

STUDY ABOUT THE ZINC TRANSFER FROM SEWAGE SLUDGE INTO AGROECOSYSTEMS

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ABSTRACT. Zn is one of the micronutrients (MICRO_n) necessary in active support of plant life (Pengel & Graham 1995). Organic fertilization with sewage sludge, obtained either through processing or by composting, provides moderate concentrations of Zn in the agricultural environment. The evolution of these concentrations was studied by increasing doses of sludge between 0 and 50 t.ha⁻¹, with and without chemical fertilizers: NP type. Thus, the average of total Zn from soil ranged between 63 and 111 mg.kg⁻¹ d.w. for processed sludge and between 14 and 67 mg.kg⁻¹ d.w. for composted sludge, in comparison with the toxic limit of 200 mg.kg⁻¹ d.w. Mobile Zn experienced was very significant growth and evident in all crop plants, namely between about 2 mg.kg⁻¹ d.w. and 19 mg.kg⁻¹ d.w. for maize, providing very good indices $I = 0.965$, between 2 and 7.5 mg.kg⁻¹ d.w. for wheat in the second year ($I = 0.884$), between 2 and 15 mg.kg⁻¹ d.w. for soybean ($I = 0.932$) and between 2 and 20 mg.kg⁻¹ d.w. wheat in year four, with $I = 0.948$. Given these mobile Zn concentrations, plants have absorbed and used specifically MICRO_n, depending on the crop species. Zn in leaves of plant in bloom showed direct relationships and increasing accumulations in all cases. Zn concentrations determined ranged between 8 and 12 mg.kg⁻¹ d.w. maize, between 29 and 41 mg.kg⁻¹ d.w. wheat-2, between 61 to 90 mg.kg⁻¹ d.w. in soybean and between 13 and 25 mg.kg⁻¹ d.w. wheat-4. MICRO_n Zn in the final phase was deposited in the grain. Its concentrations was also increasing, but with more moderate positions. Maize deposited Zn in grains between 20 and 25 mg.kg⁻¹ d.w., wheat-2 between 60 and 82 mg.kg⁻¹ d.w., soybeans between 50 and 60 mg.kg⁻¹ d.w., and wheat-4 between 34 and 39 mg.kg⁻¹ d.w. Sludge compost filed maize kernels with Zn

between 23 and 26 mg.kg⁻¹ d.w., and wheat between 20 and 23 mg.kg⁻¹ d.w. Determinations have shown that Zn provided by sewage sludge fertilization favored plant growth in agricultural environmental conditions.

KEYWORDS: *Zn, sewage sludge, maize, winter wheat, soybeans*

INTRODUCTION

Zn in soil crops culture consists of primary and secondary forms. Richness of soil Zn occurs in both forms of the initial mineralogical reserves (Brennan 2005) and the degree of literacy practiced in such area over time. The average concentrations of Zn are between 20-30 units to 300 mg.kg⁻¹ d.w. (Alloway 2008). Forms of Zn in soil are different and are distinguished by two characteristics: energy of retention and availability to plants. Depending on these MICRO_n Zn varies from strong forms retained to the soluble and occur in plants and vegetation for relative equilibrium states (Sharma 2006). Sewage sludge rich in Zn could contribute to the accumulation of chemical elements in soil, only with the agricultural environment protection (Westfall et al. 2005). Zinc is absorbed from the soil as Zn²⁺ ions and less in other forms (He et al. 2005). Along with other heavy metals Zn occupies octahedral positions by partial replacement of Al, Fe and Mn in the structure of clay minerals. Zn can be incorporated and hydrated like oxides of Fe and Mn present in the specific formations (small bowls or concretions) of podzolic soil, or surface coatings on clay minerals. Zn in soil have one of the complex system (Welch & Graham 2005), due to several factors favorable or not: soil reaction (pH), redox potential, mineral composition, soil phosphate levels, rainfall and temperatures, crop eco-systems. In soil type luvic/ podzolic weakly acid pH (5.1- 6.5) Zn for plants becomes more accessible than otherwise. Luvic soil may be present in such an environment study (tester) of this heavy metal in the agricultural field. Zn²⁺ ions are relatively easily bypassed in the soil solution (SSol) even if the redox potential is oscillating between wet or dry soil. Between zinc and phosphorus concentrations: Zn-P relationship, there is a relative

