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Immobilization-remineralization of NO_3-N and total N balance during the decomposition of glucose, sucrose and cellulose in soil incubated at different moisture regimes

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Abstract

A laboratory incubation experiment was conducted to study the effect of organic amendment and moisture regimes on the immobilization-remineralization of NO_3-N and total N balance in soil fertilized with KNO_3. Immobilization of NO_3-N was very rapid in soil amended with glucose and sucrose followed by a remineralization of organic N and accumulation of mineral N. Cellulose caused a slow but continued immobilization and did not show net accumulation of mineral N during 8 weeks of incubation. At the end of incubation, a significant increase in total N and organic N content of the soil was observed which is perhaps attributable to the activity of free living N_2 fixers. Although N losses seemed to have occurred at 100% WHC through denitrification in soil amended with glucose and sucrose, main cause of NO_3 elimination was microbial immobilization.

Introduction

Many studies reported in the literature show heavy losses of N through denitrification under conditions of high moisture (Craswell and Martin, 1974) and in the presence of easily oxidizable C compounds (Bowman and Focht, 1974; Burford and Bremner, 1975; Stanford *et al.*, 1975). Losses through denitrification are also reported from the rhizosphere of plants where rhizodeposition serves as C source for the denitrifiers (Eskew *et al.*, 1977; Neyra *et al.*, 1977; Neyra and van Berkum, 1977).

Many of the studies on denitrification are based on the determination of gases evolved from soil (Colbourn *et al.*, 1984; McRae *et al.*, 1968; Rolston *et al.*, 1982). Other workers have studied the balance of NO_3-N and have based their interpretations on the disappearance of the latter (Focht, 1978; Lund *et al.*, 1978; Mulvaney and Kurtz, 1984). In many instances, however, no consideration has been given to the immobilization of NO_3-N by soil microorganisms when plenty of easily oxidizable C source is provided in such studies. Although microbes prefer NH_4 as N source, immobilization of NO_3-N has also been reported (Azam and Malik, 1985; Azam *et al.*, 1986a, b; Ladd *et al.*, 1977; Nommik, 1981; Voroney and Paul, 1984). Studies on total N balance under these conditions may therefore be of interest. The objective of the present investigation was to study the effect of available C and moisture on immobilization-remineralization of NO_3-N and total N balance.

Materials and methods

Soil used in this study was a clay loam collected from the experimental area of the Institute. It contained 0.6% C and 0.059% N. Electrical conductivity of the soil was 1.9 mmhos cm^{-1} and pH 7.8. Fifty-g portions of the air dried and sieved (<0.2 mm) soil were filled in 100 ml capacity plastic containers and amended with 1% glucose, sucrose

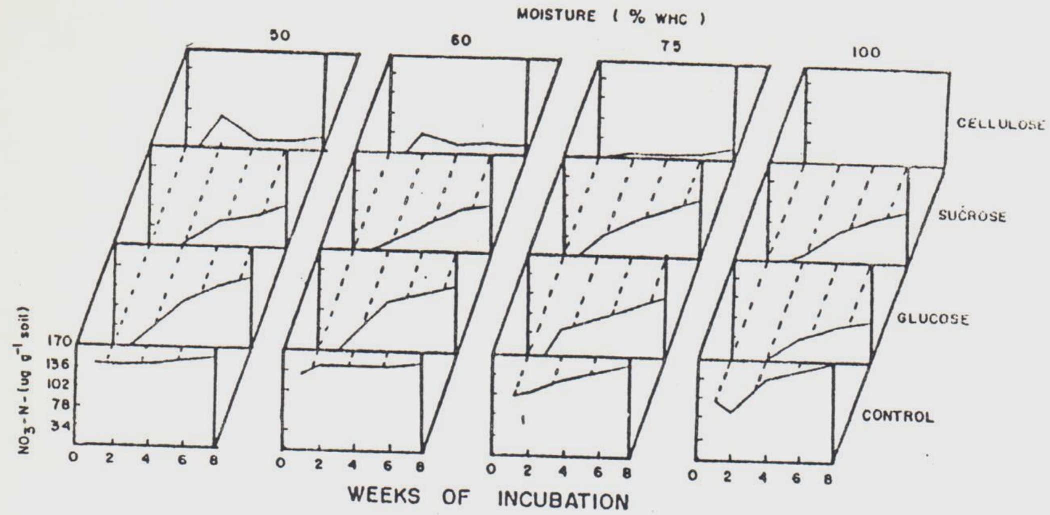

Fig. 1. Changes in NO_3-N content of soil during incubation at different moisture regimes after amendement with glucose, sucrose and cellulose.

