energy driven to the photosynthetic pathway (qP) in the first trifoliolate leaf, while in cv. Lagoa qP decreased with 17%. Accordingly, in cv. 1183 Y decreased strongly with 32%, while in cv. Lagoa Y was less affected (Table 2).

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.

Table 1.

Parameters of chlorophyll fluorescence in dark adapted leaves of control and drought stressed bean plants

	F ₀	F _m	F _v	F _v /F _m
		1183		
Control	433±21	2094±93	1653±79	0.793±0.036
Droughted	551±23* (126)	1615±75* (77)	1060±51** (64)	0.658±0.031* (83)
		Lagoa		
Control	465±22	2165±96	1707±78	0.784±0.035
Droughted	508±24 (110)	1994±91 (92)	1488±70* (87)	0.743±0.033 (95)

* P<0.5; ** P<0.1

Table 2.

Parameters of chlorophyll fluorescence in light adapted leaves of control and drought stressed bean plants

	Y	qP	qN	ETR
		1183		
Control	0.524±0.023	0.819±0.036	0.337±0.014	124.2±5.3
Droughted	0.359±0.01** (68)	0.464±0.022** (57)	0.491±0.02** (146)	87.4±4.2** (71)
		Lagoa		
Control	0.496±0.024	0.836±0.038	0.358±0.017	142.7±6.6
Droughted	0.398±0.017* (81)	0.693±0.034* (83)	0.429±0.02* (120)	111.3±5.2* (80)

* P<0.5; ** P<0.1

Concerning electron transport rate (ETR) the plants from studied cultivars were significantly affected and presented reduction of 29% (cv. 1183) and 20% (cv. Lagoa).

In the present work the increase of F₀ and decrease of F_m under drought stress occurred concomitantly to a decrease in F_v/F_m (Table 1) in the studied cultivars. That seems to indicate, to some extent, the occurrence of chronic photoinhibition due to photoinactivation of PSII centers, possibly attributable to D1 protein damage (Campos, 1998). Photoinhibitory impact over PSII might be occurred in wheat droughted leaves since a given light intensity (even at low PPFD) is potentially in greater excess under stress conditions, which usually limit photosynthetic activity. Indeed, during illumination of *Zea mays* wilted leaves, a strong inhibition of PSII efficiency was observed even under moderate PPFD (Saccardy et al., 1998). Low relative leaf water content clearly predisposes the leaves to photoinhibitory damage, and the inhibition of photosynthetic activity could in fact reflect an inactivation of PSII activity and the concomitant uncoupling of non-cyclic photophosphorylation, as shown in *Nerium oleander* (Björkman and Powles, 1984). F_v/F_m reflects the maximal efficiency of excitation energy capture by "open" PSII reaction centers. A decrease in this parameter indicates down regulation of photosynthesis or photoinhibition. First trifoliolate leaf showed a slight decrease in this parameter (Table 1). This is the result of a large proportion of absorbed light

energy not being used by the plants in the photosynthesis process, as shown by the increase in qN (Table 2).

Conclusions

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 (1987) 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. Lagoa was more efficiently protected than in the cv. 1183, as indicated by fluorescence measurements. In conclusion, cv. Lagoa showed a higher drought tolerance in what concerns photosynthetic activity since F_v/F_m was maintained, Y and qP were significantly less affected than in the other cultivar, and it presented a lower increase in qN. Cv. 1183 can be considered as drought sensitive.

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