antagonism, revealed only in certain situations. In neutral and alkaline soils Zn is precipitated as $Zn(OH)_2$, very little accessible for plants (Gangloff et al. 2002). In carbonated soils rich in humus and application of amendments, Zn is least accessible. Under these conditions the tendency of nutrient is to form slightly soluble compounds by precipitations as carbonates, hydroxides and phosphates. In soils using balanced fertilizer, especially organic, including sludge, it creates conditions using zinc absorption and biological processes in which it is involved. Thus, Zn is essential for protein synthesis, DNA synthesis, cell division and growth in both plants and animals or humans (Ho 2004, Walker & Black 2004, Çakmak 2008). By using different doses of sludge, that this favorable environment for Zn agro-available, some excesses occur that could induce phyto-toxic phenomena plants. In this paper some results are made on field crops: maize, winter wheat and soybeans have grown and developed in terms of progressive doses of processed sludge and composted sludge, both rich in zinc.

MATERIALS AND METHODS

During the 7 years (between 2004 and 2010) were initiated the complex experiments. In the first experiment (2004-2007) plants were grown by the structure: 1-maize, 2-winter wheat, 3-soybean, 4- wheat. In normal cultivation technologies these plants were fertilized with various organic- mineral doses. Thus, the following doses of processed sludge were applied: $0 \text{ t}\cdot\text{ha}^{-1}$, $5 \text{ t}\cdot\text{ha}^{-1}$, $10 \text{ t}\cdot\text{ha}^{-1}$, $25 \text{ t}\cdot\text{ha}^{-1}$, $50 \text{ t}\cdot\text{ha}^{-1}$. Chemical fertilizers were differentiated into three levels: unfertilized, needs to $\frac{1}{2}$ of normal and normal doses (1/1). Plants have received such $N_{50}P_{50}$ /maize, $N_{60}P_{40}$ /wheat 2, $N_{30}P_{30}$ /soybean and $N_{40}P_{40}$ /wheat 4 for doses $\frac{1}{2}$ and $N_{120}P_{80}$ /maize, $N_{120}P_{80}$ /wheat 2, $N_{60}P_{60}$ /soybean and $N_{80}P_{80}$ /wheat 4 for the 1/1 doses. Sludge doses were applied in the same quantities in the first two years, maize and wheat in the second year following that soybean and wheat in the past year to receive their residual effect. The experimental plots/variants were area of 100 m^2 , in three replications. In other experiments (2008-2010) were cultivated maize and winter wheat, both in vegetation pots and in the field, a simple rotation of two years. Composted sludge doses were the same as in the first experiment and chemical fertilizers were: N_0P_0 , $N_{50}P_{50}$ and $N_{100}P_{100}$ in both crops. Experimental

variants type vessels had volumes of 15 liters- about 20 kg soil in five repetitions, and those in the field were surface of 25 m², four repetitions.

Chemical analyses were performed in accordance with the latest european standards and methodologies: soil total zinc (Zn_{TF}), leaves (Zn_{LV}) and beans (Zn_B) – ISO 11047-99, mobile forms of Zn (Zn_{MF}) – ISO 14870-99. Plant samples were collected at both the flowering period and maturity of beans. Leaves were collected as follows: around the cobs of flourished maize, last 3 leaves including standard wheat leaf, and middle position of flourished stems and pods formed at the base of soybean. Soil samples were collected from arable horizon with agrochemical devise: 0-20 cm, during blooming and maturity in both experiments. The data obtained were processed statistically by Anova test (analysis of variance) and using correlations and regressions by Excel program.

