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Full Length Research Paper

Distribution of zinc in maize plants as a function of soil and foliar Zn supply

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Zinc is an essential micronutrient for the regular and healthy growth and reproduction of plants, animals and humans and it is obtained from daily dietary intakes Therefore, the deficiency of this nutrient is a consequence of its low concentration in food. In this sense, increasing the density and the bioavailability of Zn in edible parts of plants is fundamental to produce better crops. The objectives of the study were to investigate the zinc (Zn) uptake by maize plants after fertilization with Zn either via soil or via foliage. It was carried out a greenhouse pot experiment using a Typic Hapludox. Maize plants were harvested 100 days after seeding and Zn concentrations were determined in leaves and roots. The experimental design consisted of five doses of Zn applied via soil as well as via foliar, with three replications, totaling 30 experimental samples. Zinc was applied as zinc sulfate solution in the foliage at the third and fifth weeks after seeding. The zinc sulfate solution was applied to soil before seeding. The Zn concentrations in roots and shoots of plants were analyzed. The results were submitted to ANOVA and regression using the software SAS. Zinc concentrations in maize were increased at 5% of significance by F test by the application of Zn doses in soil and in the foliage. The application in soil was more effective than in the foliage.

Key words: Zn fertilization, Zn deficiency, Maize yield.

INTRODUCTION

Zinc is a micronutrient for the regular and healthy growth and reproduction of plants, animals and humans. Graham et al. (1992) commented that there is a critical level required for zinc in the soil before roots will either grow into it or to function effectively. The metabolic functions of zinc are influenced by on its strong tendency to form tetrahedral complexes with N-, O- and particularly S-ligands and thereby to play both a functional (catalytic) and a structural role in enzyme reactions. Although over 70 metalloenzymes containing zinc have been identified, these only account for a relatively small proportion of the total zinc in a plant (Marschner, 1995).

When the supply of available zinc for plants is inadequate, crop yields are reduced and the quality of crop products is normally damaged. In plants, zinc plays a key role as a structural constituent or regulatory co-factor of a wide range of different enzymes and proteins in many important biochemical pathways. These are mainly concerned with carbohydrate metabolism, both in photosynthesis and in the conversion of sugars to starch, protein metabolism, auxin (growth regulator) metabolism, pollen formation, the maintenance of the integrity of biological membranes, the resistance to infection by certain pathogens (Alloway, 2008). Necrosis and leaf chlorosis are described as symptoms of toxicity of Zn, and frequently show disturbances in mineral nutrition, such as iron deficiency and reduced uptake and transport of water and several elements (Ca, Mg, K and Mn) by plants (Benavides et al., 2005).

Principles for use of micronutrient fertilizer were well developed in the latter part of the last century. By 1990 it was clear that Zn deficiency in humans were already major and still increasing problems, especially in developing countries, but also and enormous health cost

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*Corresponding author email:ana3carol@yahoo.com.br in developed countries (Graham, 2008). The potential impact of zinc deficiency on infant, child, and maternal health in developing countries was not recognized by the United Nations until 1997, when zinc was included among the micronutrient deficiencies listed as a priority in the Third Report on the World Nutrition Situation (ACC/SCN, 1997). Zinc supplementation can reduce morbidity from a number of common childhood infections, especially diarrhea, pneumonia, and possibly malaria. In addition, zinc deficiency is an important cause of stunting (Umeta et al., 2000). Because Zn interacts with such a vast number of proteins, symptoms of Zn deficiency in humans may be many and indiscriminate, and consequently many disease states are not associated with its deficiency when they should be. (Graham, 2008).

Zn fertilizers increase both the yield and quality of several crops, including wheat (Hu et al., 2003; Cakmak, 2008), rice (Liu et al., 2003), and peas (Fawzi et al., 1993). Given most Brazilian soils present low Zn concentrations (Gonçalves Junior et al., 2006; Nascimento et al., 2006), the proper management of Zn fertilization can increase the concentrations of Zn in plants edible parts. This is of paramount importance for adequate levels of this nutrient in the human diet.

