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Glucose and Cellulose Decomposition and Subsequent Transformation of S and P in Soil

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Abstract: Glucose and cellulose decomposition and subsequent transformation of sulphur (S) and phosphorus (P) in were examined. S was applied @ 0 and 20 μg as $MgSO_4.7H_2O$ together with either 3000 μg glucose-C or 3333 μg cellulose-C, 250 μg N, 200 μg P and 250 μg kg^{-1} soil. Microbial respiration (CO_2 evolution), inorganic SO_4-S and available P were monitored over 30 days during incubation at room temperature at different intervals of time. Both glucose and cellulose decomposition rates responded positively to the S application. Respiration rate in glucose amended soil was approximately 3 times higher than cellulose. In glucose amended soil, 71 % and in cellulose amended soil, 51 % of the added C was decomposed at the end of the incubation period. Concentration of SO_4-S varied significantly during incubation. Mineralization followed by immobilization was observed and maximum net immobilization was 14 and 8 μg S g^{-1} soil for cellulose plus S_{20} and glucose plus S_{20} treatments, respectively. During incubation glucose and cellulose amendment caused immobilization of P.

Key words: Glucose, cellulose, sulphur and phosphorus

Introduction

Carbon substrate added to soil, is utilized by the soil microbial biomass, part being mineralized and released CO_2 and part being immobilized into soil organic matter and also incorporated into new microbial tissue. The addition of large quantities of C substrate to an S deficient soil will cause S immobilization and may bring about S limitation of the microbial biomass (Chapman, 1997). Though present in root exudates, large quantities of glucose are never likely to be added to soils, except experimentally. Cellulose, however, represents the from in which the bulk of carbon is added to soil. Stewart *et al.* (1966) found that more S was required for the decomposition of cellulose than that of glucose. If the soil is low or lacking in S, further microbial growth could be limited by S instead of C (Chowdhury *et al.*, 2000).

Sulphur and phosphorus transformation in soil are microbiologically mediated and depend on the type and size of soil microbial population and the physiological state of the organisms. The forms of organic S present in the soil also plays an important role in determining the ease of sulphur mineralization (Ghani *et al.*, 1992). The transformation of soil organic S to inorganic SO_4-S, i.e., S mineralization, and the reverse process, the incorporation of SO_4-S into soil organic compounds, play important roles in the cycling of S within the soil. The incorporation of SO_4-S into the soil organic pool, including the microbial biomass is commonly referred to as S immobilization. However, this study was aimed at knowing whether glucose and cellulose decomposition is sulphur limited or not and the decomposition pattern of glucose and cellulose and subsequent transformation of S and P in soil.

Materials and Methods

Soil: The soil (0-15 cm depth) was collected from a selected area of Horticulture Farm, BAU, Mymensingh. The soil was a silty loam, pH 6.17 and contained 0.61% organic C, total N 0.06% and $CaCl_2$-extractable SO_4-S of 6.0 mg g^{-1} soil. Undecomposed plant materials were removed by hand and the soil was sieved (< 2mm). Samples were conditioned aerobically at room temperature and at 40% water holding capacity (WHC) for 7 days. This allowed the soil microbial population to stabilize, minimizing the effects of soil handling and preparation. Immediately after conditioning, the soil was used for the glucose experiment. Conditioning was continued for 35 days until the cellulose experiment started.

Treatments and experimental design: Two separate experiments, one with glucose and the other with cellulose were conducted sequentially and laid out in completely randomized design (CRD). For both glucose and cellulose experiments, two levels of S as $MgSO_4.7H_2O$ @ 0 and 20 μg S g^{-1} soil was added with soil along with a control were used as treatment. For each treatment, a nutrient solution was prepared by dissolving appropriate amounts of NH_4NO_3 and KH_2PO_4 in distilled water as sources of N, P and K respectively. In case of glucose, 50 g soil (oven dry basis) was weighed in a 100 mL glass jar and amended with 2 mL D-glucose solution containing 3000 μg C and an aliquot of the nutrient solution having 250 μg N, 200 μg P and 250 μg K g^{-1} soil, along with two levels of S. In the case of cellulose, each soil sample was prepared similarly, except that cellulose (3333 μg C g^{-1} soil) was applied as powder before the addition of nutrient solution. Two milliliters of nutrient solution (without glucose, cellulose or S) was also added to the control soil to maintain N, P, K and moisture contents equivalent to those of amended soils.