RESULTS AND DISCUSSIONS

Zn contents in crops eco-medium

Following determinations performed annually, soil Zn contents demonstrate the heavy metal through both forms and through mobile forms. Total zinc in soil fertilized with sludge processed stood at average values considered to good. Thus, in the four years Zn_{TF} varied between 53 and 206 mg.kg⁻¹ d.w. from maize in the first year, between 52 and 120 mg.kg⁻¹ d.w. for wheat in the second year, 50 to 123 mg.kg⁻¹ d.w. for soybean, and between 40 to 98 mg.kg⁻¹ d.w. for wheat last year. Values of total Zn in soil fertilized with sludge compost ranged between 51 and 112 mg.kg⁻¹ d.w. from maize crop and 4 to 19 mg.kg⁻¹ d.w. in winter wheat (Table 1). Podzolic soil studied showed that without organic fertilizer rich in zinc may appear so-called deficiencies or weaknesses (Brennan 2001, Alvarez & Gonzales 2006, Graham 2008).

Due to the positive effect of sludge introduced into the soil, mobile Zn (Zn_{MF}) saw positive developments, very important to all crops (Figure 1). Depending on the dose used Zn_{MF} evolved from 2 mg.kg⁻¹ d.w. in check plot to 19 mg.kg⁻¹ d.w. at high doses in maize. In other years Zn_{MF} ranged from 2-7 mg.kg⁻¹ d.w. in wheat 2, 3-15 mg.kg⁻¹ d.w. in soybean and between 2 and 19 mg.kg⁻¹ d.w. for wheat last year (4).

Table 1. Zn contents from soil ($\text{mg}\cdot\text{kg}^{-1}$ d.w.), total forms (Zn_{TF}) by sludge type used

Sludge type	Heavy metal	Maize	Wheat 2	Soybean	Wheat 4	Toxic limit
Processed sludge	Zn, limits media	53 – 206 111,2	52 – 120 79,1	50 – 123 78,1	40 – 98 63,0	250*
Composted sludge	Zn, limits media	51 – 112 67,1	4 – 19 14,0	-	-	250*

