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EFFECT OF SILICON COMPOUNDS ON SULPHUR OXIDATION IN AGRICULTURAL LOAM SOIL

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Abstract

Sulphur in the form of sulphate is an essential nutrient for plants and microbes. The oxidation of reduced sulphur in soil is usually regarded as a microbial process, although some non-biological oxidation of the element has been demonstrated in sterile soils. The aim of this research was to investigate the effect of silicon compounds on sulphur oxidation, in agricultural loam soil which was amended with silicic acid, sodium and potassium silicates, incubated at 25^0C under aerobic conditions. Lithium chloride ($LiCl_2$) 0.1 and 0.5 M was used as extracting agent. Solutions of the soil were analysed for sulphate-S on 7, 14, 21 and 28^{th} day of incubation, using turbidimetric analysis method. Present study, carried out in Sheffield, UK, shows that silicon compounds stimulate the sulphur oxidation to a significant level in agricultural loam soil.

Keywords: Sulphur oxidation, soil, silicon.

Introduction

Sulphur, occurs in organic and inorganic states in soil, that is essential nutrient for life. Microbes are important agents in mineralising organic sulphur compounds in soil. Plants and microorganisms normally take it up as sulphate. Despite its availability in large amounts in the earth's crust, sulphur supply in the soil is insufficient for the growth of plants. Sulphur deficiencies are found to occur in soils throughout the world (Bixby and Beaton, 1970). Sulphur may be obtained from the weathering of soil minerals, from the atmosphere, and from organically bound sulphur. On the earth's surface it is available as elemental sulphur, sulphides (reduced), and sulphates (oxidised). Plants contain as much sulphur as phosphorus, and sulphur is as important as nitrogen in the formation of proteins (Killham, 1994). Sulphur and nitrogen, both are constituents of protoplasm. Plants obtain their sulphur containing amino acids (e.g. cystine and methionine) by reducing dissolved sulphate. The oxidation of reduced sulphur in soil is usually regarded as a microbial process (Wainwright, 1978a), although some non-biological oxidation of the element has been demonstrated in sterile soils (Nor and Tabatabai, 1977; Wainwright and Killham, 1980). In the presence of available electron acceptors, sulfide, elemental sulphur, thiosulphate, tetrathionate, trithionate and sulphite are oxidised by both chemical and biological pathways. A variety of micro-organisms are capable of oxidising sulphur in the environment including members of the genus *Thiobacillus,* a number of heterotrophs, the photosynthetic sulphur bacteris, and the colourless, filamentous sulphur bacteria (Burke *et al.* 1974). Wainwright, (1978b) has commented, that in most soils only the thiobacilli, and heterotrophs play an important role in sulphur oxidation, the exceptions being flooded soils where the aquatic bacteria predominate. The aim of the work presented here, was to determine the effect of silicon compounds e.g. silicic acid, sodium silicate and potassium silicate on sulphur oxidation, when added in different amounts to agricultural loam soil. Since silicon fertilizers are also applied to crops, in several countries to increase

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productivity and sustainable production (Jian Feng,1999).

Materials and Methods

1. Effect of different amounts of silicic acid, sodium silicate and potassium silicate on sulphur-oxidation in agricultural soil in 14 days

To 100g triplicate set of fresh soil (Sieved < 4 mm), 1g elemental sulphur, 1,5,10 and 20g each of silicic acid, sodium silicate and potassium silicate, plus 2ml deionised water (sterile) were added and mixed thoroughly in polythene bags. Control was set-up without silicon compounds added. All the soil samples were then incubated aerobically, at 25^{0}C for 14 days. Analysis was made by diluting 1g soil to 20ml lithium chloride (0.1M) solution in screw capped glass bottles (150 ml) and shaken at 70 rpm by using orbital shaker for 15 minutes. The soil solution was then filtered by Whatman N0: 1 filter paper. Clear soil extract was analysed for sulphate-S by using turbidimetric analysis.

2. Effect of different amounts of silicic acid, sodium silicate and potassium silicate on sulphur-oxidation in agricultural soil in four weeks.

