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Easily leachable zinc extracted with the $BaCl_2$ reagent and correlation with more labile micronutrient fractions in an acidic soil

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Zinc deficiency is widely reported in agricultural production. Several Zn sources have been used to correct Zn deficiency in crops, including in navy bean, a crop which is a very sensitive to this microelement. Such fertilization can produce a residual effect that benefits subsequent crops, but it also tends to cause environmental pollution. It would therefore be advisable to study the effects of fertilizers on soils and plants in order to optimize their fertilization effects and minimize their environmental impact. Zinc fractions provide a good insight into Zn behaviour in relation to the transformation of Zn added to soil. Few studies have sought to determine the relative importance of different Zn fractions in Zn leaching. Another approach to determine the quantity of potentially leachable Zn involves determining the amount of easily leachable Zn by means of the BaCl2 extraction procedure.

A navy bean (*Phaseolus vulgaris*, L.) (Garrafal Rabona Enana Esmeralda, Fito S.A., Barcelona, Spain) greenhouse experiment was conducted in pots with three plants and 10 kg of a Typic Haploxeralf soil deficient in Zn (pH_w, 6.13, 1:2.5 w/v; texture USDA, sandy loam). Basal fertilization was applied with 50 mg N kg^{-1}, 50 mg P kg^{-1} and 50 mg K kg^{-1}. Doses of 0 (control), 5 and 10 mg Zn kg^{-1} of six commercial liquid Zn fertilizers were added to the pots and each treatment was replicated three times. The soils were analysed at the end of the experiment (after 60 days). The Zn distribution in the most labile fractions was then determined: F1, water soluble plus exchangeable Zn (1 g of soil extracted with 10 mL NH_4NO_3 1 M, pH 7, shaken for 4 h at 120 rpm), and F2, organically complexed Zn (fulvic plus humic acids) (30 mL $Na_4P_2O_7$ 0.1 M, pH 10, shaken for 20 h at 120 rpm). The easily leachable Zn fraction was extracted from 3 g of soil with 30 mL of 0.01 M $BaCl_2$ (2h at 260 rpm).

Multifactor analysis of variance (with a probability level of $P \leq 0.05$) was carried out and showed differences between the Zn treatments but not between the repetitions. The quantities of Zn extracted from each soil sample in F1 (0.67-3.41 mg kg^{-1}, average 2.16 mg kg^{-1}) and F2 (1.99-7.78 mg kg^{-1}, average 5.51 mg kg^{-1}) were only a small in comparison with the total micronutrient content. The same occurred with the easily leachable Zn (0.89-8.07 mg kg^{-1}, average 4.85 mg kg^{-1}). From the statistical study, it was deduced that there was a positive and significant correlation between the two fractions (n = 13), with a correlation coefficient of r = 0.93 ($P<0.0001$), and also between F1 and F2 with the easily leachable Zn (having r values of 0.94 and 0.95 respectively, $P<0.0001$). The easily leachable Zn in all soils treated with Zn in this experiment included the first fraction (F1) and a part of the second fraction (F2), which was sequentially extracted from the soil. The best equation obtained for multiple regression analysis was $\text{Zn-BaCl}_2 = -0.76 + 0.75 \times \text{Zn-(F1+F2)}$, ($R^2$=92%).

Therefore, under our experimental conditions, the correlations obtained between easily leachable Zn and the fractions F1 and F2 of the soils were positive and significant ($P<0.0001$), especially with respect to the sum of the fractions F1 and F2.