Pedosphere **26**(4): 474–485, 2016
doi:10.1016/S1002-0160(15)60058-3
ISSN 1002-0160/CN 32-1315/P
© 2016 Soil Science Society of China
Published by Elsevier B.V. and Science Press

PEDOSPHERE

www.elsevier.com/locate/pedosphere

Optimizing Nitrogen Use Efficiency for No-Till Corn Production by Improving Root Growth and Capturing NO_3-N in Subsoil

Eduardo F. CAIRES[1,*], Renato ZARDO FILHO[2], Gabriel BARTH[3] and Helio A. W. JORIS[1]

[1] *Department of Soil Science and Agricultural Engineering, State University of Ponta Grossa, Ponta Grossa 84030-900 (Brazil)*
[2] *Green Circle Growers, 51051 US Highway 20, Oberlin OH 44074 (USA)*
[3] *ABC Foundation Research and Agricultural Development, Castro 84165-700 (Brazil)*

(Received December 24, 2015; revised April 21, 2016)

ABSTRACT

Subsoil acidity restricts root growth and reduces crop yields in many parts of the world. More than half of the fertilizer nitrogen (N) applied in crop production is currently lost to the environment. This study aimed to investigate the effect of gypsum application on the efficiency of N fertilizer in no-till corn (*Zea mays* L.) production in southern Brazil. A field experiment examined the effects of surface-applied gypsum (0, 5, 10, and 15 Mg ha^{-1}) and top-dressed ammonium nitrate (NH_4NO_3) (60, 120, and 180 kg N ha^{-1}) on corn root length, N uptake, and grain yield. A greenhouse experiment was conducted using undisturbed soil columns collected from the field experiment site to evaluate NO_3-N leaching, N uptake, and root length with surface-applied gypsum (0 and 10 Mg ha^{-1}) and top-dressed NH_4NO_3 (0 and 180 kg N ha^{-1}). Amelioration of subsoil acidity due to gypsum application increased corn root growth, N uptake, grain yield, and N use efficiency. Applying gypsum to the soil surface increased corn grain yield by 19%–38% and partial factor productivity of N (PFP_N) by 27%–38%, depending on the N application rate. Results of the undisturbed soil column greenhouse experiment showed that improvement of N use efficiency by gypsum application was due to the higher N uptake from NO_3-N in the subsoil as a result of increased corn root length. Our results suggest that ameliorating subsoil acidity with gypsum in a no-till corn system could increase N use efficiency, improve grain yield, and reduce environmental risks due to NO_3-N leaching.

Key Words: ammonium nitrate, grain yield, N uptake, nitrate leaching, partial factor productivity of nitrogen, soil acidity

Citation: Caires E F, Zardo Filho R, Barth G, Joris H A W. 2016. Optimizing nitrogen use efficiency for no-till corn production by improving root growth and capturing NO_3-N in subsoil. *Pedosphere*. **26**(4): 474–485.

INTRODUCTION

No-till adoption exceeds 111 Mha worldwide (Derpsch *et al.*, 2010). The area under no-till has grown rapidly, especially in South America, where countries, including Argentina, Brazil, Paraguay, and Uruguay, use this practice on about 70% of total cultivated area (Derpsch *et al.*, 2010). In Brazil, the cultivated area under no-till has rapidly increased to 32 Mha. In this cropping system, ammoniacal fertilizers are used as the nitrogen (N) source. Soil acidification as a result of the nitrification by ammoniacal fertilizer use in no-till systems has been well documented (Ismail *et al.*, 1994; Bowman and Halvorson, 1998; Caires *et al.*, 2015).

Fertilizer N use is expanding globally to satisfy the food demand of a growing world population. However, more than half of the N added for crop fertilization is currently lost to the environment (Lassaletta *et al.*, 2014; Snyder *et al.*, 2014). Nitrate nitrogen (NO_3-N) leaching from intensive farming systems is of increasing environmental concern worldwide because of increased concentrations of NO_3-N in ground- and surface waters (Di and Cameron, 2002; Kumazawa, 2002; De Ruijter *et al.*, 2007; Zhao *et al.*, 2007). Typically, NO_3-N leaching loss occurs when NO_3-N accumulation in the soil profile coincides with, or is followed by, a period of excess water drainage (Di and Cameron, 2002). High NO_3-N concentrations in drinking water can be a health hazard for humans (Townsend *et al.*, 2003), and NO_3-N drained into surface waters can deteriorate water quality, causing eutrophication that leads to algal blooms and fish poisoning (Howarth, 1988).

Agricultural intensification through the adoption of best management practices involving no-till and crop rotation while achieving high yields improves crop utilization of fertilizers added to the system (Jayasundara *et al.*, 2007; Spargo *et al.*, 2008; Liu and Wiatrak, 2011). In addition, agricultural intensification plays a key role in minimizing the environmental issues related to N fertilizer use (Jayasundara *et al.*, 2007; Snyder *et al.*, 2014).

