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Carbon sequestration of the poikilohydric moss carpet vegetation in semidesert sandy grassland ecosystem

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ABSTRACT Seasonal change in diurnal CO_2 exchange of the desiccation-tolerant ectohydric moss *Tortula ruralis* was investigated *in situ* to determine its contribution to CO_2 exchange of the carbon balance of the temperate semi-arid sandy grassland ecosystem. A hemisphere perspex chamber (20 cm in diameter) was used to measure the CO_2 gas exchange of the moss cushions. Diurnal course of air temperature, surface temperature of moss carpet, and photosynthetic photon flux density were also monitored. The seasonal characteristics of the diurnal course of net CO_2 assimilation in *T. ruralis* showed strong dependence on microclimatic conditions. The highest daily carbon fixation rates were measured in December and January. In summer, the moss carpet of the community remained mainly dormant and the daily C-balance started to increase again in October. During the year the daily C-balances of *T. ruralis* was positive. These results demonstrate that the *T. ruralis* contribute significantly to the C-balance of the sandy grassland vegetation in the large of the year.

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KEY WORDS

carbon balance
diurnal CO_2 gas exchange
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Mosses being poikilohydric they cannot regulate their water content, their water loss is determined by saturation deficit, boundary layer resistance and the radiation environment and they desiccate and get rewetted as a daily routine (Proctor 1979).

In the temperate climate extensive temperate continental areas are covered by grassland in which small poikilohydric species are dominant. In these grasslands like in temperate semidesert grasslands the amount of precipitation is small and during the hot and even cool but dry periods only water vapour in the air and dew formation can serve as more or less regular water sources for hydration (Link and Nash 1984; Büdel and Lange 1991).

Even in the middle of Europe, Hungary has areas where the relatively low and unevenly distributed yearly precipitation and the sandy soil with its small water holding capacity result in a semi-arid grassland. In this grassland the small poikilohydric plants, first of all the moss *Tortula ruralis* contribute considerably to the total cover (20–80%) forming a poikilohydric mat vegetation. So this moss undoubtedly has an important role in the function of this community (Csintalan et al. 2000).

Recent results also have shown that *T. ruralis* can absorb water to above the water compensation point even from near-saturated air, and suggest that dew deposition sufficient to be obvious to the eye should be enough to yield a positive daily carbon balance.

However, further field measurements are needed to establish the frequency and the overall length of the photosynthetically active period during the course of the year and to elucidate their seasonal and annual carbon balance. This is especially important task because there is no data about the seasonal and annual C-balance of the temperate poikilohydric (dominated) vegetation.

The principal aim of our present paper was to describe the seasonal and annual CO_2 exchange and C-balance of the poikilohydric moss cushions in a semi-arid sand temperate grassland ecosytem.

Materials and Methods

Tortula ruralis (Hedw.) Gaertn. ssp. *ruralis*, the most abundant ectohydric desiccation tolerant moss species of the calcareous semi-arid sandy grassland, *Festucetum vaginatae danubiale*, was investigated *in situ*. In stand of the community near Vácrátót large patches are covered by *T. ruralis*, appearing as “black spots” in summer because of the dark colour of the desiccated moss carpet.

Moss cushions selected for gas exchange measurements were situated in an open (vegetation gaps) and in a more closed grassland stand. Moss cover was 60-80% in the open and 20-50% in the closed stand. Gas exchange measurements were carried out by using a LiCOR-6200 IRGA (LICOR) operated in a closed system on 5 cushions at each site with 3 replicate measurements on each cushion. The gas exchange chamber was a perspex hemisphere of 2 dm^3 volume. Diurnal course of gas exchange mesurements on moss cushions includes correction for soil respiration measured separately by placing same chamber on bare ground.

The field measurements were carried out by 3 to 4 weeks through a year starting with 13th November, 2000.

