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CAN THE CONTRASTING CARBON BALANCES OF FORESTRY-DRAINED PEATLANDS BE EXPLAINED BY DIFFERENT PRIMING EFFECTS?

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SUMMARY

We measured soil respiration rates of two forestry drained peatlands (nutrient-rich and nutrient-poor site) in laboratory conditions. The nutrient-rich site has been previously observed to act as a carbon source whereas the nutrient-poor site is a carbon sink. We examined whether the decomposition of old peat is enhanced by root exudates (priming effect). This was studied at the natural abundance level (^{14}C) and by adding ^{13}C-labelled glucose to peat samples. The results show that the nutrient-rich peat is characterized by higher basal soil respiration rates. However negative priming or no priming was observed in both experiments and in both peat soils.

KEY WORDS: forested peatlands, nutrient status, isotopes, flux measurements

INTRODUCTION

Peatlands contain a considerable amount of carbon (C) and land use changes on them are likely to cause C losses to the atmosphere (Gorham 1991). About half of the original peatland area has been drained in Finland, mainly for forestry use (Korhonen et al. 2008, Vasander et al. 1996). We have studied C cycle on two forestry-drained peatlands in Southern Finland. The peatlands are located close to each other and both were drained about 40 years ago. These two sites differ in nutrient status; the nutrient-rich site was originally fen and the the nutrient-poor site was a bog. According to the eddy covariance measurements conducted at both sites, the nutrient-rich site, Lettosuo, is a source of C to the atmosphere (Lohila et al. 2010), whereas the nutrient-poor site, Kalevansuo, is a strong C sink (Lohila et al. 2011). We hypothesize that the differences in C balance between these two sites could be explained by the peat nutrient status and in particular by the differences in priming effect between the sites. Priming effect stands for a change in old C decomposition when fresh C is added to soil. We aim to explain the observed differences in CO_2 balances by the data obtained with laboratory-based experiments including isotopic measurements.

MATERIAL AND METHODS

To gain more information on below-ground C-processes we have studied the priming effect in two separate experiments: 1) at the natural abundance level (^{14}C) by planting Scots pine (*Pinus sylvestris*) seedlings to peat and 2) by adding ^{13}C-labelled glucose to bare peat

samples, thus simulating root exudation. Peat for these two experiments was collected from both of the study sites and the experiments were conducted in laboratory.
In the Experiment 1 we used microcosm systems (Pumpanen et al. 2009) to simulate plant-soil conditions and took advantage of the natural difference in ^{14}C (age) between soil and plants. We used deep (old) and surface (young) peat for 56 microcosm systems. The peat was incubated for six months before the experiment started. To 32 of these pots a pine seedling was planted and the residual 24 pots remained without seedling. The microcosms were placed in a green house, where air and soil temperatures were controlled. Photosynthesis and respiration were measured altogether four times every one to two months. Since the nutrient balance in peat soil may be unfavourable for seedlings to grow, we fertilized the microcosm systems weekly since the first measurement round. In the end of the experiment $^{14}CO_2$ respired from the soil was collected with molecular sieves and the ^{14}C samples were prepared and analyzed by the Radiocarbon Dating Laboratory in the University of Helsinki. To see more clearly the difference between the old (old peat) and the fresh (seedling) C, which is needed to reliably apply the isotopic mixing models for source partitioning, the $^{14}CO_2$ dating was done only for the deep peat samples.

In the Experiment 2 the excretion of recent photosynthates was simulated by adding ^{13}C-labelled glucose to half of 120 peat samples. Peat for these samples was collected from both of the study sites few weeks before the experiment. To 60 of the peat samples (30 labelled and 30 non-labelled) also nutrients were added and 30 were left without nutrients and glucose. Respiration was measured during three weeks and the gas samples of $^{13}CO_2$ were taken regularly. The CO_2 of soil respiration was analyzed with the gas chromatograph and the $^{13}CO_2$ samples with the isotope ratio mass spectrometer (Thermo Fisher Finnigan Delta Plus). In this experiment only surface peat was used.

