# Autonomous *in situ* measurement of daily courses of the net $CO_2$ exchange rate in a moss from alpine environment

(*Short Communication*)

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## Abstract

Moss-dominated vegetation type is considered one of the the most productive community type in treeless alpine environments in European mountains. In this study, net carbon exchange rate (NCER) of alpine moss *Polytrichum commune* was measured by automatic $CO_2$ exchange station unit. Samples of mosses were collected in a mountains from the site located above tree line (1420 m a.s.l.), and transferred to Brno, Czech Republic. Then the cluster of moss (23 cm in diameter, 30 cm in depth) including dead parts was placed into open measuring chamber end exposed to local climate for two weeks in autumn 2019. The chamber closed by a transparent lid repeatedly each 20 min and NCER measured by the system. Data on photosynthetically active radiation (PAR), relative air humidity (RH), and moss temperature (T) were recorded as well. Maximum/ minimum dark respiration reached 1.0 and 0.2 μmol ($CO_2$) $m^{-2}$ $s^{-1}$. The highest NCER was found - 0.6 μmol ($CO_2$) $m^{-2}$ $s^{-1}$ was caused by photosynthesis of moss clump at the temperature within the range of 14.5-17.5°C and 100% of relative air humidity.

***Key words:*** Jeseníky Mts., *Polytrichum*, NCER, moss photosynthesis, respiration

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## Introduction

Net carbon exchange rate (NCER) rate of $CO_2$ between the vegetation-covered land and the atmosphere comprises the net difference of photosynthetic carbon uptake and the respiration of autotrophs and heterotrophs of the particular ecosystem (Reichstein et al. 2012). In general, negative NEE values indicate net assimilation or $CO_2$ uptake by the autotrophs, whereas the positive NEE values indicate net respiration or $CO_2$ loss, both from vegetation and soil (Chen et al. 2014). Soil respiration has several components comprising root respiration, heterotrophic respiration, soil fauna respiration and non-biological $CO_2$ production (Xu and Shang 2016).

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Recently, there is a wide variety of applications of semi- of fully-automated measuring systems for $CO_2$ exchange rate of terrestrial ecosystems. In agronomy research, $CO_2$ emissions released from soil were measured on the spots differing in tillage management (Krištof et al. 2014), fertilized with digestate from an agricultural biogas plant (Czubaszek 2019). Measurements of NCER in non-agricultural lands are much less frequent. However, several studies have been done within the last decade focussing *e.g.* semiarid ecosystems (Zengeni et al. 2016), mountainous grasslands (Balogh et al. 2007), alpine ecosystems (Strimbeck et al. 2019), moss-dominated Scandinavian peatland (Koskinen et al. 2014), Cenral-European forests (moss cover) – Goulden and Grill (1997), sub-Arctic moss patches in Abisco field experimental plots (Street et al. 2012).

In polar regions, several attemps has been done in the measurements of NCER by the use of automated systems. Lamoureux and Lafreniere (2013) reported NCER from the mesic tundra vegetation type in the Canadian Arctic. Similarly, Gagnon et al. (2017), investigated peatland vegetation in permafrost ecosystems in Canadian Arctic. Recently, the studies conducted in the Arctic biome have been revied and critically evaluated (Virkkala et al. 2018).

The aim of the study was to determine the $CO_2$ exchange of moss *Polytrichum* sp. from alpine environment, as dependent on daily courses of temperature, radiation and hydration status of the cluster of the moss including death biomass.

## Material and Methods

The samples of *Polytrichum commune* Hedw. mosses were collected in moss patches in the Jeseníky Mts., locality Tabulové rocks (1460 m a.s.l.). During main part of vegetation season (form the beginning of April till late September), daily average temperatures ranges form 4.8 to 21°C with long therm average 11.3°C at the collection site ([1]). Collected samples formed intact monospecific moss community that was transferred to Brno where kept cooled until used in the below-specified exposition experiment. The experiment was done on the EEL laboratory open field plot (Masaryk University Campus, Brno, Czech Republic).

*Autonomous measurement of NCER*

In four-weeks-lasting exposition experiment, the moss samples were exposed to changing environmental conditions mimicking those usually reported within active part of vegetative season in the natural environment. In the paper, we present only two weeks with contrasting temperature, *i.e.* October 20$^{th}$-27$^{th}$, and November 5$^{th}$-12$^{th}$, 2019. During the exposition, a physiological activity of the moss community was evaluated using autonomous $CO_2$ exchange station unit (ACE, ADC BioScientific Ltd., UK). The station assembly consists of a motorised moveable arm containing an infra-red gas analyser (IRGA) to measure $CO_2$ concentration (Fig. 1.). In the measuring compartment, the chamber was delimited by a 23 cm in-diameter collar. The moss samples were installed to the fulfill collar part of measuring/exposition chamber of the unit. The NCER was evaluated in 20 min. interval.

