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Short communication

Cattle manure and grass residues as liming materials in a semi-subsistence farming system

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Abstract

A field experiment was conducted on an acid soil in a semi-subsistence farming area of KwaZulu-Natal, South Africa to investigate the possibility of using organic amendments as liming materials within a minimum tillage (strip cultivation) system to produce maize. Amendments (cattle manure, grass residues and dolomitic lime) were incorporated to a depth of 20 cm in bands 15 cm wide down plant rows at rates of 10 and 20 t ha^{-1} (in the amended area) for organic materials and 2.5 and 5.0 t ha^{-1} for lime. The remainder of the field remained untilled. Additions of cattle manure rapidly increased soil pH, and concentrations of exchangeable K, Ca and Mg and extractable P were also greatly elevated. Grass residue additions increased pH progressively and increased exchangeable K and Mg and those of dolomitic lime increased pH, exchangeable Ca and Mg. Addition of each of the amendments decreased concentrations of exchangeable Al; the effect was greatest for animal manure after 6 weeks and for lime and grass residues at harvest. At harvest, addition of all three amendments had significantly reduced concentrations of both phytotoxic monomeric and total Al in soil solution. The system not only resulted in an increase in pH and extractable nutrients in row soil compared to that in the inter-row but also an increase in the size and activity of the soil microbial community. Maize yields were increased by additions of amendments under both unfertilised and fertilised conditions and yields were generally greatest at the higher rate of addition. Under unfertilised conditions, cattle manure treatments gave the greatest yields. Fertiliser additions increased yields greatly particularly in the control, grass residue and lime treatments. It was concluded that the strip tillage system used is a practicable way of applying high rates of organic materials to soils, that cattle manure has a rapid liming effect as well as being a nutrient source and that grass residues from rangeland decompose slowly and, therefore, have a slow liming effect.

Keywords: Lime; Organic amendments; Soil acidity; Strip tillage

1. Introduction

The southern tropical belt of the world is an area where acid soils predominate. This belt includes southeast Asia, Africa and central South America where much of the agriculture is semi-subsistence farming. Acid soil infertility (particularly Al toxicity) can be the major limitation to crop production in these areas. Conventionally, soil acidity is corrected by large applications of calcitic or dolomitic lime. However, for many resource-poor farmers, carrying out semi-subsistence agriculture, unavailability and/or the high cost of lime effectively prevents its use. Under such conditions, alternative means of managing soil acidity need to be developed. A number of researchers have suggested that organic residues (e.g. plant residues, animal manures and composts) might be used as alternative liming materials and that their application can increase plant growth in acid soils by ameliorating Al toxicity (Pocknee and Sumner, 1997; Wong et al., 1998; Mokolobate and Haynes, 2002).

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It was suggested by Mokolobate and Haynes (2002) that in semi-subsistence farming systems, organic residues could be incorporated into soil in the plant rows (e.g. in a 15–20 cm wide band) at relatively high rates (e.g. 10–20 t ha^{-1}) prior to planting a crop and that this would cause a substantial liming effect. In this way only 30–40% of the field would be tilled (down the plant rows where the manure was incorporated) so the effective manure application rate over the field would be only 2–8 t ha^{-1}. Such a minimum tillage system would also help minimise erosion losses of soil. The purpose of this study was to test this hypothesis in a field experiment within a village-based agricultural system in KwaZulu-Natal, South Africa (where soil acidity is a major limitation), using resources readily available in the locality (viz. cattle manure and grass residues from surrounding rangeland). In addition to measuring soil pH, exchangeable and soluble Al and extractable macronutrient concentrations, the effects of organic residue addition on the size and activity of the soil microbial community and on the activity of enzymes involved in mineralisation of N, P and S were also quantified.

2. Materials and methods

2.1. Site and soil description

The study was conducted in a semi-subsistence farm in a Zulu village at Ogogwini administered by the EMBO Traditional Authority on the south coast of KwaZulu-Natal. Mean annual rainfall in the locality is 939 mm and mean monthly temperatures range from a maximum of 22 °C in January to a minimum of 16 °C in June. Soil at the site is classified as Inanda form, Glenariff family (Soil Classification Working Group, 1991) or a Humic Ferrasol (FAO). The soil (0–10 cm) had the following properties: organic C = 40 g kg^{-1}, pH_{water} = 5.0, pH_{KCl} = 4.1, AMBIC P = 3 mg kg^{-1}, exchangeable Ca = 28 $mmol_c$ kg^{-1}, Mg = 12.8 $mmol_c$ kg^{-1}, K = 2.7 $mmol_c$ kg^{-1} and Al = 33 $mmol_c$ kg^{-1}, effective CEC = 64 $mmol_c$ kg^{-1}, aluminium saturation = 51%. The site had been fallow for 6 months prior to which it had been cropped with maize.