The fraction of respiration originating from the peat decomposition was calculated using the following mixing models:

for the Experiment 1

$$f = \frac{pMC_s - pMC_p}{pMC_m - pMC_p}$$

where,
f is the fraction of respiration,
pMC_s is per cent of modern carbon (atmospheric C before year 1955) of peat with seedling,
pMC_p is the pMC of plain peat,
pMC_m is the pMC of modern carbon (here 105),

and for the Experiment 2

$$f = \frac{\delta^{13}C_l - \delta^{13}C_n}{\delta^{13}C_g - \delta^{13}C_n}$$

where,
$\delta^{13}C_l$ is the $\delta^{13}C$-value of labelled peat,
$\delta^{13}C_n$ is the $\delta^{13}C$-value of non-labelled peat,
$\delta^{13}C_g$ is the $\delta^{13}C$-value of ^{13}C-glucose

RESULTS

Experiment 1: Natural abundance (^{14}C)

The initial results show that the soil respiration (µg CO_2 g^{-1} DW h^{-1}) was higher in microcosms with planted seedlings than in the plain peat due to the root and rhizosphere respiration (Fig. 1 a and b). In the surface peat the seedlings were growing faster and better than in the deep peat. That can be seen in the respiration rates as the amount of root biomass was also higher. But also in the beginning of the experiment the surface peat samples respired more than the deep peat. The respiration of plain peat was quite similar in all of the treatments and there were no differences in the plain peat respiration between the sites. The increase in the plain soil respiration after the first measurement round was probably due to the fertilization (Fig. 1b).

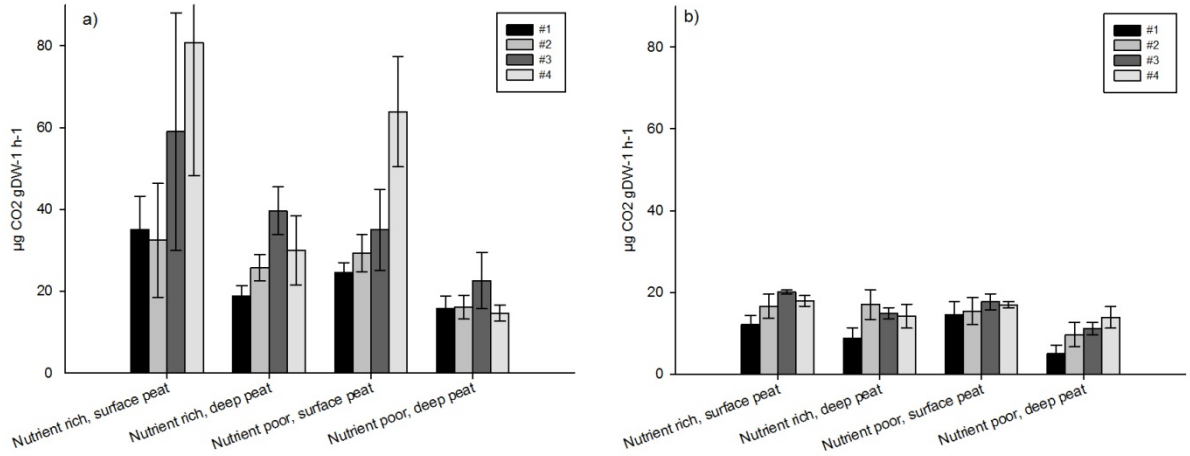

Figure 1. Respiration of four different peat treatments (nutrient-rich and -poor sites, deep and surface peat) during four measurement rounds in Experiment 1. 1a) The soil, root and rhizosphere respiration (µg CO_2 g^{-1} DW h^{-1}) and 1b) the respiration of plain peat. The error bars denote 95% confidence intervals.

The results of ^{14}C dating are shown in table 1. As expected, the ^{14}C of respiration was much younger in those microcosm systems were a seedling was planted. The pMC-values indicate percent of modern C (atmospheric C before year 1955). No significant differences in $\delta^{13}C$-values could be seen.

Table 1. Radiocarbon ages and pMC values of CO_2 originating from plain deep peat and deep peat+seedling (mean ±SD, n=5).

