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EFFECT OF NITROGEN AND PHOSPHORUS ON THE RE-ESTABLISHMENT AND GROWTH OF *CAMPYLIUM STELLATUM* AND *SCORPIDIUM SCORPIOIDES* ON CALCAREOUS SPRING FEN

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SUMMARY

Calcareous tufa-forming spring fens are among the most endangered mire types worldwide. The restoration of spring fens is very complicated and the most crucial task is to restore a moss carpet. In 2010 we started with an experiment aimed to study the effect of N and P addition on the establishment and growth of the two key moss species on an area of spring fen that was formerly weakly drained but now has a raised up water table. Preliminary results indicated a positive effect of P (but not of N) on the growth of the *Scorpidium scorpioides*. The positive effect of P on the growth of *Campylium. stellatum* was less evident.

KEYWORDS: brown mosses, calcareous tufa, Estonia, field experiment, water level

INTRODUCTION

The composition and distribution of plant cover (vascular plants and bryophytes) in calcareous tufa forming fens is determined by three main factors: continuously deposited tufa, high water level and limited nutrient status for the growth of plants. These conditions are unfavorable for many plant species but favorable for many rare species. In Estonia the distribution of *Juncus subnodulosus*, *Selaginella selaginoides*, *Saxifraga hirculus* and many orchid species is mostly related with spring fens (Ilomets *et al., in press*). Furthermore, bryophytes are considered ecologically important in calcareous fens. Being reliable indicators, they reflect the mineral status and water level of the fen. *Campylium stellatum* (Hedw.) J.Lange & C.Jens. and *Scorpidium scorpioides* (Hedw.) Limpr. are two of the common bryophyte species in spring fens in Estonia. However, these two species are found at somewhat different water levels: *C. stellatum* is mostly found slightly higher above the water table (Mälson and Rydin, 2009) while *S. scorpioides* prefers wet carpets where the water level is near or at the surface.

Even though calcareous spring fens are mineral-rich habitats, the availability of nutrients for plant growth is limited. There are several studies in which the growth of *S. scorpioides* at various water levels and/or water chemistry are analysed but studies with *C. stellatum* at different nutrient levels are much rare.

In this study we experimentally investigate the effect of N and P addition on the growth and distribution of the two widespread fen moss species at three different water level gradients. We hypothesized that the species differ in their response to N and P addition and water level.

MATERIALS AND METHODS

In 2010 we set up 5-year-long fertilization experiment in Paraspõllu fen in North Estonia (Fig. 1). At the beginning of 20th century the area was drained with ditches with the intention to use the fen as hayfield and pasture. In 2010 the water level (WL) was raised at the experiment area. Earlier studies have shown that the experimental area belongs to *Molinia caerulea - Schoenus ferrugineus* group (Ilomets *et al.*, 2010). The moss species composition (found 19 species) reflected the calcareous-rich fen situation, but the distribution of most species was sporadic, with the mean coverage below 1%. We removed litter and *M. caerulea* tussocks from the experimental area (15 x 10 m) and set up 3 experimental blocks with slightly different water level.