**Fig. 1.** Automated Soil $CO_2$ Exchange System (ACE) with the samples of *Polytrichum commune* installed in exposition collar.

Within the first 30s, the measurement started with ambient $CO_2$ concentration determination. Then after closing the chamber, the $CO_2$ concentration in the light chamber (volume of 1 l) was determined. The air flow was set to 200 $\mu mol.s^{-1}$ and the time limit for the measurement with closed chamber was 5 min. The NCER in $\mu mol.m^{-2}.s^{-1}$ was calculated by the system using the equation $NCER=(u/a)*\delta c*10^3$, where $u$ is volumetric air flow, $a$ is the area covered by measuring chamber and $\delta c$ is the difference between ambient and the concentration of $CO_2$ through the chamber. Additionally, the system was equipped with sensors providing the temperature of the sample (Pt-100), as well as incident light irradiance (photosynthetically active radiation). During the exposition period, the relative air humidity and air temperature in the chamber were measured and recorded in 5 min. interval by a Minikin TH datalogger (EMS Brno, Czech Republic).

From measured daily courses of the NCER, temperature, air humidity, and PAR, the two contrasting periods were analysed in this study: (i) from October 20$^{th}$ to 27$^{th}$ when daily temperature maximum ranged from 13 to 15°C, and (ii) from November

$5^{th}$ to $12^{th}$ when daily temperature maximum not exceed 10°C. To analyse the photosynthetic activity as well as the respiration of measured moss community, daily average NCER, temperature, air humidity, and PAR were calculated separatly for light and dark part of the photoperiod.

## Results

Variation of NCER, temperature, air humidity, and PAR during the two contrasting weeks from the *Polytrichum commune* in situ exposition are shown on Fig. 2. During analysed period the NCER ranges from -0.6 μmol.$m^{-2}$.$s^{-1}$ (recorded 27.10.2019 13:09) to 16 μmol.$m^{-2}$.$s^{-1}$ (recorded 22.10.2019 19:56). The temperature minimum was -2.6°C (recorded 1.11. 2019 5:05) and maximum was 18.8°C (recorded 15.10.2019 14:18). The air humidity did not decreased under 81% during the whole exposition period (the minimum of 81.8% corresponded with temperature maximum record).