	AGE	DELTA	pMC(%)
Nutrient-rich, only peat	1770 ±119	-26.3 ±1.0	79.6 ±1.15
Nutrient-rich, with seedling	693 ±205	-27.1 ±0.5	91.1 ±2.3
Nutrient-poor, only peat	2022 ±504	-26.4 ±1.2	77.3 ±4.8
Nutrient-poor, with seedling	1355 ±127	-25.0 ±1.9	83.9 ±1.4

With the help of the mixing model the respiration of the peat soil, measured from the microcosms with seedlings, was divided into two parts; root-derived and soil-derived CO_2. According to the initial results the soil-derived respiration of plain peat was similar or higher than in those peat samples with seedling, which indicates no or negative priming, i.e. similar or lower peat decomposition in the presence of roots and root leachates. The respiration rates in the nutrient-rich peat with the seedling were on average 15.9% higher than those in the plain nutrient-rich peat. The respiration rate of the nutrient-poor peat samples with seedling was on average 80.4% of the respiration of the nutrient-poor plain peat samples. However, the difference was not statistically significant. The seedling-derived respiration, originating from the roots and rhizosphere, was on average 45.2% and 23.7% of the total respiration in the nutrient-rich and nutrient-poor samples, respectively. The soil-derived respiration of the nutrient-rich peat with seedling was 32.1% higher than the soil-derived respiration of the nutrient-poor peat with seedling. The respiration rates of plain peat were similar in the nutrient-rich and -poor peat.

Experiment 2: Labelling with ^{13}C

According to the preliminary results of the experiment with ^{13}C-labelled glucose additions, simulating root exudation, negative priming was observed in all of the treatments. The soil respiration of plain peat was higher in non-labelled peat samples when compared to the calculated soil derived respiration of the labelled samples. The respiration rate of nutrient-rich peat with added ^{13}C-glucose was on average 26.5% lower than the respiration of plain peat. In the treatment with ^{13}C-glucose and nutrients added, the nutrient-rich peat respired 25.5% less than the plain peat. Plain nutrient-poor peat respired 34.6% more than the nutrient-poor peat samples with added ^{13}C-glucose and the respiration rate of nutrient-poor peat with nutrients was 27.5% higher than the respiration rate of the nutrient-poor peat with ^{13}C-glucose and nutrients. According to these initial results, the nutrient addition had no statistically significant impact on the respiration rates. However, the differences between the nutrient-rich and nutrient-poor peat samples were significant. The respiration rate of nutrient-rich peat with ^{13}C-glucose was 53.6% higher than of the nutrient-poor peat with ^{13}C-glucose. The plain nutrient-rich peat respired 47.6% more than the plain nutrient-poor peat. In the samples with added fertilizers, the respiration rate of the nutrient-rich samples had a respiration rate 55.2% higher than of the nutrient-poor peat. When also ^{13}C-glucose was added to these fertilized peat samples, the nutrient-rich peat respired 56.4% more than the nutrient-poor samples. To conclude, in all treatments the respiration rates were about twice as high in nutrient-rich peat than in the nutrient-poor peat.

DISCUSSION

Negative priming or no priming at all was observed in both experiments and at both study sites. Thus, according to the initial results, the fresh plant-derived carbon does not increase the peat decomposition. Additionally, we showed that the nutrient status does not play a crucial role in plant-mediated impacts on the peat decomposition. Thus, the overall differences in the C balances between the two sites under examination cannot be explained by different activation/deactivation of peat decomposition in the presence of plants (priming effect). However, the results of the labelling experiment showed that the basal respiration rate of the nutrient-rich peat is much higher than that of nutrient-poor, which can at least partly explain the observed differences in the ecosystem CO_2 balances. In the natural abundance experiment the difference was not so clear; the soil respiration rates being close to each other. This might be due to the longer incubation time in the Experiment 1: most of the easily

available C has probably been used already during the incubation. The seedlings grew better in the surface peat than in the deep peat. In addition, the nutrient-rich surface peat was more favourable for growth of the seedlings than the nutrient-poor surface peat. As a conclusion, the *in situ* respiration was higher in the nutrient-rich site, Lettosuo, but the difference between the sites disappeared quickly in the laboratory conditions. High soil respiration rates *per se* could explain the net C loss at the nutrient-rich site, observed earlier, even though the tree growth is much greater there. However, more studies are needed to confirm that.

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