Transformation and plant availability of copper in pasture soils

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ABSTRACT

The response of pasture to copper (Cu) fertilisers in most soils is very short-lived necessitating frequent applications of Cu fertilisers. The short-term response to Cu by plants is attributed to the ready adsorption of Cu by organic matter and other soil components. Cu distribution among these different fractions and the relative availability of these fractions for plant uptake, are fundamental to an understanding of the transformation of Cu in soil. As Cu has not been routinely analysed in the past, there is no standard soil test extractant in New Zealand. The use of single chemical extractions in routine soil analysis is a fast and simple way to evaluate the availability of soil nutrients to plants. Farmers require accurate information on the length of time that Cu applications remain fully effective in order to supply the Cu required for the grazing animal. Pasture provides the main source of Cu for grazing animals. There is a need to define the rates of change in the effectiveness of Cu fertiliser over the range of soil and climatic conditions encountered in New Zealand.

The specific objectives of the study were: (i) to investigate the effect of soil components on the sorption and desorption of added and native Cu in soils; (ii) to examine the soil and fertiliser properties that influence the effectiveness of Cu topdressing in terms of increasing Cu uptake by pastures; (iii) to determine the transformation of Cu added through fertiliser applied to soils; (iv) to quantify the forms of Cu in soils using a sequential fractionation procedure; (v) to identify the forms of Cu in various soil test extractants and to assess the efficiency of these soil test extractants in predicting Cu uptake; (vi) to estimate the effects of N and P fertilisers on the uptake of native Cu by ryegrass; (vii) to examine at the residual effectiveness of two Cu source fertilisers as influenced by N fertiliser, lime and EDTA additions; and (viii) to evaluate the seasonal influence on the availability of native and added Cu to pasture.

Copper sorption and desorption isotherms were determined for a number of soils (Manawatu, Tokomaru, Ramiha, Ngamoka and Mangamahu) before and after the removal of various soil components. A series of glasshouse and field trials were carried out using three Cu sources, five soils and four Cu levels. The dry matter yields of ryegrass and Cu concentration in the herbage were monitored over a number of harvests. The soil was collected from the glasshouse trial at various intervals and analysed for different fractions (exchangeable, organic, oxide and residual) and were extracted with various soil test extractants. Copper extracted from the soils was correlated with the Cu concentration in the herbage.

A second glasshouse trial with two soils, four levels of nitrogen (N) and five levels of phosphate fertiliser was conducted. The dry matter (DM) yield and the Cu concentration in the ryegrass were measured. The effects of N fertiliser, lime and EDTA addition on the availability of residual Cu was investigated in a separate glasshouse trial. A series of field trials were conducted, in the same paddocks, to examine the effect of season on the uptake of Cu from two Cu sources.

The differences in the chemical characteristics of the soils resulted in some variation in the sorption and desorption of Cu between the soils. Soil pH, organic carbon, iron and aluminium oxides play a major role in the sorption and desorption of Cu in soils. Organic matter and oxides are important in adsorption reactions, but differences exist in their relative importance. Increasing levels of Cu increased the Cu concentration in plants. Sources of Cu fertiliser have a significant effect on DM yield, and Cu concentration at all harvests. Soil pH, organic matter, CEC and clay content correlated with Cu concentration in plants. Cu uptake in grasses decreased with time after fertiliser application. Organic and oxide bound Cu contributed >80% of total Cu in all the soils. The organically bound Cu fraction was highest in soils with high levels of organic matter. Both the organically bound and the oxide bound fractions of Cu decreased with time after fertiliser application, indicating a possible decrease in the availability of Cu. Soil exchangeable, organic and oxide bound fractions of Cu were correlated with soil organic matter, CEC and clay content. Both the organic and oxide bound Cu were correlated with plant Cu uptake. The major forms of Cu extracted by the soil test reagents include organically bound, followed by oxide bound, residual and exchangeable forms. The ratios of different forms of Cu strongly suggest that Cu is residing mainly in the organic form and increases in this order: exchangeable < residual < oxide < organic. The efficiency of chemical extractants in extracting the Cu from the soil followed: TEA-DTPA > Mehlich-3 > Mehlich-1 > 0.02M $SrCl_2$ > 0.1M HCl > 1.0M NH_4NO_3 > 0.01M$CaCl_2$ > 0.1M $NaNO_3$ > 0.01M $Ca(NO_3)_2$.

Increasing levels of both N and P fertilisers increased both the DM yield and the uptake of native Cu. Increasing levels of N increased both the DM yields and the Cu concentration in soils with residual Cu. The effect on Cu concentration persisted beyond the first cut only at the highest N addition. Increasing levels of lime increased the DM yield of pasture, but decreased the Cu concentration in pasture at the highest level of lime addition. Increasing levels of EDTA increased the Cu concentration in soils and thereby increased the Cu concentration in the pasture. The application of 1000 kg lime ha^{-1} and 50 kg N ha^{-1} was very effective in enhancing plant availability of residual Cu in soils, but EDTA increased the plant available Cu to toxic levels. The highest application rate of lime and N fertiliser decreased the exchangeable and free Cu in the Ngamoka soil, but EDTA showed the opposite effect.

In the field experiment Cu levels have no significant effect on DM yield during all seasons. The field study shows differences in seasonal response to added Cu. Increasing levels of Cu increased the Cu concentration in pasture. Types of Cu fertiliser have a significant effect on Cu concentration. The differences in pasture growth and Cu concentrations in plants seasonally could be attributed to the differences in air and soil temperature, soil moisture content and solar radiation patterns within the trial period.

Adsorption and desorption reactions are likely to be the major factors controlling the availability of Cu to plants. The major forms of Cu that can be extracted by soil test extractants are the organically bound, followed by oxide bound, residual and exchangeable forms. Organic and oxide bound Cu were the main sources of plant available Cu. The uptake of native Cu and residual Cu from soils showed that N and lime at 50 kg N ha^{-1} and 1000 kg lime ha^{-1} levels increased the Cu concentration, and EDTA also increased the plant available Cu to toxic levels. The effect of N, lime, and EDTA on the availability of residual Cu in ryegrass needs further investigation. Both the glasshouse and field trials indicate that Cu uptake is internally regulated by the growth of pasture and externally affected by the transformation of Cu in soils.

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