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Chlorophyll fluorescence quenching analysis of *Solanum nigrum* in relation to water deficit

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ABSTRACT Chlorophyll fluorescence quenching was studied in intact attached leaves of atrazine-susceptible (AS) and atrazine resistant (AR) biotypes of *Solanum nigrum* in relation to water deficit. Comparative studies on light response changes of chlorophyll fluorescence showed that AR plants have a lower electrontransport rate (ETR) and photochemical quenching (qP), and a less effective non-photochemical quenching (NPQ). We observed that photosystem II (PSII) function of both biotypes of *S. nigrum* is tolerant to drought stress.
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KEY WORDS

Solanum nigrum
water deficit
D1 protein mutant
chlorophyll fluorescence

Drought is one of the major important environmental factors limiting photosynthetic CO_2 assimilation. Photosynthesis is impaired mainly as a consequence of stomatal closure. The photosynthetic apparatus appears to be relatively tolerant to dehydration (Chaves 1991). Only when drought is prolonged leading to severe cell dehydration, structural and functional reorganization of PSII can be induced, and the electron transfer and CO_2 assimilation can be additionally affected (Giardi et al. 1996).

Triazine-resistant weeds have Ser→Gly substitution in the 264 position of the photosystem II reaction centre D1 protein, causing a decreased binding of both atrazine and Q_B (Pfister and Arntzen 1979). Atrazine resistant biotype also displays pleiotropic effects, including both structural and functional changes of the PSII complexes in the chloroplast. Triazine-resistance reflected in reduced rate of PSII electrontransport (especially between acceptors Q_A and Q_B), shade-type chloroplast structure, including changes in light-harvesting proteins and lipid/fatty acid composition (Szigeti and Lehoczki 2003) and in modified light response of chlorophyll fluorescence characteristics (Darkó et al. 1996; Váradi et al. 2003).

Our aim was to compare the effects of serious water shortage on PSII of atrazine-susceptible (AS) and resistant (AR) biotypes of *Solanum nigrum.* In this paper, we studied the effect of long-term water deficit on PSII activities by measuring chlorophyll fluorescence.

Materials and Methods

Plant material: potted AR and AS *S. nigrum* plants were grown in soil in the growth chamber under moderate (350 μmol photons m^{-2} s^{-1}) light conditions, 16 h light period and 25-28°C. The plants were irrigated every 2 d throughout the experiments. The youngest, fully expanded intact leaves of about 40-45-day-old plants were used as control. This time irrigation was stopped in several plant containers, and the measurements were repeated every 3-4 d to capture different degrees of drought.

Chlorophyll fluorescence measurements. Chlorophyll fluorescence measurements were carried out in dark adapted leaves with a pulse amplitude modulated fluorometer (PAM-200 Walz, Germany). In the measurements the standard setting of Run 8 were used according to the PAM-200 handbook (Operating Manual, 1st Edition, 1997). Before start of the Run 8, initial fluorescence yield (Fo) and maximum fluorescence yield (Fm) were determined on dark adapted samples with a saturating pulse (3000 μmol m^{-2} s^{-1} PFD). After start of the Run 8, a 5 min preillumination at 210 μmol m^{-2} s^{-1} actinic light (AL) intensity was applied in order to allow light adaptation of the sample and activation of Calvin cycle enzymes. Then AL changed to 60 μmol m^{-2} s^{-1} PFD and increased every 5 min until 1250 μmol m^{-2} s^{-1} PFD has reached (10 steps). The quenched levels of maximum chlorophyll fluorescence (Fm') parameters were determined at each AL level by saturated pulses (3000 μmol m^{-2} s^{-1} PFD, of 1 s duration) applied to the leaves at the end of 10 s AL illumination. After the AL have been switched off, far-red light was exerted for the determination of the minimal (Fo') level of fluorescence for correct determination of qP and Fv'/Fm' at each light intensity. The terminology suggested by van Kooten and Snel (1990) was used. From measured parameters (Fo, Fm, Fo', Fm' and the steady state fluorescence level, Fs) the optimum quantum yield (Fv/Fm), photochemical quenching coefficient (qP), non-photochemical quenching (NPQ) and relative quantum yield of PSII photochemistry (QY) were calculated according to Schreiber et al. (1986); Genty et al. (1989); Bilger and Björkman (1990), respectively.