To 100g triplicate samples of agricultural soil (Sieved <4mm), 1g elemental sulphur, 1,5,10 and 20g each of silicic acid, sodium silicate and potassium silicate, plus 2ml deionised water (sterile) were added into polythene bags and mixed thoroughly. Control was set-up lacking added silicon compounds. All the soil samples were then incubated aerobically at 25^{0}C for 7,14,21 and 28 days. Analysis was made by diluting 1g soil to 20 ml lithium chloride (0.5 M) solution in screw capped glass bottles (150 ml) and shaken at 70 rpm by using orbital shaker for 15 minutes. The soil solution was then filtered by Whatman No:1 filter paper. Clear soil extracts were analysed for sulphate-S by using turbidimetric analysis. Dry weight of the soil was determined by weighing dried soil samples (overnight at 60^{0}C), using sensitive electrical balance. pH of the soil solutions was also measured by using a glass electrode pH meter.

Analysis of inorganic sulphur ions

(a) Turbidimetric analysis of sulphate-S (Hesse, 1971)

To 5ml filtrate in 25ml volumetric flask, 1g $BaCl_2$. $2H_2O$ and 2ml of gum-acacia (0.25%w/v), were added and mixed, and the volume was made up-to 25ml with distilled water. The white suspension resulting from precipitation of barium sulphate, was measured at 470nm by spectrophotometer. The concentration of SO_4^{2-} -S was determined by reference to a standard curve (0-100 µg SO_4^{2-}-Sml^{-1}) prepared from a standard solution on $Na_2SO_4.10H_2O$. Standard sulphate-S solution was prepared by dissolving, 0.443 grams of sodium sulphate ($Na_2SO_4.10H_2O$), in 1000 ml of distilled water which gives the concentration 100 µg SO_4^{2-} - Sml^{-1}.

Results and Discussion

Effect of different amounts of silicon compounds on sulphur oxidation in agricultural loam soil

Sulphate concentrations, reflecting sulphur oxidation, generally increased with increasing amounts of silicon compounds such as silicic acid, sodium silicate and potassium silicate to amended agricultural loam soil, that have the most pronounced stimulatory effect. $LiCl_2$ (0.1M) was used as extracting agent. The extract was analysed for the investigation of sulphate in agricultural loam soil on 14th day. In this case, sodium silicate proved to have the most marked stimulatory effect of the

three silicon compounds used (Fig.1). Changes in sulphate concentration (extracted with $LiCl_2$, 0.5 M) in the agricultural loam soil following amendment with silicic acid and sodium and potassium silicate over a 28 days incubation period are shown in (Fig. 2). In the case of silicic acid the previously observed trend of increasing sulphate concentration following amendment is generally seen over the entire 28 days incubation; and with the exception of the 21st day sample, this observed increase in sulphate concentration correlates with increasing amount of added silicon. (Fig.2a). Increased sulphate concentrations were seen following amendment at all concentrations of added sodium silicate for the first 14 days, after which there is a tendency for the reverse to occur, and sulphate concentrations are lower than the control result (Fig. 2b). The same trend is broadly seen following sulphur amendment with potassium silicates (Fig.2 c).

The results show that the silicon compounds used here stimulate sulphur oxidation in soils, leading to increased sulphate concentrations, at least during the first 14 days of the incubation period, with sulphate concentrations increasing with increasing amount of added silicon compounds. After 14 days, with the exception of silicic acid, sulphate concentrations fall below the control value. The reasons for the initial stimulation in sulphur oxidation are unclear, although they occur with all three compounds used, and not just sodium silicate, the effect is unlikely to be due solely to increases in soil pH.

An interesting subsidiary point arises from these results, namely how long should arbitrary based soil incubation studies be conducted. Clearly, had the above experiment been terminated at days 14 of the incubation period, the reported effect would be that silicon compound stimulate sulphur oxidation in this soil. However, the reverse is true if we consider results obtained from days 14-28 of the incubation period. These observations beg the question, what would the trends have been over the following 28 days had the incubation experiment been continued. Clearly the length of the incubation used in such experiments is a matter of accepted practice, rather than being a particularly meaningful period.

