Acta Scientific NUTRITIONAL HEALTH (ISSN:2582-1423)
Volume 5 Issue 8 August 2021
Research Article

Zinc Oxide Nanoparticle in Foliar Nutrition of Maize Crop in Southern Amazonia

Willian Tsuyoshi Kume*, Felipe Adolfo Litter, Márcia de Almeida Carneiro, Luana Marques Campos, Marco Antonio Camillo de Carvalho and Gustavo Caione

Agronomy, Mato Grosso State University, Alta Floresta, Mato Grosso, Brazil

***Corresponding Author:** Willian Tsuyoshi Kume, Mato Grosso State University, Alta Floresta, Mato Grosso, Brazil.

Received: June 18, 2021
Published: July 09, 2021

Abstract

Adequate nutrition management of maize crop is essential when aiming at high yields and grain quality. In this context, Zn fertilization stands out since its content increase in grains used for human consumption is an alternative to alleviate malnutrition. Therefore, the aim of the present study was to evaluate foliar fertilization as a supplement, with alternative Zn doses and sources in the maize crop in southern Amazonia. The field experiment was conducted in Alta Floresta, Mato Grosso State, in dystrophic red yellow Oxisol. A randomized block design in a 4x2 factorial scheme was used, with four doses (0, 250, 500 and 1000 g ha^{-1}) and two sources ($ZnSO_4$ and ZnO 40 nm) with foliar application during R1 stage. At the end of the experiment, the cob diameter, mass of 100 grains, number of grain rows per cob, Zn content in grains and productivity were evaluated. Foliar application of doses and sources of Zn did not promote significant difference between treatments. This was possibly due to the low mobility of the micronutrient in the plant. Thus, it is suggested to apply higher doses, or more than one foliar application along the maize crop cycle.

Keywords: Foliar Fertilization; Biofortification; Nanotechnology; Malnutrition; Zn Sources

Introduction

Zinc (Zn) metabolic deficiency in humans is considered a worldwide health problem and it is estimated that about 17% of the world population share this condition. This fact is further aggravated in developing countries. For example, in South Asian regions this index can reach 30%. This micronutrient deficiency occurs predominantly in children and pregnant women and is associated with the death of 800,000 people a year [1]. One of the main factors associated with this deficiency is the intake of low Zn content food.

Despite consensus that adequate feeding through food diversification and supplementation is the key to alleviate this situation, these practices are limited in developing countries where the diet is poor and based in only one grain [2]. Additionally, it is known that about 30% of the soils available for agriculture in the world have inadequate levels of Zn, which ends up reflecting on the micronutrient content in the grains, and consequently in the population's health [3,4]. Thus, the production of biofortified grains, that is, grains with higher levels of micronutrients, using agricultural practices, is the object of many studies [5]. In this context, the maize crop stands out, since it is the most widely grown crop in the world used as raw material for making several food products, animal food, oil and ethanol [6].

The application of Zn in the crop can be carried out both via soil or leaves. However, when the focus is on biofortication, foliar fertilization has shown promising results. Although foliar application is considered a complement to soil application, due to low mobility of this micronutrient in the plant, a supplementary fertilization of this micronutrient on the leaves is associated with an increase in Zn content in the grains [7-10].

Regarding Zn sources, Zn sulfate ($ZnSO_4$) is a totally soluble source and the most widely used. However, due to its solubility it could cause some phytotoxic effects, since all Zn^{2+} is released at the application time [11,12]. Thus, alternative sources such as nanoparticulated Zn oxide have been studied [13-16]. Compared with traditional sources, Zn nanofertilizers make the micronutrient available to plants for a longer period of time by promoting its gradual release, which is beneficial for better nutrient uptake [17]. Nevertheless, field experiments are still scarce and there is no standard in the literature on variables such as dose, time of application and size of nanoparticles when this type of source is used.

Hence, studies on Zn nanometric sources and doses in the foliar fertilization of the maize crop are essential for the production of biofortified grains. Therefore, the aim of the present study was to evaluate foliar fertilization as a complement, with alternative doses and sources of Zn in the maize crop in southern Amazonia.