*250 – Ord. 344/2004

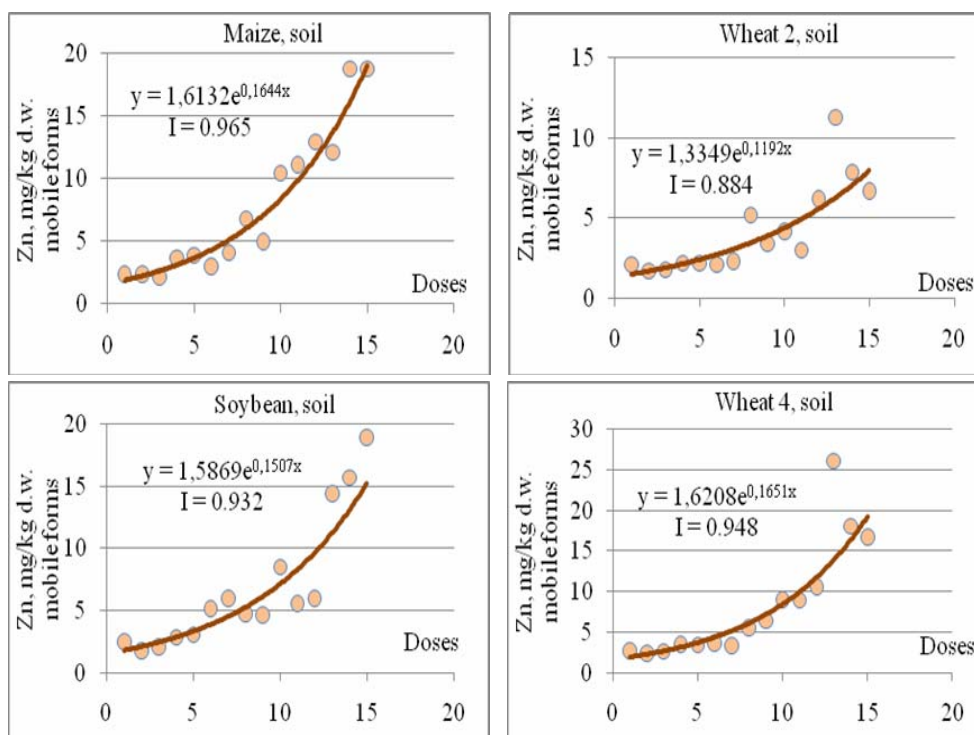


Figure 1. Correlations between Zn concentrations, mobile forms (Zn_{MF}) and sludge & chemical doses used

Given the critical limits of Zn, it is considered that the data ranges from positive values to ensure optimal conditions for plant uptake studies (Zou et al. 2008).

Influence of experimental factors on the content of Zn in leaves and beans.

In terms of new food, plants have absorbed and trans-located Zn in vegetative organs, which after mature Zn was stored in grains. Recent research has shown that the normal average plant zinc concentration is around $20 \text{ mg.kg}^{-1} \text{ d.w.}$, with a range between 7 and $30 \text{ mg.kg}^{-1} \text{ d.w.}$ (Brennan 2005, Alloway 2008).

In the analysis of plant leaves at flowering, critical concentrations of Zn can be at the following levels: $11\text{-}14 \text{ mg.kg}^{-1} \text{ d.w.}$ in maize, $11\text{-}15 \text{ mg.kg}^{-1} \text{ d.w.}$ in wheat 2, $10\text{-}20 \text{ mg.kg}^{-1}$ in soybean (Alloway 2008). To these results, the concentrations of Zn in leaves of three different plants were characteristic (Figure 2). In the flowering stage the Zn content from maize leaves was from 7 to $12 \text{ mg.kg}^{-1} \text{ d.w.}$, in wheat 2 leaves contained between 28 and $42 \text{ mg.kg}^{-1} \text{ d.w.}$ Zn concentrations in soybean leaves located at flowering were higher and that was between 62 and $90 \text{ mg.kg}^{-1} \text{ d.w.}$ Wheat from last year, Zn content was between 12 and $25 \text{ mg.kg}^{-1} \text{ d.w.}$ The difference between wheat 2 and wheat 4 (year 2 and year 4) can be explain by ensuring water from rain in year 2 and the drought year 4.

In the final stage- of maturity, mature seeds contained zinc at concentrations with quite smaller differences at other levels to blooming period. Thus, maize contained Zn between 20 and $25 \text{ mg.kg}^{-1} \text{ d.w.}$, thus approximately double than the leaves. Zn from wheat 2 mature grains was between 60 and $83 \text{ mg.kg}^{-1} \text{ d.w.}$. Here concentrations in wheat grains were double like the flowering period. Soybean had Zn levels in the $47\text{-}60 \text{ mg.kg}^{-1} \text{ d.w.}$ Compared with flourished period, soybean had less Zn deposited in grains. Zn content for wheat 4 mature grains was between 34 and $39 \text{ mg.kg}^{-1} \text{ d.w.}$, more than in flowering plant leaves.

Correlations obtained between organic- mineral fertilizers doses with Zn concentrations in grains shows that there has been a true export of this $\text{MICRO}_n\text{-Zn}$ (Figure 3).

By fertilization with composted sludge, concentrations of Zn in mature grains of maize and wheat have evolved specific positive- Figure 4.