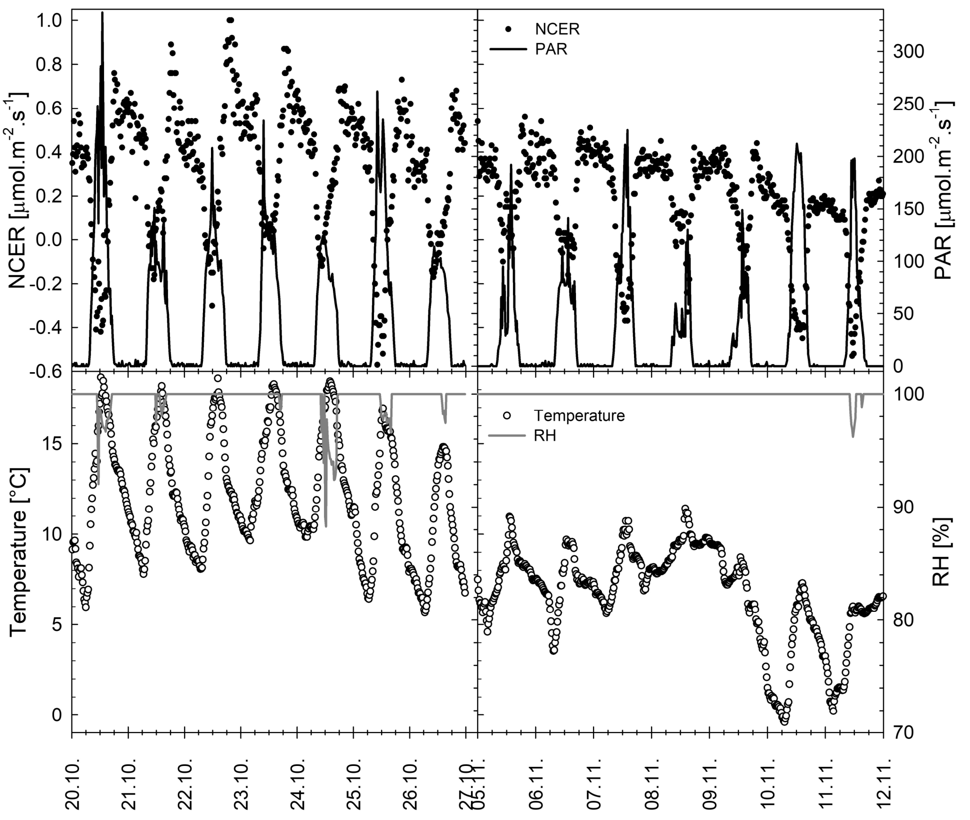


**Fig. 2.** Daily courses of the net $CO_2$ exchange rate (NCER), photosynthetically active radiation (PAR), air temperature and relative humidity (RH) in two selected weeks of exposition of *Polytrichum commune* to changing environmental factors in simulated *in situ* environment.

Within the first selected period the NCER values ranged from -0.6 to 1 μmol.m$^{-2}$.s$^{-1}$ with light period average ranging from -0.15 to 0.28 μmol.m$^{-2}$.s$^{-1}$ and from 0.40 to 0.61 μmol.m$^{-2}$.s$^{-1}$ in the dark. The light-part-photoperiod temperatures averages ranges from 11 to 15°C and from 7.4 to 11.4°C during dark-part-photoperiod. The PAR daily average ranges from 78 to 125 μmol.m$^{-2}$.s$^{-1}$ (for datail *see* Fig. 3.).

Within the second selected period, the NCER values ranged from -0.6 to 0.6 μmol.m$^{-2}$.s$^{-1}$ with light period average ranging from -0.27 to 0.09 μmol.m$^{-2}$.s$^{-1}$ and from 0.15 to 0.39 μmol.m$^{-2}$.s$^{-1}$ in the dark. The light-part-photoperiod temperatures averages ranges from 5.2 to 9.9°C and from 2.3 to 8.8°C during dark-part-photoperiod. The PAR daily average ranges from 28 to 130 μmol.m$^{-2}$.s$^{-1}$.

The average air humidity during the dark-part of the fotoperiod kept at 100% within both selected weeks. During the light-part of the fotoperiod in the first selected week the average air humidity varied from 96.5 to 99.9%, however in the second week kept at 100%.