Materials and Methods

Experimental site

The experiment was conducted at the State University of Mato Grosso (UNEMAT), Campus 2, Alta Floresta, Mato Grosso State, Brazil, at the coordinates 9 ° 51'40.02 S and 56 ° 4'11.18 W, 224 meters altitude, during October 2019 to March 2020. Soil was classified as a Dystrophic Red Yellow Oxisol [18] and local monthly rainfall during the experiment varied around 300 mm (Figure 1). Soil sampling was carried out at a 0-20 cm depth for the purpose of assessing soil fertility. Results of these analysis are shown in table 1 [19].

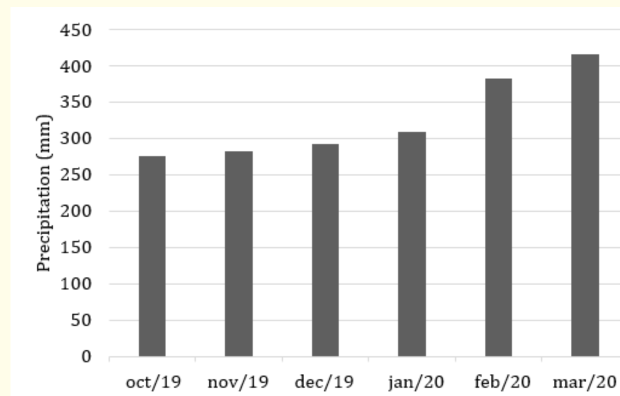

Figure 1: Monthly rainfall according to BDMEP - INMET from October 2019 to March 2020.

pH		$P_{mehlich}$ (1)	K(1)	K(1)	Ca(2)	Mg(2)	Al(2)	H+Al(3)	Zn(2)
H_2O	$CaCl_2$	----mg dm^{-3}----		------------------cmol$_c$ dm^{-3}---------------------					-mg dm^{-3}-
5.6	5.0	1.6	55	0.14	2.40	0.39	0	1.94	0.3
------------------------ Calculated results ------------------------							----------- Physical properties -----------		
T	SB	V	m	K	Ca	Mg	Sand	Silt	Clay
-cmol$_c$ dm^{-3}-		----------------------- % -----------------------					-------------------- g kg^{-1} --------------------		
4.9	2.9	60.1	0	2.9	49	8	614	77	309

Table 1: Soil chemical and physical properties in the experimental area. UNEMAT - Alta Floresta, 2020.

T: Cation exchange capacity at pH 7; SB: sum of bases; V: base saturation; m: saturation by Al; % K, Ca, Mg: saturation per element.

(1) Mehlich 1; (2) KCl 1 mol L^{-1}; (3) Calcium acetate 0.5 mol L^{-1}.

The Hybrid Corn 22S18 Top2 from "Sempre Sementes" was sown manually on October 26th, 2019, aiming at 60,000 plants ha^{-1} and harvested on March 9th, 2020.

Along with planting fertilization was carried out within the sowing line. 100 kg ha^{-1} of P_2O_5 (20 kg ha^{-1} of split corrective fertilization + 80 kg ha^{-1} of sowing fertilization) and 60 kg ha^{-1} of K_2O were applied, using MAP ((NH_4) H_2PO_4) and KCl as sources, respectively, taking into account an expected maize grain yield of 8 t ha^{-1}. In V7 stage, top dressing was applied with 70 kg ha^{-1} of N and 30kg ha^{-1} of K_2O, with urea and KCl as sources, respectively [19].

Before planting, atrazine was applied at a dose of 5 L ha^{-1} with a volume of 300 L ha^{-1} and preventive controls against pest attack in the crop were carried out using Engeo Pleno® (thiamethoxam + lambda-cyhalothrin) in V6 stage at a dose of 250 mL ha^{-1} with a volume of 200 L ha^{-1}.

Experimental design and procedures

The experimental design used was in randomized blocks with four replications in a 4 x 2 factorial arrangement. The treatments were composed by the combination of four doses of Zn applied via leaf (0, 250, 500 and 1000 g ha^{-1} of Zn) [20] and two sources: zinc sulfate ($ZnSO_4$) and zinc oxide (ZnO 40 nm). Each plot had a total area of 11.25 m^2 consisting of five maize lines of 5 m length spaced 0.45 m. The three central lines were considered as the useful area of each plot, excluding 1 m at each side for evaluation purposes.

