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Insufficient Sulfur Nutrition of Yellowed Spruce and Beech in the Southern Black Forest

By

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Summary

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In the southern Black Forest Norway spruce and European beech stands were fertilized with $MgSO_4$ in spring 1988 to mitigate extreme magnesium deficiency diagnosed by foliar and soil analyses. In addition to a remarkable recuperation of all fertilized trees at the end of the growing season, in the leaves of fertilized beech trees the SO_4-S content as well as the organic-S fraction had increased compared to the control trees. In 4-year-old needles of fertilized spruces the SO_4-S contents were much higher than in current needles. Comparing the organic-S/total-N ratios of fertilized and control trees it became evident that a reasonable part of the absorbed sulfate had been metabolized. It is concluded that the sulfur nutrition of both spruce and beech can be insufficient in the southern Black Forest - an area with relatively low sulfur deposition.

Introduction

Since the beginning of the 1980's, pronounced yellowing symptoms have been observed within Norway spruce (*Picea abies* (L.) Karst.) and European beech (*Fagus sylvatica* L.) stands in the southern Black Forest at elevations higher than 700 m a.s.l. Poor Mg supply of the soil has been determined to be the dominant factor in the development of this type of forest damage. Diagnostic field experiments with mineral salt fertilizers which have been conducted since 1984, have shown that fertilization can reduce the symptoms within one growing season (HÜTTL 1985, LIU 1989). Quick and sustained effects on the Mg nutrition of the trees have been achieved after application of $MgSO_4$ fertilizers like "Kieserit" (HÜTTL 1991, ENDE 1991). In a similar field experiment the effects of $MgSO_4$ application on the sulfur nutrition of young beech and spruce trees were examined.

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Materials and Methods

In late summer 1987, Mg deficiency symptoms (intercostal chlorosis) had been observed in a naturally regenerating stand of European beech mixed with 10-year-old planted Norway spruce. The site is located near the ambient air measuring station "Münstertal" at the western edge of the southern Black Forest and has a northerly aspect at an elevation of 870 m a.s.l. The stand receives about 1700 mm precipitation annually. The atmospheric sulfur input is less than 16 kg ha^{-1} $year^{-1}$ (MIES 1987). The soil is an acid brown earth derived from a very base-poor granite. After plant and soil analyses, in June 1988 the magnesium sulfate fertilizer 'Kieserit' ($MgSO_4 \cdot H_2O$; 22 % SO_4-S) was applied in three different doses (500, 1000 and 2000 kg ha^{-1} fertilizer). Each plot measured ca. 25 x 50 m. Leaf samples of at least 15 beech trees per plot were collected one day before and every three weeks after treatment until leaves became senescent, using only the third to seventh youngest leaves of the terminal shoot (mixed samples, no replications). Needle samples of at least 10 spruce trees per plot were collected in winter 1988, one growing season after fertilization, and were separated in current and 4-year-old needles (4th whorl, mixed samples, no replications). Leaf and soil samples were analyzed as described by ALDINGER 1987. Total sulfur estimations were carried out using a Leco analyzer. Sulfate-S in leaves was determined by the method of KELLY & LAMBERT 1972. The organic-S fraction was calculated from total S minus sulfate-S.

Results and Discussion

The leaf analyses at the end of the growing season (Table 1) showed optimal supply of N, P and K but confirmed the observed extreme Mg deficiency of the beech trees of the control plot (cf. HÜTTL 1991). The sulfate-S content accounted for 10 % of total sulfur in the leaves of these trees. The total-S content (1.59 mg g dry $weight^{-1}$) was within the average range (cf. HOFMANN & KRAUSS 1988). However, in the leaves of the fertilized beech trees the sulfate-S content was increased three- to seven-fold compared to that of the control plot. After fertilization with 500 and 1000 kg ha^{-1}, approximately 30 % of total sulfur was found in the sulfate-S fraction, while the higher dose of 2000 kg ha^{-1} resulted in a sulfate-S content of 50 % (Table 1).

Table 1. Diagnostic fertilization trial in a young European beech (*Fagus sylvatica* L.) stand: mineral contents in leaves 9 weeks after fertilization with "Kieserit" ($MgSO_4 \cdot H_2O$) (Data adapted from ENDE & ZÖTTL 1990).

Plot	N	P	S_{total}	SO_4-S	K	Ca	Mg	Mn	Zn
kg ha^{-1}	(mg g DW^{-1})							(μg g DW^{-1})	
0	20.1	2.01	1.59	0.17	7.62	4.49	0.23	994	23
500	18.7	1.61	2.19	0.66	5.43	7.04	0.71	1454	31
1000	18.3	1.47	1.98	0.54	5.79	4.92	0.67	1013	28
2000	19.9	1.51	2.30	1.22	5.84	6.27	0.68	1407	33

Since a substantial part of the fertilizer sulfate had been taken up, S/N ratios were calculated to evaluate the metabolization of sulfate. In the control plot, in late summer the organic-S/total-N ratio approached a value of 0.030 (Fig. 1) which is considered typical for an undisturbed sulfur metabolism (e.g. for radiata pine: KELLY & LAMBERT 1972). At the fertilized plots the sulfate-S contents were increased after six weeks after fertilization. But at the end of the growing season the organic-S/total-N ratio also approached 0.030 (500 and 1000 kg ha^{-1}), indicating that a substantial part of the sulfate had been metabolized. Only at high $MgSO_4$ fertilization (2000 kg ha^{-1}) there was no evidence for an improvement of sulfur nutrition.