Plant roots uptake Zn as Zn^{2+} cation which is component of synthetic and organic complexes (Havlin et al., 2005; Oliveira & Nascimento, 2006). The zinc available to plants is in the soil solution or adsorbed in a labile form. The soil factors affecting the availability of zinc to plants control the amount of zinc in the soil solution and its sorption-desorption from/into the soil solution. These factors include: the total zinc concentration, pH, organic matter concentration, clay concentration, calcium carbonate concentration, redox conditions, microbial activity in the rhizosphere, soil moisture status, concentrations of other trace elements, concentrations of macro-nutrients, especially phosphorus, and climate (Alloway, 2008). Soil pH is the main factor affecting Zn distribution in soil pools, since this element is readily adsorbed in exchange cation sites at above-neutral pH and made available at low pH values (Broadley et al., 2007; Havlin et al., 2005).

Taking in account the Zn role in plant nutrition as well as the importance of supplying Zn to plants in an adequate and cost-effective approach, the work aimed to compare zinc levels in maze plants after two different Zn applications to plants, i.e., via foliar and via soil.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse using a Typic Hapludox soil from Igarassu town, Pernambuco state, Brazil (7°50' S and 34°54' W). The soil sample was characterized (EMBRAPA, 1997) and presented the following characteristics: pH H_2O (1:2.5): 5.6; CEC: 6.95 $cmol_c\ kg^{-1}$; calcium: 2.45 $cmol_c\ kg^{-1}$; magnesium: 2.05 $cmol_c\ kg^{-1}$; sodium: 0.07 $cmol_c\ kg^{-1}$; potassium: 0.12 $cmol_c\ kg^{-1}$; organic carbon: 1.24%; organic matter: 2.09%; nitrogen: 0.12%; phosphorus: 18.1 mg kg^{-1}, zinc: 2.48 mg kg^{-1}, copper: 0,2 mg kg^{-1}, iron: 172.0 mg kg^{-1}, manganese: 4.71 mg kg^{-1}. Soil samples were submitted to fertilization as follow: 300 mg kg^{-1} of P_2O_5; 40 mg kg^{-1} of S; 100 mg kg^{-1} of N; and 150 mg kg^{-1} of K_2O (Novais et al, 1991). Then, ten liter pots were filled with soil and five seeds of maize (*Zea mays*) hybrids Pioneer 30R75 were sown in each pot. After emergence, only one plant was left in each pot for the experiment. Zn was foliarly applied as zinc sulfate at the third and fifth week after seeding whereas zinc sulfate was applied into the soil before sowing. The experimental design consisted of five doses of Zn applied either to soil or leaves, with three replications, totaling 30 experimental units. Zn doses applied to soil were based on the dose recommend by Fageria (2000) of 20.0 mg dm^{-3} as zinc sulfate (23% Zn). Thus, the applied doses were 0; 10; 20; 40; and 80 mg dm^{-3} of Zn. For foliar application, doses were based on Abreu et al. (2007): 10 g L^{-1} of zinc sulfate (23% Zn). Therefore, the doses used were 0; 5; 10; 15 and 20 g L^{-1} of zinc sulfate applied at the third and fifth week after sowing. At the end of the experiment, the height of 100-day old plants was measured. The plants were harvested and separated into roots, stems and leaves, which, after being washed in distilled water and dried in an oven of forced air at 70ºC to constant weight, they were weighed and ground in a mill type Wiley. Subsequently, the nitropercloric digestion of these materials was performed for determination of Cu and Zn in the extracts by atomic absorption spectrophotometry according to EMBRAPA (1999). The results were submitted to ANOVA and regression analyze using the software SAS (SAS Inst., 2002).

