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Desiccation survival times in different desiccation-tolerant plants

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ABSTRACT There is not exact information on the longevity of the desiccated period after what the desiccation tolerant plants can recover their photosynthetic structure and function. Generally, the longer the period spent in a desiccated state the less is the potential to full metabolic recovery. We know just that vascular DT-s can survive longer desiccated periods than cryptogams. Therefore, in the case of three cryptogam DT species: the moss *Tortula ruralis*, and the lichens *Cladonia convoluta*, and *C. furcata*, and two vascular monocotyledonous DT species: *Xerophyta scabrida*, and *Coleochloa microcephala* were examined the recovery of their net CO_2 assimilation during rehydration (following stored in dry stage for different lengths). According to our results the cryptogams were able to recover their photosynthetic activity just after 4 months or less, while the leaves of *X. scabrida* and *C. microcephala* remained able to revive after 2-11 years of desiccation.
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KEY WORDS

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chlorophyll fluorescence

Desiccation tolerant (DT) plants can revive after shorter or longer periods in the air-dried desiccated state. DT plants may be subdivided into homoiochlorophyllous DT (HDT) and poikilochlorophyllous DT (PDT) groups (Tuba et al. 1994). Much have been published on the different aspects of the photosynthetic responses of DT plants but we still do not have enough information on the longevity of the desiccated period what the photosynthetic green tissues of the DT plants can survive. Previous work on the survival of DT plants has only investigated viability and recovery of water relations (*e.g.* Gaff 1977; Bewley 1979; Alpert 2000) and has not dealt with the time limit to metabolic and photosynthetic recoverability in DT-s. We report here the recovery of respiration, photosynthesis and the reconstitution of photosynthetic apparatus during rehydration after different years spent in an air dry state in the leaves of some HDT (the lichens *Cladonia convoluta*, *Cladonia furcata*, and the moss *Tortula ruralis*) and PDT (*Xerophyta scabrida* and *Coleochloa microcephala*) plants.

Materials and Methods

Plant materials

The green algal photobiont (*Trebouxia*) lichens *Cladonia convoluta* (Lam.) P.Cout. Vain. and *Cladonia furcata* (Huds.) Schrad. and the ectohydric moss *Tortula ruralis* (Hedw.) Gaertn et al. ssp. ruralis (see also Tuba et al. 1996) were originally growing in the stand of the *Festucetum vaginatae danubiale* grassland near Vácrátót, Hungary (5 km E of Budapest) at 180 m altitude.

Xerophyta scabrida (Pax) Th. Dur. et Schinz, is a member of the Velloziaceae family (Velloziales, related to the Bromeliales). *Coleochloa microcephala* Nelmes, is a member of the Cyperaceae family (Cyperales). Air-dried leaves of both species were collected in Tanzania (Uluguru Mts., SSW of Morogoro town at 650 m altitude) by Pócs by the end of the dry season in 1988 and 1999, respectively.

Rehydration procedure, measurement of gas exchange, and fluorescence induction kinetics

Rehydration procedure and CO_2 exchange in light and dark measurements were carried out as described by Tuba et al. (1994; 1996). Flurescence parameters (chlorophyll-fluorescence induction values of a dark-adapted sample, $F_v/F_m = (F_m\text{-}F_o)/F_m$, and $Rfd(m) = (F_m\text{-}F_s)/F_s$ were measured as described by Csintalan et al. (1999).

Results

The three HDT plants

Only the HDT plants stored in dry stage for maximum 4 months or just freshly collected ones were able to recover their photosynthetic structure and function (after 48 hours of rehydration) from among the mosses/lichens stored different lengths in dry stage (Table 1).

In details, just the freshly collected two *Cladonia* species showed fluorescence parameters characteristic for normally functioning lichens. Additionally, the "fresh" lichens were able alone to reassum their net CO_2 assimilation (after 48 hours of rehydration). Of moss *T. ruralis* rehydrated after 4 months and 3 years of desiccated period displayed fluorescence parameters similar to completely functioning mosses. Only the mosses stored in dry stage for 4 months or less were reached net CO_2 assimilation, while the samples with longer dry period recovered only their respiration activity.

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Table 1. Fluorescence parameters, CO_2 assimilation and dark respiration rates of HDT *Tortula ruralis*, *Cladonia convoluta*, and *C. furcata* 48 hours after rehydration (following different lengths of desiccated period).

