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Interspecific variations of photochemical properties in a xerotherm grassland community

Sz Veres[1]*, O Mile[1], R Láposi[1], G Lakatos[2], I Mészáros[1]

[1]Department of Botany, Debrecen University, Debrecen, Hungary, [2]Department of Applied Ecology, Debrecen University, Debrecen, Hungary

ABSTRACT In this work the role of xanthophyll cycle and its relation to the photosynthetic activity in the dominant species of a semiarid sandy grassland community (*Potentillo-Festucetum pseudovinae)* were studied during the stressful summer period. The total amount of xanthophyll cycle pigments (violaxanthin, anteraxanthin, zeaxanthin) related to total chlorophyll content (VAZ pool) showed considerable interspecific alterations and it was 2-3 times larger in the summer period than in spring. The changes in the xanthophyll cycle, the potential (F_v/F_m) and actual photochemical efficiency ($\Delta F/F_m'$) of PSII, as well as, the results of parallel measurements on their daily dynamics show that zeaxanthin has a major role in the photoinhibition in the photosynthetic apparatus during the summer stress on sandy grassland species. In July, the decreases of F_v/F_m was accompanied with increases of NPQ at the 100-120% extent depending on the species.
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KEY WORDS

chlorophyll fluorescence
non-photochemical quenching (NPQ)
photochemical efficiency of PSII
semiarid grassland
xanthophyll cycle

Species of semiarid sandy grassland are exposed to intense abiotic stresses during the summer months, such as high light stress combined with high temperature and drought effects. In these stress situations the basic physiological processes are modified, especially the photosynthetic activity may be strongly affected. In stressed plants only a part of light energy can be used to drive photosynthetic electron transport, though excitation energy may accumulate and potentially damage the photochemical systems (Siefermann-Harms 1987). The role of xanthophyll cycle components have been revealed as being decisive in heat dissipation of excess excitation energy in light-harvesting complexes with respect to the capacity for photochemical utilization. The contents of zeaxanthin + antheraxanthin are correlated with non-radiative energy dissipation measured as non-photochemical chlorophyll fluorescence quenching (NPQ) and play an important role in protecting the photochemical apparatus against the destructive effects of excess light (Demmig-Adams 1989). The aim of this work has been to study the role of xanthophyll cycle and its relation to the photosynthetic activity in the dominant species of a semiarid sandy grassland community (*Potentillo-Festucetum pseudovinae)* during the stressful summer period.

Materials and Methods

The experimental site is situated in the sandy region of South-Eastern Hungary (Veres et al. 2002). The following typical species of the xerotherm grassland community of *Potentillo-Festucetum pseudovinae* were examined *in situ* during the summer: *Festuca pseudonvina*, *Koeleria glauca*, *Potentilla arenaria*, *Rumex acetosella*, *Thymus degenianus.* The concentration of carotenoids was determined by reverse-phase process with HPLC, (eluent solutions: ethylacetate, acetonitril: water 9:1, column: Nucleosil C18, 5µ), the measurement of chlorophylls were performed spectrophotometrically from 80% acetone extract (Wellburn, 1994). The chlorophyll fluorescence parameters (F_v/F_m, $\Delta F/F_m'$, qP, NPQ) were measured with PAM 2000 fluorometer (WALZ, Germany). The F_v/F_m was determined after 20 min. dark adaptation using specific leaf clips. The time course of $\Delta F/F_m'$ was measured on same leaves under natural light conditions. In separate experiments chlorophyll fluorescence quenching was studied after dark adaptation of detached leaves at two different actinic light intensities for 5 min. The quenching was recorded by using saturation pulses in every 20 s. This paper presents the results of measurements performed during the summer months of 1998 and 1999.

*Corresponding author. E-mail: vszilvia@tigris.klte.hu

Results and Discussion

The total amount of xanthophyll cycle pigments (violaxanthin, anteraxanthin, zeaxanthin) related to total chlorophyll content, that so called VAZ pool size became 2-3 times larger in the summer period, and showed considerable interspecific alterations, as well. From the examined species, the percentage of the VAZ pool size was the smallest in the case of *Rumex acetosella*, while the VAZ cycle could be characterized by a large de-epoxidation activity. The other extremity was represented by *Koeleria glauca* with the large VAZ pool size and relatively small degree of diurnal violaxanthin de-epoxidation. In the case of the *Rumex acetosella*, the large activity of the xanthophyll cycle can be regarded as a mechanism compensating for the small VAZ pool size. The midday depression of F_v/F_m reflects photoinhibition, which was the highest in the case of *Rumex acetosella* and also indicates the appearance of active protecting mechanisms. The values of $\Delta F/Fm'$ showed diurnal transient decreases in all the species, which is a general feature of photosynthesis in natural environment. In the case of *Festuca* and *Potentilla*, the minimal values of $\Delta F/$

Fm' at noon were low, they ranged between 0.1 and 0.2, indicating the strong over-reduction of PSII. In *Thymus* and other species the minimal ΔF/Fm' was higher (0.2 - 0.4). This indicated that the former two species were more susceptible to photoinhibition during the study period than the latter ones. The performance of the xanthophyll cycle, the potential (F_v/F_m) and actual photochemical efficiency ($\Delta F/F_m'$) of PSII, as well as, the results of parallel measurements on their daily dynamics show that zeaxanthin has a major role in the prevention of light inhibition in the photosynthetic apparatus during the summer stress on sandy grassland species.

Separate experiments assessed the susceptibility of plants to photoinhibition by exposing dark adapted leaves to two actinic light intensities (200 and 800 $\mu molm^{-2}s^{-1}$) for 5 minutes. The non-photochemical chlorophyll fluorescence quenching show much slighter daily fluctuations in NPQ values in early summer than in late summer. At the end of July large increases of NPQ was observed especially at high actinic light intensities (800 $\mu molm^{-2}s^{-1}$). In July parallelly to the increasing of light intensity, decrease of F_v/F_m was accompanied with the 100-120% increase of NPQ. Every species maintained relatively high actual photochemical activity (0.51 – 0.6 in early summer and 0.65-0.78 in summer) under both different actinic light intensities. The ratio of (1-qP/NPQ) signs the amount of the excess photons (Park et al. 1995), which is getting more important in the presence of other abiotic stress factors, like high temperature and moderate drought. The value of this index was generally higher in grasslike species (*Koeleria* and *Festuca*), than broad-leaved species. All the species can be characterised by relatively high photosynthetic electron transport rate, thus the differences were mainly resulting from different NPQ values.

The data suggest that these species have efficient non-photochemical processes to dissipate the excitation energy and thereby to protect their photosynthetic systems, which may be important elements of survival of summer extreme conditions in the semiarid habitat.

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