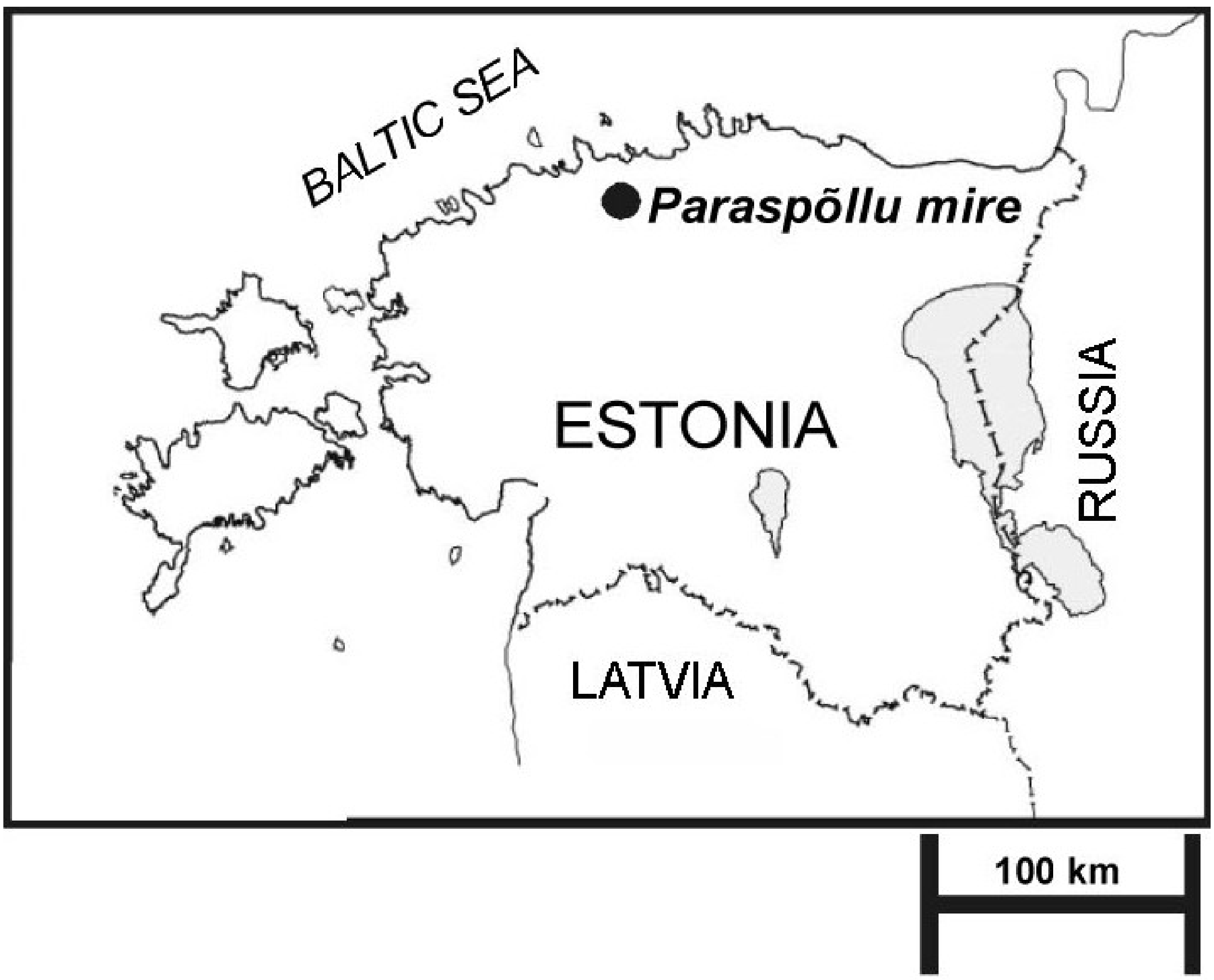

Figure 1: Paraspõllu mire location (Ilomets *et al.*, 2010).

We collected *Campylium stellatum* and *Scorpidium scorpioides* from the eastern part of Paraspõllu fen. These are two of the most common bryophyte species there. We used 40 apical stems of *S. scorpioides* cut to 2 cm per pot. *C. stellatum* was also cut into 2 cm long parts and 3-4 g fresh material was used per pot. Perforated plastic pots (130 x 90 x 45 mm), filled with peat and moss stems that were put evenly on the peat, were inserted into the surface to the same level with the peat surface around pots on the experimental area (Fig. 2).

Every experimental block contained 5 treatment levels. The pots were sprayed with solutions of NaH_2PO_4 (P1: 1.0 g P m^{-2} a^{-1}; P2: 3.5 g P m^{-2} a^{-1}); NH_4NO_3 (N1: 0.7 g N m^{-2} a^{-1}; N2: 1.5 g N m^{-2} a^{-1}) and the control pots with fen water at two weeks interval. Water level at different blocks, pH and electrical conductivity of the fen water were measured.

In autumn 2011 we collected eight samples at every treatment levels from every experimental block. In laboratory analyses the dry weight of the samples was weighed (48 h, 70 ^{o}C). Dry weight growth (DW) of both species and linear growth of *S. scorpioides* were calculated.

The analyses were performed using the program Statistica 8.0. Differences in growth of mosses between treatments and experimental blocks were tested with ANOVA.

