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PHYTOTOXIC EFFECTS OF STEEL SLAG USED AS AMENDMENT FOR ACID SOILS

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Keywords: steel slag, amendment, soil, heavy metals, phytotocicity.

ABSTRACT

Application of the amendments restores the quality of the soil by balancing the pH, the organic matter intake, increasing the water retention capacity, reducing the soil compaction and restoring the microbial community. There are, however, some problems appear due to the use of soil amendments, and these problems may increase when the amendments are steel slag and furnace slag which are parts of ferrous slag. [NAC, 2003], [Ziemkiewicz and Skousen,1998]. The slag obtained from steel mill industry contains some metals in concentrations that are higher than normal concentrations in the soil. The toxicity of metal can occur when that metal (often a nutrient for plants) is present in high concentrations. The toxicity becomes more severe at a more acidic pH of the soil, or when it is combined with other nutrient deficiencies. The phytotoxicity of a heavy metal is a result of an imbalance between the absorption element and the inability of the process of metabolism of the plant to annihilate it at the cellular level. Following the experience installed on a support material of an acid soil, a luvosoil sampled from Albota region, with 6 doses of steel slag (0 g slag / kg soil; 1 g slag/ kg soil; 2 g slag / kg soil, 3 g slag / kg soil, 4 g slag / kg soil and 5 g slag / kg soil), and corn as test plant, there were presented observations and effects referring to the treatment on corn plants. From the point of view of heavy metals translocated in the corn plants, the paper presents variations of there contents depending on the treatment with steel slag. All the concentrations of heavy metals in the corn plants were placed generally within the normal content of the plant.

INTRODUCTION

Although the chemicals may be present in the soil, not all of them can be bioavailable or phytoaccessible. The bioavailability and phytoaccessibility are terms used to describe the degree to which contaminants are accessible for absorption through the interaction with the metabolism of organisms that are exposed to such contaminants. [NAC, 2003] The harmful substances can accumulate in plant tissues at levels that affect growth and development. [Beckett and Davis, 1977]

All systems with highly acidic soils have problems with plant growth and development due to toxicity of aluminum and manganese. In cases in which the metal contaminants are present, the acidity will increase the availability of the metal. All components of an ecosystem are dependent on soil health for the system to function optimally.

MATERIAL AND METHODS

Following the experience installed on a support material of an acid soil, a luvosoil sampled from Albota region, with 6 doses of steel slag (0 g slag / kg soil; 1 g slag/ kg soil; 2 g slag / kg soil, 3 g slag / kg soil, 4 g slag / kg soil and 5 g slag / kg soil), and corn as test plant, there were presented observations and effects referring to the treatment on corn plants.

At the same time they were found significant changes in the soil reaction with highly significant increase of the pH of the soil at all treatments.

Considering the optimal pH for culture of maize between 6.0 and 7.0 [Beegle et al., 1995], from data on the reaction and pH-values of the soil and due to the effect of the treatment on the contents of the macroelements of maize plants, in order to maximize the effect of amend and to select the appropriate dose of amendment were taken into account in particular the slag doses up to 4 g / kg soil. This is to avoid excessive or improper application rates.

As regards the influence of slag on the chemical properties of the soil as well as the cation exchange properties, it was found that they were favorably influenced; the contents of exchangeable calcium and exchangeable magnesium have increased very significantly starting with variant V2 (1 g slag / kg soil). The degree of base saturation has increased significantly in all variants reaching at V6 (5 g slag / kg soil) at an amount of more than 95%. Other chemical indicators such as soil organic carbon and phosphorus have not undergone significant changes; the total nitrogen has decreased significantly starting with the first dose of treatment (1g slag / kg soil).

The heavy metals were found in normal amounts for this type of soil as a result of the chemical analysis for their identification in the soil material sampled from the Albota region. They were carried out determinations of Cd, Cu, Cr, Ni, Pb, Mn, Co, Zn. The contents (mean values) of heavy metals in luvosoil from Albota were: Cu = 19.3 mg • kg^{-1}; Cr = 15.4 mg • kg^{-1}; Ni = 15.7 mg • kg^{-1}; Pb = 19.9 mg • kg^{-1}; Mn = 859 mg • kg^{-1}; Co = 13.7 mg • kg^{-1}; Zn = 65.2 mg • kg^{-1}; Cd = bdl (below detection limit). [Gament et al., 2017]

At the same time, it is known that the steel slag has generally high specific weight (3.2 to 3.6 g / m^3) which is a consequence of the existence of the residual metals in the chemical composition of slag. [www.nationalslag.org]

In addition to the high content of calcium and magnesium and also the relatively high content of silicon, the steel slag used in the experiment has a very strongly alkaline reaction (pH = 11.86) and also has a high content of metals such as: Zn = 0.010%; Cu = 0.005%; Cr = 0.027%; Pb = 0.009%; Mn = 0.95%; Cd = 0.001%; Ti = 0.12%; Fe = 1.80%, Ni = 0.005%.