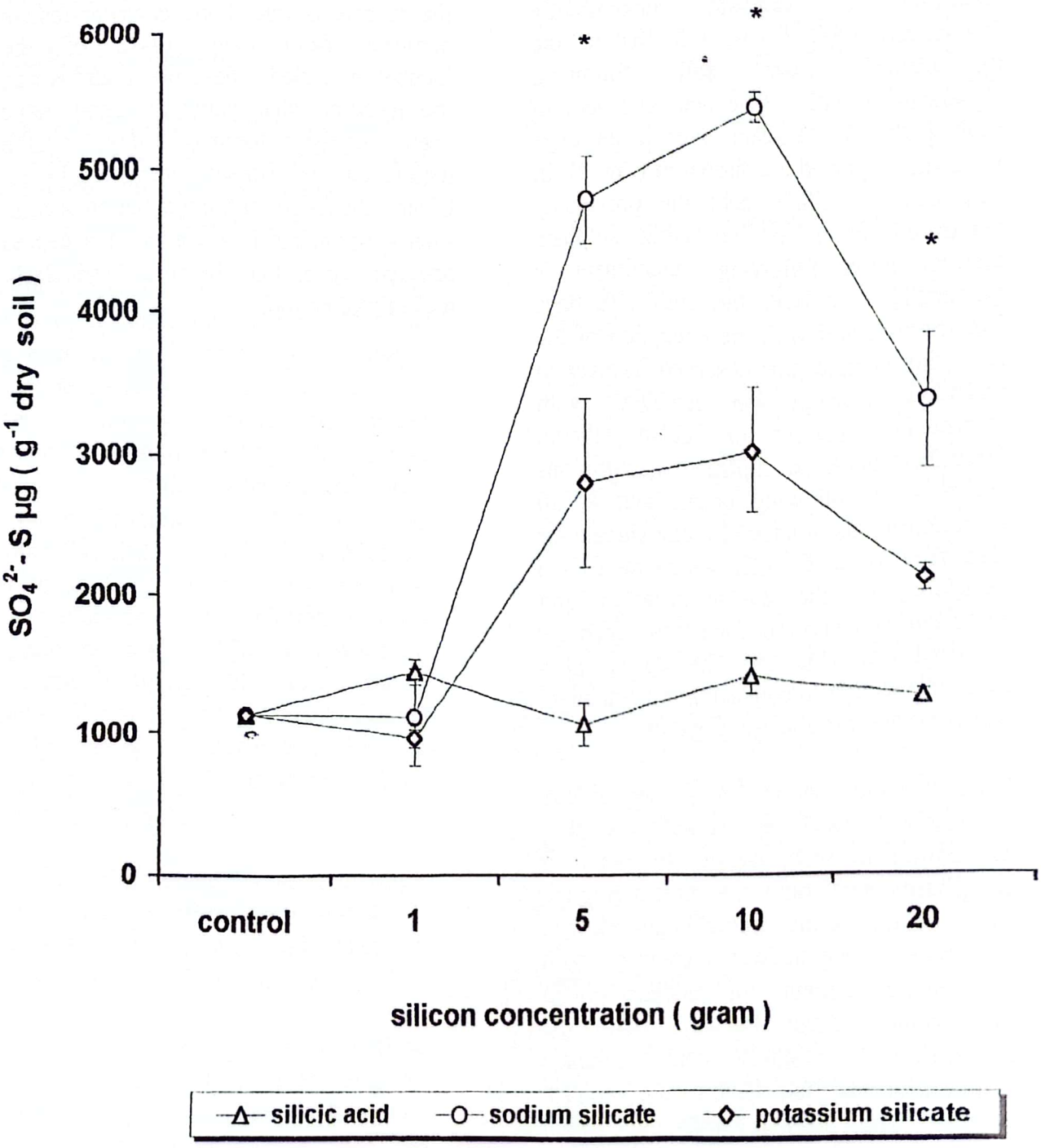


Figure (1) Effect of different amount (1,5,10 and 20g) of added silicic acid, sodium silicate and potassium silicate on sulphur oxidation in agricultural loam soil.

The experiment was carried out on 14th days of incubation using $LiCl_2$ 0.1 M extract.

Means of triplicate, ± standard error. * Significant difference from control, $P < 0.05$.