Addition of $MgSO_4$ resulted in a remarkable improvement of the vitality of the trees. Compared to the control plot, yellowing symptoms were drastically reduced upon fertilized trees and terminal shoot growth was significantly increased, showing the best effects took place following the lowest dose (500 kg ha^{-1}) application (ENDE & ZÖTTL 1990). Similar effects were observed with Norway spruce trees at the end of the growing season (Fig. 2). At the control plot, the total sulfur content of current needles was below 1.5 mg g dry $weight^{-1}$ with less than 10 % sulfate-S. At the fertilized plots, total sulfur and organic-S were increased in current as well as in 4-year-old needles. In fertilized trees, the percent of sulfate-S was much higher in 4-year-old than in current needles. This again indicates that fertilizer sulfate had been taken up by the trees and that a part of this sulfate was metabolized (especially in current needles), a part of it stored as inorganic-S (mainly in older needles).

Even though the trees investigated have been suffering from severe Mg deficiency and no statistical significance can be obtained from these single measurements, there is evidence that also sulfur supply at this site was not optimal and that fertilizer sulfate had a positive effect on tree nutrition.

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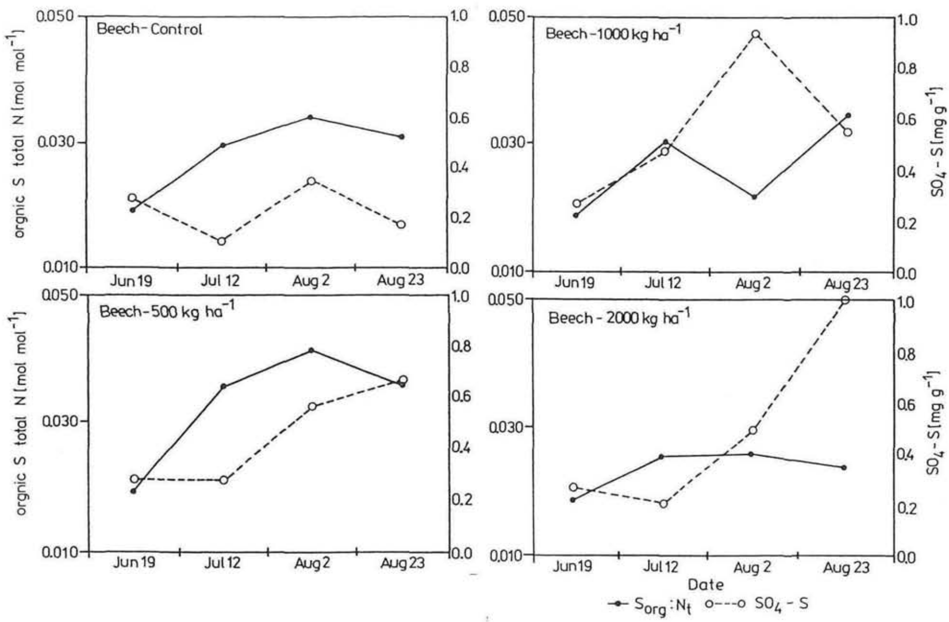

Fig. 1. Organic-S/total-N ratios and sulfate-S content in the foliage of European beech (*Fagus sylvatica* L.) after fertilization with various levels of "Kieserit" ($MgSO_4 \cdot H_2O$).

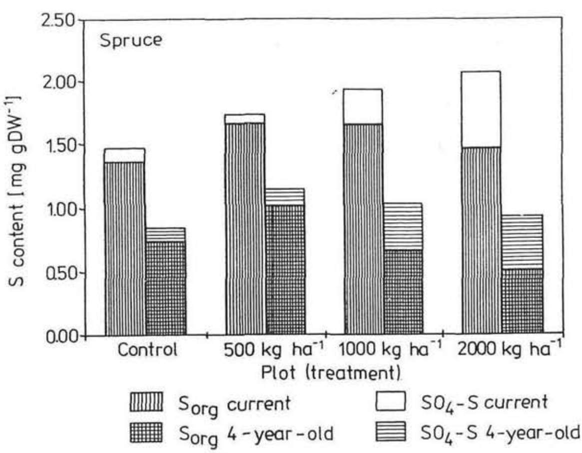

Fig. 2. Organic-S and sulfate-S content in the foliage of Norway spruce (*Picea abies* (L.) Karst.) after fertilization with various levels of "Kieserit" ($MgSO_4 \cdot H_2O$).