Effect of Liming on Ni Bioavailability and Toxicity to Oat and Soybean Grown in Field Soils Containing Aged Emissions from a Ni Refinery

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Keywords: soil pH, dolomitic lime

1 Introduction

Mitigating toxicity of soil Ni through liming might manifest itself through lower bioavailability of soil Ni, thus lower tissue concentrations of Ni. Bioavailability of dissolved metals is reduced as soil pH increases by reducing the free metal ion in solution, as competition with H^+ for negatively charged sites on soil solids decreases [1]. Plant uptake of dissolved Ni may also increase with soil pH above 5, as competition between protons and metal cations for binding sites on the biotic ligand also decreases [2,3]. However, the net effect is often a decrease in uptake. Particularly since Ni solubility also decreases with the increase in pH, and specific to Ni, addition of dolomitic lime could increase the pore water concentration of Mg^{2+}, which has been shown to reduce Ni toxicity to soil-dwelling organisms by competing with Ni for the biotic ligand [2,4]. Finally, tissue concentration of an essential trace element, such as Ni, could be somewhat influenced by the organism's tendency towards homeostasis [5], which can confound the relationship between estimated metal bioavailability and the observed toxicity. The overall objective of the present work was to generate higher-tier in situ toxicity data for elevated Ni in soils, which would confirm the observations from the several pot studies of soils from this site, as well as the framework for predicting soil Ni toxicity identified by the European Union Risk Assessment Report (EU RAR) [6]. The present multi-year study of agronomic yield of field-grown oat and soybean, occurred in three adjacent fields that had received emissions from a Ni refinery for 66 years. The soil Ni concentration in the plots ranged between 1300 and 4900 mg/kg, and each field was amended with either 50, 10 or 0 tonnes/ha of crushed dolomitic limestone. Dolomitic lime is the preferred method for restoring agricultural soils, and it contains both Ca and Mg. The goal of the present study was to test the effect of liming on agronomic yield of soybean and oat, as well as its effect on the plant availability of soil Ni.

2 Materials and Methods

Three agricultural fields near the Ni refinery in Port Colborne, ON which are known to have elevated concentrations of Ni were amended with crushed dolomitic limestone at either 50, 10, or 0 t/ha in the summer prior to the first field trial. In the first year of the study, half of the plots in each of the three fields were planted with oat (*Avena sativa* var. Rigodown), and the other half were planted with soybean (*Glycine max* var. OAC Bayfield). In the second year of the study, all plots were planted with soybean (OAC Bayfield) (as none of the soybean plots in the previous year produced useable data) and in the third year of the study, half of the plots in each field were planted with oat and the other half of the plots were planted with soybean. Agronomic yield for each plot was determined when the plants were ready for commercial harvest. The absolute yield for each plot was also expressed relative to the county average yield for that crop year, which was 2.2 t/ha (oat; 2005), 3.1 t/ha (soybean; 2006), 2.4 t/ha (oat; 2007) and 2.2 t/ha (soybean; 2007).