RESULTS AND DISCUSSION

Zinc concentration in roots and shoots of maize plants were increased by Zn application both in soil and leaves. Regarding the form of application, Zn concentrations in roots and shoots showed a similar trend. The highest values were obtained by soil application (Figure 1). The highest Zn doses promoted the maximum Zn concentration in plants both for soil (80 mg dm^{-3} of Zn sulfate) and foliar application (20 g L^{-1} of zinc sulfate). The 10 mg dm^{-3} dose applied in soil promoted a 72% increment of Zn concentration in shoots (Figure 1) while an increase of 67% was obtained with dose 5 g L^{-1} by foliar application compared to control. Zn concentration in roots increased 88% by applying 10 mg dm^{-3} of Zn in soil, whereas the doses 20, 40, and 80 mg dm^{-3} promoted increments of 38, 34, and 28%, respectively. When applied in the foliage, the 5 g L^{-1} dose increased by 32%

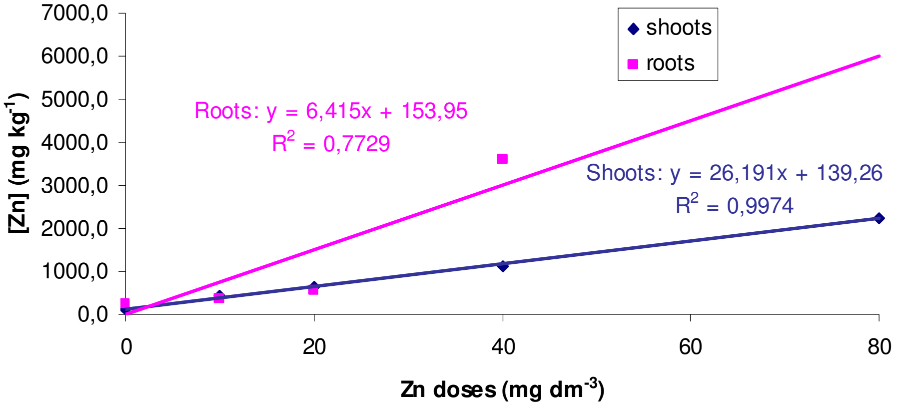

Figure 1: Zinc concentration in shoots and roots of maize plants fertilized with zinc via soil

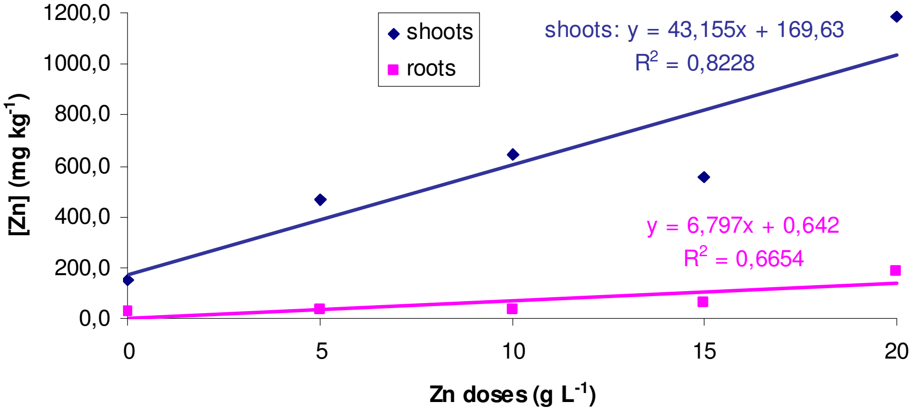

Figure 2 – Zinc concentration in shoots and roots of maize plants fertilized with zinc via foliar

in roots Zn concentration; similarly, the doses 10, 15, and 20 g L^{-1} of Zn promoted increases of 10%, 32% and 66%, respectively. Zn concentration in maize plants ranges from 25 to 150 mg kg^{-1} for shoots, depending on the soil aeration and soil temperature, moisture in the root zone as well as the genetic material (Malavolta, 2006). For the highest Zn dose applied in soil, Zn concentration in shoots was 2,258 mg kg^{-1}. On the other hand, the higher dose applied in leaves reached 1,186 mg kg^{-1} in shoots. The increasing trend of Zn uptake by plants (Figures 1 and 2) indicates that the Zn fertilization via soil as well as via foliar can both be adequate strategies to supply of Zn to maize plants, since it can be observed that the Zn uptake by shoots and roots were increased according to the increment of Zn doses.

