Title
Soil Acidity and Manganese Nutrition of Corn and Soybeans as Affected by Lime and Nitrogen Applications in an Oxisol under a No-Till System

Authors
Caires, Eduardo Fávero
Garbuio, Fernando José
Joris, Hélio Antonio Wood
et al.

Publication Date
2009-05-20

Peer reviewed

Introduction

Soil acidity limits agricultural yield in extensive areas in the world. Calcium (Ca) deficiency and aluminum (Al) and manganese (Mn) toxicity are considered major yield-limiting factors of tropical and subtropical acid soils. At lower pH the manganous Mn^{2+} is more dominate and is more readily plant available. Liming acid soils changes the availability of Mn by changing soil solution pH and the form of Mn. At higher pH the manganic form $Mn^{3,4-7+}$ dominates and is less plant available. To control soil acidity in NT, lime is broadcast on the surface without incorporation. Long-term NT systems are known to cause nutrient stratification, including pH, where high pH levels are formed in the upper few inches of the soil profile. This could create an environment of limited Mn availability for uptake. In addition, black oat residues on surface of NT soil have caused a decrease in Mn concentration in the soybean leaves (Caires et al., 2006). However, soils can acidify rapidly over a few years after application of ammonium-based nitrogen (N) fertilizers. So, the application of N fertilizers for cereal crops under NT may solubilize toxic elements such as Al and Mn due to acidification mainly in the topsoil.

This study reports a field trial that examined the effect of lime and N applications soil chemical attributes, grain yield and Mn contents in the leaf and grain of corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] grown on a NT acid loamy soil. Dolomitic lime was surface applied and $N\text{-}NH_4NO_3$ was applied in top dressing on the black oat crop grown as cover plant.

Material and Methods

Site description and soil

The experiment was carried out in Ponta Grossa, PR, Brazil (25°10' S, 50°05' W), on an Oxisol (loamy, kaolinitic, thermic Typic Hapludox). Before the establishment of the experiment, in May 2004, soil chemical and granulometric analyses of the 0–0.20 m depth showed the following results: a pH (1:2.5 soil: 0.01 M $CaCl_2$ suspension) of 4.1; exchangeable Al^{3+}, Ca^{2+}, Mg^{2+}, and K^+ contents of 12, 5, 5, and 1.7 $mmol_{(+)}\ dm^{-3}$, respectively; total acidity pH 7.0 ($H^+ + Al^{3+}$) 110 $mmol_{(+)}\ dm^{-3}$; P (Mehlich–1) 6.0 mg dm^{-3}; total organic carbon 18 g dm^{-3}; base saturation 10%; Mn (DTPA-TEA) 7.4 mg dm^{-3}, and 295, 240, and 465 g kg^{-1} of clay, silt, and sand, respectively. Considering the clay fraction, the soil had 265.8 g kg^{-1} of kaolinite, 26.8 g kg^{-1} goethite, and 2.4 g kg^{-1} hematite. At the beginning of the experiment, the field site had been used for grain cropping under the no-till system for 26 years

Experimental design, treatments and crop studies

A randomized complete block design was used, with three replications in a split-plot arrangement. In May 2004, dolomitic lime was surface applied in the plots (166.4 m^2) at rates of 0, 4, 8, and 12 t ha^{-1}. The lime rates were calculated to raise the base saturation in the topsoil (0–0.20 m) to about 40, 65, and 90%. In the subplots (41.6 m^2), N was applied at rates of 0, 60, 120, and 180 kg ha^{-1}. Nitrogen was applied as $N\text{-}NH_4NO_3$ in top dressing on the black oat (*Avena strigosa* Schreb) crop during the autumn–winter seasons of 2004, 2005, and 2006 before growing corn (2004–2005) and soybean (2005–2006 and 2006–2007) during the spring–summer seasons. Black oat was sown in June 2004 and May 2005 and 2006, at a seed density of 80 kg ha^{-1} and row spacing of 0.17 m, without fertilizers. During the flowering period, in each of the 3 years the aerial part was collected in three continuous rows of 1.0 m (0.51 m^2), and the dry biomass was evaluated. The crop black oat was then burnt down with glyphosate at 2 L ha^{-1}. Corn, hybrid AG 6018, was sown in September 2004 at a seeding rate of 5 seeds m^1 and a row spacing of 0.80 m.