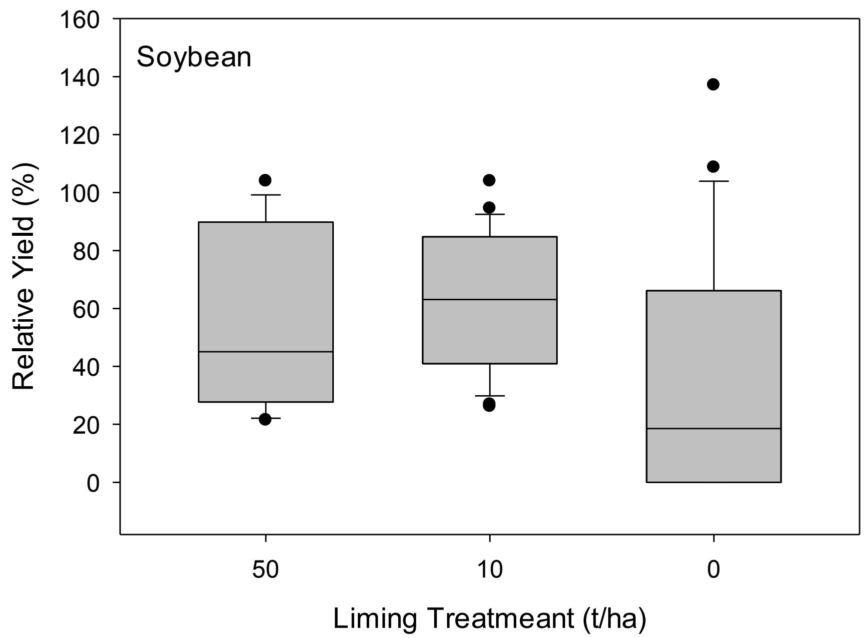
3 Results and Discussion

For soybean, relative yield was higher at 10 and 50 t/ha added lime than at 0 t/h added lime ($p < 0.05$) (Figure 1a), whereas for oat, relative yield showed no significant difference among the liming treatments ($p = 0.09$) although the pattern of response to the three liming treatments was similar to that for soybean (Figure 1b). This comparison of main effect means should be carefully interpreted, as the mean (and median, data not shown) soil [Ni] at 10 t/ha added lime was greater than at both 0 t/ha and 50 t/ha added lime, so 'effect of lime' is confounded with exposure concentration. Despite this confounding factor, liming appeared to be effective at improving agronomic yield of soybean and oat grown in soils with [Ni] ranging to nearly 5000 mg/kg, although the optimal rate of lime addition could not be identified. Without the confounding of lime addition with exposure concentration, it is possible that agronomic yield of both species would have been clearly greatest at 10 t/ha, because it substantially reduces $CaCl_2$-extractable soil [Ni] and results in a soil pH closer to optimal for cultivating most grain crops (i.e. 6) than results from adding 50 t/ha lime to soil [7]. Pagani and Mallarino [8] demonstrated that yields of soybean and corn in uncontaminated soils were sometimes improved by liming, at rates of 9, 13.5 or 22.4 Mg/ha CCE equivalent, whether or not the lime source was calcitic, dolomitic, or pure $CaCO_3$. Soil pH was increased from about 5.7 to between 6.5 and 7.3, depending on the source of lime.

4 References

1. Allen HE. 2002. Bioavailability of metals in terrestrial ecosystems: importance of partitioning for bioavailability to invertebrates, microbes, and plants. SETAC Press, Pensacola, USA.
2. Lin Y, Di Toro DM, Allen HE. 2015. Development and validation of a terrestrial biotic ligand model for Ni toxicity to barley root elongation for non-calcareous soils. Environ. Pollut. 202:41–49.
3. Rooney CP, Zhao F-J, McGrath SP. 2007. Phytotoxicity of nickel in a range of European soils: Influence of soil properties, Ni solubility and speciation. Environ. Pollut. 145:596–605.
4. Owsianiak M, Rosenbaum RK, Huijbregts MAJ, Hauschild MZ. 2013. Addressing Geographic Variability in the Comparative Toxicity Potential of Copper and Nickel in Soils. Environ. Sci. Technol. 47:3241–3250.
5. Marschner P. 2012. Miner. Nutr. High. Plants Third Ed. Academic Press, San Diego, pp 645–651.
6. European Union. 2008. European Union Risk Assessment Report: Nickel and Nickel Compounds. European Communities, Luxembourg.

7. Castro GSA, Crusciol CAC. 2013. Effects of superficial liming and silicate application on soil fertility and crop yield under rotation. Geoderma. 195:234–242.
8. Pagani A, Mallarino AP. 2012. Soil pH and Crop Grain Yield as Affected by the Source and Rate of Lime. Soil Sci. Soc. Am. J. 76:1877–1886.



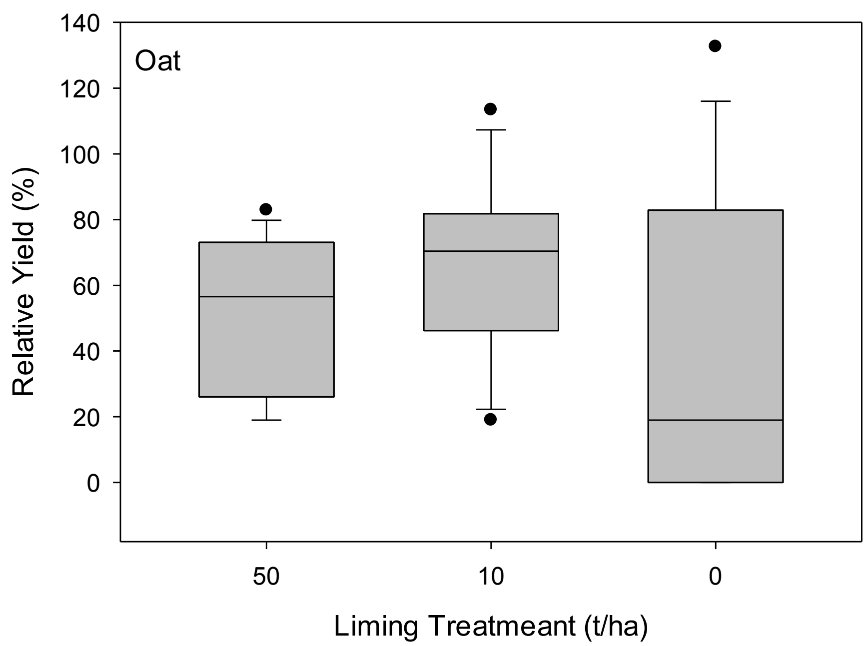


Figure 1: Agronomic yield of soybean and oat relative to county average values for the year, for each of three liming treatments.

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