Following amendment, glass jars were placed in 1L glass bottles, sealed and incubated at room temperature for 30 days. To trap CO_2 evolved by soil microorganisms during incubation, 20 mL of 1M NaOH solution was placed inside each jar. To maintain internal humidity of the 1L glass bottle, 10 mL distilled water was added at the bottom of each incubation bottle. Available S and P were determined after 3, 5, 10, 30 (in the case of glucose) and 5, 10, 15 and 30 (in the case of cellulose) days of incubation.

Microbial activity: Microbial respiration was monitored as CO_2 evolution from soil samples after 2, 4, 6, 10, 20, 30 (in case of glucose) and 2, 4, 6, 10, 15, 20 and 30 (in case of cellulose) days of incubation in the experiments. At each sampling, NaOH was renewed. Total CO_2 was then titrated with standard HCl (0.5N) using pH meter (WTW pH 522). Microbial activity was expressed as μg CO_2-C evolved g^{-1} soil day^{-1}.

Soil chemical analysis: Available sulphur in soil was determined from $CaCl_2$ (0.15%) extracts by colorimetric $BaCl_2$ precipitation method as outlined by Page *et al.* (1982). Available soil phosphorus was extracted with 0.5 M sodium bicarbonate solution (Olsen *et al.*, 1954) and develop blue colour by $SnCl_2$ reduction and measured the colour colorimetrically at 660 nm (Black, 1965).

Statistical analysis: Collected data were statistically analyzed by the computer using statistical package programme MSTAT-C developed by Russel (1986). A one way ANOVA was made by F variance test. The pair comparisons were performed by Least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

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Results and Discussion

Glucose and cellulose decomposition: During the 30 days incubation, the control soils for the glucose and cellulose amendments respired a total of 121 and 81 μg C g^{-1} soil, respectively (Fig. 3, 4) presumably by the decomposition of native soil organic matter. The lower amount of the total respired C in the same soil used for cellulose amendment might be due to the longer pre-incubation period (35 days) than glucose (7 days). However, not much change in the daily rate of respiration was observed in the control soils.

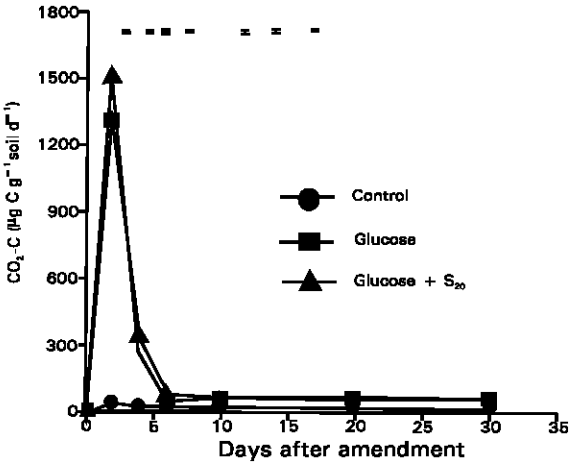

Fig. 1: The effect of addition of sulphate S and glucose on the rates of CO_2 evolution (μg CO_2 -C g^{-1} soil d^{-1}) during 30 days incubation. Bars indicate LSD < 0.05.

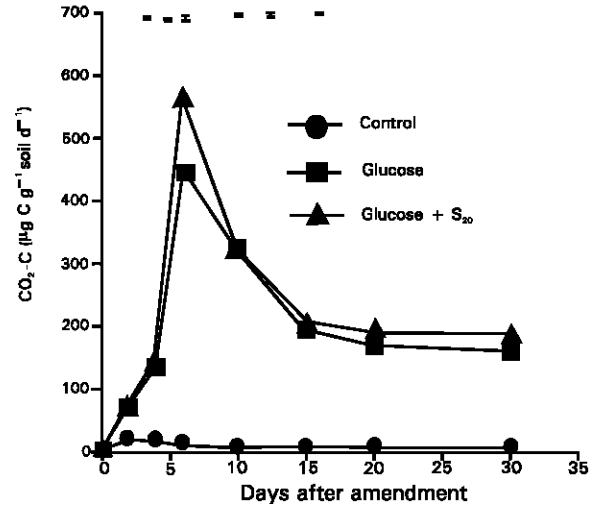

Fig. 2: The effect of addition of sulphate S and cellulose on the rates of CO_2 evolution (μg CO_2-C g^{-1} soil d^{-1}) during 30 days incubation. Bars indicate LSD < 0.05.

The results of the experiment with glucose show (Fig. 1) that in the S_0 treatment, the rate of CO_2 evolution rose to a maximum 1307 mg C g^{-1} soil d^{-1} by day 2 and then it declined and fell to almost steady state (63 mg C g-1 soil d-1) by day 6. The highest rate of CO_2 evolution was 1514 mg C g^{-1} soil d^{-1} for S_{20} treatment at day 2 which was significantly higher than control soil and S_0 treatment. This clearly indicates that S accelerated glucose decomposition resulting enhanced CO_2 evolution. From day 10 and onwards, respiration rate was almost similar among the treatments (Fig. 1).