Fertilizers were applied at rates of 126 kg ha^{-1} N, 40 kg ha^{-1} P and 44 kg ha^{-1} K. Soybeans were sown in November 2005 (cv. CD 206) and 2006 (cv. CD 214 RR) at a seeding rate of 16 seeds m^{-1} and a row spacing of 0.45 m. Fertilizers were applied at rates of 6 kg ha^{-1} N, 37 kg ha^{-1} P and 50 kg ha^{-1} K at sowing in 2005, and 33 kg ha^{-1} P and 42 kg ha^{-1} K at sowing in 2006. Corn grain was harvested from a 14.40 m^2 plot and soybean grain was harvested from a 12.15 m^2 plot. Grain yield was expressed at 130 g kg^{-1} moisture content.

Contents of Mn in leaf and grain of the corn and soybean crops

Leaf samples of corn (2004–2005) and soybean (2005–2006 and 2006–2007), composed of 30 leaves per subplot, were collected during the flowering period of the crops according to procedures described by Malavolta et al. (1997). The samples were washed, dried at 60°C, and ground. Corn and soybean grain samples were also ground to determine nutrient levels. After nitric-perchloric acid digestion of leaf and grain tissue, Mn content was determined by atomic absorption spectrophotometry.

Soil sampling and chemical analysis

Soil samples were taken from each subplot at the 0–0.05 and 0.05–0.10 m depths. Twelve soil core samples per subplot were taken by means of a soil probe sampler to obtain a composite sample. The samples were taken in May 2005, 2006, and 2007. Soil pH was determined in a 0.01 M $CaCl_2$ suspension (1:2.5 soil ⁄ solution, v ⁄ v). Exchangeable Al^{3+} and Ca^{2+} were extracted with neutral 1 M KCl in a 1:10 (v ⁄ v) soil ⁄ solution ratio. Exchangeable Al^{3+} was determined by titrating with 0.025 M NaOH and Ca^{2+} by titrating with 0.025 M EDTA.

Results and Discussion

The average production of black oat dry biomass in the first year (2004) was only 1.2 t ha^{-1} and it was not influenced by liming and N application. The late sowing of black oat (June) and the water deficit, which occurred during the vegetative stage in August 2004, certainly limited the biomass production of the crop. Surface liming increased linearly the production of black oat dry biomass in 2005 (from 3.7 to 4.5 t ha^{-1}) and 2006 (from 4.4 to 6.3 t ha^{-1}). The production of black oat dry biomass in 2005 and 2006 was not significantly modified by N application. No response of back oat to N application can be due to considerable increases in organic C and N contents that occur in NT systems, mainly in the top layers of the soil, as a result of plant residue deposition and absence of tillage.

Surface liming increased soil pH and the content of exchangeable Ca^{2+}, and decreased the exchangeable Al^{3+} level at topsoil (0–0.05 and 0.05–0.10 m), after 1, 2, and 3 years after application. Soil acidification by N-NH_4NO_3 application was little after the first year of N rates application. There was a significant decrease in soil pH and exchangeable Ca^{2+} content, and an increase in the exchangeable Al^{3+} level at topsoil (0–0.05 and 0.05–0.10 m) as a function of cumulative N-NH_4NO_3 rates applied in 2004, 2005, and 2006. Higher topsoil acidification was observed with N application in the no-lime plots. Considering the rates of lime and N-NH_4NO_3 applied during the evaluation period of the trial, soil pH 0.01 M $CaCl_2$ varied from 4.0 to 6.2, in the 0–0.05 m depth, and from 3.8 to 5.0, in the 0.05–0.10 m depth; the exchangeable Ca^{2+}

contents varied from 8 to 48 $mmol_{(+)}$ dm^{-3} and from 7 to 24 $mmol_{(+)}$ dm^{-3}, respectively at depths of 0–0.05 and 0.05–0.10 m; and the variation in the exchangeable Al^{3+} levels was from 0 to 16 $mmol_{(+)}$ dm^{-3} (0–0.05 m) and from 2 to 14 $mmol_{(+)}$ dm^{-3} (0.05–0.10 m).