Tortula ruralis					
Lengths of desiccated period	15 years	9 years	3 years	4 months	fresh
Fv/Fm = (Fm-Fo)/Fm	0.403 ± 0.080	0.353 ± 0.049	0.686 ± 0.033	0.782 ± 0.005	0.767 ± 0.007
RFd(m) = (Fm-Fs)/Fs	0.817 ± 0.195	0.673 ± 0.108	1.842 ± 0.194	3.758 ± 0.345	4.037 ± 0.309
Dark respiration (μmol.m^{-2}.s^{-1})	-2.421 ± 0.740	-6.300 ± 1.870	-2.649 ± 1.096	-1.501 ± 0.512	-1.483 ± 0.314
Assimilation (μmol.m^{-2}.s^{-1})	-3.129 ± 1.114	-6.837 ± 1.262	-2.479 ± 1.018	1.808 ± 0.665	5.845 ± 1.491
Cladonia convoluta, C. furcata	*C. convoluta*	*C. convoluta*	*C. furcata*	*C. convoluta*	*C. furcata*
Lengths of desiccated period	16 years	9 years	9 years	Fresh	fresh
Fv/Fm = (Fm-Fo)/Fm	0.257 ± 0.079	0.256 ± 0.074	0.291 ± 0.033	0.725 ± 0.012	0.717 ± 0.014
RFd(m) = (Fm-Fs)/Fs	0.357 ± 0.233	0.438 ± 0.162	0.507 ± 0.011	2.383 ± 0.385	2.033 ± 0.217
Dark respiration (μmol.m^{-2}.s^{-1})	-1.586	-2.826	-2.800	-1.025 ± 0.119	-1.180 ± 0.331
Assimilation (μmol.m^{-2}.s^{-1})	-1.422	-3.025	-2.702	6.398 ± 0.573	10.010 ± 1.162

" - " means respiration, " + " means assimilation

The two PDT plants

The leaves of *X. scabrida* and *C. microcephala* remained viable and were able to revive after 2 and 11 years of desiccation, respectively (Table 2).

In *X. scabrida* leaves stored in dry stage for as many as 11 years the fluorescence parameters characteristic for normally functioning plants were restored on the 4th day after rehydration. The rehydrated leaves kept their photosynthetically active state for 12 days, when they were capable to maintain measurably net CO_2 assimilation.

In *C. microcephala* leaves stored in dry stage for 1 year the fluorescence parameters of normally functioning plants were reached on the 3-5th days after rehydration (at this time the leaves started to turn in green) and maintained their photosynthetic activity until the 13th – 17th day. The net CO_2 assimilation of the revived leaves were present between the 2nd and 9th day and after the 10th days only respiration activity was detectable.

The degree of restoration of photosynthesis in the *C. microcephala* leaves stored in dry stage for 2 years was less extent as compared to the leaves stored to 1 year. The net CO_2 assimilation rate was lower and it was reached after longer revival period (on the 7th day).

Discussion

The longest period what DT lichens and mosses were able to survive without permanent damage to their photosynthetic system is 4-6 months while algae are usually unable to recover their photosynthesis after longer periods than 3 months (Bewley 2000). This is well supported by our results on the 3 HDT species: they are not able to recover their CO_2 assimilation ability after 4 months of desiccated period. However the leaves of examined 2 PDT species remained their capability to revive after many even remarkable number (11) of years of desiccation, too.

Table 2. Fluorescence parameters, CO_2 assimilation and dark respiration rates of PDT *Xerophyta scabrida* and *Coleochloa microcephala* during rehydration (following different lengths of desiccated period).

			Length of desiccated period
Xerophyta scabrida			
Measurement: on 16th day of rehydration			
	Fv/Fm = (Fm-Fo)/Fm	0.763 ± 0.032	11 years
	RFd(m) = (Fm-Fs)/Fs	2.302 ± 0.525	
	Dark respiration (mmol.m^{-2}.s^{-1})	4.547 ± 1.062	
	Assimilation (μmol.m^{-2}.s^{-1})	-1.267 ± 0.714	
Coleochloa microcephala			
Measurement: on 6th day of rehydration			
	Fv/Fm = (Fm-Fo)/Fm	0.769 ± 0.016	1 year
	RFd(m) = (Fm-Fs)/Fs	2.046 ± 0.195	
	Assimilation (μmol.m^{-2}.s^{-1})	2.637 ± 0.330	
Measurement: on 7th day of rehydration			
	Fv/Fm = (Fm-Fo)/Fm	0.809	2 years
	RFd(m) = (Fm-Fs)/Fs	1.690	
	Dark respiration (mmol.m^{-2}.s^{-1})	0.477 ± 0.371	
	Assimilation (μmol.m^{-2}.s^{-1})	-1.356 ± 0.390	

" - " means respiration, " + " means assimilation

These data reflect the fundamental difference between the HDT and PDT plants. The PDT strategy has evolved in habitats where the duration of the desiccated state takes months. Under these conditions it is evidently more advantageous to dismantle the whole photosynthetic apparatus and reconstitute it after rehydration. However, the HDT strategy is more favourable in habitats where the desiccated periods are short and these short periods of desiccation and rehydration frequently alternate. The quick responding HDT-s are subjected to frequent (daily) alterations, while the "longer-responding" (slower) PDT-s undergo the profound desiccation/rehydration cycles less frequent / at larger time intervals. These are reflected in the remarkable difference in the length of the survived desiccated stage of HDT and PDT plants.

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