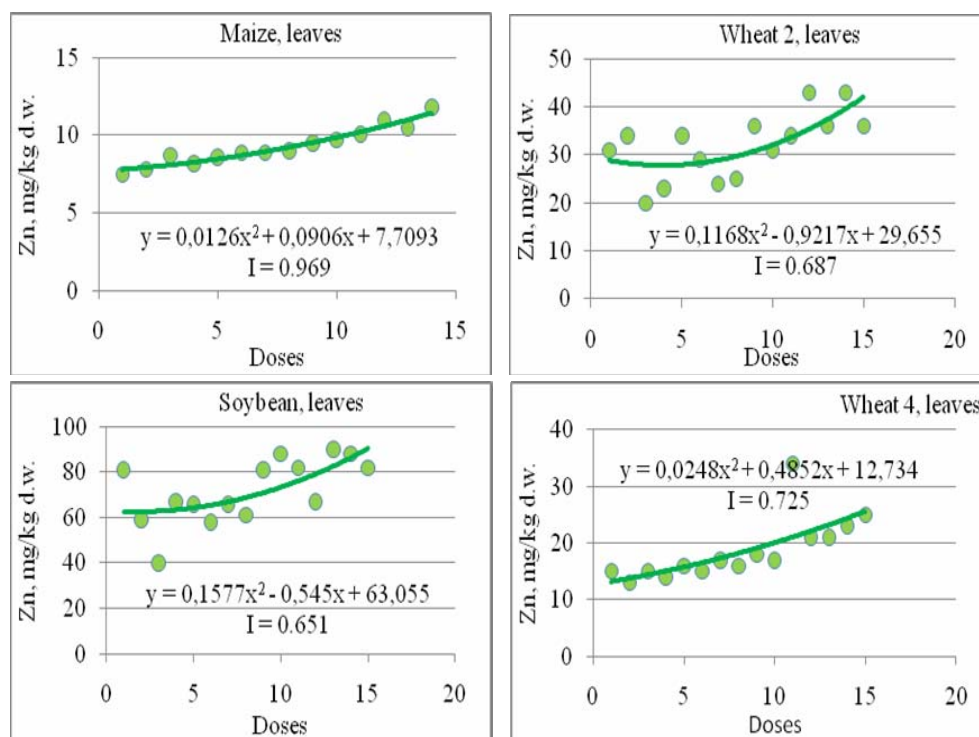


Figure 2. Correlations between Zn concentrations from plant leaves (Zn_{LV}) and sludge & chemical doses used

CONCLUSIONS

Processed or composted sewage sludge intervened in Zn regime from agricultural eco-systems. Depending on the dose applied, with and without chemical fertilizers have increased Zn contents and namely moderate total forms (Zn_{TF}) and significant mobile forms (Zn_{MF}). Mobile Zn (available) used in food plants ranged between 2 to 19 $mg \cdot kg^{-1}$ d.w., in comparison with 1.5-20 $mg \cdot kg^{-1}$ d.w. recommended (Fageria et al. 2002).