RESEARCH RESULTS

Only a subset of **heavy metals** plays an essential role in metabolic processes, acting as micronutrients. These metals are cobalt, copper, iron, manganese, molybdenum, nickel and zinc. The needs of the plant concerning the heavy metals contents have a specific purpose. For example, iron requirement is high due to the important role that this element plays in the formation of hemoproteins and Fe-S complexes. On the other hand, the demand for nickel is low because nickel supports only the activity of some enzymes. The metabolic changes in the plants due to a high content of heavy metals are the result of changes occurring at the cellular level due to translocation and distribution of these elements. From the point of view of translocation of heavy metals in the corn plants, the paper presents variations of their contents related of the treatment with steel slag.

Thus, changes in the **Copper** content of the corn plants are shown in **Figure 1**.

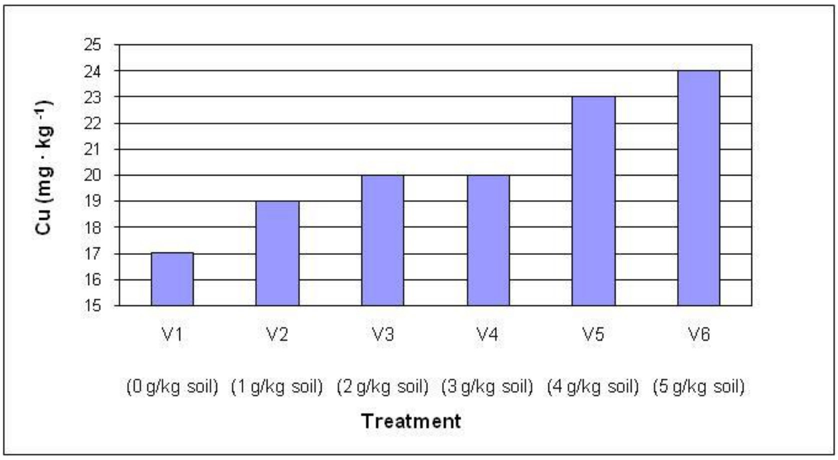

Fig. 1 Effects of steel slag application on the Copper content of the corn plants

The copper values are insignificant changed up to variant V4 (3 g slag / kg soil) and significantly increase at variant V5 (4 g slag / kg soil) and highly significant at variant V6 (5 g slag / kg soil). The leaves of corn V6 have accumulated an amount of copper of 24 mg • kg^{-1} at variant V6, a higher value compared with 17 mg • kg^{-1} at the control (without treatment).

From the point of view of the copper content of plants, starting with V5 variant (4 g slag / kg soil) and V6 variant (5 g slag / kg soil) these values slightly exceed the phytotoxic content of copper of 20 mg • kg^{-1} d.m. [Bajescu and Chiriac, 1984] According to other researchers, the copper content potentially toxic for plants, for example for sheep, it is estimated at 10 to 14 mg • kg^{-1} d.m.[Bajescu and Chiriac, 1984]

Variations in the content of **Cadmium** (**Figure 2**) are insignificant at V2 variant (1g slag / kg soil), V3 variant (2g slag / kg soil), V4 variant (3g slag / kg soil) and V5 variant (4g slag / kg soil).The cadmium content significantly increased at the V6 variant (5g slag / kg soil). All values recorded, including those from the V6 variant have not reached the cadmium content considered phytotoxic (8 mg • kg^{-1}d.m.).

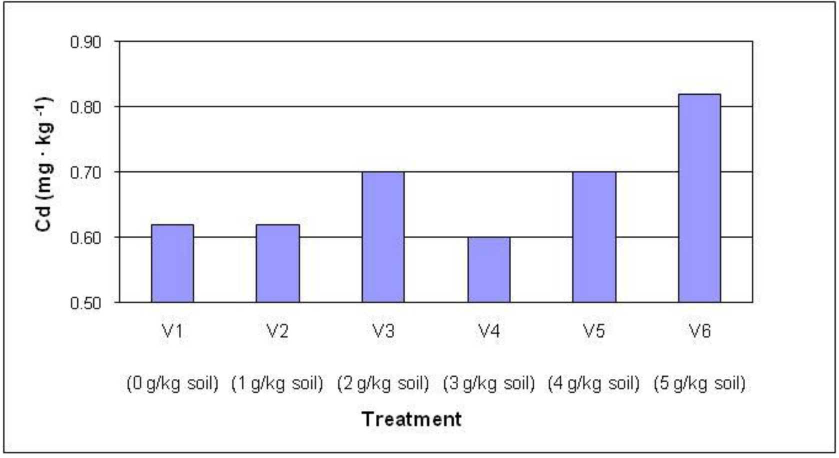

Fig.2 Effects of steel slag application on the Cadmium content of the corn plants

Effects of steel slag application on the **Lead** content of corn plants are shown in **Figure 3**.