Diurnal course of air temperature, surface temperature of the moss carpet, and photosynthetic photon flux density (PPFD) were measured simultaneously with CO_2 gas exchange by a RAYNGER II infrared thermometer (Raytek Co.) and a sunfleck ceptometer (Decagon). Diurnal change

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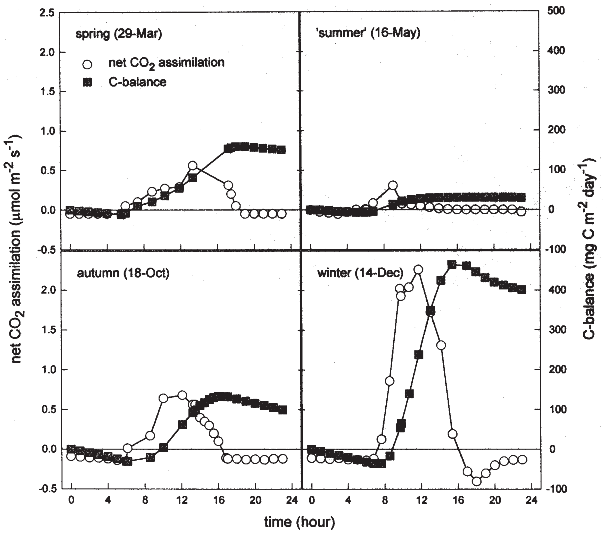

Figure 1. Diurnal changes in photosynthetic photon flux density (PPFD) and moss cushion surface temperature on typical days of the four seasons.

in water content was determined gravimetrically. Daily carbon balances were calculated by integration of the net CO_2 assimilation rates.

Results and Discussion

The seasonal characteristics of the diurnal course of net CO_2 assimilation in poikilohydric *T. ruralis* showed strong dependence on microclimatic conditions (Figs. 1 and 2) such

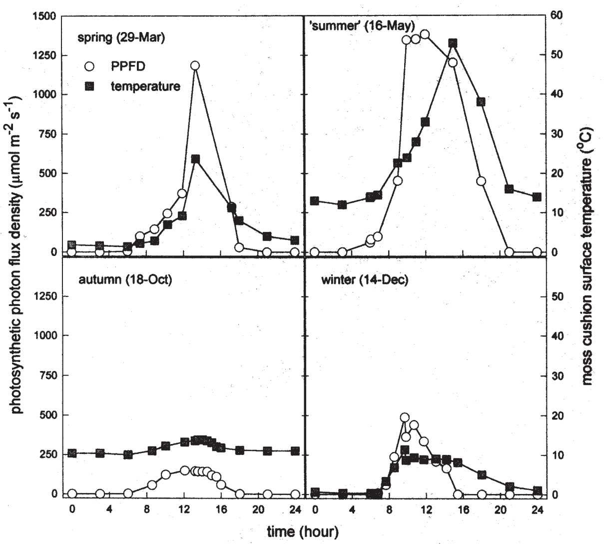

Figure 2. Diurnal changes in net CO_2 assimilation and daily C-balance of moss *T. ruralis* on typical days of the four seasons. The maximal water content (given in percentage of dry weight) of examined moss cushions were 94% in spring, 68% in summer, 152% in autumn, and 221% in winter, respectively.

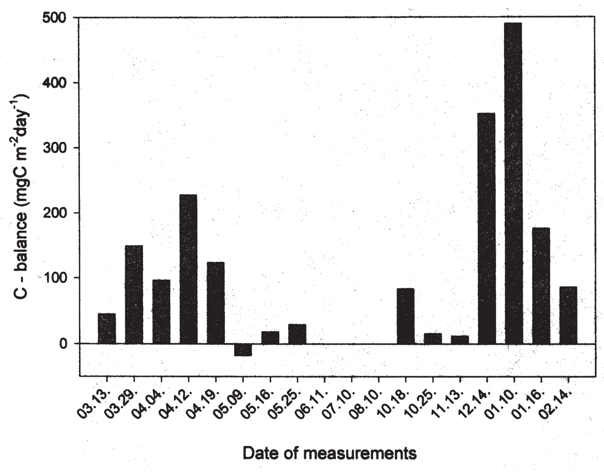

Figure 3. Seasonal change in daily C-balance of moss *T. ruralis* on the basis of *in situ* field CO_2 gas exchange measurement series in 2001.

as the photon flux density, the air temperature and the surface temperature of the moss carpet. The moisture conditions of a given day and even of the preceding days play also important role by the significant influence of the water content of this unvascular plant.

