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Effects of N-enriched sewage sludge on soil enzyme activities

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Abstract

Sewage sludge is increasingly used as an organic amendment to soil, especially to soil containing little organic matter. However, little is known about utility of this organic amendment with N-enriched or adjusted C:N ratios in soil. We studied the effects of adding of different doses (0, 100, 200 and 300 t ha^{-1}) and C:N ratios (3:1, 6:1 and 9:1) of sewage sludge on enzyme activities (β-glucosidase, alkaline phosphatase, arylsulphatase and urease) in a clay loam soil at 25 °C and 60% soil water holding capacity. Nitrogen was added in the form of $(NH_4)_2SO_4$ solution to the sludge to reduce the C:N ratio from 9:1 to 6:1 and 3:1. The addition of different doses and C:N ratios of the sludge caused a rapid and significant in the enzymatic activities in soils, this increase was specially noticeable in soil treated with high doses of the sludge. In general, enzymatic activities in sludge-amended soils tended to decrease with the incubation time. All activities reached peak values at 30 days incubation and then gradually decreased up to 90 days of incubation. Sewage sludges also the increased available metal (Cu, Ni, Pb and Zn) contents in the soils. However, the presence of available soil metals due to the addition of the sludge at all doses and C:N ratios did negatively affect all enzymatic activities in the soils. This experiment indicated that all doses and C:N ratios of sewage sludge applied to soil would have harmful effects on enzymatic activity. Some heavy metals found in sewage sludge may negatively influence soil enzyme activities during the decomposition of the sludge.

Keywords: Sewage sludge; Soil; C:N ratio; Urease; Alkaline phosphatase; Arylsulphatase; β-Glucosidase activity

1. Introduction

Interest in the disposal of sewage sludges, which contain a range of valuable nutrients (N, P, Fe, Ca, Mg) and various other macro- and micro-nutrients essential for plant growth, on agricultural land has increased during the last decade (Singh and Pandeya, 1998). One potential use for sewage sludge as a farm fertiliser and/or soil conditioner is to assist with the growth of arable land and to help improve and maintain the structure of the soil by increasing soil aeration and the water holding capacity of the soil (Pagliai et al., 1981). Previous studies have demonstrated favorable plant yield responses to the application of sewage sludge (King and Morris, 1972). In contrast, the effects of sewage sludge on biological process in soil have been questioned by some authors (Knight et al., 1997; Banerjee et al., 1997).

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Most papers concerned with the results of sewage sludge studies deal with the influence of sewage sludge on soil biological and enzymatic activity. Knight et al. (1997) observed a decrease of soil biological activity such as microbial biomass and enzyme activities, due to sewage sludge application. Conversely, Sastre et al. (1996) and Banerjee et al. (1997) found that the sewage sludge amendment increased soil microbial activity, soil respiration and enzyme activities. These differences might be a result of the heavy metal content of sewage sludge and of the decomposition rate of the sludge (Tam and Wong, 1990). Sewage sludges are a by-product of sewage treatment and contain not only nutrients and organic matter, but also contaminants such as heavy metals and synthetic organics discharged into the sewers. Because most heavy metals remain in the soil for a very long time, any additions should be considered permanent additions to the total quantity in the soil.

Considerable attention has been focused on the N content of sewage sludges (Stewart et al., 1975). With increased cost and shortage of nitrogenous fertilizer, there is increased emphasis on using sludge for its nutrient content rather than for disposal. The N content generally is considered the limiting factor which determines the application rate of sewage sludges to agricultural land (Mile and Graveland, 1972). Increased crop yields have been obtained with the use of sludges (Hinesly et al., 1972). In some cases supplemental addition of N further increased yields (Coker, 1966). Thus low C:N ratio is caused by additional nitrogen of the sludge. In addition, numerous studies suggested that different concentrations of nitrogen might predominate in different sewage sludges (Coker, 1966; Mile and Graveland, 1972; Hinesly et al., 1972). So, the behaviour and effects of N after incorporation into the soil may not be similar for different C/N ratios of sludges.

Studies of enzyme activities provide information on the biochemical processes occurring in soil. There is growing evidence that soil biological parameters may be potential and sensitive indicators of soil ecological stress or restoration. Measurements of several enzymatic activities have been used to establish indices soil biological fertility (Dick and Tabatabai, 1992). In the present study, soil enzymes representative of main nutrient cycles (C, N, P, S) were selected. Glucosidases are widely distributed in nature and their hydrolysis products as low molecular weight sugars are important source of energy for soil microorganisms. β-glucosidase catalyzes the hydrolysis of β-D-glucopyranoside and is one of the three or more enzymes involved in the saccharification of cellulose (Bandick and Dick, 1999; Turner et al., 2002). Urease is involved in the hydrolysis of urea to carbon dioxide and ammonia, which can be assimilated by microbes and plants. It acts on carbon–nitrogen (C–N) bonds other than the peptide linkage (Bremner and Mulvaney, 1978; Karaca et al., 2002). Phosphatase is an enzyme of great agronomic value because it hydroles compounds of organic phosphorus and transforms them into different forms of inorganic phosphorus, which are assimilable by plants (Amador et al., 1997). Variations in phosphatase activity apart from indicating changes in the quantity and quality of a soil's phosphorated substrates, are also a good indicator of its biological state (Pascual et al., 1998, 2002). Arylsulphatase is the enzyme involved in the hydrolsis of arylsulphate esters by fission of the oxygen–sulphur (O–S) bond. This enzyme is believed to be involved in the mineralisation of ester sulphate in soils (Tabatabai, 1994). Also, it may be an indirect indicator of fungi as only fungi (not bacteria) contain ester sulphate, the substrate of arylsulphatase (Bandick and Dick, 1999).

Soil enzymes are biological catalysts of specific reactions and these reactions depend on a variety of factors such as pH, temperature and the presence (or absence) of inhibitors (Burns, 1978). Climate, type of amendment, cultivation techniques, crop type and edaphic properties also effect enzyme catalyzed reactions. Process as related to the degradation of organic material may be followed through the action of hydrolases (Pascual et al., 1998). Nannipieri et al. (1990) pointed out that enzymatic activities are substrate specific and related to specific reactions. For this reason it is difficult to obtain an overall picture of soil status from one enzymatic activity value. The simultaneous measurement of various enzymes, on the other hand, seems to be useful to evaluate soil biochemical activity and related processes (Pascual et al., 1998).

Indeed, enzyme activities have been shown to be more sensitive total carbon concentration to soil management practices. Application of organic wastes, such as sewage sludge, as a source of organic matter is a common practice, especially to soils containing little organic matter, to maintain or improve soil quality and