or cellulose. An unamended control was also included in the study. The soil in each container was moistened with KNO_3 solution to get N concentration of 150 ug per g soil and moisture levels equivalent to 50, 60, 75 and 100% WHC. The treated soils were incubated at 30°C with enough replications to remove duplicate samples at different incubation intervals. Total N content of the soil was determined at the end of incubation by micro-Kjeldahl method (Bremner, 1965) and NH_4 and NO_3 + NO_2-N was determined at regular incubation intervals (Bremner and Keeney, 1965). Difference in the total N and organic N content of ammended (soil + N + C) and unamended (soil + N) at the end of incubation was taken as gain or loss of N.

Results and discussions

Results presented in Figure 1 show that immobilization of NO_3-N occurred in both the amended and unamended soils. Utilization of NO_3-N by the soil microorganisms in the presence of easily oxidizable C compounds has been reported by many workers (Azam and Malik, 1985; Azam *et al.*, 1986a, b; Ladd *et al.*, 1977; Nommik, 1981; Vorononey and Paul, 1984). Immobilization of NO_3-N was observed in unamended soil at least during initial stages of incubation suggesting the build up of microbial biomass after remoistening the soil. An accumulation of mineral N was, however, observed as the incubation progressed. I soil amended with glucose and sucrose, a rapid immobilization of NO_3-N was observed. Remineralization of N and an accumulation of NO_3-N proceeded quickly after 2 weeks at 50, 60 and 75% WHC but at 100% WHC accumulation of NO_3-N started after 4 weeks. In soil amended with cellulose measureable quantities of NO_3-N were observed after 2 weeks at 50 and 60% WHC indicating a slow microbial metabolism.

Figure 2 shows the NH_4-N content of the soil after different incubation intervals. Unamended soil and the soil amended with cellulose contained small amounts of NH_4-N during the entire incubation period. Maximum NH_4-N was observed in soil amended with glucose. Sucrose amended soil also had high NH_4-N content during first week of incubation. In all the amendments, small amounts of NH_4-N were observed during first two weeks of incubation. Dynamics of NH_4-N were almost similar at different moisture levels. The presence of high amounts of NH_4-N in soil amended with glucose and sucrose indicated that entire NO_3-N had already been immobilized in the first week of incubation. Therefore accumulation of NH_4-N in the soil was due to the mineralization of newly syn-

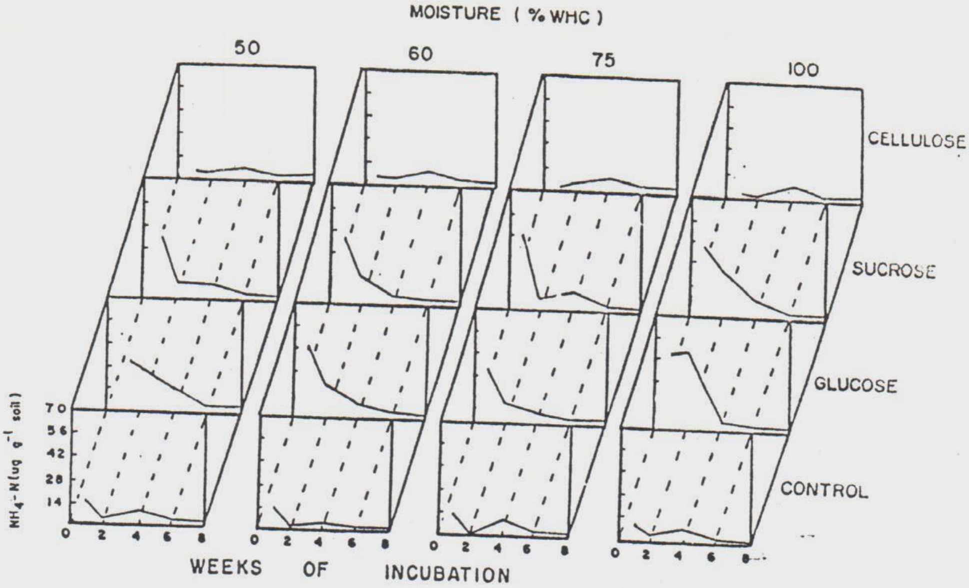

Fig. 2. Changes in NH_4-N content of soil during incubation at different moisture regimes after amendement with glucose, sucrose and cellulose.