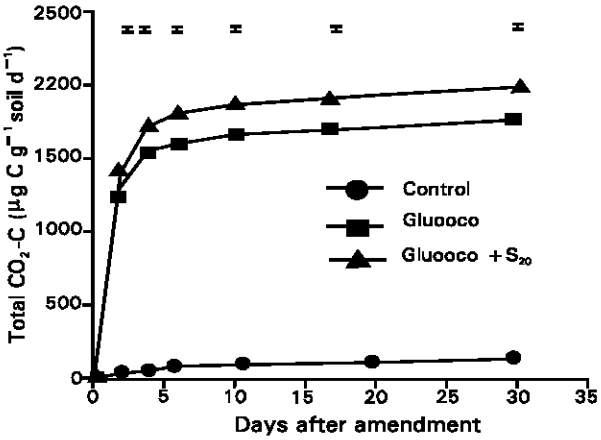

Fig. 3: The effect of addition of sulphate S and glucose on total CO_2 evolution (μg CO_2-C g^{-1} soil d^{-1}) during 30 days incubation. Bars indicate LSD < 0.05.

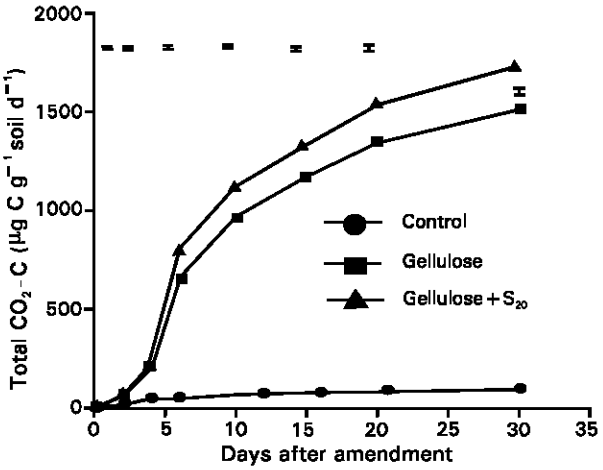

Fig. 4: The effect of addition of sulphate S and cellulose on total CO_2 evolution (μg CO_2-C g^{-1} soil d^{-1}) during 30 days incubation. Bars indicate LSD < 0.05.

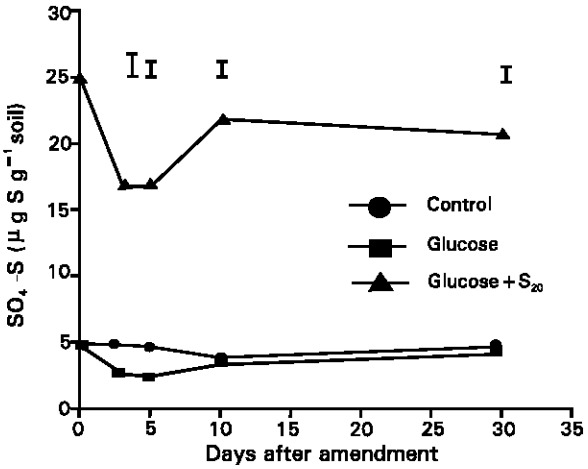

Fig. 5: The effect of sulphate S and glucose addition on $CaCl_2$-extractable S concentrations (μg S g^{-1} soil) during 30 days incubation. Bars indicate LSD < 0.05.

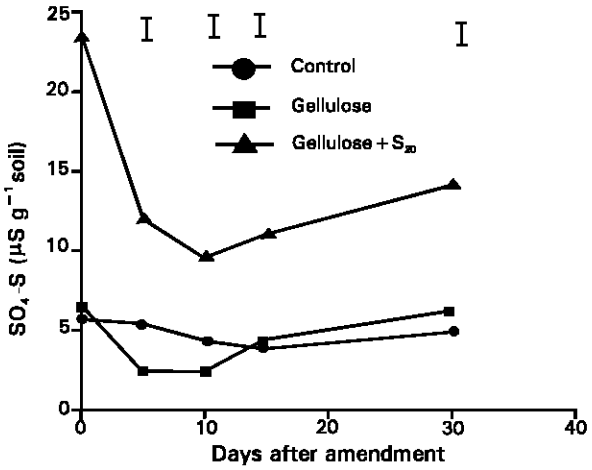

Fig. 6: The effect of sulphate S and cellulose addition on $CaCl_2$-extractable S concentrations (μg S g^{-1} soil) during 30 days incubation. Bars indicate LSD <0.05.