Increasing surface liming rate decreased linearly leaf Mn content of corn in 2004–05, at rate of 180 kg ha^{-1} N, and soybean in 2005–06, at rates of 120 and 180 kg ha^{-1} N, and in 2006–07 without N or with 60, 120, and 180 kg ha^{-1} N (Figure 1). Application of N-NH_4NO_3 rates on the black oat crop increased linearly leaf Mn content of corn (2004–05) and soybean (2005–06 and 2006–07), only in the no-lime plots. There was a close relationship ($p < 0.01$) between topsoil pH and leaf Mn content of the corn and soybean crops (Figure 2). So, the decrease in leaf Mn content by increasing lime rate and the increase in leaf Mn content by increasing N rate were provided by changes in topsoil pH.

Surface application of lime did not cause significant changes in the grain Mn content of corn (2004-05). However, increasing N rate on the black oat crop increased linearly corn grain Mn content from 4.8 to 6.4 mg kg^{-1}. Because only N application affected corn grain Mn content, there was no a close relationship between topsoil pH and corn grain Mn content (Figure 3). Soybean grain Mn content (2005-2006 and 2006-2007) was decreased by surface liming and increased by N application on the black oat crop. So, a close relationship ($p < 0.01$) was obtained between topsoil pH and soybean grain Mn content in each of the 2 years (Figure 3).

Grain yields of corn (2004–2005) and soybean (2005–2006 and 2006–2007) were not influenced by surface liming rates. The average corn yield was 9250 kg ha^{-1} and the average yield of the two soybean harvests during the trial was 3320 kg ha^{-1}. Application of N-NH_4NO_3 rates (x, in kg ha^{-1}) on the black oat crop increased quadractically ($p < 0.05$) grain yields ($\hat{y}$, in kg ha^{1}) of corn in 2004–05 ($\hat{y} = 9132 + 11.37x – 0.075x^2$, $R^2 = 0.49$) and soybean in 2006–2007 ($\hat{y} = 2998 + 4.52x – 0.026x^2$, $R^2 = 0.68$). So, the changes in Mn nutrition of the corn and soybean crops by surface liming and N application due to variation in pH at topsoil did not influence grain yields.

Conclusions

Surface lime application did not influence grain yields of corn and soybean grown on a NT acid loamy soil. Application of N-NH_4NO_3 on the black oat crop used as cover plant has low residual effect on grain yields of corn and soybean.

Surface liming increased pH at topsoil and decreased Mn content in corn leaf and soybean leaf and grain. Application of ammonium-based nitrogen fertilizer caused acidification at topsoil and increased Mn content in corn and soybean leaf and grain.

Lime and N-NH_4NO_3 applications in higher rates on the surface did not cause Mn deficiency or toxicity in the corn and soybean crops grown in an Oxisol under a NT system with a sufficient level of Mn (DTPA-TEA) in the topsoil.

References

Caires, E.F., Garbuio, F.J., Alleoni, L.R.F. & Cambri, M.A. 2006. Calagem superficial e cobertura de aveia preta antecedendo os cultivos de milho e soja em sistema plantio direto. Revista Brasileira de Ciência do Solo, 30, 87–98.

Malavolta, E.; Vitti, G.C. & Oliveira, S.A. 1997. Avaliação do estado nutricional das plantas: princípios e aplicações. 2.ed. Piracicaba: Potafos, 319p.