thesized microbial biomass. Accumulation of NH_4-N in soil supplemented with glucose has also been reported by Azam *et al.* (1986). In cellulose amendment, however, only small quantities of NH_4-N accumulated possibly because cellulose serves as a C source for extended periods of time thus maintaining a higher level of microbially contained nitrogen. Similar findings have been reported by other workers (Ahmad and Harada, 1969; Azam and Malik, 1985; Azam *et al.*, 1986a, b; Haider and Azam, 1982).

Figure 3 presents the data for gain in the organic N and total N in soil. In all the amendments, organic N content of the soil increased during incubation showing a net immobilization of applied N (Fig. 3A). In glucose and sucrose amendments, addition to organic N content of the soil decreased with increase in moisture content whereas a reverse trend was observed in cellulose amendment. Almost similar trends were observed for total N content of the soil (Fig. 3B). Overall results showed a positive N balance, refers to the difference in the total N content of the soils after incubation and at zero incubation taking native soil N and NO_3-N together) possibly as a result of the activity of free-living N_2-fixing microorganisms. However, direct estimation of N_2 fixation was not attempted.

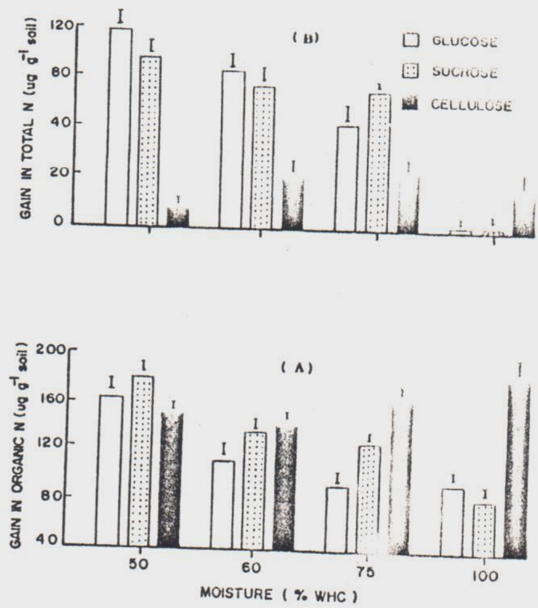

Fig. 3. Gain in organic N (A) and total N (B) of soil incubated for 8 weeks at different moisture regimes after amendment with glucose, sucrose and cellulose.

The increase in N content was highly significant in soil amended with glucose and sucrose and indicated an addition of 70–150 μg N per g soil at different moisture levels (Fig. 3A). This amounts to 7–15 mg N added per 100 g of soil for each g of glucose utilized and is somewhat surprising in view of the reported negative effects of mineral N on rhizobial N_2 fixation (Becker *et al.*, 1986; Eaglesham *et al.*, 1983). Pure culture studies have shown that different strains of Azospirillum can fix 9–18 mg N per g malate (Rai and Gaur, 1982). The results presented here show almost comparable N_2 fixation efficiency of the free living N_2 fixers in soil. At 100% WHC, however, gain in total N was almost negligible either as a result of reduced N_2 fixation or increased denitrification. Since high moisture favours N_2 fixation, the only possible explanation for low gains in N at 100% WHC is increased denitrification in soil amended with glucose and sucrose. Under conditions of high moisture, activity of aerobes may be considerably restricted resulting in a greater availability of NO_3 for denitrification during early stages of incubation. From these results, however, it is difficult to draw conclusions about the relative efficiency of immobilization and denitrification of NO_3-N. Use of ^{15}N labelled substrate may lead to a better understanding of the relative importance of the two phenomena which operate simultaneously but in opposite directions.

In summary, the results of this study indicate that disappearance of NO_3-N from the soil may not necessarily mean its loss through denitrification but microbial immobilization may be responsible for the removal of a greater part of NO_3-N from soil. The extent of immobilization and remineralization will, however, depend upon the nature of available C source and the incubation conditions. These results suggest that the presence of easily oxidizable source do cause denitrification but the overall N balance of the soil may not be affected even at quite high moisture levels and under conditions (as in this study) apparantly favourable for the process.

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