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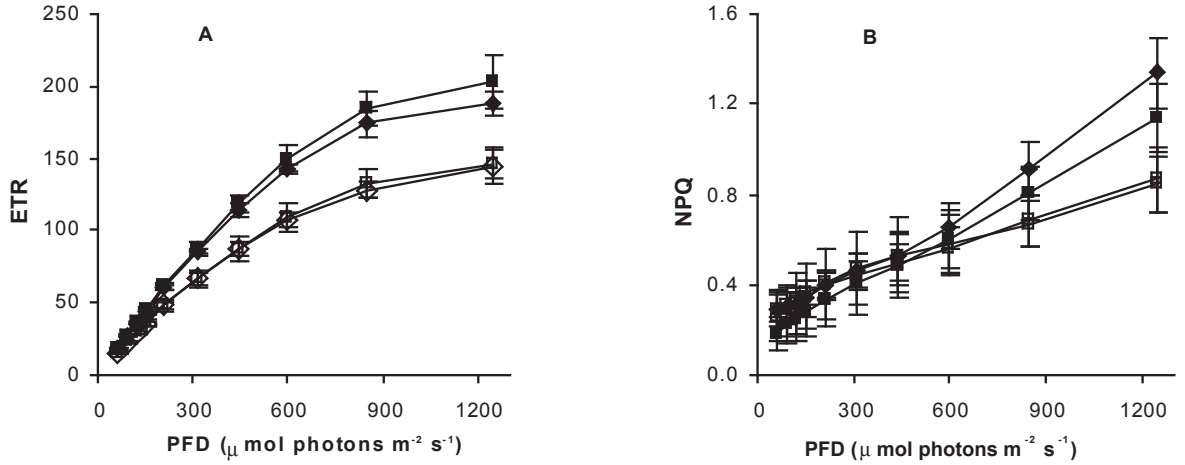

Figure 1. Light response curves of photosynthetic electrontransport rate and non-photochemical quenching of the atrazine-susceptible (close symbols) and atrazine-resistant (open symbols) biotypes of medial-light-grown *Solanum nigrum* (control (diamond) and drought stressed (rectangle)). The results are means from three independent experiments.