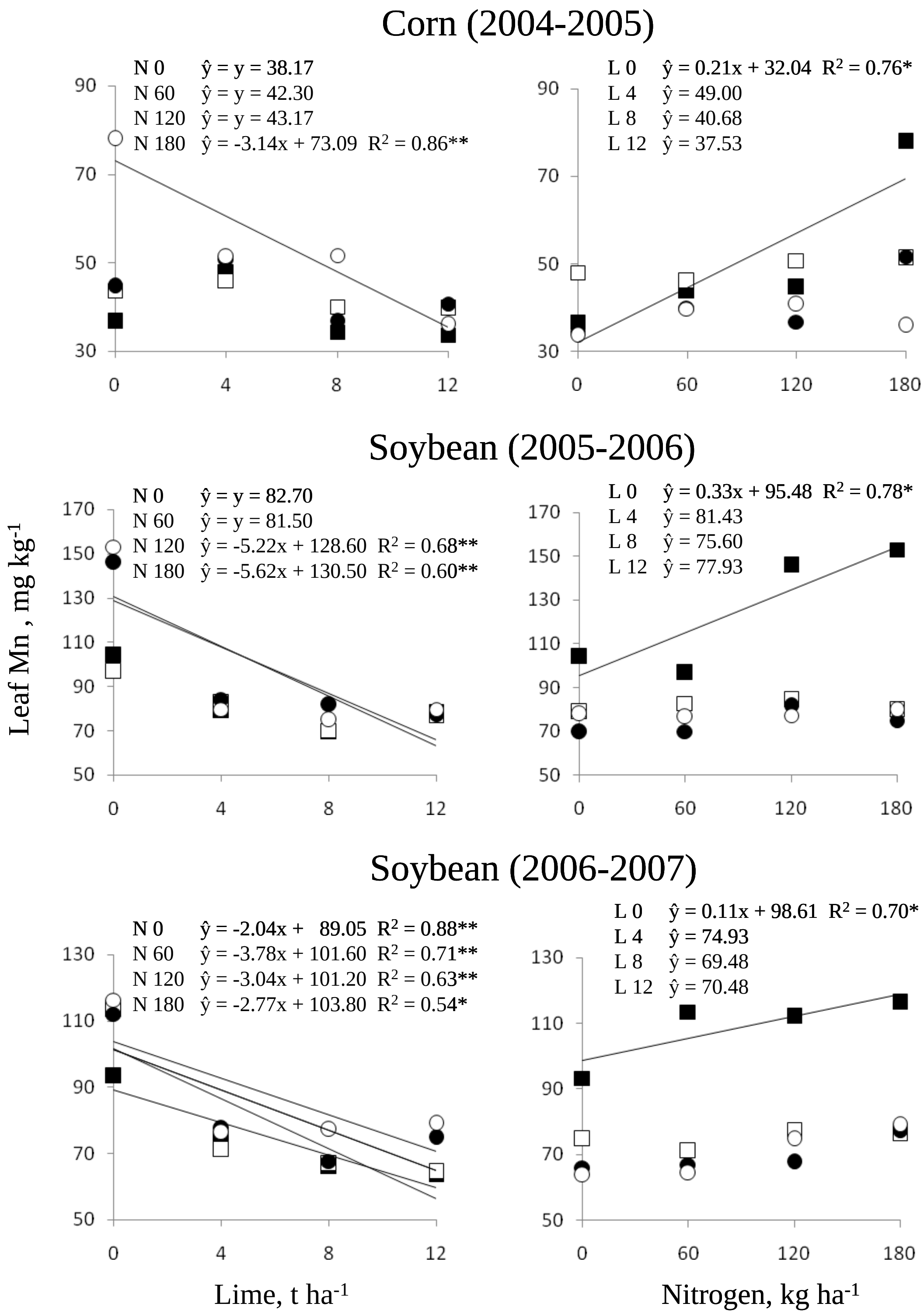

Figure 1. Leaf Mn content of corn and soybean as affected by lime and nitrogen applications. *: $p < 0.05$ and **: $p < 0.01$.