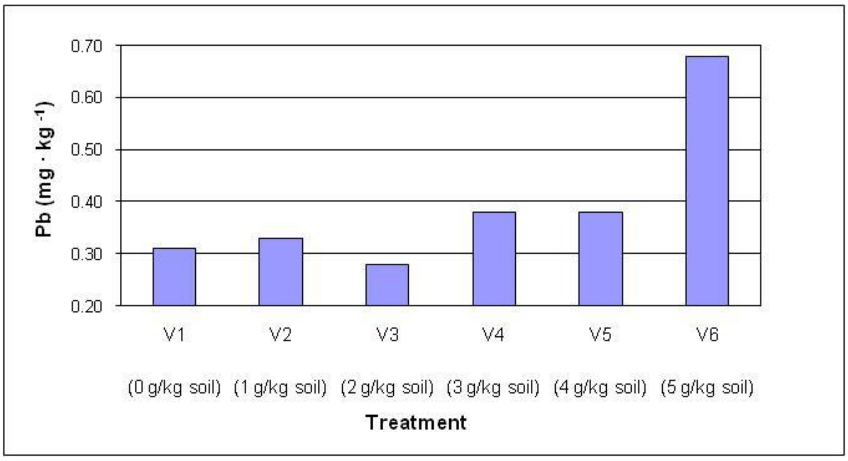

Fig.3 Effects of steel slag application on the Lead content of the corn plants

The lead content begins to increase significantly in the V4 variant (3g slag / kg soil) and V5 variant 4g slag / kg soil), and very highly significant to V6 variant (5g slag / kg soil). These values remain, however, within the normal content in plants and in the phytotoxic content (35 mg • kg^{-1} d.m.).

The **Iron** content in plants strong increases significantly at the V2 variant (1g slag / kg soil), and significantly decreases very strongly to V3, V4, V5 and V6 variants. (**Figure 4**)

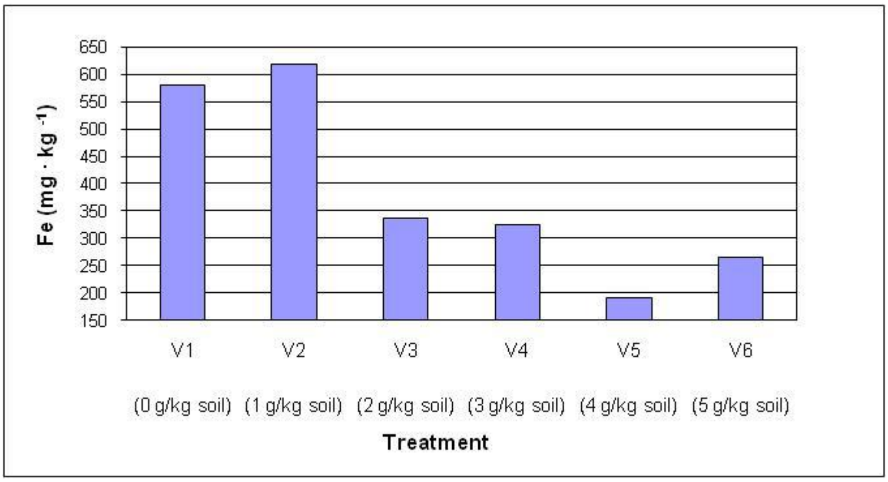

Fig.4 Effects of steel slag application on the Iron content of the corn plants

In comparison with other heavy metals, **Zinc** is much less phytotoxic. The toxicity of zinc has been reported mainly on acid soils (pH <5.7 to 6.0) where its availability is enhanced. Unlike copper, zinc is more easily absorbed and translocated by the root system into the aerial part of the plant, causing visible symptoms of toxicity. The zinc concentrations considered phytotoxic for plants are generally between 300 and 500 mg ·kg^{-1} d.m. [Bajescu and Chiriac, 1984]

Tolerance of plants to excess zinc is different. Effects of the steel slag on the zinc content of the corn plants are shown in **Figure 5.**

