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Effect of vegetation removal and water table drawdown on the non-methane biogenic volatile organic compound emissions in boreal peatland microcosms

Patrick Faubert [a,*], Päivi Tiiva [a], Åsmund Rinnan [b], Sanna Räty [a], Jarmo K. Holopainen [a], Toini Holopainen [a], Riikka Rinnan [a,c]

[a] Department of Environmental Science, University of Eastern Finland, PO Box 1627, FI-70211 Kuopio, Finland
[b] Quality & Technology, Department of Food Science, Faculty of Life Sciences, University of Copenhagen, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark
[c] Terrestrial Ecology Section, Department of Biology, Faculty of Science, University of Copenhagen, Øster Farimagsgade 2D, DK-1353 Copenhagen K, Denmark

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ABSTRACT

Biogenic volatile organic compound (BVOC) emissions are important in the global atmospheric chemistry and their feedbacks to global warming are uncertain. Global warming is expected to trigger vegetation changes and water table drawdown in boreal peatlands, such changes have only been investigated on isoprene emission but never on other BVOCs. We aimed at distinguishing the BVOCs released from vascular plants, mosses and peat in hummocks (dry microsites) and hollows (wet microsites) of boreal peatland microcosms maintained in growth chambers. We also assessed the effect of water table drawdown (−20 cm) on the BVOC emissions in hollow microcosms. BVOC emissions were measured from peat samples underneath the moss surface after the 7-week-long experiment to investigate whether the potential effects of vegetation and water table drawdown were shown. BVOCs were sampled using a conventional chamber method, collected on adsorbent and analyzed with GC–MS. In hummock microcosms, vascular plants increased the monoterpene emissions compared with the treatment where all above-ground vegetation was removed while no effect was detected on the sesquiterpenes, other reactive VOCs (ORVOCs) and other VOCs. Peat layer from underneath the surface with intact vegetation had the highest sesquiterpene emissions. In hollow microcosms, intact vegetation had the highest sesquiterpene emissions. Water table drawdown decreased monoterpene and other VOC emissions. Specific compounds could be closely associated to the natural/lowered water tables. Peat layer from underneath the surface of hollows with intact vegetation had the highest emissions of monoterpenes, sesquiterpenes and ORVOCs whereas water table drawdown decreased those emissions. The results suggest that global warming would change the BVOC emission mixtures from boreal peatlands following changes in vegetation composition and water table drawdown.

1. Introduction

Boreal and subarctic peatlands cover 350 million hectares (Gorham, 1991) and release substantial quantities of non-methane biogenic volatile organic compounds (BVOCs; Klinger et al., 1994; Janson et al., 1999; Haapanala et al., 2006; Tiiva et al., 2007). The existing knowledge on peatland BVOC emissions is collected from different microsites using different techniques. Besides the study of Tiiva et al. (2009) on isoprene emission, no other studies have attempted to isolate vascular plants, mosses and peat as sources of BVOCs.

BVOCs have an important role in the atmospheric chemistry as they take part in the formation of secondary organic aerosols (Laothawornkitkul et al., 2009). Moreover, the oxidative reactions between BVOC and OH radicals form tropospheric ozone and affect atmospheric methane (CH_4) concentration (Laothawornkitkul et al., 2009). These interactions with major greenhouse gases are a source of uncertain feedbacks on climate change (IPCC, 2007; Peñuelas and Staudt, 2010).

BVOCs are naturally released by plants via their physiology and metabolism (Loreto and Schnitzler, 2010) at a global annual rate of 700–1000 Tg (10^{12}) C (Laothawornkitkul et al., 2009). Ericaceous dwarf shrubs, grasses and sedges growing on boreal peatlands have been reported to emit BVOCs (Helmig et al., 1999; Klinger et al., 2002; Rinnan et al., 2005; Tiiva et al., 2007, 2008, 2009; Faubert

* Corresponding author. Tel: +358 40 355 3204; fax: +358 17 163191.
E-mail addresses: patrick.faubert@uef.fi (P. Faubert), paivi.tiiva@gmail.com (P. Tiiva), aar@life.ku.dk (Å. Rinnan), sanna.raty@viitasaari.fi (S. Räty), jarmo.holopainen@uef.fi (J.K. Holopainen), toini.holopainen@uef.fi (T. Holopainen), riikkar@bi.ku.dk (R. Rinnan).

