Potential Use of Combined Elemental Sulphur and Sewage Sludge as a Fertilizer

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ABSTRACT

Sewage sludge and crushed elemental sulphur (S^o) were combined in various ratios, and incubated under controlled conditions. Sulphur oxidation was strongly enhanced by addition of sewage sludge, though acidification of the mixtures prevented more than 4% of the initial sulphur to be converted to sulphate. Subsamples of these incubated mixtures were then added to soil, and compared to soil amended with S^o and Na_2SO_4. The sludge and S^o mixtures oxidized rapidly when introduced to the soil environment. Nearly 60% of the S^o from these mixtures oxidized within six weeks, compared to about 25% oxidation of S^o applied without sewage sludge. Indigenous S^o bacterial oxidzers in the sludge may explani the observed enhancement of S^o oxidation. Combinations of S^o and dewatered sewage sludge may provide an inexpensive and effective sulphur fertilizer source for western Canadian farmers in the future.

Key Words: Elemental sulphur, sulphur oxidation, sewage sludge

INTRODUCTION

Elemental sulphur fertilizer (S^o) has not proven to be an effective fertilizer source in western Canada, due to its very low rate of biological oxidation to plant-available sulphate (Swan et al, 1986; Noellemeyer et al, 1981; Solberg and Nyborg, 1986; Solberg et al, 1987). Granular forms of S^o, though easier and safer to handle, are very slow to oxidize. Very finely divided S^o, which may be applied in an emulsion, is more rapidly oxidized, but difficult to handle and apply (Ukrainetz, 1982; Janzen and Bettany, 1986 and 1987; Chapman, 1989; Nuttall et al, 1990; Karamanos and Janzen, 1991).

Maximum oxidation occurs if the S^o is thoroughly mixed in the soil (Solberg and Nyborg, 1986; Janzen, 1989; Janzen and Bettany, 1987), and if the soil is warm and moist (Janzen and Bettany, 1984). Soil pH also plays an important role. S^o oxidation acidifies the soil, and the activity of oxidizing bacteria is depressed in acid soil conditions (Gupta et al, 1988; Lawrence et al, 1988).

Recent studies have suggested that heterotrophic oxidation of S^o is stimulated by sources of organic matter (Cifuentes and Lindemann, 1993). Combination of S^o with a readily available carbon source may therefore provide a simple method of improving S^o as a fertilizer. This project examined dewatered sewage sludge as a potential amendment for stimulating S^o oxidation.

MATERIALS AND METHODS

The potential amendment of S^o with dewatered sewage sludge for production of a fertilizer product was envisioned to follow two steps. First, the S^o would be combined with sludge, and preincubated for a period of time to stimulate bacterial activity. Then, the combined S^o and sewage sludge would be applied to a sulphur deficient soil well before the crop was planted, in order to allow continued oxidation. This experiment thus followed two steps - a preincubation trial of various combinations of S^o and sewage sludge, followed by an incubation trial with the combinations added to a sulphur deficient soil.

The preincubation trial included mixtures of S^o and sludge at ratios of 8:2, 5:5, 2:8 and 0:10 on a dry weight basis. These mixtures were incubated for 10 weeks in plastic bags. The incubation chamber was maintained at 30°C and 90% Rh. Subsamples of each mixture were removed weekly for measurement of SO_4^{2-} and pH. After sampling, the mixtures were wetted to 80% of their water holding capacity. The mixtures were thoroughly mixed twice per week to improve conditions for aerobic oxidation.

For the soil incubation, treatments included subsamples from the preincubation trial from week 1, 2, 3, 5, and 7. In addition, treatments of S^o alone, Na_2SO_4 and a control with no sulphur addition were included. These treatments were added at an equivalent rate of 100 µg S per g soil to a Black Chernozemic sandy loam ('Meota') soil. Incubation conditions were identical to the preincubation study. The amended soil was sampled each week for six weeks for measurement of SO_4^{2-} and pH.

RESULTS AND DISCUSSION

Characteristics of Sludge, Sulphur and Soil

The S^o used in the experiment was a commercial grade of crushed elemental sulphur. As particle size of S^o decreases, potential oxidation increases. The S^o was passed through 60 and 100 mesh sieves to provide an estimate of particle size;

17.5% > 60 mesh (250 µm)
21.5 % < 100 mesh (160 µm)

The small amount of sulphur in the sludge would play an insignificant role as a supply of sulphur in the sludge and S^o mixtures (Table 1). The SO_4^{2-} content of the sludge exceeded 1300 ppm, which suggests an active population of sulphur-oxidizing bacteria was probably present. However, this SO_4^{2-} would again be insignificant at the rates of sludge and S^o which would be used as a fertilizer source. More importantly, the carbon and other nutrients supplied with the sludge may stimulate S^o oxidation. Previous measurement of possible pollutant elements in the Saskatoon sewage sludge indicate that these would pose no threat to the environment or food chain (Cowell and de Jong, 1991).

