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Short communication

Positive effects of sulphur fertilisation on grasslands yields and quality in Belgium

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Abstract

Atmospheric sulphur (S) depositions have been decreasing in Europe for the past 20 years. Up to now, there were no evidences of S deficiencies on cut grasslands in Belgium. The effects of S fertilisations together with incremental nitrogen (N) dressings were investigated in Belgium using small plot trials on cut grassland between 2001 and 2003. In 4 cases out of 13, S supply increased dry matter yields on average by 0.8 t ha^{-1} y^{-1}. Response to S appeared to depend on the site, the year, the N fertilisation level and the soil. Grass S content was significantly increased and N:S ratio decreased by S fertilisation. High N:S ratio (>14) was observed in grasslands without S fertilisation even with a moderate N supply. It is concluded that S deficiency can be feared for cut grassland in Belgium mainly on light textured soils after a wet winter.

Keywords: S deficiency; Grassland; N:S ratio

1. Introduction

During the last decades, sulphur (S) deficiencies on agricultural crops have been observed throughout Europe (Zhao et al., 2002). These observations have increased resulting mainly from the diminution of atmospheric sulphur deposition but also from higher crop yields and changes in fertilisation practices (Ceccotti, 1996). Sulphur shortage limits grass growth, protein production (Murphy and O'Donnell, 1989) and nitrogen (N) use efficiency that lead to higher risk of nitrate leaching (Brown et al., 2000). Up to now, there is no evidence of S deficiencies on grasslands in Belgium. However, in 1998, Bussink and Den Boer (2000) observed sulphur shortages on grass in the Netherlands, a neighbouring country with a similar atmospheric S deposition. Therefore S shortage can be feared in Belgium. An experimental network was established to check whether sulphur deficiencies might occur on Belgian grassland and set the bases for S fertilisation advices.

2. Materials and methods

Between 2000 and 2003, eight cutting grasslands were selected for potential sulphur deficiency (Table 1). The site selection was done considering the presence of one or more of the next characteristics: light textured soil, soil with low organic matter content, shallow soil and site location in regions with relatively low sulphur depositions, far from industrial areas and the deep of the water table. Sites 3, 4 and 5 have a shallow soil (±45 cm depth). Concomitant sites differ for their pH (sites 1 and 2), soil carbon content (sites 4 and 5) and water table deepness (at site 7 (1 m) higher than at site 8). At all sites, the grassland was mainly composed of *Lolium perenne* excepted at site 3, where it was a pure stand of *Lolium multiflorum*.

2.1. Fertilisation

At each site the effects of several sulphur (Table 2) and nitrogen treatments were measured. Sulphur was supplied as K_2SO_4 (17% S) except at site 4 ($MgSO_4$, 20% S), in split application before each of the three first cuts. At all sites nitrogen was supplied as NH_4NO_3 at three levels N_1, N_2 and N_3 except at sites 2 and 8 where there was only the N_2. The medium level (N_2) was on average about 80 kg N ha^{-1} cut^{-1}. The N_1 and N_3

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Table 1
Site location, climate and soils characteristics

Site no.	Site name	Location	Alt. (m)	Annual mean temperature (°C)	Annual rain (mm)	Age[a] (y)	Soil		
							Type[b]	pH[c]	%C
1	Bocholt 1	51°10′N 5°34′E	45	10.7	845	4	Sand	4.7	2.2
2	Bocholt 2	51°10′N 5°34′E	45	10.7	845	4	Sand	6.3	2.5
3	Heure	50°17′N 5°17′E	260	10.0	818	1	Clay loam	5.9	3.1
4	Michamps 1	50°00′N 5°42′E	540	8.5	1109	3	Silt loam	6.0	2.1
5	Michamps 2	50°00′N 5°42′E	540	8.5	1109	3	Silt loam	6.4	3.3
6	Nethen	50°47′N 4°40′E	45	11.0	747	0	Silt loam	7.4	0.8
7	Tielen 1	51°14′N 4°53′E	20	11.0	748	4	Sand	4.6	2.7
8	Tielen 2	51°14′N 4°53′E	20	11.0	748	4	Sand	4.8	2.8

Alt.: altitude, rain: rainfalls (mm y^{-1}).
[a] Age of the grassland at the beginning of the experiment.
[b] Classification of the International Society of Soil Science (Black, 1968).
[c] pH and %C (carbon content) of the 0–15 cm.

levels were respectively lower (40 kg N ha^{-1} cut^{-1}) and higher (105 kg N ha^{-1} cut^{-1}) than the N_2. Phosphorus (P) and potassium (K) were applied according to soil analyses. The P as triple super phosphate (except at site 4) and the K as KCl taking into account the K of the K_2SO_4. At site 4, the P and K fertiliser was PK (18–18) that also supplied about 25 kg S in spring 2001.