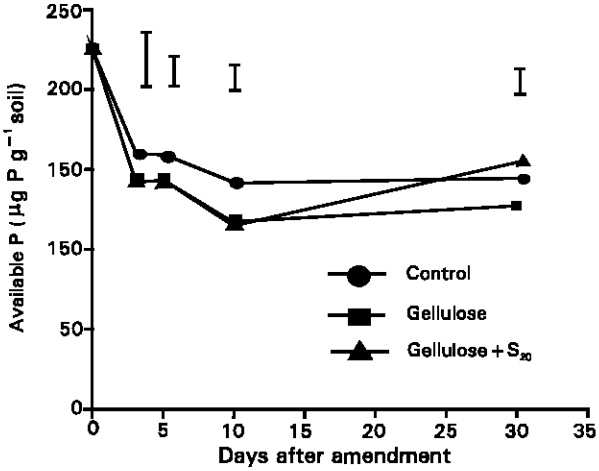

Fig. 7: The effect of sulphate S and glucose addition on $NaHCO_3$-extractable P concentrations (μg P g^{-1} soil) during 30 days incubation. Bars indicate LSD <0.05.

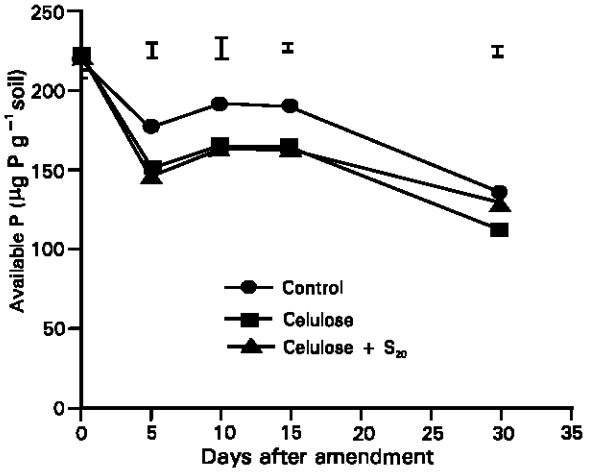

Fig. 8: The effect of sulphate S and cellulose addition on $NaHCO_3$-extractable P concentrations (μg P g^{-1} soil) during 30 days incubation. Bars indicate LSD <0.05.

During 30 days incubation of glucose amended soil, a total of 2133 mg C g^{-1} soil respired in case of S_20 treatment which was significantly higher than S_0 (1898 μg C g^{-1} soil) and control (122 μg C g^{-1} soil) treatments (Fig. 3).

While in the cellulose amended soil, the respiration rate was much slower than glucose. From day 2, respiration started to rise and the maximum respiration rate (568 μg C g^{-1} soil d^{-1}) occurred in the S_20 treatment by day 6 which was significantly higher than S_0 (446 μg C g^{-1} soil d^{-1}). The respiration rate in all the treatments then gradually decreased but remained much higher than control soil at the end of the experiment (Fig. 2).

The highest rate of respiration in the glucose amendment (1514 μg C g^{-1} soil d^{-1}) was approximately 3 times higher over the highest rate in cellulose (568 μg C g^{-1} soil d^{-1}) amendment. Respiration rate was also found to be accelerated by S in cellulose amended soil. After 30 days incubation, a total of 1719 μg C g^{-1} soil was respired in S_{20} treatment which was significantly higher over S_0 (1496 μg C g^{-1} soil) and control (81 μg C g^{-1} soil) treatments (Fig. 4).

Glucose, a simple, soluble, low molecular weight substrate, presumably diffuses relatively readily within the soil matrix to sites of the location of decomposing organisms, where it is utilized rapidly and with lower utilization efficiencies (Amato and Ladd, 1992). At the end of 30 days incubation, however, 71% of the added glucose C was mineralized as CO_2-C while it was only 51% in case of cellulose.

Carbon mineralization was found to be S dependent for both the amendments. Stewart *et al.* (1966) found that the rates of glucose and cellulose decomposition in soils were dependent on the available S level. On the other hand S requirement for glucose and cellulose decomposition rate was not the same. The results of the present study support the observation made by Stewart *et al.* (1966) and Chapman (1997) that less S is required for glucose decomposition than for cellulose decomposition. In this experiment, net immobilization was 14 and 8 μg S g^{-1} for cellulose plus S_{20} and glucose plus S_{20} treatment in cellulose and glucose amended soil, respectively (Fig. 5, 6). The extra S required for cellulose decomposition over that of glucose might be due to the need for extracellular enzyme synthesis. Stewart *et al.* (1966) also reported that some extra S was required during cellulose decomposition. The lower S requirement during glucose decomposition might be the result of the rapid turnover of the biomass formed and hence rapid turnover of the immobilized S (Chapman, 1997). Higher respiration rate in the glucose amended soil over cellulose was also observed by Chowdhury (2000).