*Corresponding author. E-mail: efcaires@uepg.br; efcaires@hotmail.com.

Subsoil acidity is a serious problem in vast areas of global crop production regions (Fageria and Nascente, 2014). Reduced base cation (especially calcium, Ca^{2+}) contents and aluminum (Al^{3+}) toxicity in the subsoil affect root growth and restrict the plant's capacity to access water and nutrients (Carvalho and van Raij, 1997).

Gypsum, a by-product of the phosphoric acid industry, is readily available in many parts of the world. In Brazil, approximately 4.8 Tg of gypsum are produced each year (van Raij, 2008). When applied to the soil surface, gypsum moves down the soil profile during drainage and increases Ca^{2+} supply while reducing levels of toxic Al^{3+} (Sumner, 1995). Improved root growth and higher absorption of water and nutrients by roots have been observed as a result of gypsum application (Carvalho and van Raij, 1997; Garnett *et al.*, 2009), and the beneficial effects of gypsum on no-till corn production have been well documented (Caires *et al.*, 2011; Dalla Nora and Amado, 2013). Gypsum application potentially promotes root development in deeper soil layers and thus may improve N use efficiency by increasing N uptake, especially from NO_3-N that has moved to the subsoil and that might otherwise be lost. In addition, gypsum contains sulfur (S) and the interaction between N and S may also influence plant N uptake (Stewart and Porter, 1969; Salvagiotti *et al.*, 2009).

Nitrogen use efficiency can be obtained using various methods. An inexpensive and efficient method is use of the index partial factor productivity of nitrogen (PFP_N), which consists of evaluating incremental crop yield improvement per kg of applied N (Dobermann, 2007). However, the use of undisturbed soil columns is an efficient alternative as it enables verifying actual N uptake from soil NO_3-N through measuring the NO_3-N content of leached liquid and the total N taken up by the plant.

This study examined the effect of gypsum application on N use efficiency in no-till corn production and the resulting improvement of root growth and capture of NO_3-N in the subsoil. We hypothesized that ameliorating subsoil acidity with the application of gypsum could improve root growth and increase the efficiency of N fertilization in no-till corn production.

MATERIALS AND METHODS

Site description

A field experiment was conducted in Tibagi (24°30′ S, 50°26′ W, 826 m altitude), Paraná, Brazil. The climate at the site is categorized as the Cfb type (mesothermal, humid, subtropical) with mild summer and frequent frosts during the winter, according to the Köppen-Geiger System (Peel *et al.*, 2007). The average maximum and minimum temperatures are 22 and 13 °C, respectively, and the annual precipitation is approximately 1 550 mm. The soil of the field is an Oxisol (clayey, kaolinitic thermic Typic Hapludox) that had been used for grain cropping under a continuous no-till system for five years. Table I shows the results of chemical (Pavan *et al.*, 1992) and particle-size distribution (EMBRAPA, 1997) analyses for various soil depths in July 2009, before initiation of the field experiment. In this area, various rates of gypsum and NH_4NO_3 are applied during corn production.

Field experiment

The field experiment was conducted during the period from September 2009 to February 2010. A randomized complete block design with three replications in a 4 × 3 factorial arrangement was used such that a total of 12 treatments consisted of applications of gypsum at 0, 5, 10, and 15 Mg ha^{-1} and ammonium nitrate (NH_4NO_3) at 60, 120, and 180 kg N ha^{-1}. Gypsum was broadcast on the soil surface 7 d before sowing and NH_4NO_3 was applied as a top dressing at the V_4 stage (four fully developed leaves). The gypsum used was a by-product of the phosphoric acid industry and contained 220 g kg^{-1} Ca, 155 g kg^{-1} S, and 153 g kg^{-1} water. The plot size was 6 m × 7 m.

Seeds of a corn (*Zea mays* L.) hybrid DKB 240YG were sown in September, 2009, following a black oat winter cover crop in early spring, at a rate of 6.5 seeds m^{-1} and row spacing of 0.8 m. The corn hybrid used was classified as moderately tolerant to Al^{3+} toxicity according to tests performed in nutritive solution by Coelho *et al.* (2015). At the time of sowing, 45 kg N ha^{-1}, 48.9 kg P ha^{-1}, and 50 kg K ha^{-1} were applied as basal fertilizers. Corn grains were harvested from a 10-m^2 plot in February 2010 (six months after gypsum application) and the grain yield was expressed at 130 g kg^{-1} moisture content. Crop residues were retained on the soil surface following grain harvest.

Total rainfall during the full cycle of corn development was 994 mm (Fig. 1). The average rainfall for the same period in this region is 766 mm, giving an excess of 228 mm rainfall over the average during corn crop development. According to the reported water demands during each corn crop stage (Andrade *et al.*, 2006), the water supplied by rainfall was higher than necessary for proper corn development during the culti-

Download English Version:

https://daneshyari.com/en/article/4581254

Download Persian Version:

https://daneshyari.com/article/4581254

Daneshyari.com