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et al., 2010). Furthermore, BVOC emissions from *Sphagnum* spp. mosses have been measured in boreal peatlands of Northern Europe and North America (Helmig et al., 1999; Janson et al., 1999). A wide variety of BVOCs are also released from soil, peat material and litter, where the metabolism of microorganisms is responsible for the release and uptake of BVOCs (Beckmann and Lloyd, 2001; Insam and Seewald, 2010).

Global warming is expected to decrease the water table in boreal peatlands following increased evapotranspiration, which would trigger a hydric stress on vegetation and peat (IPCC, 2007). Hydric stress on vegetation of Mediterranean species affects the BVOC emissions either positively or negatively depending on the severity of drought, plant species and season (Llusià et al., 2006; Peñuelas and Staudt, 2010). In the boreal region, hydric stress increases the BVOC emissions over the canopy of Scots pine forest (Lappalainen et al., 2009). In boreal peatlands, water table drawdown decreases isoprene emission from vegetation (Tiiva et al., 2009). In soil, an increase in oxic conditions reduces the amount and diversity of BVOCs (Insam and Seewald, 2010). In boreal peatland soil, water table level regulates biogeochemistry and peat decomposition (Strack, 2008; Mäkiranta et al., 2009), which could affect BVOC emissions.

This study aimed to distinguish the boreal peatland BVOCs (excluding isoprene presented in Tiiva et al., 2009) released from vascular plants, mosses and peat in dry microsites, i.e. hummocks, and wet microsites, i.e. hollows. The study was done using microcosms. We also assessed the effect of water table drawdown on the BVOC emissions in the hollow microcosms. We expected vascular plants, mosses and peat to release distinct BVOC mixtures. The water table drawdown was hypothesized to reduce the BVOC emissions due to increased BVOC uptake in the oxic peat layer as suggested for isoprene (Tiiva et al., 2009). Furthermore, we investigated if the potential effects of vegetation and water table drawdown would also show in the BVOC emissions from peat samples taken from the microcosms after the 7-week-long experiment.

2. Materials and methods

2.1. Peatland microcosms and growth conditions

The microcosms originated from an ombrotrophic peatland, Turvesuo peatland, in Suonenjoki, Central Finland (62°40′N, 26°58′E, 102 m a.s.l.; Tiiva et al., 2009). The microcosms (depth 40 cm, diameter 10.5 cm) were cored on 31 October 2006 directly into PVC tubes and plugged at the bottom. The microtopography of the microcosms represented two types: hummocks (water table 20 cm below the moss surface) and hollows (water table at moss surface level). The hummock vegetation consisted of a moss (*Sphagnum fuscum* (Schimp.) Klinggr.) cover with sedges (*Eriophorum vagin*atum L. and *Carex pauciflora* Lightf.), dwarf shrubs (*Andromeda polifolia* L., *Vaccinium oxycoccos* L., *Empetrum nigrum* L.) and a lichen (*Cladina rangiferina* (L.) Nyl.). The hollow vegetation had a uniform cover of the moss *Sphagnum majus* (Russow) C. Jens., the protruding sedge *Rhynchospora alba* (L.) Vahl. and the herb *Scheuchzeria palustris* L.

After the collection, the microcosms were stored in a dark refrigerated room (1–2 °C) until 23 February 2007. During this period, the water table of the microcosms was maintained at the natural level by watering with water collected from the peatland and with distilled water once the stock of peatland water ended.

