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DECOMPOSITION OF PEAT DURING SIMULATED SUMMER DROUGHT

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SUMMARY

Drained peat areas are a source of carbon. Dry summers are expected to occur more often due to climate change. During a dry period anaerobic peat is exposed to oxygen. This oxic period could release the 'enzymic latch' on decomposition, thereby increasing the carbon flux. In this study, the influence of a dry period of one to eight weeks on decomposition and mineralisation is studied. *Carex* peat samples showed pyrite oxidation as pH declined and SO_4 concentrations rose. Unexpectedly, no changes in soluble and condensed phenols were seen. Thus, no sign of an enzymic latch was discovered in Dutch peat areas.

KEY WORDS: Peat, phenolic substances, summer drought, decomposition, mineralisation

INTRODUCTION

Peatlands are globally important sinks of carbon. Their ability to sequester carbon has resulted in a storage amounting to one third of the current total global soil carbon pool while covering only 3 % of the total land surface (Rydin *et al.*, 2006). However, reclamation of peatlands results in a switch from carbon storage into carbon release (Laiho, 2006). For instance, agricultural use of peat soils requires a lowering of the water table, thereby increasing oxygen intrusion and facilitating aerobic decomposition, which results in peat shrinkage and soil subsidence. Adjusting water tables to the subsided soil surface leads to a vicious cycle with regular lowering of water tables and continuing subsidence (Schothorst, 1977). Simultaneously, vast amounts of CO_2 is emitted and nutrients are released (Van Beek *et al.*, 2007; Van den Akker *et al.*, 2008).

Because of climate change, dry events are expected to occur more often in the nearby future (Van den Hurk *et al.*, 2006). Water tables drop when evaporation exceeds precipitation and, consequently, anoxic peat payers are exposed to oxygen. The consequence of increased aeration is a stimulation of decomposition and increased CO_2 emissions (Laiho, 2006; Ellis *et al.*, 2009; Reiche *et al.*, 2009). Thus, climate change and related dry summers could deteriorate the problems in the drained Dutch peat areas as increased aeration stimulates decomposition.

According to the 'enzymic latch theory', phenols play a crucial role in the decomposition rates of peat during and after a dry period (Freeman *et al.*, 2001). Phenols are compounds in

which a hydroxyl group is directly attached to a benzene ring, examples are lignin and tannin. Soluble phenols are indicated to function as a 'latch' on decomposition of peat soils. Their presence hampers the activity of hydrolytic enzymes such as sulphatase, phosphatase and β-glucosidase. In a field survey, the CO_2 emission was found to be strongly correlated with the activity of phenol oxidase, the enzyme responsible for degradation of phenols (Freeman *et al.,* 2001).

The degradation of phenols, which is performed by microorganisms that excrete the enzyme phenol oxidase, is an aerobic process. Indeed, laboratory manipulations showed that phenol oxidase activity is higher during aerobic conditions compared to anaerobic conditions. In addition, higher phenol oxidase activity resulted in lower concentration of phenols (Freeman *et al.,* 2001). So far, the 'enzymic latch theory' would predict that events of lower water tables would accelerate both anaerobic decomposition during the dry period as well as anaerobic decomposition when the water table has raised again (Freeman *et al.,* 2001).

However, reality might be more complicated as changes in water table are associated with changes in pH (Braekke, 1987; Nilsson *et al.,* 1996). Phenol oxidase activity is very sensitive to pH; the activity more than doubles when pH increases from 5 to 8 (Pind *et al.,* 1994). Changes in water table in peat areas have been associated with changes in pH, both on a short and a long-term. Where drainage leads to an increase in acidity (Toberman *et al.,* 2010), hampering drainage leads to a rise in pH (Toberman *et al.,* 2008). These changes in pH can imply that increased aeration does not lead to increased activity of phenol oxidase and, hence, decomposition. However, subsequent rewetting can accelerate decomposition as pH rises (Fenner *et al.,* 2011). Thus, when we incorporate pH changes in the 'enzymic latch theory': first, anaerobic decomposition of peat is slow due to a latch that phenols exert on decomposition and hydrolytic enzymes in particular; second, the expected rise in phenol oxidase activity due to increased aeration could be suppressed due to pH changes; and third, pH rise following rewetting stimulates decomposition to levels higher than previously measured.