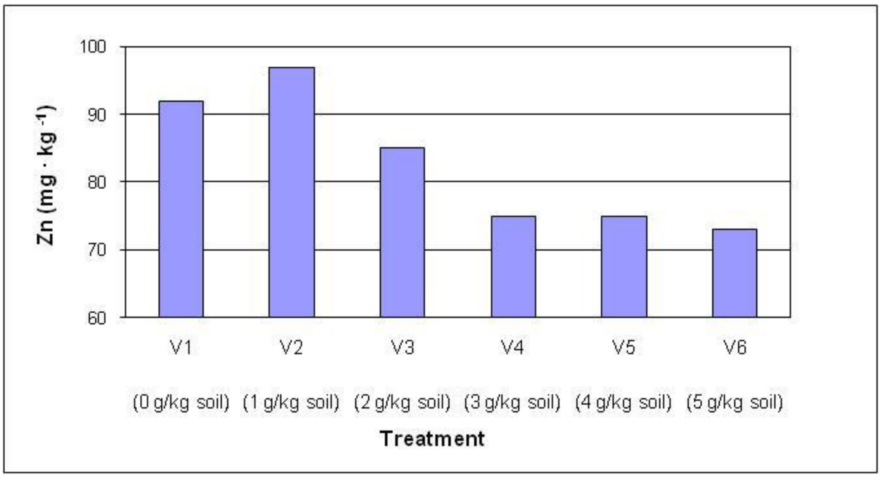

Fig.5 Effects of steel slag application on the Zinc content of the corn plants

The concentration of zinc significantly increases at the variant V2 (1g slag / kg soil) and strongly significantly decreases in the variant V3 (2g slag / kg soil. Also, the zinc content very highly significant decreased at V4 (3g slag / kg soil), V5 (4g slag / kg soil) and V6 (5g slag / kg soil).

Considering, generally, the phytotoxic zinc content of 200 mg· kg^{-1}d.m. it is found that the contents in corn plants did not exceed this value.

In excessive amounts, **Cobalt** is highly toxic up to moderately toxic to plants and animals. Cobalt toxicity is manifested by chlorosis and necrosis of leaves, often followed by drying the whole plant. The level of cobalt in plants decreases with increasing pH's. The amendment of soil and especially superamendment can reduce the concentration of cobalt in plants. From **Figure 6** it is found that the concentration of cobalt in the corn plants grown on luvosoil treated with steel slag has a very highly significant decrease in all variants.

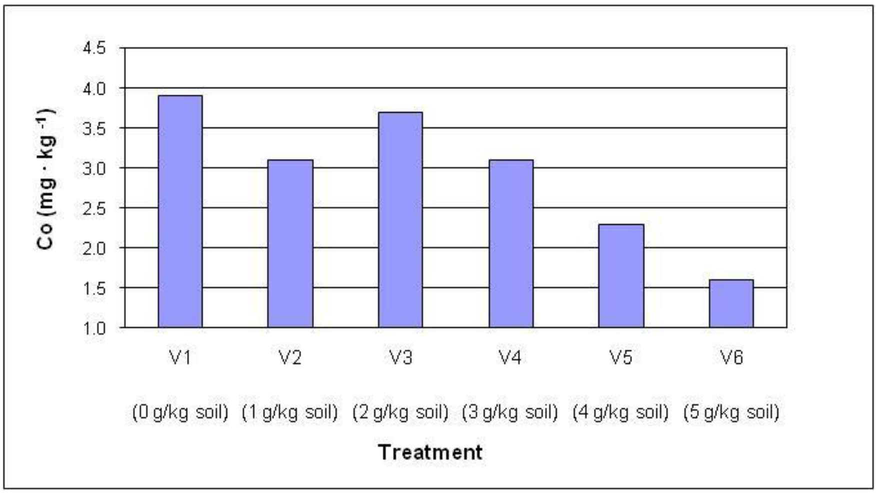

Fig.6 Effects of steel slag application on the Cobalt content of the corn plants

The **Manganese** toxicity generally manifests itself at the soils with the pH ≤5,5 , the high concentration of H^{+} ions favoring the predominance of the Mn^{2+} ions that are easily accessible in the plants.