2.2. Organic amendments

Cattle in the area are allowed to graze the native grassy rangelands around the villages during the day but are brought back to the village and held in pens (Kraals) each night. Cattle manure was collected from the floor of a kraal and will have contained a small amount of soil contaminant. It had an elemental content (dry weight basis) of organic C = 273 g kg^{-1}, N = 14 g kg^{-1}, S = 2.5 g kg^{-1}, P = 1.4 g kg^{-1}, Ca = 8 g kg^{-1}, Mg = 5 g kg^{-1}, K = 1.2 g kg^{-1} and Na = 0.8 g kg^{-1}, and Zn = 91 mg kg^{-1}, Cu = 21 mg kg^{-1}, Mn = 537 mg kg^{-1}, Fe = 1827 mg kg^{-1} and Al = 16430 mg kg^{-1}. It had a pH_{water} of 8.8 and $CaCO_3$ content of 17 g kg^{-1}. Grass was cut from native rangeland. It had an elemental content (dry weight basis) of: organic C = 415 g kg^{-1}, N = 8 g kg^{-1}, S = 1.5 g kg^{-1}, P = 1.0 g kg^{-1}, Ca = 3.8 g kg^{-1}, Mg = 1.3 g kg^{-1}, K = 5.4 g kg^{-1} and Na = 1.2 g kg^{-1}, and Zn = 21 mg kg^{-1}, Cu = 3.2 mg kg^{-1}, Mn = 377 mg kg^{-1} and Fe = 218 mg kg^{-1}.

2.3. Experimental treatments and design

The experiment was a split plot design with three replicates per treatment. Plots were 4 m long and 2 m wide and each plot was separated from adjoining ones by a 1 m distance. The main treatments comprised 3 rates of cattle manure (0 (control), 10 (manure 1), and 20 t ha^{-1} (manure 2)), 3 rates of grass residues (0 (control), 10 (grass 1), and 20 t ha^{-1} (grass 2)) and 3 rates of lime (0 (control), 2.5 (lime 1), and 5.0 t ha^{-1} (lime 2)). The lime 2 rate was that recommended by the KwaZulu-Natal Department of Agriculture Fertiliser Advisory Service to raise pH_{water} to about 5.5 and lower the percentage acid (Al^{3+} and H^+) saturation of the effective cation exchange capacity to less than 20% (i.e. the lime recommendations for maize on the study soil). Amendments were incorporated to a depth of 20 cm in bands 15 cm wide down plant rows (spacing between rows was 50 cm). Only 30% of the field was tilled (i.e. the 15 cm wide bands) and rates of application of manure, grass and lime were calculated on an area basis of the tilled portion of the field only. Thus, application rates on a field basis are 30% of those outlined above.

Experimental plots were split, and one half was fertilised with a basal dressing of N, P, K and the other was not. Fertiliser rates, as recommended by the KawaZulu-Natal Department of Agriculture Fertilise Advisory Service, were 75 kg N, 122 kg P and 75 kg K ha^{-1} and these were applied to the 15 cm wide amended bands. Seeds of maize (cultivar PAN 6710) were sown down the centre of bands with an intra-row spacing of 40 cm.

2.4. Soil sampling and analyses

Soil sampling was carried out twice, 6 weeks after planting and at harvest (20 weeks after planting). From each sub-plot, soil samples (0–15 cm) were taken, eight from within the crop row and eight from the centre of the inter-row space (20–30 cm out from the plant rows).

Soils were analysed for organic C, pH in water and 1 M KCl, exchangeable (1 M KCl-extractable) Al, exchangeable (1 M ammonium acetate-extractable) Ca, Mg and K (Blakemore et al., 1972), available P by the AMBIC method (Farina, 1981) and exchangeable (2 M KCl-extractable) NH_4- and NO_3-N. Soil solution was extracted by centrifugation (Elkhatib et al., 1987) and monomeric (Al_{mono}) and total (Al_T) Al in solution were measured by PCV methods (Kerven et al., 1989; Menzies et al., 1992). Microbial biomass C was measured by fumigation-extraction (Vance et al., 1987), basal respiration by CO_2 evolution