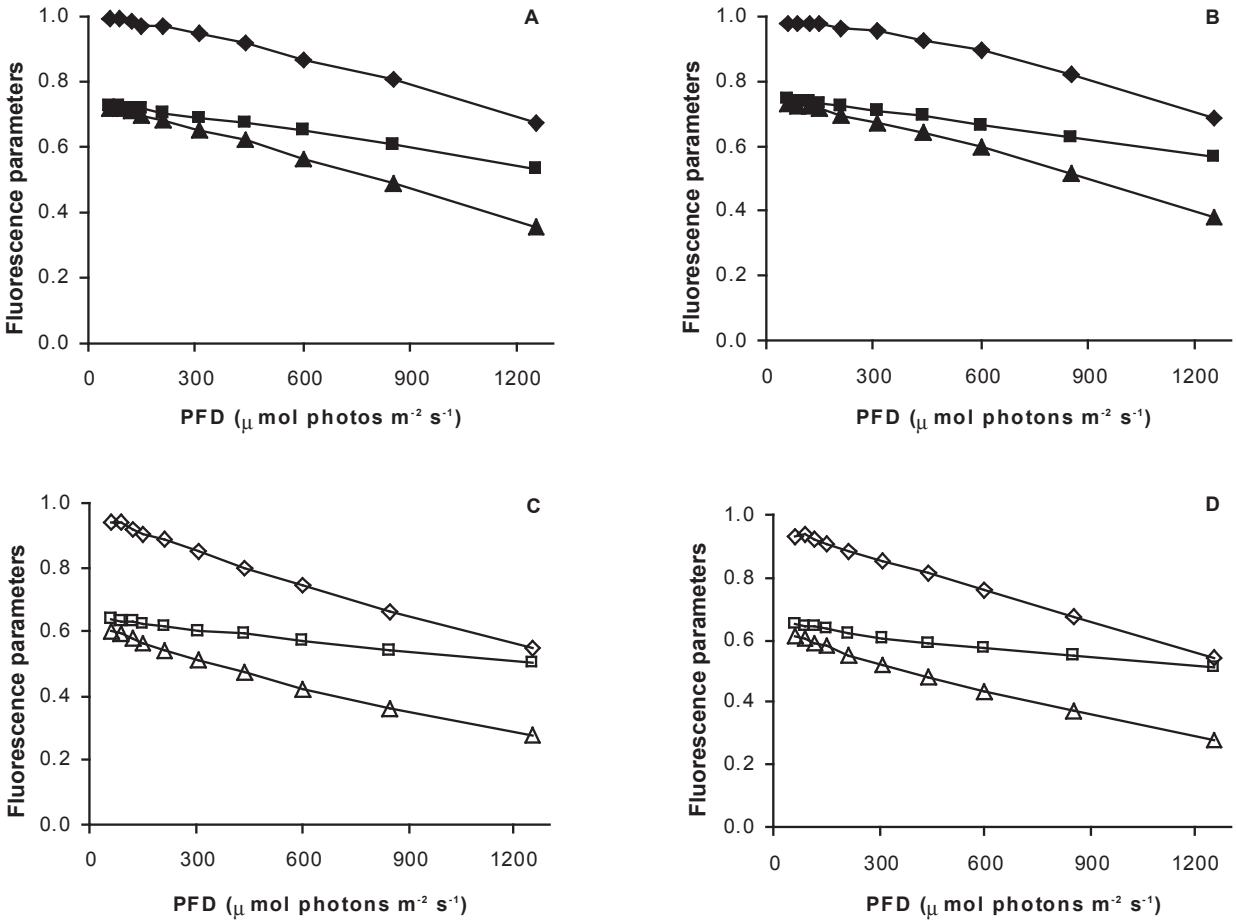

Figure 2. Light response curves of fluorescence parameters of the atrazine-susceptible (close symbols) and atrazine-resistant (open symbols) biotypes of medial-light-grown *Solanum nigrum* under well-watered conditions (A and C) and during progressive water shortage (B and D). The diamond symbols signify the photochemical quenching (qP), the rectangle symbols represent the Fv'/Fm' parameter, and the triangle symbols indicate the effective quantum yield (QY). The results are means from three independent experiments.

Results and Discussion

Photochemical efficiency of PS II (Fv/Fm) was 0,81±0,02 and 0,79±0,02 for well watered AS and AR plants, respectively. Water deficit did not cause changes in Fv/Fm within 10 days. However, there are marked differences between chlorophyll fluorescence parameters in well watered AS and AR biotypes. The light responses of calculated fluorescence quenching parameters, NPQ, ETR and qP, and QY and Fv'/Fm' are shown on (Fig. 1) and (Fig. 2), respectively. The values of ETR (Fig. 1A) and NPQ (Fig. 1B) increased with rising AL intensity, but for the AR biotype they remained generally below the values for the AS plant (Fig. 1). The light responses of QY and qP of well watered plants demonstrated a lower PSII efficiency in the AR biotypes at all light intensities (Figs. 2A and B). Moreover, it can be proved that the values of Fv'/Fm' parameter on low light intensities differ slightly to the advantage of the AS *S. nigrum* plants, but not significantly. Furthermore, this distinction reduced at higher light intensities. Only a similar difference was observed for all chlorophyll fluorescence parameters for AS and AR biotypes after 10 days progressive dehydratation (Figs. 2B and 2D). Thus, we did not find any significant changes in the light responses of PSII electrontransport rate, photochemical and non-photochemical quenching between well watered and drought stressed plants.

It seems, that the effects of moderate or severe water deficit are not reflected at the level of photosystem II function in AS and AR biotypes of *S. nigrum* plants as revealed by chlorophyll fluorescence measurements. We concluded, that PSII function of both biotypes of *S. nigrum* is well prevented from water stress.

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