Leaf applications of Zn were carried out at the R1 stage in the morning. It was done using a constant pressure knapsack sprayer at a volume of 2 L $plot^{-1}$. Plastic canvas surrounding the plots were used to reduce the contamination of neighboring plots due to the drift effect.

Traits measured

Ten cobs were harvested per plot, then they were threshed and the grains weighed and stored in identified paper bags, correcting humidity to 130 g kg^{-1} to calculate productivity [21]. The productive characteristics evaluated were number of rows per cob and cob diameter, which were evaluated in 10 cobs per plot. The mass of 100 grains was determined in a sample of grains per plot. The grains were ground in a Willey mill, digested (HNO_3, $HClO_4$) and the Zn content determined by inductively coupled plasma optical emission spectrometry (ICP-OES).

Statistical analysis

Data obtained were subjected to analysis of variance and F test. Source averages were compared using the Tukey test at 5% probability, while those of doses using a polynomial regression study and both with the aid of Sisvar statistical software [22].

Results and Discussion

Foliar fertilization with Zn did not have a significant effect on the production components, Zn content in grains or grain productivity of the maize crop (Table 2), which was not expected.

Zn doses (g ha^{-1})	Cob diameter (mm)	Mass of 100 grains (g)	Number of rows per cob	Zn content in grains (mg kg^{-1})	Productivity (kg ha^{-1})
0	46.99	40.43	17.66	71.32	9666.23
250	47.16	40.10	17,41	69.89	8957.06
500	46.82	39.78	17.69	69.51	9812.61
1000	47.17	40.57	17.60	74.94	9698.28
Zn Source					
$ZnSO_4$	46.63	39.80	17.42	70,75	9390.13
ZnO	47.44	40.64	17.77	72.08	9676.96
F Test					
Dose	0.110^{ns}	0.278^{ns}	0.363^{ns}	1.544^{ns}	1.518^{ns}
Source	2.731^{ns}	1.578^{ns}	2.897^{ns}	0.447^{ns}	0.824^{ns}
Dose x Source	3.037^{ns}	0.315^{ns}	1.148^{ns}	1.479^{ns}	2.325^{ns}
CV (%)	2.97	4.71	3.31	7.89	9.38

Table 2: Productivity, cob diameter, mass of 100 grains, number of rows per cob and Zn content in the grains related to the application of Zn sources and doses in the maize crop. Alta Floresta - MT, 2020.

^{ns}: not significant by the F test.

A hypothesis to explain this lack of treatments effect on the production components was the time of application of the micronutrient in the R1 stage, with the objective of obtaining biofortified grains with Zn. During V4 and V6 stages the number of cobs and grains is defined, confirming the production potential [23]. Thus, it is at this time that productivity is established. However, due to the low mobility of Zn in the phloem, it was decided to apply it at the beginning of the reproductive stage, since the effects of foliar application occur on the organs that received the application [24]. In order to have good results in fertilization it is important to justify, know and define the factors (time of application, source, dose, number of applications, climatic conditions, among others) that must be controlled in the practice of foliar nutrition for each element.

In addition, positive responses to fertilization with Zn, mainly foliar, occur in conditions where the soil has low levels of this micronutrient [25,26]. Although Zn content of the experimental area is classified as low, according to the Cerrado manual, during the experiment there was no evidence of Zn deficiency. Additionally, the productivity of all treatments was similar and higher than the Brazilian average, which is 4.9 t ha^{-1} [27], suggesting sufficiency of the micronutrient in the plant.

It is worth mentioning that even though the Zn content found in the soil before planting is low, according to the interpretation manual used [19], it may have been sufficient for the hybrid seeds used. Even during development of the crop, it can have nutrients input, such as Zn, through other fertilization practices (nitrogen, potassium and phosphate), which even in small amounts, it can contain Zn in their composition, as well as through mineralization of organic matter, since the area had considerable plant biomass on the surface. It should also be noted that the Cerrado manual is not suitable for the Amazon region and inconsistencies regarding the classification of P contents have already been reported [28-30], being the classification of Zn content possibly not ideal for the region.

Foliar application, although necessary in particular situations, is used as a complement to traditional fertilization and is recommended when the soil content is low. Thus, when the crop is properly nourished, the practice has a low probability of responding to fertilization with the nutrient [31].

