Effects of Ca:Mg ratio and pH on soil properties and grass N yield in drained peat soil

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Abstract

In three dairy grasslands on peat, minerals were added to manipulate the soil Ca:Mg ratio with or without effect on pH. The responses of soil properties and grass N yield were measured. $CaCO_3$ application led to higher soil Ca:Mg ratio and pH_{KCl} compared to the untreated control, decreased N_{total} and C_{total}, and increased P availability. Grass N yield increased in the first year by 21 kg N ha^{-1} whereas soil N_{total} decreased by 380 kg N ha^{-1} in the same period. $MgCO_3$ reduced the Ca:Mg ratio, had little influence on soil parameters and no effect on grass N yield. In contrast, $CaSO_4$ and $MgSO_4$ did not influence pH_{KCl} but reduced grass N yield in most cases. We conclude that grass N yield was not linked with changes in Ca:Mg ratio but with soil pH. To avoid potentially large soil losses of C and N, the current agricultural advice on pH management in peat grasslands should be better adapted to local edaphic characteristics.

Keywords: grassland, lime, gypsum, kieserite, soil pH, N_{total}, C_{total}

Introduction

Reducing soil organic matter (SOM) decomposition while maintaining sufficient grass production for dairy farming is a major challenge in drained peat soils. From a large data set in 20 dairy grasslands on peat, including grass N uptake and the natural variation in soil properties, Deru *et al.* (2019) concluded that the Ca:Mg ratio in the topsoil was the best single soil parameter predicting the unfertilized grass N yield (a proxy for soil N supply). Their results suggested that a higher Ca:Mg ratio may increase the uptake of mineralized N by grassland due to improved soil structure, rooting and water availability, in line with the work of Dontsova and Norton (2002), without increasing the N mineralization itself. This raised the question whether the soil Ca:Mg ratio in peat grasslands can be manipulated to influence the grass N uptake without affecting SOM decomposition.

Materials and methods

A study was carried out on three peat grasslands with different initial soil Ca:Mg ratios (6.9, 4.0, 2.9). Four minerals were added to increase or decrease the Ca:Mg ratio: two with an expected effect on pH ($CaCO_3$ and $MgCO_3$) and two without such an effect ($CaSO_4$ and $MgSO_4$). Amounts were based on applications of 2,500 kg Ca ha^{-1} and 760 kg Mg ha^{-1}, resulting in higher CO_3 or SO_4 applications in the treatments with Ca compared to those with Mg. In each grassland, a randomized block experiment with five treatments (including an untreated control) in four blocks was laid out. During the application year (2014), the farmers continued their normal grassland management. In 2015 and 2016, the experiment was not grazed and no fertilizer was applied, but grass was harvested four times per year, including weighing and sampling for dry matter and total N. In February 2015, soil Ca:Mg ratio was measured. In October 2015, soil pH_{KCl}, C_{total}, N_{total} and P availability (P_{AL}) were measured in 0-10 cm. Additional information on methods is given in Deru *et al.* (2021).

Results and discussion

Soil Ca:Mg ratio was influenced by treatments at the three grasslands as expected (increase with added Ca and decrease with added Mg; Table 1). Soil pH_{KCl} was increased by added CO_3 containing minerals, but not by SO_4 containing minerals. C_{total} was reduced by CO_3 (equivalent to a loss of 2.8 Mg C ha^{-1}) but not by SO_4. N_{total} and P_{AL} were influenced only by $CaCO_3$; N_{total} negatively (equivalent to a loss of 380 kg N ha^{-1}), and P_{AL} positively.

Unfertilized grass N yield was increased in the $CaCO_3$ treatment with 21 kg N ha^{-1} compared to the control (yielding 203 kg N ha^{-1}) during the first year following mineral addition, but not in the subsequent year (Figure 1). Thus, the extra grass N yield after liming with $CaCO_3$ was only 6% of the reduction in the previously mentioned soil N stock (N_{total}). The minerals containing SO_4 reduced grass N yield in both years. Regression analysis showed no correlation between Ca:Mg ratio and unfertilized grass N yield, but grass N yield was positively correlated with pH.

Conclusions

Addition of Ca- and Mg-containing minerals in peat grasslands influenced the soil properties especially for $CaCO_3$, the treatment with the highest CO_3 input. Contrary to our hypothesis, grass N yield was primarily linked with changes in soil pH and not with changes in Ca:Mg ratio. Grass N yield increased (+21 kg N ha^{-1}) one year after applying the $CaCO_3$ mineral, but the coinciding strong decrease in the soil N stock (-380 kg N ha^{-1}) indicated low utilization of the (extra) mineralized N and a disproportional environmental risk of increasing the pH of peat soils. The results of our experiment do not support Ca:Mg ratio as a useful measure of soil quality for increased herbage production in peat grasslands without extra losses of C and N. To avoid those losses, the agricultural pH advice for peat grasslands should be better adapted to the local soil properties that influence SOM decomposition, such as initial pH and P availability. Moreover, advice should be specific in terms of the type and quantity of mineral to be used, based on the expected effect on pH and SOM mineralization.

Table 1. Treatment effects on soil chemical properties. Means with the same superscript are not significantly different (α=0.05).

Parameter	*P*-value	Control	$CaCO_3$	$CaSO_4$	$MgCO_3$	$MgSO_4$
Ca:Mg ratio	<0.001	4.6[c]	6.4[d]	6.3[d]	3.8[b]	2.5[a]
pH_{KCl}	<0.001	4.7[a]	6.1[c]	4.7[a]	5.0[b]	4.8[a]
C_{total} (g 100 g^{-1})	0.008	20.9[b]	20.5[a]	21.1[b]	20.4[a]	21.1[b]
N_{total} (g 100 g^{-1})	0.006	1.70[b]	1.63[a]	1.68[b]	1.67[b]	1.69[b]
P_{AL} (mg P_2O_5 100 g^{-1})	0.002	45.1[a]	50.0[b]	43.6[a]	46.0[a]	45.1[a]

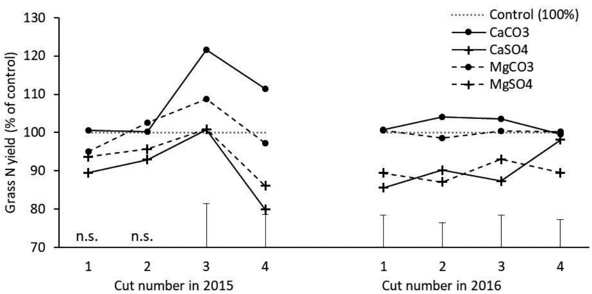

Figure 1. Unfertilized grass N yield (kg N ha^{-1}) per cut in 2015 and 2016, expressed as a percentage of the control plots. Vertical bars on the x-axis represent the LSD per cut in case of significant ($P \leq 0.05$) treatment effect. Mean values of the control plots for each consecutive cut are 72, 44, 62 and 40 kg N ha^{-1} in 2015 and 76, 57, 45 and 43 kg N ha^{-1} in 2016.

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