Forest Sciences

Northern Interior Forest Region

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Sulphur Fertilizer Trial in the West-Central Interior of British Columbia

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Introduction

Nitrogen fertilizer trials with immature lodgepole pine have demonstrated that actual or induced sulphur deficiencies are common in the central interior of British Columbia (Brockley 1996). In general, soils from around the world have carbon to sulphur ratios (C:S) of approximately 100:1, which is considerably more concentrated than the 300 - 500:1 ratios found in soils of the interior. These inherently low levels of S appear to be a combined effect of little atmospheric S inputs (being far from the ocean and with little history of industrial pollution), with regular losses of S through volatilization during forest fires.

Sulphur is a necessary element in tree nutrition, but, in addition, S deficiencies might limit key processes in soils, such as N-mineralization, decomposition and N-fixation. Most fertilizer trials have examined the effects of N additions with or without S on site productivity. Few field studies have addressed the possible role of S alone in ameliorating nutrient cycling in S-deficient forest soils.

The objective of this experiment was to test whether S fertilization alone would improve available S (as sulphate) and potential N availability (as mineralizable N) in forest soils of west-central British Columbia, and to determine the effect of S additions alone on tree growth and nutrition. Sulphur fertilizer was added (75 kg S/ha as gypsum) onto three broadcast burn lodgepole pine plantations (6 years old) and differences in tree growth, foliar nutrition and soil chemistry to unfertilized controls after 5 years are reported here.

Figure 1. Weighing out the sulphur fertilizer.

Methods

The experiment was established on 3 sites in west-central British Columbia, between the towns of Burns Lake and Smithers. The “Tintagel” site was located in the dry-cool variant of the Sub-Boreal Spruce zone (SBSdk), situated on mesic sites (the 01 White spruce-Spirea-Purple peavine). The “Fulton” site was located in the moist-cold variant of the Sub-Boreal Spruce zone (SBSmc), on mesic sites (01 White spruce-Huckleberry). The “McKendrick” site was located in the moist-cold variant of the Englemann Spruce-Subalpine fir zone (ESSFmc) on 01 Subalpine fir-Huckleberry-Leafy liverwort sites.

The sites were logged in 1987 and broadcast burned in 1988. Three blocks were located at each site, with one replicate of the treatments in each block. The plots were 30 m by 30 m in size, with 49 lodgepole pine seedlings (2+0 PSB 211) planted at 2.5 x 2.5 m spacing in 1989. In early June of 1997, calcium sulphate fertilizer was broadcast by hand to the plots at a rate of 75 kg S/ha.

Twenty-five forest floor (15 x 15 cm) and mineral soil (0-20 cm) random subsamples from each experimental unit were composited into five samples for chemical analysis. Soils were sampled for a previous experiment in 1989, then again in June 1995 (prefertilize) and in June 2001 (five years after sulphur applications). Lodgepole pine height was measured in the fall of 1995 (prefertilize), and again in September 1998 (two growing seasons after fertilization) and September 2000 (four growing seasons after fertilization). One leader from the second whorl of 25 randomly selected seedlings were bulked to form five composite foliar samples for each experimental unit at the same time.

Results

<u>Soils</u>

There was no changes detected in total S of the forest floor and mineral soil, five years after fertilization (Table 1). Available S (SO_4) of the mineral soil was quite variable in the fertilized plots, and mean values were somewhat higher than controls ($p = 0.147$), which could reflect a small, residual effect of fertilization. Mineral soil pH showed a weak decline ($p = 0.08$) after sulphur fertilization. Mineralizable N was highest after tree removal, and declined over time, although forest floor min-N had stabilized in the last 5 years (Fig. 2). There was no effect of S additions on min-N concentrations in either the forest floor or mineral soil (Table 1). Soil carbon concentrations had also decreased since the forest stands were harvested, especially in the forest floor (Fig. 2).

<u>Foliar</u>

Foliar concentrations before fertilization (six year old trees) suggested the stands were N deficient (< 12 g kg^{-1} N), as well as susceptible to S deficiencies if fertilized (N/S ratio > 13) (Brockley 2000). There were some improvements in foliar S concentrations two and four years after fertilization, but the increases, at less than 5%, were quite small (Table 2). Foliar N concentrations were marginally higher in fertilized plots after four years, but overall there was no consistent change in foliar N/S ratios at year 4 compared to year 0. Foliar N concentrations were not found to be as low in the subsequent remeasurements, so these stands might not be as nitrogen deficient as originally suspected. Foliar boron was also significantly higher after fertilization, and approached values considered adequate (Table 3). Other foliar nutrients in year 4 were generally adequate.

<u>Tree growth</u>

The lodgepole pine at the start of the experiment were 6 years old, and approximately 2 m tall. There was a small difference in total height to begin the experiment which was accounted for by covariate analysis. The height increment in year 2 and year 4 was slightly better in the fertilized plots, but the difference was very small at only 2 cm, on average (Table 2).

Table 1. Year 5, post-fertilizer results for selected soil properties. Treatment means for all three sites.

