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Liming in the transition to no-till under a wheat–soybean rotation

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Abstract

Soil and subsoil aluminium toxicity has been one of the main limiting factors for soybean and wheat yields in tropical soils. Usually liming is the most effective way to deal with soil acidity and Al toxicity, but in no-till systems the soil is not disturbed making it impossible to incorporate lime in the arable layer, and lime has been usually applied on the soil surface. In this paper soybean and wheat responses to lime applied on the soil surface and/or incorporated in the soil arable layer were evaluated during the transition from conventional tillage to a no-till system. The experiment was conducted for 3 years in Paraná, Brazil, using a wheat–soybean rotation. Lime rates ranging from 0.0 to 9.0 t ha^{-1} were incorporated down to 20 cm and 4.5 t ha^{-1} were spread or not on the soil surface. Soil samples were taken down to 60 cm, 39 months after the first lime application. Soil chemical characteristics were affected by lime application down to 60 cm deep in the profile. Soybean responded to lime irrespective of application method, but the highest accumulated yield was obtained when lime was incorporated into the arable layer. For wheat, the more sensitive the cultivar, the greater was the response to lime. During the introduction of a no-till system, lime must be incorporated into the arable layer when the wheat cultivar is Al-sensitive.

Keywords: Aluminium; Base leaching; Calcium; Magnesium; Organic acids

1. Introduction

Soil acidity is responsible for crop yield limitations in 1.2×10^9 ha in South America and 3.8×10^9 ha in the world (Eswaran et al., 1997). In Brazil most of the agricultural soils show low pH, high Al and Mn contents and low base saturation (Olmos and Camargo, 1976). Aluminium toxicity is the main limiting factor. Liming was shown to be an effective way to deal with soil acidity and Al toxicity (Rosolem et al., 2004), but soybean response to lime has been inconsistent, ranging from 35 to 75% (Siqueira, 1989; Quaggio et al., 1998; Caires et al., 2005), while wheat response depends on cultivar sensitivity to low pH (Bataglia et al., 1985; Okuyama and Costa, 1990).

In no-till systems the soil is not disturbed and lime cannot be mixed into the arable layer of the soil. Responses to surface liming have been observed and some hypotheses have been raised to explain such effect: Fine lime particles may be transported off the surface with rain water; organic matter mineralization releases nitrate and sulphate that may be paired with Ca, Mg and K ions and leached through the soil profile (McMahon and Thomas, 1976; Blevins et al., 1978; Oliveira and Pavan, 1996); Nitrification of nitrogen fertilizers generates nitrate that can pair with base ions and be leached together. Lime applied on soil surface raises the soil solution pH above 6.0 (Salet, 1994), and when soil solution pH is above 5.5 the species HCO_3^- is stable (Bohn et al., 1979). In such conditions HCO_3^- can be leached along with Ca^{2+} and Mg^{2+}, alleviating

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soil acidity below the soil layer in which lime has been applied (Oliveira and Pavan, 1996; Caires et al., 2005). Downward movement of bases in soils under no-till may also be affected by plant residues that are left on soil surface. Rain water running through the residues can wash organic ligants (L) off this straw that can combine with the cations in soil and be leached together through the profile (Rosolem et al., 2004; Ziglio et al., 1999).

Surface-applied lime reaction time in no-till systems is affected by lime rate, soil chemical and physical characteristics, fertilizer management, crop rotation and lime reactivity. A decrease in exchangeable Al content and an increase in soil pH, Ca and Mg contents down to 40 cm in the soil profile was observed by Oliveira and Pavan (1996) 32 months after lime was spread on soil surface. Caires et al. (1999) observed similar effects 18 months after lime application. However, there are reports that the effects were confined to the first 5 cm of the soil 34 months after lime application on the surface (Pöttker and Ben, 1998).

Generally there is no difference in crop response when lime is ploughed down or applied on soil surface in long-established no-till systems (Macedo et al., 1979; Pöttker and Ben, 1998; Weirich Neto et al., 2000). Sá (1999), comparing cultivars differing in their tolerance to soil acidity reported that tolerant and sensitive cultivars responded positively to lime applied either incorporated or applied on the soil surface and no significant differences were observed between methods of lime application. However, there is no reliable information on crop response to methods of lime application during the transition from conventional to no-till systems as well as on the need or convenience to use tolerant cultivars during this period. When establishing a no-till system on pastureland, 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 (Caires et al., 2006a).

An experiment was conducted to evaluate the effects of lime rates incorporated down to 20 cm and/or spread on soil surface, during the implementation of a no-till system, on soil acidity alleviation and on the response of a soybean–wheat rotation using wheat cultivars differing in their tolerance to soil acidity.

2. Materials and methods

The experiment was conducted at the Agronomic Institute of Paraná, Ponta Grossa Regional Research Center, located at 25° 12′ S and 50° 09′ W. The soil was a clayey, kaolinitic, thermic Rhodic Hapludox. The site had been in fallow for 5 years and weeds were mowed in April of the first year of the experiment. In June the area was split in blocks and soil samples were taken at depths of 0–20, 20–40 and 40–60 cm. Each composite sample comprised 10 sub-samples. Selected soil chemical characteristics and particle size distribution were determined (Table 1).

Rates of lime (199 g kg^{-1} of Ca, 138 g kg^{-1} of Mg, ECCE = 91%) corresponding to 0.00, 2.25, 4.50, 6.75 and 9.00 t ha^{-1} were applied to 6.0 × 10.2 m plots and disked down in the soil arable layer late in July of the first year. In the second and third years of the experiment the plots were split in subplots that received or not an additional rate of 2.25 t ha^{-1} of the same lime each year, just before soybean planting. This rate was calculated to raise soil base saturation to 70%, considering the results obtained from soil samples taken from the 0–20 cm layer when the experiment was started (Caires et al., 2005).

Soybean cultivar Embrapa 58 was planted in the first and second years and Embrapa 133 in the third. Wheat cultivars Iapar 29, Iapar 53 and Br 35 were planted to sub-subplots (3.0 m × 3.2 m) in the winter using a plot drill. Iapar 29 is Al-sensitive, recommended for soils with less than 5% of Al saturation; Iapar 53 is moderately tolerant to Al, recommended for soils with Al saturation below 35%; and Br 35 is Al-tolerant (IAPAR, 2000). The presence of plant residues in the soil surface is paramount for the success of no-till in Brazil. In this experiment black oat (*Avena strigosa*) was planted early in August in order to make the transition to no-till. At heading, 100 days after plant emergence, a rolling knife was passed over the black oats. Glyphosate was applied at 0.75 kg ha^{-1} a.i. every year before soybean was planted. Soybean was planted on 27 November, 20 November and 7 December, using 300 kg ha^{-1} of a 0–25–15 N, P_2O_5, K_2O fertilizer every year. The experiment was harvested on 23 April, 4 April and 5 May on the first, second and third years, respectively.

Before wheat was planted every year, the weeds were killed with glyphosate (0.96 kg ha^{-1}a.i.) plus 2.4 D amine (0.8 kg ha^{-1} a.i.). Wheat was planted on 3, 10 and 2 July, each year, using 12 kg ha^{-1} of N, 40 kg ha^{-1} of P and 25 kg ha^{-1} of K. At tillering 40 kg ha^{-1} of N, as ammonium sulphate, was topdressed. Harvests were on 06, 11 and 09 November, on the first, second and third year, respectively. Soybean and wheat were harvested using a plot Harvester and grain yields were calculated considering 13% of grain humidity.