Australian Journal of
Crop Science
AJCS

AJCS 12(02):217-220 (2018) ISSN:1835-2707
doi: 10.21475/ajcs.18.12.02.pne656

AUSTRALIAN JOURNAL OF CROP SCIENCE | SUBMITTED: 02-APR-2017 | REVISED: 17-OCT-2017 | ACCEPTED: 17-OCT-2017

Efficiency of zinc sulfate ($ZnSO_4$) absorption, transport and use in Zn-coated seed of wheat (*Triticum aestivum*).

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Abstract

This study was conducted in a laboratory with the aim of evaluating zinc absorption, transport, and use efficiencies in wheat from seeds coated with zinc sulfate. Two batches of wheat seeds (BRS 276) were used, one with high vigor and the other low vigor. The treatments consisted of using the commercial product in the form of zinc sulfate ($ZnSO_4$). The seeds were coated with levels of 0, 1, 2, 3, and 4 $ZnSO_4$ per kg of seeds. We also added 3 mL of fungicide (carboxin + thiram), 0.8 mL of polymer and enough water to make up 15 mL of syrup for 1 kg of seeds. The experimental design was entirely randomized with four repetitions. After the treatment, the following indices were calculated based on the plants dry material and nutrient content: Absorption Efficiency, Transport Efficiency, and Use Efficiency. The data showed a positive interaction between seed treatments and polymers, in which seed coatings had a good appearance, coloring, distribution, and product adherence to their surface. The results showed that applying the higher doses of the $ZnSO_4$ nutrient to seeds cause greater Zn absorption efficiency, lower Zn transport and use efficiencies.

Keywords: micronutrient; physiological quality; seed treatment.
Abbreviations: Zn_ Zinc; ZnSO4_Zinc Sulfate; HClO4_ perchloric acid; EDTA_Ethylenediamine tetraacetic acid; IAA_andolacetic acid; HNO3_nitric acid.

Introduction

Various macronutrients play important roles in determining plant growth, harvest, product quality and crop resistance to stress and producers frequently find specific nutritional deficiencies involving only one nutrient, such as Zn in wheat crops. Zinc (Zn) is essential for the homeostasis of a plant's nutritional state and for some physiological processes. It is also an activator and structural component of enzymes (Orioli Júnior et al., 2008) and is crucial for preserving the structure of macromolecules in cellular membranes to maintain their integrity and ion transportation through the membranes functioning (Hafeez et al., 2013). One way of providing plants with nutrients is treating the seeds with macro or micronutrient based products. The principle behind this type of treatment is the translocation of the applied elements from the seeds to future plants (Oliveira et al., 2010), having the advantage of uniform distribution and the application of small doses. The absorption of Zn applied to seeds occurs almost integrally, increasing reserves of this element, since it is translocated from the seed to the plant during and after germination. It has been observed that, 30 days after emergence seed Zn-treatments can account for 55.5% of Zn in soy, 64% in bean, and 69% in wheat (Muraoka, 1981). The corn seeds treated with sources of $ZnSO_4$ and Zn-Biocrop (2.5 g Zn kg^{-1} of seed doses), zinc content was increased around 18 times (from 47 to 900 and 850 µg g^{-1}, respectively), maintaining germination and high vigor (Ribeiro & Menezes, 1996). These values were not toxic and meant greater Zn availability for initial plant growth. It is obvious that treating seeds with this element increases germination and plant growth. The good enzymatic activity and function of cellular membranes are crucial for germination because they interfere with the synthesis and degradation of compounds during reserve mobilization, as well as in cellular expansion, division, and growth, which occurs during germination (Nonogaki et al., 2010). Efficiency of treating seeds with Zn depends on the translocation of Zn from seed to plant. Thus, reserves of this micronutrient in seeds are important sources for plant nutrition (Tunes et al., 2012). Some authors consider Zn immobile; while others believed on intermediate mobility of this element to plants, when there is a high supply of Zn. Many vegetable species translocate appreciable quantities of this element from old leaves to growth organs (Overvoorde et al., 2010). However, when the same species are under deficient conditions, they present low mobility of this nutrient from old leaves, where Zn commonly accumulates. Wheat is one the most widely cultivated winter crops in the South of Brazil and is one of those responsible for Brazilian economic performance. However, the productivity of this crop fluctuates annually and from region to region, due to various factors such as nutritional deficiency, disease, pests, and soil fertility. Previous results have indicated benefits of treating seeds, in terms of germination and physiological potential, for various species such as rice (Funguetto et al., 2010), sorghum (Santos et al., 2008), and castor bean (Oliveira et al., 2010.