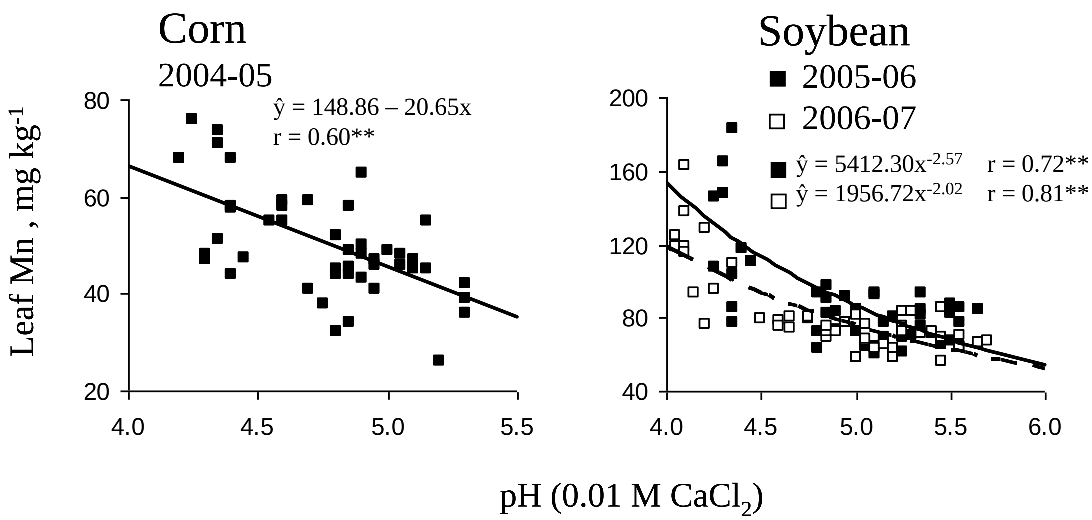

Figure 2. Relationship between soil pH (0.01 M $CaCl_2$) at 0–0.10 m depth and leaf Mn content of corn and soybean. **: $p < 0.01$.

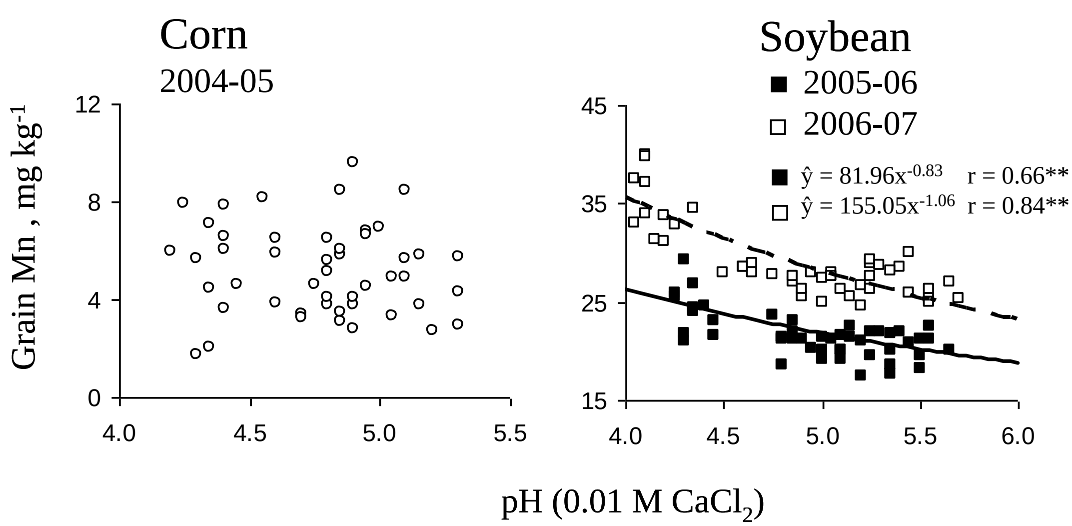

Figure 3. Relationship between soil pH (0.01 M $CaCl_2$) at 0–0.10 m and grain Mn content of corn and soybean. **: $p < 0.01$.