	Total S (g kg^{-1})	Avail. SO_4 (mg kg^{-1})	Min.-N (mg kg^{-1})	Soil pH (H_2O)
Forest floor				
Control	0.843	14.6	295	5.14
S fertilize	0.871	16.5	279	5.15
p < F	*0.599*	*0.513*	*0.643*	*0.860*
Mineral soil				
Control	0.075	3.5	17.0	4.93
S fertilize	0.062	5.6	12.1	4.76
p < F	*0.403*	*0.147*	*0.246*	*0.080*

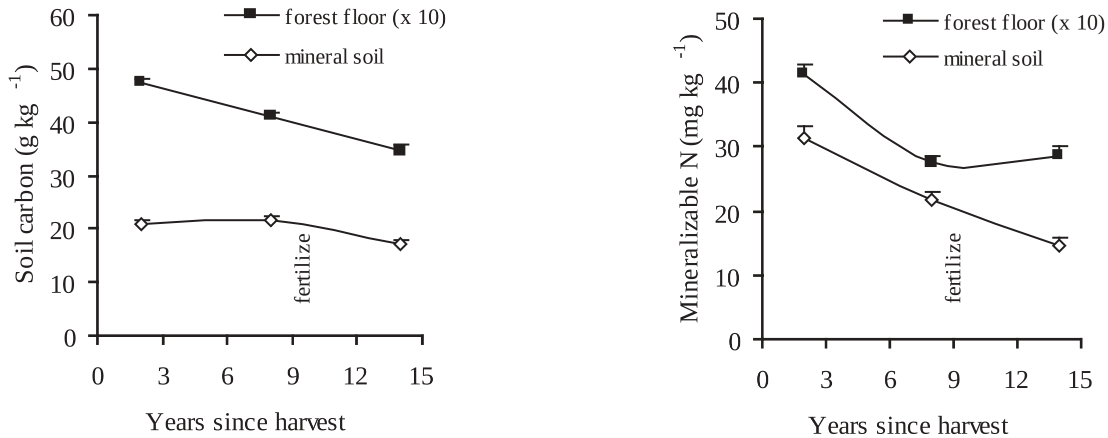

Figure 2. Trends in soil carbon and mineralizable nitrogen concentrations since tree harvest, both treatments combined. The point at which the current fertilization experiment began is indicated at year 9.

Table 2. Lodgepole pine foliar and growth response to sulphur (S) fertilization at 2 and 4 years post-treatment. Mean values for all three sites.

	Year 0 (Pre-fertilize)	**Year 2** (Post-fertilize)	**Year 4** (Post-fertilize)
	Foliar N (g kg^{-1})		
Control	10.7	13.4	13.2
S Fertilize	10.8	13.0	13.5
p < F	*0.659*	*0.141*	*0.128*
	Foliar S (g kg^{-1})		
Control	0.675	0.742	0.810
S Fertilize	0.679	0.779	0.833
p < F	*0.679*	*0.041*	*0.052*
	Foliar N/S ratio		
Control	15.9	18.1	16.4
S Fertilize	16.0	16.8	16.3
p < F	*0.849*	*0.004*	*0.593*
	Height (cm)	**Height growth (cm)**	
Control	192	53	45
S Fertilize	215	55	47
p < F	*0.023*	*0.047*	*0.170*

Discussion

Despite the widespread S deficiencies often found in soils of the interior, there appeared to be very little benefit from gypsum applications to these young lodgepole pine plantations. Tree uptake of the S was minor, increases in growth were quite small, and no differences could be detected in the soil S or N status that might improve site potential over time.

The relatively small response by lodgepole pine to the added S suggests N was the more growth-limiting nutrient, despite slightly to moderately deficient foliar S concentrations (0.80-0.10 g kg^{-1}; Brockley 2001). A more significant uptake of S would likely require a combined N + S fertilizer to stimulate tree growth (Brockley 1996).

Table 3. Foliar nutrient concentrations of lodgepole pine, four years after sulphur (S) fertilization. Mean values for all three sites combined.

	Mass (g per 100)	N (g kg^{-1})	P (g kg^{-1})	S (g kg^{-1})	Ca (g kg^{-1})	K (g kg^{-1})	Mg (g kg^{-1})	B (mg kg^{-1})	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Zn (mg kg^{-1})
Treat. (*p* < F)	*0.130*	*0.128*	*0.853*	*0.052*	*0.934*	*0.783*	*0.544*	*0.030*	*0.964*	*0.650*	*0.494*
Control	2.39	13.2	1.5	0.81	1.6	5.4	0.86	12	3.1	28	40
S fertilize	2.53	13.5	1.5	0.83	1.6	5.5	0.84	14	3.1	29	41
Adequate†	-	> 13.5	> 1.2	> 1.0	> 1.0	> 4.0	> 0.8	> 15	> 3	> 30	> 15

† Brockley 2001

Additions of elemental S have been found to reduce soil pH and negatively affect microbial biomass and activity in some forest and agricultural soils, especially after excessive or long-term S inputs. The gypsum application caused a fairly small decrease in mineral soil pH, which was likely a minor factor in the outcome of the experiment. The lack of response to S additions might instead reflect the more fundamental limitation of available carbon to microbial activity. The incorporation of S into microbial biomass requires an amendment with carbon (cellulose, for example) to stimulate microbial growth and activity. In contrast, these broadcast-burn sites have had declining concentrations of soil carbon over the 14 year period since tree harvest, which suggests there have been little of the necessary inputs of fresh carbon to incorporate the added S.

For these reasons the addition of 75 kg S per ha was difficult to detect after 5 years, and likely much of the added S had either been adsorbed on soil colloids or leached through the soil. There may be some long-term benefits to site productivity in increasing the S status of these interior forest soils, but correcting these deficiencies is apparently not so readily accomplished.

In young plantations the tree rooting is not yet very extensive, reducing the potential for plant uptake, while soil carbon and microbial biomass tend to decline, also reducing the potential for long-term incorporation of S into soil organic matter. A more strategic time to fertilize might be when stands are more fully occupying a site at canopy closure and organic matter inputs are theoretically increasing. Further research into the relationships between factors such as soil organic matter, microbial activity and stand development might therefore improve our ability to correct S deficiencies.

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