Despite the technique of applying Zn via seeds being promising, there are few studies involving wheat, especially in relation to crop nutrition. Therefore, this paper aimed to evaluate Zn absorption, transport, and use efficiencies in wheat after coating the seeds with zinc sulfate.

Results and Discussion

Seed coating

The evaluation of coating quality was carried out using a visual scale that varies from 0 (naked seed) to 10 (excellent coating), verifying coating uniformity and seed appearance in around 50 seeds per experimental unit. The coated wheat seeds were classified as nine for a pale pink coloring (high vigor) and eight for a strong pink coating (low vigor) and thus presenting good polymer adherence.

The data analysis showed a positive interaction between seed treatments and polymers, in which seed coatings had a good appearance, coloring, distribution, and product adherence to their surface.

Efficiency of absorption

For efficiency of absorption (Fig. 1), the zinc sulfate source reached a maximum efficiency of 79% at $ZnSO_4$ doses of 0.004 mol. At zero doses, efficiency was lower than all the other studied doses (Fig. 1a). This effect may be associated with Zn activating enzymes such as dehydrogenases, aldolases, enolases and isomerases, intensifying respiration, and consequently, ATP production for the processes that require energy such as germination (Taiz and Zeiger, 2013). Studies conducted by Ohse et al. (2012) regarding the germination of watermelon seeds treated with 0.95 g of Zn kg^{-1} of seeds verified an increase, when they used zinc sulfate as a source of this nutrient.

With regard to the low vigor batch (Fig. 1b), the efficiency of absorption was also greater using 4 mL of $ZnSO_4$ doses, with a maximum efficiency of 60%. Similar results were observed by Zn treating of canola seeds, in which significant differences in germination between the different Zn doses applied (Pletsch et al., 2014).

Efficiency of transport

The Zn transport efficiency is represented in Fig. 2. Thus, $ZnSO_4$ doses applied to wheat seeds caused a quadratic decrease in Zn transport efficiency for both high and low vigor batches. It is also observed that, in the absence of Zn (control sample), efficiency was greater than all others doses studied (Fig. 2a, b). The low concentration in the substrate can be explained by this fact that, all of the Zn contained in the seed was transported to the aerial part to play its physiological role in plant nutrition. The quantity of zinc was 45.63 and 43.56 mg kg^{-1} in high and low vigor seeds, respectively. Thus, they can be adapted to meet nutritional needs in the plantlets initial growth phase.

Funguetto et al. (2010) observed that Zn transport efficiency is an important factor, explaining 53% of production of different rice cultivars. These results are related to the participation of Zn in synthesizing Indole acetic acid (IAA), the main growth regulator from the class of auxins involved in vegetal growth (Taiz and Zeiger, 2013).

Efficiency doses of Zn

A marked decrease was observed in Zn use efficiency with increasing $ZnSO_4$ doses for the two wheat seed batches (Fig. 3). The lower efficiencies obtained in the high and low vigor batches were 2.68 and 2.92 g of dry material per mg of accumulated Zn, respectively, when the highest Zn dose applied. Thus, the seeds from the low vigor batch (Fig. 3b) would be more efficient in Zn use. According to Funguetto et al. (2010), it is assumed that the increase in dry matter resulting from the Zn treatment are linked to the involvement of this nutrient in various metabolic processes promoting plant growth; thus, causing an increase in the photosynthetically active area.