On 23 February 2007, the microcosms were moved into growth chambers (Weiss Bio 1300, Weiss Umwelttechnik Gmbh, Reiskirchen-Lindenstruth, Germany) where they went through a progressive acclimation period before the measurements. The growth chambers simulated the average weather conditions of May in central Finland for the ten first days (temperature 7.5–15.2 °C, humidity 54–82%, light/dark cycle 19 h/5 h, maximum photosynthetic photon flux density – PPFD – received by vegetation 300 μmol m^{-2} s^{-1}), then June conditions for eight days (temperature 10.1–17.7 °C, humidity 57–88%, light/dark cycle 20 h/4 h, maximum PPFD 300 μmol m^{-2} s^{-1}) and finally July conditions (temperature 15.0–22.4 °C, humidity 64–96%, light/dark cycle 20 h/4 h, maximum PPFD 450 μmol m^{-2} s^{-1}) for the duration of the experiment (seven weeks).

2.2. Experimental design

The treatments of vegetation removal and water table drawdown were applied during the simulated June conditions. The hummock microcosms were subjected to three levels of vegetation removal: 1) no removal (from here on 'intact vegetation'), 2) removal of the above-ground part of vascular plants by cutting down to the moss surface ('moss'), 3) removal of all above-ground vegetation by cutting to 2 cm depth below the former moss surface ('peat'). The water table of hummock microcosms was maintained natural during the experiment, i.e. at 20 cm depth below the moss surface. The microcosms were put in four growth chambers ($n = 4$), each treatment represented once in each chamber.

The hollow microcosms were subjected to vegetation and water table treatments in a full factorial design. The vegetation removal consisted of 1) no removal ('intact vegetation') and 2) removal of all above-ground vegetation by cutting to 2 cm depth below the former moss surface ('peat'). The water table treatment consisted of 1) maintaining the natural water table at moss surface ('0 cm') and 2) a drawdown of 20 cm below the moss surface, applied by drilling holes in the PVC tubes ('−20 cm'). The hollow microcosms were put in six growth chambers ($n = 6$), each treatment represented once in each chamber. All microcosms were watered daily with distilled water during the experiment.

2.3. BVOC sampling

BVOCs emitted from the microcosms were sampled weekly, five times during the experiment, starting one week after the growth conditions were turned to July. The sampling technique was a conventional push–pull system used for measurement of BVOC emissions from the whole plant/soil system (Tholl et al., 2006; Ortega and Helmig, 2008; Tiiva et al., 2009; Faubert et al., 2010). Air sampling was done using a transparent polycarbonate chamber (thickness 1.5 mm, diameter 13 cm, height 30 cm; Vink Finland, Kerava, Finland) placed on a plastic collar fixed around the top of the microcosm. Water was put in the groove of the collar to air-tighten the chamber headspace. A small battery-operated pump (12 V Rietschle Thomas, Puchheim, Germany) pulled the air sample through an Automatic Thermal Desorption (ATD) steel tube (Perkin Elmer, Boston, MA, USA) filled with a combination of Tenax TA and Carbopack B adsorbents (100 mg of each, mesh 60/80, Supelco, Bellefonte, PA, USA).

Air sampling for BVOCs lasted 30 min, during which air volume of 6 l was sampled. The outflow was set to 205 ml min^{-1} (corresponding to a flow of 200 ml min^{-1} through the sample tube) with a flow meter (Agilent Flow Tracker 1000, Agilent Technologies Inc., Wilmington, DE, USA). In order to prevent air leakage from outside into the chamber, a slightly superior inflow was maintained by pumping air at a rate of 215 ml min^{-1} (Staudt et al., 2000; Tiiva et al., 2009). The BVOC concentrations in the inflow air were considered to be negligible thanks to the purification system consisting of a charcoal filter to remove BVOCs and a MnO_2 scrubber to remove ozone (Ortega and Helmig, 2008). During the sampling period, the