At pH values above 6, the development of potentially toxic Mn content is unlikely, except poorly drained soils and compaction phenomena where the conditions of strong reducing favor the formation of Mn^{+2}. This explains the strong and significant decreases of the concentrations of manganese in corn plants (luvosoil experience of Albota) starting with the first variant of treatment, V2 (1g slag / kg soil). The very strong and significant increase of Mn concentration at V6 variant (5g slag / kg soil) can be explained by the very high content of the amendment applied. However, the amount of manganese of 207 mg • kg^{-1} d.m. in plants does not exceed the value of 300 mg • kg $^{-1}$ d.m. at which may occur symptoms of toxicity. [Bajescu and Chiriac, 1984] **Figure 7.**

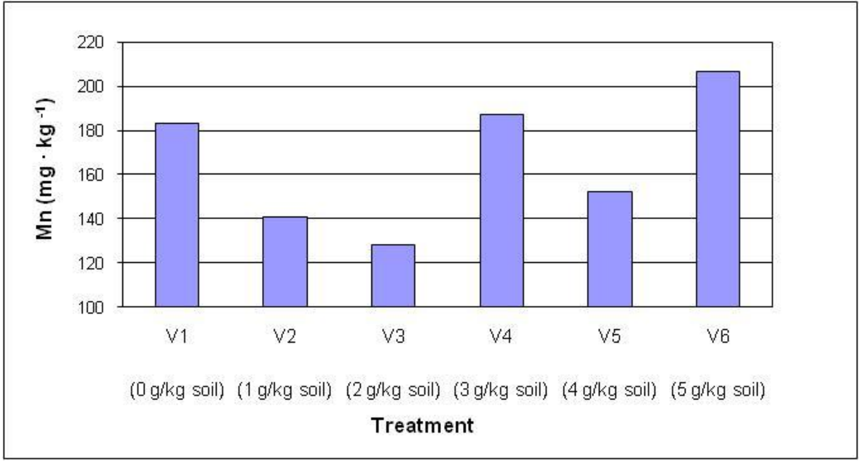

Fig.7 Effects of steel slag application on the Manganese content of the corn plants

In the polluted soils, **Nickel** does not form sparingly soluble compounds, its retention in the soil occurs strictly by adsorption mechanisms. It can be removed from the soil solution by adsorption to the clay soil, to the hydroxides of manganese and iron and the organic matter. The request of the plants for nickel content is low because it supports only the activity of some enzyme.

In the experiment with the luvosoil from Albota region, the effect of the application of the steel slag on the nickel content of the corn plants are shown in **Figure 8**. Nickel shows significant changes with regard to its content at variants V2 (1g slag / kg soil), V3 (2g slag / kg soil) and V6 (5g slag / kg soil) and a significant increase in the variants V4 (3g slag / kg soil) and V5 (4g slag / kg soil).

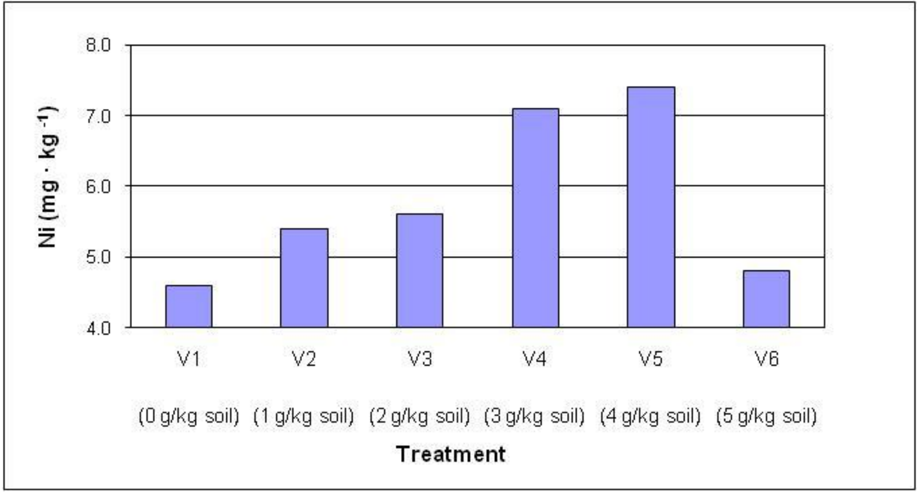

Fig.8 Effects of steel slag application on the Nickel content of the corn plants

CONCLUSIONS

- The levels of Cadmium, Copper, Cobalt, Manganese, Nickel, Lead, Zinc and Iron analyzed in the corn plants, due to the treatment of luvosoil from Albota region with different doses of steel slag (0 g slag / kg soil; 1 g slag / kg soil; 2 g slag / kg soil, 3 g slag / kg soil, 4 g slag / kg soil and 5 g slag / kg soil) showed slight changes insignificant in general. The increasing or decreasing of changes has been dependent on the treatment;

- All the concentrations of heavy metals in the corn plants have been generally placed within the normal content of the plant.

ACKNOWLEDGMENT

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