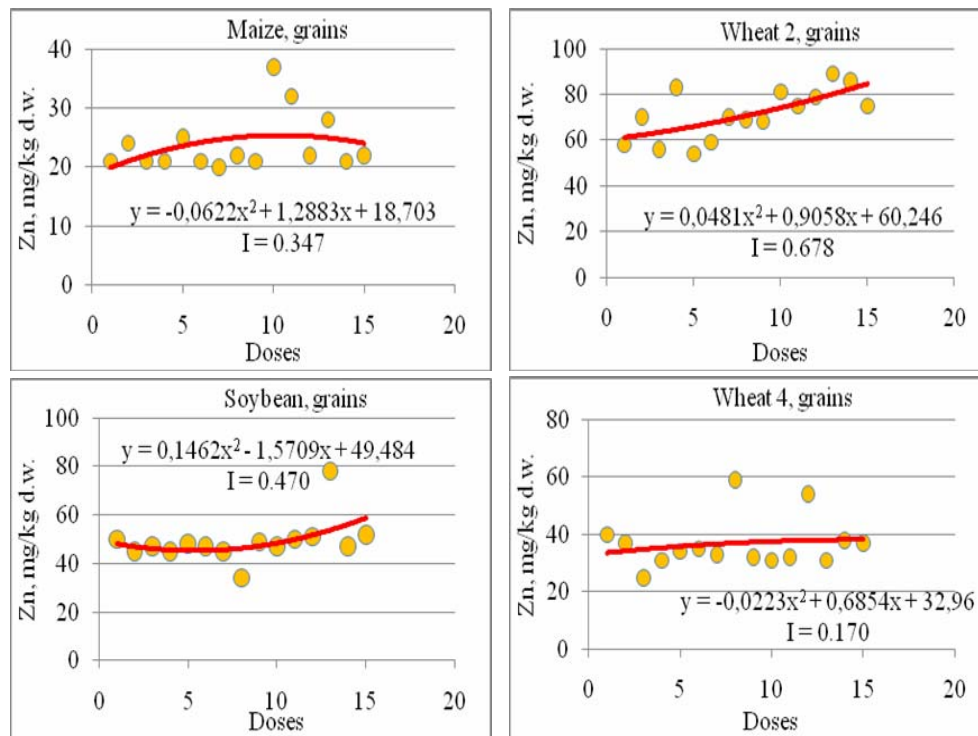


Figure 3. Correlations between Zn concentrations from plant grains (Zn_{GR}) and sludge & chemical doses used

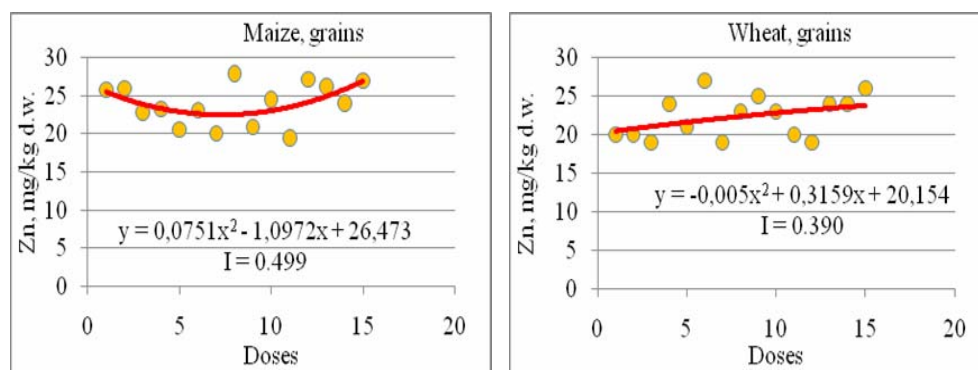


Figure 4. Correlations between Zn concentrations from plant grains (Zn_{GR}) and sludge compost & chemical doses used

With a high concentration of Zn_{MF} , plants absorbed Zn^{2+} ions in specific concentrations. Sludge doses favored Zn absorption in an ascending trending. Thus, in blooming time leaves contained Zn between: 7-12 $mg.kg^{-1}$ d.w. in maize, 28-42 $mg.kg^{-1}$ d.w. in wheat 2, 62-89 $mg.kg^{-1}$ d.w. in soybean and 13-24 $mg.kg^{-1}$ d.w. in wheat 4.

Zinc has been shown to be a micronutrient ($MICRO_n$) necessary in plant life. It was absorbed relatively easily from soil fertilized with sludge, was trans-located throughout the plant and used in many bio-chemical processes (Alloway 2008).

After the specific physiological functions, Zn was been stored in grains, like final product of plant growth and development. Depending on processed sludge doses Zn_{GR} varied between: 20-25 $mg.kg^{-1}$ d.w. in maize, 60-83 $mg.kg^{-1}$ d.w. in wheat 2, 46-60 $mg.kg^{-1}$ d.w. in sobean and 34-39 $mg.kg^{-1}$ d.w. in wheat 4. On Zn_{GR} sludge compost doses ranged from 23 to 26 $mg.kg^{-1}$ d.w. in maize kernels and between 20-23 $mg.kg^{-1}$ d.w. in wheat grains.

Data obtained with the use of sludge: the shape of processed and composted, in agricultural ecosystems were enrolled in non-dangerous limits for both soil and plants. For this reason this type- controlled, can be considered one of useful organic fertilizers for field crops.

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