Table 1. Nutrient characteristics of Saskatoon dewatered sewage sludge.

Element	Concentration (%)
S	0.50
N	0.90
P	1.45
K	0.37
C	9.80

The soil used in the incubation experiment was sampled from the surface 10 cm of a farm field which had no previous applications of sulphur. The initial SO_4-S content of the soil was 9.8 ppm, which would be deficient for normal plant growth.

Preincubation Experiment

The final SO_4^{2-} concentration of the mixtures did not exceed 1% after 10 weeks of incubation (Figure 1). The SO_4^{2-} concentration of sludge alone remained stable during the preincubation period. For the mixtures, the SO_4^{2-} concentration was higher when the sewage sludge fraction of the mixture was increased. Sewage sludge stimulated S^o oxidation, but did not result in a high concentration of SO_4^{2-} accumulated at the end of the preincubation.

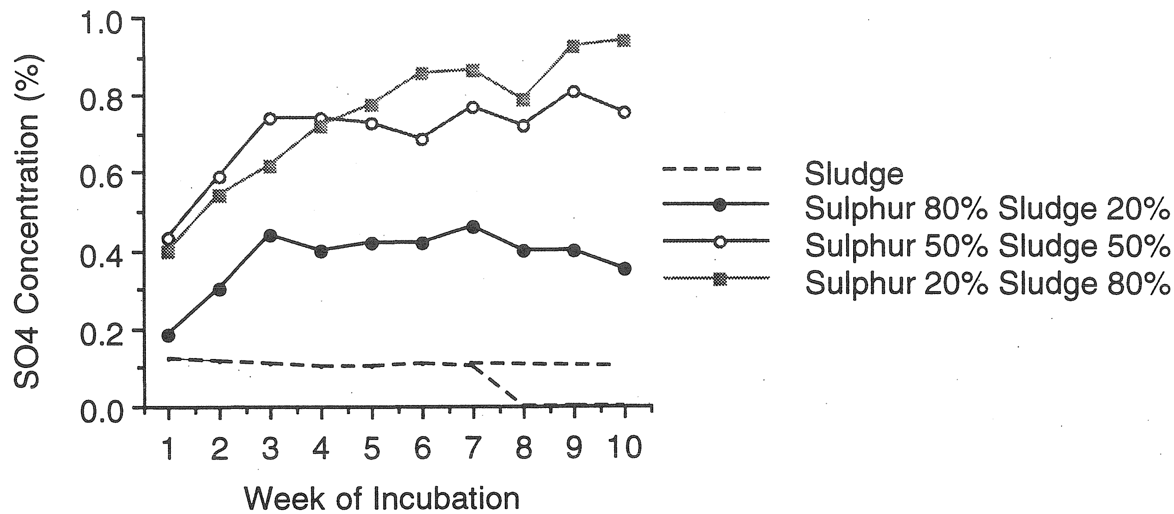

Figure 1. Sulphate concentration of sewage sludge alone and in mixture with S^o during the preincubation period.

The fraction of S^o oxidized to SO_4^{2-} was calculated for each treatment, while accounting for the original SO_4^{2-} contributed by the sludge. S^o oxidation was increased as the proportion of sewage sludge was increased in the mixtures (Figure 2). Over a 10 week period, only 0.3% of the S^o was oxidized to SO_4^{2-} when the mixture consisted of 20% sludge, but increased to 4.2% when the mixture was 80% sludge.

Sharply reduced pH due to S^o oxidation appeared to limit continued oxidation in the mixtures, and this effect was buffered by a higher proportion of sludge in the mixture (Figure 2).

Soil Incubation

Incubation of soil with the subsamples from the preincubation trial and with S^o and Na_2SO_4 would mimic activity in a fertilized fields soil, though probably at an increased rate of S^o oxidation. Nearly 100% of the added SO_4^{2-} from the NaSO4 source was accounted for at each sampling point throughout the soil incubation (Figure 3). This suggests that SO_4^{2-} immobilization and gaseous loss would have been minimal in the soil for all treatments.