2.2. Yields and analyses

The treatments were distributed in a randomised block design with 4 replicates. Plots were at least 2 m × 5 m size of which a minimum of 0.80 m × 5 m was harvested and weighted fresh. Grass samples were taken on each plot and DM calculated after drying (105 °C). Depending on the location and the year, each plot was cut 2–5 times a year (Table 2). Grass samples were analysed for nitrogen content by NIRS. Total sulphur concentration of the forages samples of sites 1, 6 and 7 was analysed by the Dumas method with an automated combustion analyser (LECO FP2000).

2.3. Statistics

The sulphur effect on cuts and annual DM yields was determined with a general linear model procedure (N, S and block factors). The factors and the N × S interaction effects were tested by using all the other interactions as residual (Dagnelie, 2003). Sulphur treatments considered were S_0 and mean, for each block, of all the other S treatments called S_+. For the determination of the optimal sulphur fertilisation, all S treatments were considered separately. The deficient cuts were the replicates. Means were compared with the Tukey test (Systat, 1998).

3. Results

In 2002, the sulphur fertilisation increased significantly ($p < 0.05$) annual dry matter yields at site 1, 4, 6 and 7 (Table 3). At these sites, the S_+ treatment increased DM yields from 0.2 to 1.1 t ha^{-1} at the N_2 and N_3 fertilisation levels. At all sites, N fertilisation increased annual DM yields ($p < 0.001$) except at site 7 in 2002. No N × S interaction was observed ($p > 0.05$) whatever the site or the year.

The main positive effects of S supply on DM yield were observed on the first and third cuts (Table 4). At site 1, the sulphur supply also improved significantly the first cut and the annual yields at the N_2 and N_3 level but not significantly. During the 3 years of experimentations, 7 cuts out of 51 responded significantly to the sulphur dressing.

To approximate the amount of S required to avoid S deficiency, mean effects of the S application on the deficient cuts were determined (data not shown). For all cuts and N levels, the

Table 2
Annual fertilisations: sulphur and cut number in function of the site and the year

Site no.	Year	Number of cuts	Treatments S (kg S ha^{-1} y^{-1})				
			S_0	S_+			
				S_1	S_2	S_3	S_4
1	2001–2002	5–5	0	24	60	–	–
2	2003	5	0	24	60	–	–
3	2001	2[a]	0	8	16	24	40
4	2001–2002–2003	3–4–3	0	36	60	–	–
5	2003	3	0	36	60	–	–
6	2001–2002	2[a]–5	0	8	16	24	40
7	2001–2002	5–5	0	24	60	–	–
8	2003	4	0	24	60	–	–

[a] Followed during the second half of the growing season.

Table 3
Annual dry matter yields mean (t ha^{-1} y^{-1}) and (standard deviation) in function of S and N fertilisations of S deficient grasses

Site	Year	Treatments						Statistics S effect (*p*)
		N_1		N_2		N_3		
		S_0	S_+	S_0	S_+	S_0	S_+	
1	2002	10.2 (0.89)	10.7 (0.88)	12.2 (1.11)	13.0 (0.48)	11.7 (0.72)	12.8 (0.62)	0.050*
4	2002	6.0 (0.37)	6.5 (0.32)	9.6 (0.81)	9.8 (0.94)	9.7 (0.90)	10.7 (0.27)	0.020*
6	2002	12.9 (1.05)	13.3 (0.56)	16.9 (0.55)	17.5 (0.24)	18.3 (0.97)	18.8 (0.44)	0.037*
7	2002	10.0 (0.28)	10.6 (0.81)	10.7 (0.85)	11.7 (0.76)	10.3 (1.00)	11.1 (0.38)	0.005**

*$p<0.05$, **$p<0.01$, ***$p<0.001$.