The quality and quantity of phenols that are present in *Sphagnum* peat contrasts with other peat types. For instance, the presence of *Sphagnum* acid and tannins have a profound inhibitory effect on decomposition resulting in lower mass loss of *Sphagnum* litter compared to *Carex* litter (Verhoeven *et al.,* 1997; Aerts *et al.,* 1999; Scheffer *et al.,* 2001). However, dry events might remove this distinction. (Fenner *et al.,* 2011) found that the CO_2 emissions after drought of oligotrophic peat, in comparison with meso- and eutrophic peat, increased most compared to the pre-drought situation. Conversely, (Toberman *et al.,* 2010) found the highest activity of phenol oxidase and the highest concentration of soluble phenolics in mesotrophic peat compared to oligo- and ombrotrophic peat. Thus, the role of peat type in phenol oxidase activity and soluble phenol concentration remains unclear.

In addition to differences in peat type and their expected response to drought there is an effect of land use on peat soil characteristics. In the Netherlands, most peat areas are used for agriculture, primarily as meadows for dairy farming. This land use implies, besides drainage, fertilisation. The effects of this land use on the role of phenols in the decomposition of peat soils have been marginally investigated. For example, the highest amounts of extractable phenols were found in permanent grasslands, while the lowest amounts were found in agricultural fields (Maciak *et al.,* 1986). (Maciak *et al.,* 1986) did not find an effect of 25-year fertilisation on phenolic content. However, controversy exists as (Matocha *et al.,* 2004) revealed that nitrogen fertilisation could suppress phenol oxidase activity. So, lack of clarity

remains concerning the effect of fertilisation on phenol concentration and the activity of phenol oxidase.

In presented study the effects of an aerobic period on the decomposition of anaerobic *Carex* and *Sphagnum* peat samples was explored, using samples from peat meadows under natural and agricultural land use. A 14-week anaerobic incubation experiment was performed, of which 1 to 8 weeks were aerobic. Extractable and condensed phenols, as well as a number of extractable nutrients, were measured at the end of the experiment. We hypothesized, in line with the 'enzymic latch theory' (Freeman *et al.,* 2001; Fenner *et al.,* 2011), that part of the phenols would be degraded during the aerobic period after which, even in anaerobic conditions, decomposition is accelerated compared to the pre-aerobic situation. It is expected that both in aerobic and anaerobic conditions the decomposition of *Sphagnum* peat samples from the nature reserve is slowest due to the high concentration of phenols. The *Sphagnum* peat samples from an agricultural meadow will decompose faster due to the increased nutrient content which could, according to (Fenner *et al.,* 2011), stimulate decomposition. The decomposition rate of the *Carex* derived peat samples will be higher than the decomposition rate of *Sphagnum* derived peat samples due to higher concentration of phenols and lower nutrient availability in the *Sphagnum* samples. Like in the *Sphagnum* samples, *Carex* peat samples from a nature reserve will decompose slower than the samples from an agricultural meadow.

MATERIALS AND METHODS

Peat samples were taken from agricultural peat meadows (A) and nature reserves (N), both in eutrophic *Carex*-forest peat (C) and oligotrophic *Sphagnum* peat (S) layers, resulting in four peat types (AC, AS, NC and NS). The four peat types were sampled (end of March 2011) from anaerobic layers. Five replicate samples were collected at each location using an Edelman soil corer. The samples were directly transferred into anaerobic incubation bags (Anaerocult A mini, Merck, the Netherlands) and transported in a cool box. Samples were stored at 4°C until the start of the experiment (within one week after sampling). 10 g of fresh peat and 15 mL of demineralised water were put in 300 mL infusion flasks. Flasks were closed with airtight rubber stoppers and repeatedly flushed with N_2 gas to ensure anaerobic headspaces. For each peat sample, there were five treatments: 0, 1, 2, 4 and 8 weeks of aerobicity during the fourteen-week experiment. Dry weight was determined by drying two samples from each replicate (70°C, 48 h).