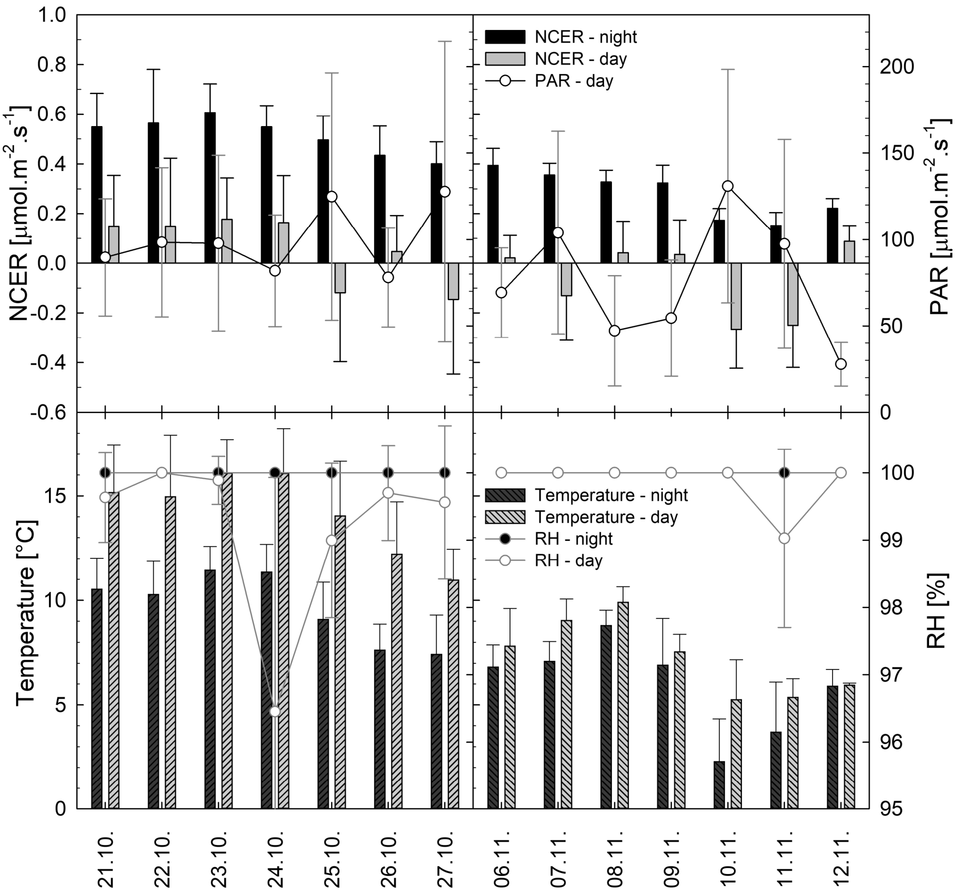


**Fig. 3.** Average net $CO_2$ exchange rate (NCER), photosynthetically active radiation (PAR), air temperature and relative humidity (RH) evaluated for dark (night) and light (day) part of the day in the two selected weeks of exposition of *Polytrichum commune* to changing environmental factors in simulated *in situ* environment. The data points are means ±SD.

## Discussion

Relatively high values of $CO_2$ efflux (*i.e.* NCER during night) recorded especially during the first week of the measurements can be, similarly to Kim et al. (2014), attributed to the temperature dependent moss and microbial respiration suggesting the temperature sensitivity of *P. commune.* Maximum photosynthetic performance, as demonstrated by the negative NCER values found on October 25$^{th}$, and November 11$^{th}$ indicated high net photosynthetic rate. For *Polytrichum* sp., high photosynthesis is reported by *e.g.* Juutinen (2016). Such high rates of photosynthetic $CO_2$ fixation of the species, however, decline with increasing latitude as reported by Sveinbjornsson and Oechel (1983). However, the rate of net photosynthesis, NCER respectively, recorded for *Polytrichum commune* was well comparable to the evidence reported by Aljaste (2011) for *Sphagnum* sp.

NCER values with prevailing photosynthesis, *i.e.* negative NCER in Fig. 3, were found on the days with daily mean PAR higher than 100 μmol m$^{-2}$ s$^{-1}$. This indicate rather PAR- than water-limited photosynthesis within the measured period. Indeed, the moss community maintained high level of thallus hydration throughout the experiment. Moreover, it is well established that mosses in alpine and polar regions keep high photosynthetic rates even during partial water loss from thallus (Uchida et al. 2002). The species within the genus *Polytrichum* have several adaptations helping them to keep water and maintain photosynthesis. Among them, the ability of water transport from the base of the plant thanks to a very simple system of water-conducting cells is of major importance. Leaf morphology also helps *Polytrichum* sp. to optimize water use in photosynthesis since the upper leaf surface possesses special structures. The upper surfaces of the leaves are covered with parallel ridges of photosynthetic cells. The ridges help to maintain water in photosynthesising cells even during drying conditions in windy days. Between the ridges, moist air is trapped which prevents the leaves from fast drying.

The relative contribution of mosses to system level carbon exchange in the treeless Arctic and alpine systems is considered to be noticeable. However, the earlier studies attempting quantification of the contribution of mosses were rather site-specific and did not postulate general relationships to ecosystem carbon exchange rate (see *e.g.* Oechel and Collins 1976, Sommerkorn et al. 1999). Recent study of Douma et al. (2007) reported variation of moss contribution along large latitudinal and topographic gradients, however, did not quantify the temporal development of moss gas exchange throughout the year. They found, however, that mosses may account for an average of 60% of net ecosystem exchange (NEE). It has been reported for tundra biome that mosses may be substantial part of ecosystem level $CO_2$ fluxes. Douma et al. (2007) showed that moss contribution to ecosystem carbon uptake varied between 14 and 96%, with an average contribution of around 60% in Northern Sweden and Svalbard. Seasonality of moss contribution to NCER is also important issue. The same authors report the crucial role of mosses in the carbon cycle especially during spring when leaves of deciduous vascular plants are not yet fully developed but mosses do perform photosynthesis.

In order to understand carbon dynamics in moss-dominated treeless alpine environment, additional study is needed monitor separately the $CO_2$ exchange rates in mosses and microbial soil and dead organic matter respiration. It is our intention to evaluate this part of NCER in the forthcoming study. In principle, below-ground respiration can be divided into vascular plant root and microbial respiration, but to distinguish these two sources is difficult if not impossible in field measurements in moss-dominated communities (Sorensen et al. 2019).

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