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Lime application in the establishment of a no-till system for grain crop production in Southern Brazil

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Abstract

Brazil has extensive pasturelands that could be used, in part, for grain production. A no-till system was established on pastureland to obtain a suitable method for liming upon conversion from pasture to a no-till cropping system. The study was conducted during the period from 1998 to 2003, in Paraná State (Brazil), on a clayey, kaolinitic, thermic Rhodic Hapludox. Soil chemical properties and grain production were evaluated after application of dolomitic lime. The experimental treatments were: control (no lime), split application of lime on the surface (three yearly applications of 1.5 t ha^{-1}), surface lime (4.5 t ha^{-1}), and incorporated lime (4.5 t ha^{-1}). The lime rate was calculated to raise the base saturation in the topsoil (0–0.20 m) to 70%. The cropping sequence was: soybean (*Glycine max* L. Merril), barley (*Hordeum distichum* L.), soybean, wheat (*Triticum aestivum* L.), soybean, corn (*Zea mays* L.), and soybean. When surface-applied, liming neutralized acidity and increased exchangeable Ca^{2+} + Mg^{2+} to a depth of 0.10 m, and to a depth of 0.20 m, when incorporated. Split application of lime on the surface resulted in a slower neutralization reaction only in the first year after liming. Soil pH increased with liming and resulted in a decline of exchangeable Al^{3+} and an increase in base saturation. At 0–0.05 m depth, lime incorporation resulted in lower levels of soil organic matter than surface application. It took 4–5 years after lime incorporation for soil organic matter to return to its baseline value. Liming increased grain yield in only one crop of soybean, and only when lime was surface-applied at the full rate. However, cumulative grain yield was higher with liming than in the control treatment (no lime), regardless of the application method. Surface application of lime, at either full or split rates, was the best alternative to neutralize soil acidity when establishing a no-till system on pastureland because, in addition to conserving soil structure, it provided a greater economic return.

Keywords: Soil acidity; Dolomitic lime; Surface application; Lime incorporation; Conservation tillage; Tropical soils; South America

1. Introduction

In many areas of the world, soil acidity limits agricultural yield. Soil pH affects nutrient solubility and influences the sorption or precipitation of nutrients containing Al, Mn, and Fe. For plants, increasing the pH

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of acidic soils improves macronutrients availability of while reducing the solubility of Al and Mn. Soil acidity problems are commonly corrected by liming. However, liming, in general, does not reduce soil acidity beyond the point of placement, which depends on leaching of salts throughout the soil profile.

In tropical and subtropical regions, a no-till system, with diversified crop rotation, is one of the most effective strategies to improve the sustainability of agriculture, and minimize soil and nutrient losses by erosion. No-till cropping system increases organic carbon and nitrogen contents, mainly in the top layers of the soil, as a result of plant residue deposition and absence of disturbance. The increase in organic matter content increases cation exchange capacity (CEC) and biological activity. No-till has rapidly increased the cultivated area in Brazil—currently estimated at some 17 million hectares.

To control soil acidity in no-till, lime is broadcast on the surface without incorporation. Several experiments, conducted under diverse soil and climatic conditions, have attested to the viability of surface liming, after the establishment of this cropping system, for crop production (Moschler et al., 1973; Lal, 1976; Blevins et al., 1978; Hargrove et al., 1982; Grove and Blevins, 1988; Caires et al., 2000).

No-till affects some chemical characteristics related to soil acidity, which may influence plant development. The higher content of organic matter (Bayer et al., 2000; Rhoton, 2000) and the greater concentration of P on the soil surface (Rhoton, 2000) under no-till are two factors, which may reduce Al toxicity (Ernani et al., 2002). The rise in soil CEC, due to the higher content of organic matter, can provide sufficient concentrations of exchangeable cations, even in highly acidic soils (Caires et al., 1998). In addition, soil cover reduces water loss by evaporation and provides more available moisture in the surface layers, which may promote nutrient uptake under adverse acidic soil conditions (Caires and Fonseca, 2000).

There are 170 million hectares (Mha) of pastureland in Brazil, of which 100 Mha or 59% are cultivated and 70 million (41%) are native pastures, which could, at least in part, be used for grain production. Crop establishment under no-till in these areas, without causing soil disturbance, would be advantageous considering the conservation of the chemical and structural properties of the soil, effective erosion control, and the economics of lime incorporation and soil tillage operations. However, if soil acidity is not adequately alleviated, root growth and crop yield may be compromised.

Under a no-till system, introduced in a field site in Southern Brazil and previously used as cropland under conventional till systems, downward neutralization of soil acidity, and movement of bases were the same whether dolomite lime was applied to the soil surface or incorporated in the 0–0.20 m soil layer (Oliveira and Pavan, 1996). These results raise doubts about the need to incorporate lime to neutralize soil acidity upon conversion from pastures to a no-till cropping system aimed at grain production.

A no-till system was established on pastureland to obtain a suitable method for liming recommendations upon conversion from pasture to a no-till cropping system. Soil chemical properties and the grain crop production were evaluated after liming. Dolomitic lime was surface applied, at full or split rates, or incorporated.

2. Materials and methods

2.1. Site description and soil

The experiment was conducted on Regina Farm in Ponta Grossa (PR, Brazil) (25°10′S, 50°05′W). The soil is an Oxisol (clayey, kaolinitic, thermic Rhodic Hapludox), previously used as pastureland. At the beginning of the experiment, soil chemical and granulometric analyses of the 0–0.20 m depth showed the following results: pH (1:2.5 soil: 0.01 mol l^{-1} $CaCl_2$ suspension) of 4.6; exchangeable Al^{3+}, Ca^{2+}, Mg^{2+}, and K^+ contents of 0.30, 2.50, 2.00, and 0.36 $cmol_{(+)}\,dm^{-3}$, respectively; total acidity ($H^+ + Al^{3+}$) of 7.80 $cmol_{(+)}\,dm^{-3}$; P (Mehlich-1) of 0.3 mg dm^{-3}; total organic matter of 53 kg m^{-3}; and 580, 130, and 290 g kg^{-1} of clay, silt, and sand, respectively. The subsoil (0.20–0.40 m) had 1.20 $cmol_{(+)}\,dm^{-3}$ of Ca^{2+}, 0.80 $cmol_{(+)}\,dm^{-3}$ of Al^{3+}, and 600 g kg^{-1} of clay.

2.2. Experimental design, treatments, and crop studies

A randomized complete block design was used and four treatments were replicated three times. Plot size