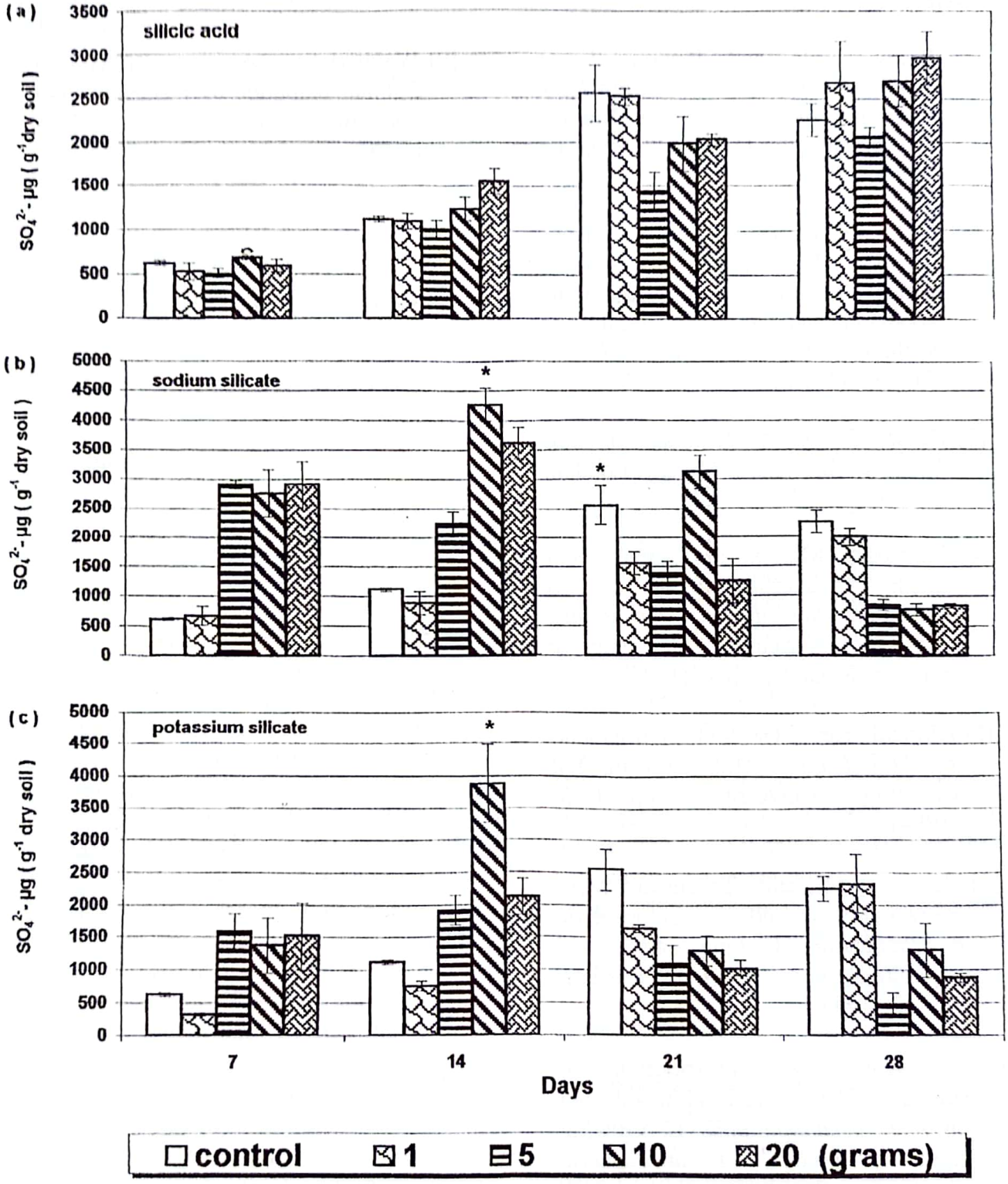


Figure (2) Effect of different amount of added (a) silicic acid (b) sodium silicate (c) potassium silicate on sulphur oxidation in agricultural loam soil.

The experiment was carried out on 7,14, 21 and 28th days using 0.5 M $LiCl_2$ extract.

Means of triplicate, ± standard error. * Significant difference from control, $P < 0.05$.

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