Samples were put on a rotary shaker in dark conditions (100 rpm, 20°C). At the start of the aerobic period the flasks were opened for two hours; at the end of the aerobic period the flasks were flushed with N_2 gas again and closed. After 14 weeks, water extractions were done by adding 85 mL of demineralised water, shaking on a rotary shaker (1 h, 100 rpm) and filtering the samples (Whatmann GF/C). After extraction, the soil samples were frozen using liquid nitrogen and freeze-dried. pH, NO_3, NH_4, PO_4 and DOC were determined the day after extraction (Continuous Flow Analyser, Skalar, Breda, the Netherlands). The concentration of soluble phenols was determined two days after extraction, following the procedure of Box (1983), using the Folin-Ciocalteau reagent. Freeze-dried samples were ground using a ball mill to determine organic matter content by loss-on-ignition (550°C) and condensed phenols by using a methanol extraction following colouring with the Folin-Ciocalteau reagent.
Gas samples were taken throughout the experiment, however, due to technical problems, the production of CO_2 and CH_4 is still unknown.

Differences between peat types were explored using a 1-way ANOVA (SPSS 16), and posthoc comparisons (Least Significant Differences). Treatment effects were tested per peat type using 1-way ANOVA (SPSS 16). Results are considered significant when $p \leq 0.05$.

RESULTS

The concentration of soluble phenols was highest in *Sphagnum* samples and lowest in *Carex* samples, irrespective of land use (Fig. 1a). The aerobic periods did not influence the concentration soluble phenols. The concentration of condensed phenols was lowest in Agriculture *Carex* samples, followed by Nature *Carex* samples (Fig 1b). *Sphagnum* samples showed the highest concentration of condensed phenols. Like the soluble phenols, treatment did not affect the concentration of condensed phenols.

The pH of all peat types, except Agriculture *Sphagnum*, dropped because of the aerobic treatments (Fig. 1c). In Nature *Carex* the pH in the anaerobic treatment was 5.5, while exposing the samples to oxygen for a eight-week period resulted in a pH of 3.8. Also the *Carex* samples from an intensively used meadow showed a drop in pH, from from 5.2 to 4.0. Together with drops in pH a rise in soluble SO_4 was noticed in the Agriculture *Carex* and Nature *Carex* samples (Fig 1d). The SO4 concentration remained low in the *Sphagnum* samples.

The concentration of soluble NO_3 (Fig 1e) and NH_4 (Fig 1f) was not affected by the treatments. There were peat type effects detected, whereby Agriculture *Carex* showed the highest amount of these nutrients.

The results for PO_4 and DOC are not shown but did not reveal treatment effects. Agriculture *Sphagnum* released the highest amount of PO4 (95 ± 7 mg/kg DM) that was about five times higher than the amount released by the other peat types. Nature *Carex* released minimal amounts of DOC, while Agriculture and Nature *Sphagnum* released the highest amounts.

CONCLUSION

A fourteen-week anaerobic incubation experiment with one to eight aerobic weeks did not result in significant differences in soluble or condensed phenols between the treatments. Also extractable nutrients, NO_3, NH_4, PO_4, and DOC were not affected by the aerobic periods. These results do not reveal more information concerning the function of the enzymic latch of phenols in anaerobic layers of peat areas with *Carex* or *Sphagnum* peat both under agricultural land use and natural land use. The time span during which the enzymic latch of phenols can function was not discovered. *Carex* peat samples, both from intensively and extensively used meadows showed a drop in pH with increasing length of the aerobic period. Simultaneously the extractable SO4 increased, suggesting pyrite oxidation.

