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Zinc bound to manganese oxides in soils in a greenhouse flax crop to which several zinc chelates were added

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Zinc is a micronutrient that is essential for all plants, and some, such as flax, are particularly sensitive to Zn deficiencies. Like other micronutrients, total soil Zn is distributed between different fractions. These fractions have variable affinities for different soil components. A definition of the different chemical pools of Zn that exist in soils in relation to its bioavailability: water-soluble Zn, exchangeable Zn, Zn complexed with organic matter, carbonate-bound Zn, Zn inorganically precipitated or Zn occluded with iron or manganese oxides, and Zn entrapped in primary and secondary minerals. In order to know the fraction bound to specific soil components, it is necessary to make a sequential extraction.

In this study, we analyzed Zn bound to manganese oxides fraction, in two different soils. These soils were fertilized with several (natural and synthetic) Zn chelates and then flax (*Linum usitatisimum* L.) was cultivated in a greenhouse experiment.

The soils used were: soil I, pH 6.1, clay content 10%, EC 37.1 μs/cm and OM 0.50%; soil II, pH 8.1, clay content 18%, EC 178 μs/cm, OM 1.29% and total carbonate 13.4%. Zinc fertilization consisted of applying 0, 5 and 10 mg/kg of Zn to these soils in the form of eight chelates: Zn-EDTA, Zn-DTPA-HEDTA-EDTA, Zn-EDDHSA, Zn-S,S-EDDS, Zn-polihydroxiphenilcarboxilate, Zn-aminelignosulfonate, ZnEDTA-HEDTA and Zn-HEDTA. We also performed a control treatment without any micronutrient fertilization. All treatments were carried out in triplicate and involved a basal fertilization (100 mg N/kg, 120 mg P/kg, 146 mg K/kg and 60 mg S/kg). This experiment was conducted without leaching. The extraction method used $NH_2OH{\cdot}HCl$ 100

mM (ratio 1:10, soil:extractant) as a reagent and the extraction conditions were 20°C during 30 minutes of rotative agitation. These analyses were repeated three times.

Multifactor variance analysis, with a confidence level of 95%, was carried out for the variable "Zn bound to manganese oxides" using the following factors: soil (df 1), fertilizer treatment (df 16) and repetition (df 2). In all cases, the addition of Zn chelates led to an increase in this fraction with respect to the control. We obtained significant differences between treatments (probability $P < 0.0001$) and soils ($P < 0.0001$), but not between repetitions. Furthermore, there were significant interactions between soil and treatment factors ($P < 0.0001$). We established the following order according to fertilizers added at a rate of 10 mg Zn/kg: Zn-S,S-EDDS $\sim$ Zn-EDTA-HEDTA $\sim$ Zn-DTPA-HEDTA-EDTA $\sim$ Zn-HEDTA $\geq$ Zn-polihidroxifenilcarboxilate $\geq$ Zn-EDDHSA $\geq$ Zn-aminolignosulfonate. Duncan's method for separating means revealed two homogenous groups with respect to the soil factor (soil I, 3.11 mg Zn/kg; and soil II, 0.75 mg Zn/kg). The amount of Zn bound to manganese oxides was therefore highest in soil I. The Zn concentration in this fraction in soil I was 4.1 times greater than in soil II.