POTENTIAL USES OF FLUIDISED BED BOILER ASH AS A LIMING MATERIAL, SOIL CONDITIONER AND SULPHUR FERTILISER

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Abstract

A fluidised bed boiler ash, produced by the New Zealand Dairy Corporation (NZDC FBA) as a by-product resulting from the combined combustion of high S coal and limestone, was chemically characterised and evaluated as a potential liming material, soil conditioner and S source in some representative New Zealand soils.

Chemical analysis showed that slaked NZDC FBA had a pH_{water} of 12.4 and $CaCO_3$ equivalent of 51.8%. The "lime" in FBA is mainly $Ca(OH)_2$, making it a quicker acting, more caustic material than limestone. FBA contained 6.2% S, 25.4% Ca (dry weight basis) and negligible amounts of P, K and Mg. Mineralogical analysis indicated that approximately 50% of the S in the slaked FBA is gypsum ($CaSO_4.2H_2O$) with the remainder being water insoluble ettringite ($Ca_6Al_2(SO_4)_3(OH)_{12}.26H_2O$).

A field trial was established on a permanent dairy pasture (predominantly ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*)) on peat soil, in Moanatuatua peatland, Waikato, New Zealand, to examine the effectiveness of FBA as a soil conditioner to overcome soil water repellency, a liming material and a S source. The treatments included the untreated control and three rates of FBA (1000, 6616 and 26462 kg FBA ha^{-1}, wet weight basis), which were surface dressed onto the pasture. Three rates of lime, which had the same $CaCO_3$ equivalent as the corresponding rates of FBA, were included for comparison.

Using the molarity of ethanol droplet (MED) test, the air dried peat soil sampled in summer was classified as severely water repellent (MED > 2.2). Fatty acids were identified as the fraction most responsible for the repellent character of the peat soil. Only the high rate (26462 kg ha^{-1}) of FBA significantly reduced water repellency of surface peat soil and increased the rate of water infiltration into the dry peat. The hydrophobic nature of the peat soil was probably modified by the high alkalinity of applied FBA, which removed or saponified fatty acids from the soil particle surface.

However, normal liming and fertiliser rates (6616 kg ha^{-1} or less) of FBA application, as well as all the lime treatments, had negligible effect on the water repellency of the peat soil. Therefore, it is not practical to use FBA as an amendment to minimise water repellency on peat soil.

The FBA treatments significantly increased pasture yield, in the field trial during eight months of the experimental period, mainly by improving herbage S nutrition status. In spring, the S concentrations in herbage from the FBA treatments were raised from a deficient level of 0.20% S (the untreated control) to 0.27 - 0.40% S. The ettringite-sulphate in FBA acted as a slow-release S fertiliser and high rates of FBA application maintained the raised S concentrations in the herbage for the eight month period. The presence of ettringite implies that application of FBA-sulphate has the potential to reduce the leaching loss of sulphate, a common problem in many New Zealand soils.

In a laboratory incubation and leaching study using repacked peat soil cores, the effect of surface applied FBA and lime on base and solute movement in soil was investigated. The results indicated that FBA was an effective alternative to agricultural lime to neutralise the acidity of peat soil. Although surface-applied FBA had no significant effect on decreasing subsurface soil acidity as measured by pH change in the peat soil, the Ca^{2+} ions released by FBA dissolution moved down to subsurface soil much faster than those released from lime. Increased Ca^{2+} ion concentration in subsurface soil can alleviate the acidity constraints on pasture root growth through the antagonistic relationship between Ca^{2+} and H^{+} ions. In contrast to the lime treatment, however, FBA caused significant leaching of native soil exchangeable K^{+}. Therefore, K fertilisers should accompany FBA application to peat soils.

In order to examine the effect of topsoil incorporated FBA on the subsurface acidity in mineral soils, six acidic topsoils (0 - 100 mm) were tested for their ability to "self-lime" through sulphate sorption from gypsum treatment. Two soils, from the yellow-brown loam, or Allophanic soil (the Patua soil) and the yellow-brown earth, or Ultic soil (the Kaawa soil) groups (orders), which contrasted strongly in their reaction to gypsum treatment, were chosen for further study. Lime, FBA and Flue gas desulphurisation gypsum (FGDG) were incorporated in the top 0 - 50 mm of repacked columns of the Patua and Kaawa soils, at rates containing Ca equivalent to 5000 kg ha^{-1} of $CaCO_3$. Each column was leached with 400 mm of water. After leaching, one set of the columns were sliced into sections for chemical analysis, and another set was used for growing lucerne (*Medicago sativa*. L) as a root bioassay.

In the columns of the variable charged, allophanic Patua soil, topsoil incorporated NZDC FBA ameliorated top and subsurface soil acidity through liming and the "self-liming effect" induced by sulphate sorption, respectively. The soil solution pH of the top and subsurface layers of the Patua soil were raised to pH 6.40 and 5.35 respectively, by the FBA treatment, compared with pH 4.80 and 4.65 in the control treatment. Consequently phytotoxic labile monomeric Al concentration in soil solution of the FBA treatment was reduced to less than 0.1 µmol Al dm^{-3}, compared with that of 8 - 64 µmol Al dm^{-3} in the untreated control. These changes were associated with greatly improved lucerne root growth in the subsurface of the Patua soil after FBA treatment. FGDG had a similar "self-liming effect" on subsurface of the Patua soil, but not the topsoil. Whereas FBA raised the pH of the Kaawa topsoil, no "self-liming effect" of subsurface soil by sulphate sorption was observed on the Kaawa soil, which is dominated by permanently charged clay minerals. Application of FBA and FGDG to both soils, however, caused significant leaching of native soil Mg^{2+} and K^{+}. These nutrients were displaced from the exchange sites by the relatively high concentration of Ca^{2+} released from dissolution of gypsum. In contrast, the topsoil incorporated lime had little effect on either the subsurface soil acidity or nutrient leaching.

NZDC FBA is an ideal by-product for correcting topsoil and subsurface soil acidity in yellow-brown loam (allophanic) soils, but only topsoil acidity on yellow-brown earth (Ultic) soils, dominated by clays with permanent charge. Mg and K fertiliser application would be recommended when a soil is treated with FBA or other gypsiferous materials.

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Table of contents

Chapter 3

Chemical properties of fluidised bed boiler ash relevant to its use as a liming material and fertiliser

Chapter 4

Measurement of water repellency in a peat soil and its amelioration with fluidised bed boiler ash

Chapter 5

Effect of fluidised bed boiler ash on peat soil acidity and pasture growth

Chapter 6

Solute movement in a peat soil amended with fluidised bed boiler ash

Chapter 7

Amelioration of subsurface soil acidity by surface incorporated gypsiferous by-products. I. Soil solution chemistry

Chapter 8

Amelioration of subsurface soil acidity by surface incorporated gypsiferous by-products. II. Effects on root growth

Chapter 9

Summary

List of figures

List of tables