Effect of glucose, cellulose and S on the transformation of SO_4-S: The concentration of $CaCl_2$ extractable SO_4-S decreased significantly in all the treatments and reached to minimum at day 5 and 10 in the glucose and cellulose amendments, respectively (Fig. 5, 6). In glucose amended soil, the treatments glucose alone and glucose plus S_{20} showed similar pattern of S transformation i.e., immobilization and mineralization but on prolonged incubation the pattern of transformation differed significantly (Fig. 5).

After commencement of immobilization it continued upto day 5 and then mineralization started for both glucose alone and glucose plus S_{20} treatment in glucose amended soil. The decrease in SO_4-S was initially rapid in the glucose amended soil but it slowed down with extended incubation upto day 30. This observation was in agreement with the findings of O'Donnell *et al.* (1994) who measured the immobilization of added SO_4-S in a number of soils with different properties. Rapid decrease in SO_4-S was also observed in cellulose amended soil and immobilization reached to maximum at day 10 for both cellulose alone and cellulose plus S_20 treatments (Fig. 6). Concentration of SO_4-S then increased gradually upto the end of the experiment. But from the net immobilization point of view, the highest were 14 and 8 μg S g^{-1} for cellulose plus S_{20} and glucose plus S_{20} treatment in case of cellulose and glucose amended soil, respectively.

The concentration of the $CaCl_2$ extractable S did not differ significantly in control soil and glucose alone or cellulose alone

treatments. Control soil showed statistical identity with glucose alone treatment (at day 10 and 30), with cellulose alone treatment (at day 15 and 30), for glucose and cellulose amended soil, respectively (Fig. 5, 6). But glucose plus S_{20} or cellulose plus S_{20} treatments showed significant variation with other treatments irrespective of sample for both glucose and cellulose amended soil. The concentration of the extractable S in both the cellulose and cellulose plus S_{20} treatments decreased rapidly following the maximum respiration rates and then slightly increased. Same result was also observed by Saggar *et al.* (1981). These authors suggested that in the cellulose treated soils turnover of the soil S occurred as the unlabelled organic S was mineralized and labelled S was immobilized. However, because of the increased demand of the active microbial biomass (as evident from the increased respiration rates) the amount of S immobilization was far greater than that released from the break down of organic S, resulting in net immobilization of S in these soils.

It was also evident from the results of Chowdhury *et al.* (2000) that the concentration of SO_4-S decreased simultaneously with the increase in S in the concentration of biomass. S_{0r} the initial immobilization of the added SO_4-S occurred mostly into biomass S or partially transformed into soil organic matter. Ghani *et al.* (1993) also showed that in glucose treated soil, in the short term (3 days), upto 90% of the incorporated ^{35}S reached the microbial S pool.

Effect of glucose, cellulose and S on the transformation of available P: P availability was significantly affected by both glucose and cellulose amendment. Significant immobilization of P took place during incubation. No significant effect of S application was observed upto day 10 for both glucose and cellulose amended soil. From 0 to 10 days of incubation, glucose alone and glucose plus S_{20} (Fig. 7) and cellulose alone and cellulose plus S_{20} (Fig. 8) maintained similar statistical identity in glucose and cellulose amended soils, respectively. At day 30, application of S on the transformation of available P was found to be significant. P mineralization was observed 154 μg P g^{-1} soil in glucose plus S_{20} treatment which was statistically higher than glucose alone (126 μg P g^{-1} soil) and unamended soil (144 μg P g^{-1} soil) at day 30. Net immobilization of P was higher in cellulose amended soil than glucose amended soil. In glucose amended soil, 106 and 108 μg P was immobilized for glucose alone and glucose plus S_{20} treatments, respectively, while in cellulose amended soil, 111 and 94 μg P was immobilized for cellulose alone and cellulose plus S_{20} treatments, respectively.

During decomposition of glucose and cellulose, such immobilization of P might have occurred due to the microbial assimilation of P. Immobilization-mineralization sequence was also reported by Pushpa *et al.* (1995). They further reported that P becomes locked up in microbial tissues in the first instance and is subsequently released during incubation period.

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