The S^o added without sewage sludge oxidized to SO_4^{2-} slowly (Figure 1). After six weeks, and accounting for soil SO_4^{2-} content, only 25% of the S^o was accounted for as SO_4^{2-}. In contrast, all combinations of S^o and sewage sludge were effectively oxidized to SO_4^{2-}. There was no appreciable difference in oxidation rates between combinations of S^o and sewage sludge which had been preincubated for various lengths of time. There was also little difference in the final SO_4^{2-} release between different ratios of S^o and sewage sludge, although increased sewage sludge content did favour oxidation initially. After accounting for soil SO_4^{2-}, the average release of SO_4^{2-} from the combinations of S^o with sewage sludge was 57%. This amount was well over twice as high as S^o alone, and about 70% of the Na_2SO_4 source.

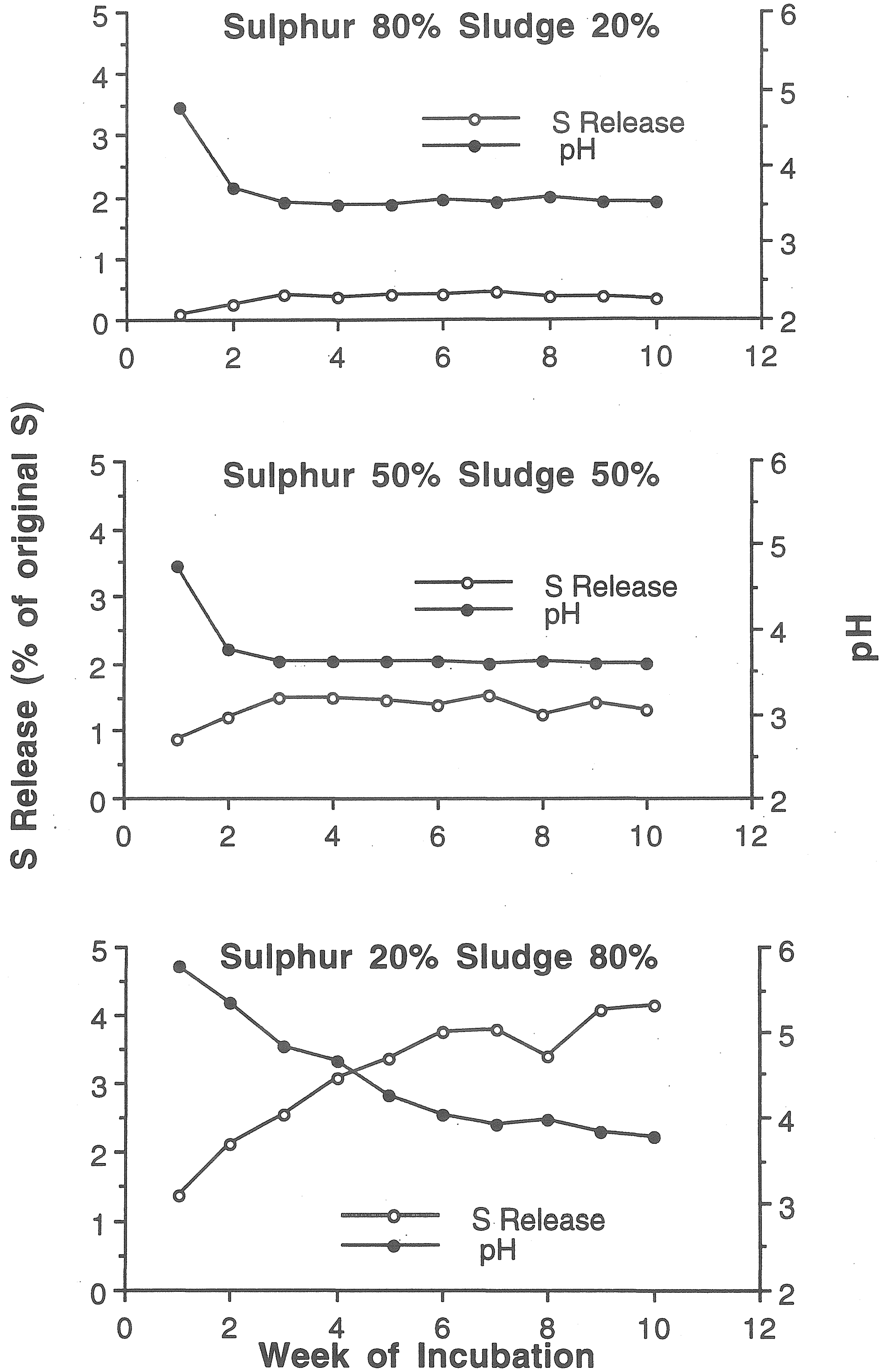

Figure 2. Percentage of S^o oxidized to SO_4^{2-} and pH of the mixtures over the course of the preincubation period.