Table 4
Mean dry matter yields (t ha^{-1} y^{-1} of DM) and (standard deviation) of sulphur deficient cuts in function of S and N fertilisations

Site	Year	Cut	Treatments						Statistics S effect (*p*)
			N_1		N_2		N_3		
			S_0	S_+	S_0	S_+	S_0	S_+	
1	2001	1	1.2 (0.23)	1.0 (0.21)	1.2 (0.46)	1.7 (0.36)	1.7 (0.41)	2.2 (0.37)	0.027*
	2002	1	2.1 (0.31)	2.3 (0.27)	3.4 (0.58)	3.8 (0.53)	3.0 (0.69)	4.0 (0.42)	0.020*
	2002	3	1.5 (0.22)	1.6 (0.10)	1.8 (0.26)	2.1 (0.14)	1.7 (0.28)	2.0 (0.10)	0.003**
4	2002	1	2.6 (0.25)	3.4 (0.30)	4.8 (0.38)	4.6 (0.54)	4.8 (0.43)	5.6 (0.12)	0.002**
6	2002	3	2.0 (0.15)	2.2 (0.12)	3.2 (0.12)	3.4 (0.10)	3.7 (0.09)	4.1 (0.10)	<0.001***
7	2002	3	1.6 (0.20)	1.8 (0.18)	1.8 (0.13)	2.1 (0.13)	1.5 (0.15)	1.9 (0.14)	<0.001***
	2002	5	1.2 (0.08)	1.3 (0.17)	1.1 (0.19)	1.4 (0.11)	1.1 (0.13)	1.2 (0.07)	0.007**

*$p<0.05$, **$p<0.01$, ***$p<0.001$.

DM yields were calculated relatively to the S_0 treatment. Means were compared at each N fertilisation level with the cuts as replicates. Sulphur treatments with less than three replicates were not included (i.e. 12 and 36 kg S ha^{-1} y^{-1}). On average, no S effect was observed at the N_1 level. Applying 24 kg S ha^{-1} y^{-1} was enough to avoid sulphur deficiency at the other N fertilisation levels (N_2 and N_3).

Sulphur and nitrogen content of the forages were determined for all cuts harvested at sites 1, 6 and 7 (data not shown). The S fertilisation always increased S content of the grass ($p<0.05$). Sulphur content ranged from 1.1 to 4.3 g S kg^{-1} DM (mean 2.4 g S kg^{-1} DM) without S supply and raised from 1.8 to 6.0 g S kg^{-1} DM (mean 3.6 g S kg^{-1} DM) with S fertilisation higher than 40 kg ha^{-1} y^{-1}. Applying S never influenced grass nitrogen content significantly ($p>0.05$) and always raised the N:S ratio ($p<0.05$). For the medium nitrogen fertilisation level (N_2) without S, about 40% of the grasses samples had an N:S ratio higher than 14 indicating risks of sulphur deficiencies (Dijkshoorn and Van Wijk, 1967).

4. Discussion

Reponses to S fertilisation were mainly observed on sandy soils (site 1, 6 and 7) and at the beginning of the growing season probably because of a too low S mineralisation (Sylvestre, 1965) but also due to sulphate leaching during winter. Indeed, the highest responses to the S fertilisation were observed in 2002. That year was preceded by a wet winter (September to March) with 773 mm rainfalls that was much higher than the normal, 494 mm (IRM, 2002).

In these experiments, the highest mineral nitrogen supply was close or higher than the fertilization rates now allowed in some areas of Belgium (Anonymous, 2007). These amounts were supplied to obtain high growing potential and to test the occurrence of sulphur deficiency when the grass S requirement is the highest. However even with lower rates of nitrogen supply, corresponding to normal commercial intensive farming systems (about 80 kg N ha^{-1} cut^{-1}), sulphur deficiencies were observed. These results indicate that using mineral nitrogen intensively without supplying sulphur may lead to S deficiency. It should be mentioned that, in commercial farms, while considering sulphur fertilisation, a significant part of the nitrogen is supplied with the organic fertilisation that influence positively sulphur availability to plants (Reddy et al., 2002) and therefore decreases the risks of S deficiency. While deficiency is feared or observed, it seems unnecessary to supply more than 24 kg S ha^{-1} y^{-1}. With higher S application no yield response is expected but it could raise grass S content close or higher than toxicity level reported for cattle nutrition (4.0 g S kg^{-1} DM, National Research Council, 2001). This could be a problem if grass is the only feedstuff for the cattle.

5. Conclusion

Sulphur can be limiting for plant growth in intensive farming system, after a rainy winter, mainly on sandy soils. Considering that in Belgium like in most of the Western Europe S depositions will keep on decreasing (Jonson et al., 2003), S deficiencies will probably be more frequent. Adjusting S to N fertilisation could become essential to ensure optimal plant growth but over fertilisation has to be avoided to keep grass S content adequate for ruminants nutrition. Therefore S fertilisation advices have to be developed.

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