The height of plants presented the highest values for the higher doses for Zn applied both in soil and in the foliage (Figures 3a and 3b), but the values were more effective when Zn doses were applied in soil (Figure 3a).

Adequate supply of Zn might also contribute to the enrichment of maize grains, a staple crop responsible for the nutrition of millions of people in the developed countries (Allen et al., 2006). Although some authors state that the efficiency of foliar application is higher than ground fertilization (Malavolta, 2006), the Zn uptake by roots was more effective in this study. A study carried out by Amiri et al (2008) also presented this trend in apple, which foliar application of Zn resulted in decreasing fruit yield and quality. Several chemical (soil pH, redox potential or nutrient interactions), physical (organic matter content, soil texture, or clay content and type) and biological factors (mycorrhizae formation, phytosiderophore release) operating at the root–soil interface may affect availability and absorption of zinc and subsequently, zinc efficiency (Hacisalihoglu and Kochian, 2003).

CONCLUSIONS

Both the foliar and soil fertilization were efficient for increasing Zn concentration in maize plants and also

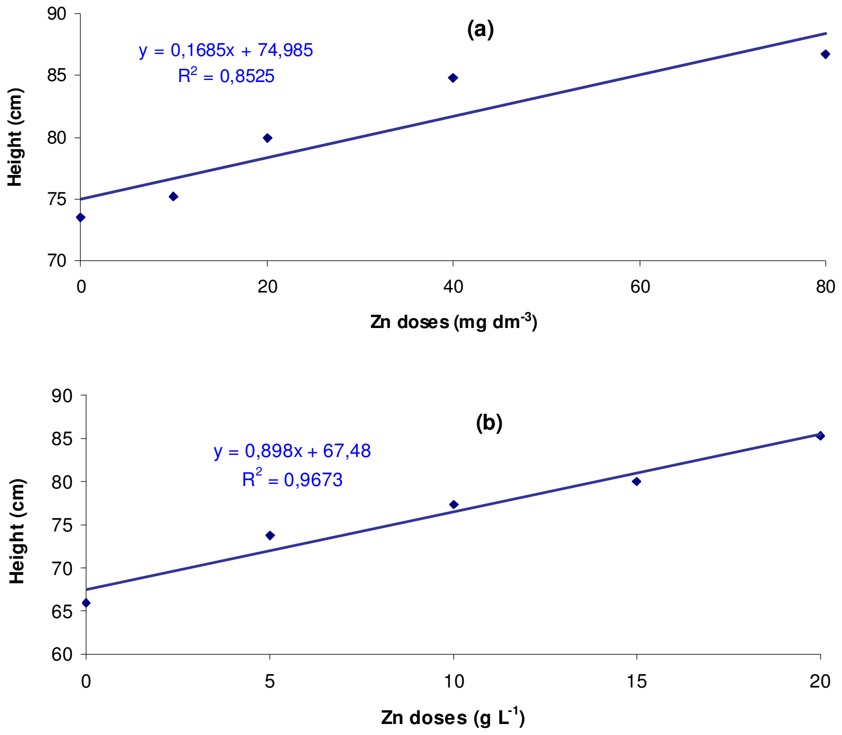

Figure 3 – Height of maize plants fertilized with zinc via soil (a) and via foliar (b).

contributed for their growth.

The highest values of Zn concentration in plants were observed when Zn was applied via soil.

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