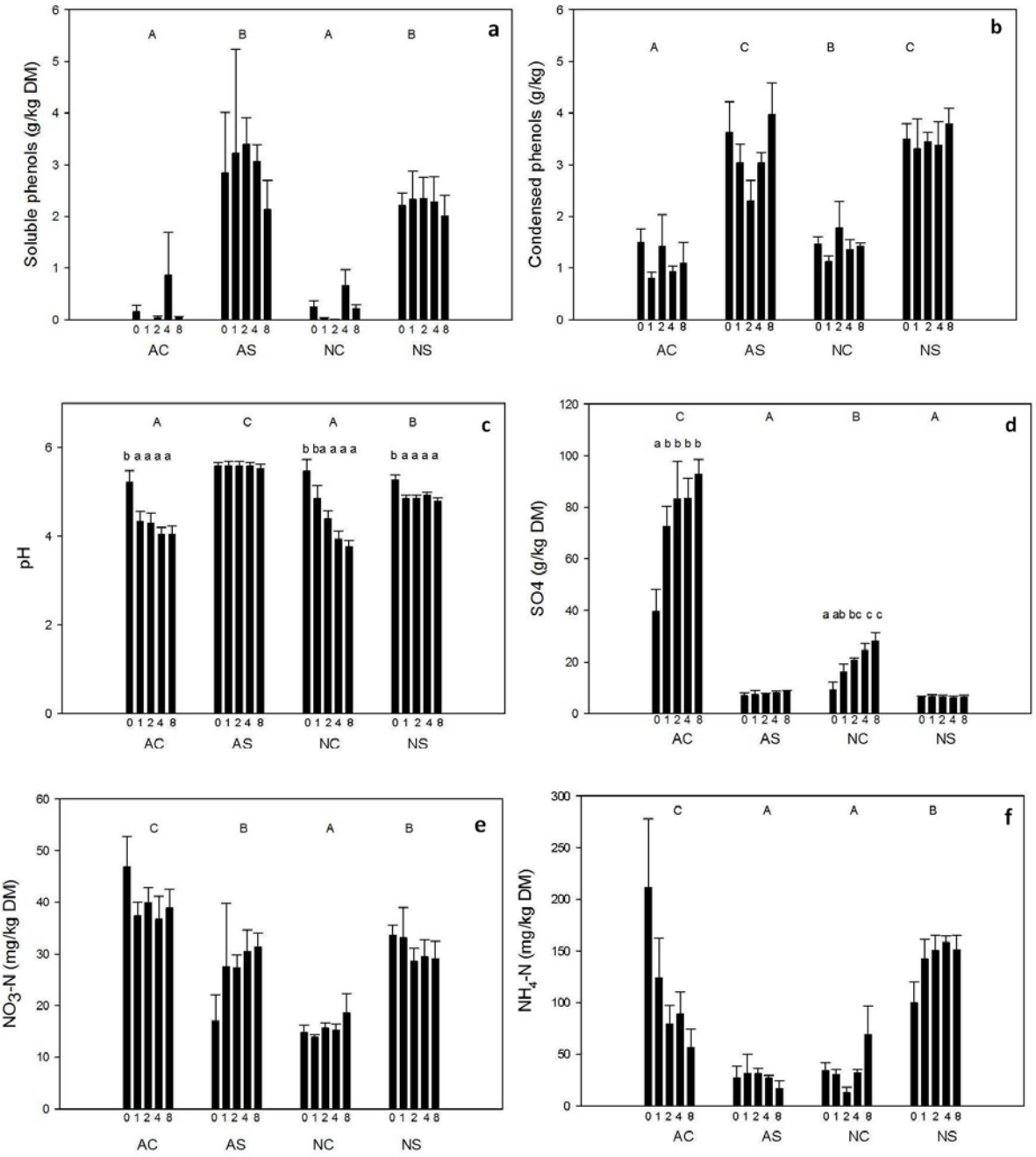

Figure 1: a) Extractable soluble phenols, b) condensed phenols (right panel), c) pH, d) SO_4, e) NO_3, f) NH_4 at the end of the incubation experiment. Numbers under the bars indicate the length of the aerobic period in weeks. AC=Agriculture *Carex*, AS= Agriculture *Sphagnum*, NC=Nature *Carex*, NS=Nature *Sphagnum*. Error bars represent the standard error of five replicates. Peat types with no letters in common are significantly different (ANOVA, $p<0.05$); treatments with no letters in common are significantly different (ANOVA, $p<0.05$).

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