The summer and late spring months was not favourable for *T. ruralis* due to the frequent drought, direct exposure and small amount of dew-fall during the dawns, whereas the months from late autumn to early spring ensure more intensive CO_2 assimilation by balanced distribution of precipitation, higher air humidity, and lower daily radiation. This is well reflected in the quantum use efficiency of net assimilation, too (Figs. 1 and 2).

The seasonal change in daily carbon balance (Figs. 2 and 3) also indicates that the above 4-5 months was the most favourable for *T. ruralis*. The highest daily carbon fixation rates were measured in December and January.

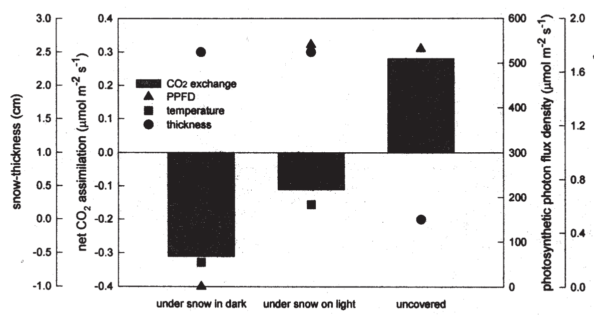

Figure 4. Effect of snow cover on net CO_2 assimilation of moss *T. ruralis* on a slightly clouded day in March. The light intensity was around 500 µmol m^{-2} s^{-1}. The water content of moss cushions was 182% of dry weight.

During the spring, the days are getting longer, the temperature and light intensity are increasing, thereby favouring higher CO_2 assimilation rates. However on account of the increasing water vapour deficit the active period of the days becomes shorter thereby decreasing the daily carbon balance (Fig. 3, 04.04, 04.12).

Simultaneously with the rising daily average temperature of the days, the moss cushions are metabolically inactive during larger part of the day. Occasionally the dew-fall at dawns still results in rehydration and reactivation. However the short CO_2 assimilation period due to the fast desiccation in the morning cannot compensate for the carbon loss during the dark thus the C-balance becomes negative (Fig. 3, 05.09). In summer, the moss carpet of the community remains mainly dormant and the daily C-balance starts to increase again only in October (Fig. 3, 10.18).

In winter the C-balance is significantly influenced by the snow cover. Examining the light transmission through the snow layer and the effect of its thickness on CO_2 assimilation, we previously found that *T. ruralis* was able to photosynthesize under 15 cm thick blanket of snow cover on clear days. Considering the light transmission and insulation features of snow cover, and that it prevents the moss cushions against drying out on windy days, the snow seems to be favourable up to 5 cm for this moss species.

In the course of the presented diurnal field experiment series, on a slight cloudy day in March (light intensity was around 500 μmol m^{-2} s^{-1}) the net CO_2 assimilation of *T. ruralis* under 2.5 cm thick snow layer was higher than the dark respiration, but the rate of photosinthesis could not exceed the intensity of respiration rate (Fig. 4). Removing the snow cover, the net assimilation rapidly increased and turned positive by the daily C-balance.

Conclusion

During the year the daily C-balances of *T. ruralis* was positive except the days, in which the mosses spent in dry, metabolically inactive state. These results demonstrate that the *T. ruralis* contribute significantly to the C-balance of the sandy grassland vegetation in the large of the year.

The performed yearly series of these measurments give basic informations abaut the C-balance of poikilohydric moss carpet vegetation in semi-arid sandy grassland.

Acknowledgments

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