Regarding Zn content, the absence of statistical difference may be linked to the low mobility of the nutrient in the phloem sap and the low capacity of foliar penetration, from 2 to 5% [24], limiting its arrival to the grains. However, the value found is in agreement with the literature, which ranges between 33.8 to 70 mg kg^{-1} in the grains [32], demonstrating that the plant Zn content was adequate even when it was not applied, obtaining average levels above the upper limit described above. Nevertheless, field studies using nanometric Zn sources report an increase of Zn content in maize grains when the application was split throughout the phenological stages of the crop, even with adequate soil levels.

For example, when the application was carried out in the silk (R1) and blister (R2) stages it was possible to verify at the end of the experiment a 37% increase in Zn content in the grains with a nanometric source compared to the control and 29% in relation to the $ZnSO_4$ source [33]. In addition, the application in V7 and V8 stages promoted an increase of 70% in Zn content in the grains when the nanometric source was compared to the control [34].

It was also found that the foliar application of a mixture of micronutrients containing Zn (4.7%), Fe (2%), Cu (0.3%), B (1%) and Mn (2%) in the wheat crop (*Triticum aestivum*) promoted an increase in micronutrient content. The treatments differed at the time and number of applications, namely: T1 - water; T2 - application during tillering; T3 - application during tillering and stem elongation; and T4 - application during tillering, elongation of the stem and cobs. It was found that T4 had higher levels of Zn, Cu, Mn, Fe and B in 21, 47, 22, 22 and 25%, respectively, in wheat flour compared to T1. These results reinforce the importance of knowing and defining all the factors that interfere in the efficiency of foliar fertilization for each element, because according to the results found here and others available in the literature, these have shown to be decisive.

Conclusion

The supplementary foliar application of Zn doses and sources in the field did not promote significant difference between doses, source or the combination of factors when applied in the R1 stage. Due to the low mobility of this micronutrient in the plant, it is suggested that the application of higher doses, or more than one foliar application during the crop cycle, is necessary to increase the Zn content in the grains.

Bibliography

1. Nriagu J. “Zinc Deficiency in Human Health”. In Encyclopedia of Environmental Health, edited by Jerome Nriagu, Elsevier (2011): 789-800.
2. Khush GS., *et al*. “Biofortification of crops for reducing malnutrition”. *Plant Biotechnology Reports* 6.3 (2012): 195-202.
3. Sillanpaa M. “Micronutrients and the nutrient status of soils: a global study”. FAO Soils Bulletin. ed. 48. Jokloinen: Werner Söderström Osakeyhtiö (1982).
4. Sillanpaa M. “Micronutrient assessment at country level: An international study”. Soils Bulletin. ed. 63, FAO, Jokloinen: Werner Söderström Osakeyhtiö (1990).
5. Gómez-Galera S., *et al*. “Critical evaluation of strategies for mineral fortification of staple food crops”. *Transgenic Research* 19.2 (2010): 165-180.

6. Rouf S., *et al*. “Maize - A potential source of human nutrition and health: A review”. *Cogent Food and Agriculture* 2.1 (2016): 1-9.

7. Aziz M., *et al*. “Foliar application of micronutrients enhances crop stand, yield and the biofortification essential for human health of different wheat cultivars”. *Journal of Integrative Agriculture* 18.6 (2019): 1369-1378.

8. Pandey N., *et al*. “Foliar application of Zn at flowering stage improves plant's performance, yield and yield attributes of black gram”. *Indian Journal of Experimental Biology* 51.7 (2013): 548-55.

9. Cakmak I., *et al*. “Agronomic biofortification of cereals with zinc: a review”. *European Journal of Soil Science* 69.1 (2017): 172-180.

10. Sadeghzadeh B. “A review of zinc nutrition and plant breeding. Journal of soil science and plant nutrition”. *Maragheh* 13.4 (2013): 1-17.

11. Prado RM., *et al* “Sources of zinc applied via seed in the nutrition and initial growth of corn cv. Fort”. *Bioscience Journal* 2 (2007): 16-24.

12. Santos F., *et al*. “"Relation of Toxicity in Corn Seeds Treated with Zinc and Salicylic Acid"”. *Communications in Soil Science and Plant Analysis* 48.10 (2017): 1123-1131.