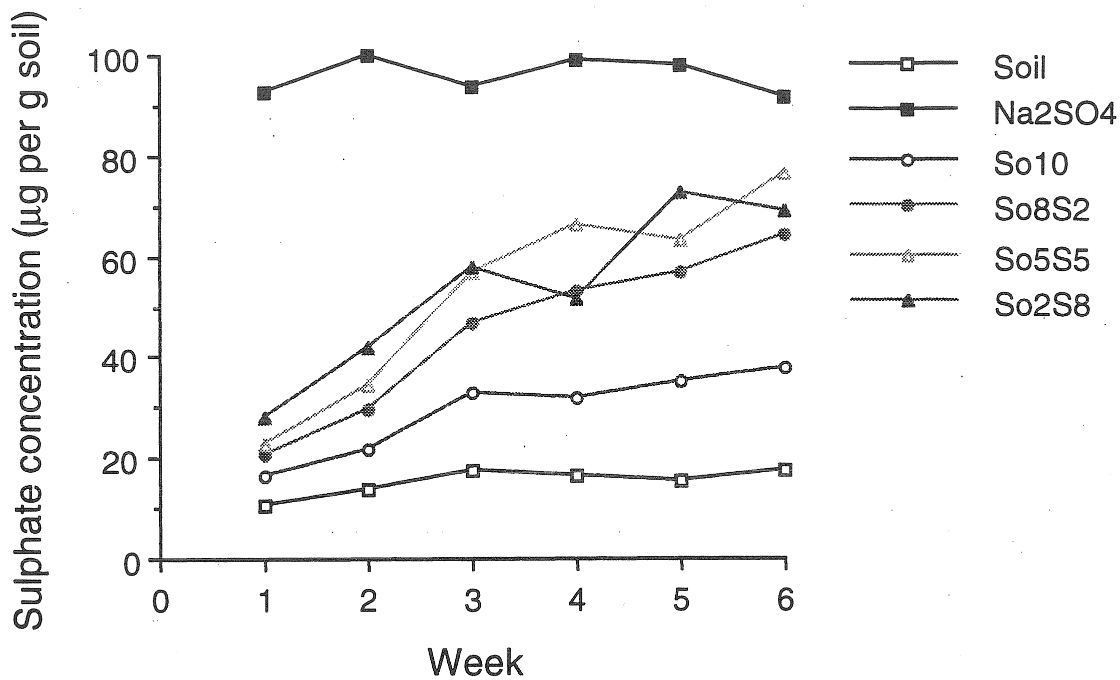

Figure 3. Sulphate content of soil during incubation after amendment with S^o, Na_2SO_4, and combinations of S^o and sewage sludge at a rate of 100 µg S per g soil.

Soil pH was not measurably affected by sulphur addition in the soil incubation. After six weeks, the pH of soil amended S^o and sewage sludge combinations averaged 7.98, while soil without any sulphur added had a pH of 8.07.

CONCLUSIONS

Sulphur oxidation was stimulated when combinations of S^o and dewatered sewage sludge were incubated together, and when they were added to soil. Based on these results, the preincubation step would probably not need to exceed one week if combinations of S^o and dewatered sewage were produced as a fertilizer. There is apparently an active population of sulphur oxidizing bacteria present in the sewage sludge, which quickly respond to the presence of S^o. The sewage sludge also provides a carbon and nutrient source for microbial growth. However, there was little difference in the effectiveness of the S^o and dewatered sewage combined in different ratios when added to soil. Oxidation of S^o rapidly proceeded after all of the combinations were added to a soil. In comparison, oxidation of S^o applied without sewage sludge was very slow during incubation in soil.

Acidification of the preincubation mixtures appeared to limit S^o oxidation, and SO_4^{2-} content did not exceed 1%. If a fertilizer product is required that immediately supplies a high concentration of SO_4^{2-}, this problem would need to be overcome.

The results of these initial incubation trials are very promising. Combining S^o with sewage sludge may produce an effective and inexpensive fertilizer for farmers.

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