RESULTS

Average water level (WL) differed significantly between experimental blocks in 2011 ($F=10.420$; $p<0.001$). The WL at experimental blocks varied between (-2) to (-3) cm. Average pH of the fen water at experimental blocks was 7.1 and electrical conductivity 285 µS cm^{-1}.

After the first experimental year the growth in dry weight (DW) of the samples showed similar trend in both moss species at different treatment levels (Table 1).

Table 1: Growth (g per pot) in dry weight (DW) of *S. scorpioides* (S.s) and *C. stellatum* (C.s) at different treatment levels. Values sharing the same letter are not significantly different ($p>0.05$)

	Cont.	*P1*	*P2*
S.s DW	**1.02^{a}**	1.11^{a}	**1.60^{b}**
C.s DW	1.17^{a}	1.67^{a}	1.76^{a}
	Cont.	*N1*	*N2*
S.s DW	1.02^{a}	1.24^{a}	0.99^{a}
C.s DW	1.17^{a}	1.30^{a}	0.98^{a}

Figure 2: Photo of one experimental block in Paraspõllu fen in autumn 2011.

Significant effect was observed between experimental blocks and the linear growth of *S. scorpioides* ($F=3.943$; $p=0.03$). The growth was highest at the 3rd and the lowest at 1st block (average water levels -2.6 cm and -2 cm, respectively).

There was no significant effect in N treatment; still we found a relationship in case of *S. scorpioides* between N treatment on different blocks and DW ($F=4.800$; $p=0.015$), the DW was highest on the 2nd block (average water level -2.9 cm) and differed significantly from the 1st and 3rd blocks. However, P treatment had significant effect on *S. scorpioides* DW ($F=4.269$; $p=0.022$), the higher was the concentration of P, the higher was the growth in DW. We found no significant effect of N or P on *C. stellatum* growth ($p=0.390$ and 0.176, respectively).

DISCUSSION

First year results may be too preliminary to estimate the growth of brown mosses in the field experiment; however initial results still may give us important information of the possible restoration succession for the few next years.

Fen bryophytes are considered to be adapted to grow on relatively high water levels. Still, there are differences in the response of two key moss species, *C. stellatum* and *S. scorpioides* to water level. We found no differences in *C. stellatum* growth between our experimental blocks at different water levels. This may refer to the importance of other environmental factors or the wider tolerance to water level. It corresponds well with the data from Mälson and Rydin (2007) that showed that the growth of *C. stellatum* is not strongly influenced by very small (approximately 5 cm) water level differences.

Also we did not find any significant correlations in *C. stellatum* growth and N or P addition. There are studies that have analysed the regeneration capabilities of *C. stellatum* after surface liming (Mälson and Rydin, 2007) or competition between *C. stellatum* and other fen bryophytes (Mälson and Rydin, 2009) but studies of *C. stellatum* response to increased N or P addition are rare. Despite that *C. stellatum* prefers habitats slightly above the water level in fens (Mälson and Rydin, 2009), Clapham (1940) showed that *C. stellatum* is one of the most abundant mosses in earlier stages in the succession from open water to carr, forming extensive mats. However, *C. stellatum* seems to have wider tolerance in the case of water level and nutrient concentration in its surrounding environment.

Contrary to the results of *C. stellatum*, we found that average water level at our experimental blocks was an important factor in case of *S. scorpioides* growth. There were differences concerning the linear and dry weight growth of the species. Even though we could not find any relationship between these two measured growth types, the linear growth was depressed on the first year at the block where the WL was highest but the DW growth was highest on the 2nd block (WL lowest) on plots treated with N, indicating possible N limiting effect in *S. scorpioides* growth when the WL is low. However, growth rates stayed lower on high N treatment plots than on control plots, suggesting the need for further investigation to make any conclusive decisions.

Characteristic rich fens where *S. scorpioides* is growing are considered to be P-limited (Kooijman, 1993). However, it has been noted that if the concentration of P is too high, this species disappears (Kooijman and Hedenäs, 1991). Our results indicate the increase in DW growth of *S. scorpioides* with the addition of P. Thus, to rely on the results from Kooijman and Hedenäs (1991), even our highest concentration of P treatment was not too high to decrease the vitality of *S. scorpidium* but contributed to higher growth rates of the species.

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