13. Power KW., *et al*. “Research Strategies for Safety Evaluation of Nanomaterials. Part VI. Characterization of Nanoscale Particles for Toxicological Evaluation”. *Toxicological Sciences* 90.2 (2006): 296-303.

14. Delfani M., *et al* “Some Physiological Responses of Black-Eyed Pea to Iron and Magnesium Nanofertilizers”. *Communications in Soil Science and Plant Analysis* 45.4 (2014): 530-540.

15. Du W., *et al*. “Comparison study of zinc nanoparticles and zinc sulphate on wheat growth: From toxicity and zinc biofortification”. *Chemosphere* 227 (2019): 109-116.

16. Yan L., *et al*. “Physiological and metabolic responses of maize (Zea mays) plants to Fe 3 O 4 nanoparticles”. *Science of The Total Environment* 718 (2020): 1-36.

17. Liu R., *et al*. “"Potentials of engineered nanoparticles as fertilizers for increasing agronomic productions"”. *Science of The Total Environment* 514.1 (2015): 131-139.

18. Santos., *et al*. “Sistema brasileiro de classificação de solos”. EMBRAPA, 3rd ed. (2013).

19. Sousa., *et al*. “"Cerrado: Soil correction and fertilization"”. Embrapa technological information, 2nd ed (2004).

20. GALRÃO EZ. “Methods of applying zinc and assessing its availability for corn in a dark-red, clayey Oxisol, cerrado”. *Brazilian Journal of Soil Science* 20 (1996): 283-289.

21. Mari GF., *et al*. “Residual Effect of Zinc Application Doses and Methods on Nutrition and Productivity of Corn”. *American Journal of Plant Sciences* 6 (2015): 298-305.

22. Ferreira DF “Sisvar: a computer system for statistical analysis”. *Ciência e Agrotecnologia [Science and Agrotechnology]* 6 (2011): 1039-1042.

23. Fancelli A., *et al*. “Corn Phenology”. *Potafos - Agronomic Information* 78 (1997): 1-6.

24. Rios J., *et al*. “"The use of biovesciles to improve the efficiency of Zn foliar fertilization"”. *Journal of Colloids and Interface Sciences* 173.1 (2019): 899-905.

25. Rosolem C., *et al*. “Zinc translocation and root growth in corn”. *Brazilian Journal of Soil Science* 24.4 (2000): 807-814.

26. Drissi S., *et al* “Response of corn silage (Zea mays L.) to zinc fertilization on a sandy soil under field and outdoor container conditions”. *Journal of the Saudi Society of Agricultural Sciences* 16.2 (2015): 145-153.

27. Contini E., *et al*. “Corn - Characterization and Technological Challenges”. *Brazilian Agribusiness Challenges Series – Embrapa - cnptia* 1 (2019): 1-45.

28. Pereira HS. “Phosphorus availability classes in soils from the north of Mato Grosso cultivated with piatã grass”. State University of Mato Grosso, Master in Biodiversity and Amazonian agroecosystems (2017).

29. Lourini SH “Phosphorus availability classes in soils from the north of the state of Mato Grosso cultivated with Mombasa grass”. State University of Mato Grosso, Master in Biodiversity and Amazonian agroecosystems (2017).

30. Maria LS. “"Interpretation of phosphorus availability in soils cultivated with Panicum maximum CV BRSZURI and Urochloa decumbens in southern Amazonia"”. State University of Mato Grosso, Master in Biodiversity and Amazonian agroecosystems (2018).

31. Fernández V., *et al*. “From plant surface to plant metabolism: the uncertain fate of foliar-applied nutrients”. *Frontiers in Plant Science* 4.298 (2013): 1-5.

32. Hinesly T., *et al*. "Zinc and Cd accumulation by corn in breeds grown on sludge amended soil". *Agronomy Journal* 70.3 (1978): 425-428.

33. Subbaiah L., *et al* "Novel Effects of Nanoparticulate Delivery of Zinc on Growth, Productivity, and Zinc Biofortification in Maize (Zea mays L.)". *Journal of Agricultural and Food Chemistry* 64.19 (2016): 3778-3788.

34. Tiwari PK. "Effect of zinc oxide nanoparticles on germination, growth and yield of maize (Zea mays L.)". Anad Agricultural University, PhD in Soil Science and Agricultural Chemistry (2017).

Volume 5 Issue 8 August 2021