We observed that applying $ZnSO_4$ to seeds results in greater Zn absorption efficiency and lower Zn transport and use efficiencies, as doses of the nutrient are increased.

Materials and methods

Plant materials and laboratoty

The trials were carried out at the Didactic Laboratory for Seed Analyses, belonging to the Phytotechnology Department of the Post Graduate Program in Seed Science and Technology at the Federal University of Pelotas (UFPel). Two batches of wheat seeds were used, one with high vigor (86%) and the other low vigor (73%), cv. BRS 276 obtained from Brazilian Agricultural Research Corporation (EMBRAPA).

Treatments and doses

The commercial product Quimifol Seed 78 was used, with a Zn source in the form of zinc sulfate ($ZnSO_4$), in which each 100 mL of this solution provides 78 g of zinc (757.50 g l^{-1}). The 0, 1, 2, 3, and 4 mL of $ZnSO_4$ kg^{-1} of seeds were tested. We also added 3 mL of fungicide (carboxin + thiram), 0.8 ml of Poly Seed CF® polymer (high vigor batch) or Collor Seed polymer (low vigor batch), and enough water to make up 15 ml of syrup for 1 kg of seeds. The seeds were coated manually, using 0.3 kg of seeds per experimental unit, with the product mixture in plastic bags and the seeds added afterwards. The seeds were stirred up until the product was distributed and the seeds covered completely. Then the seeds were left to dry at room temperature for 24 hours. The effects of the $ZnSO_4$ doses on nutritional efficiency was evaluated in 8 sub-samples of 12 seeds for each treatment, sown at a depth of 2 cm in plastic cups containing soil and maintained at a temperature of 20 ºC in a controlled environment.

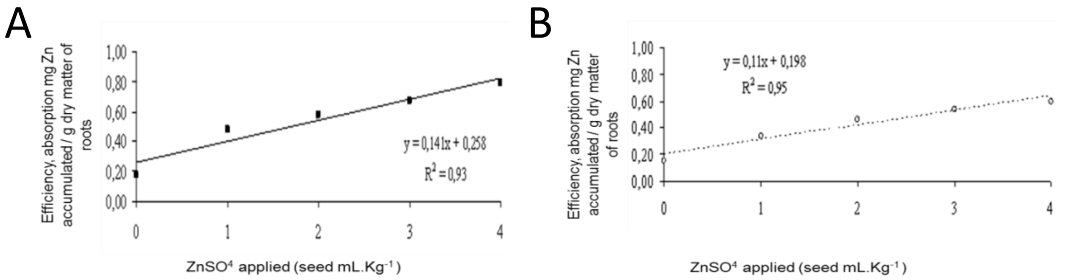

Fig 1. Effect of different $ZnSO_4$ doses in high and low vigor wheat seeds on Zn absorption efficiency. *UFPel*, Pelotas, RS, 2015. *Coating: $ZnSO_4$ + fungicide + polymer + water. A) high vigor batch; B) low vigor batch

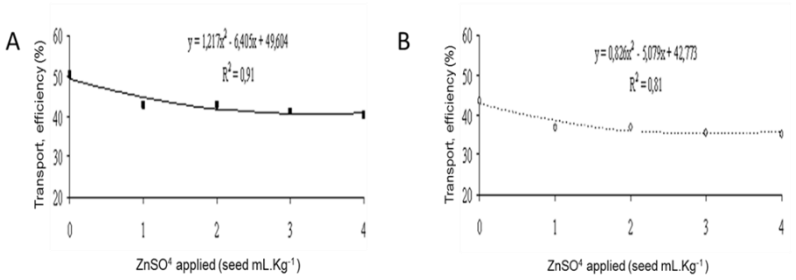

Fig 2. Effect of different $ZnSO_4$ doses in high and low vigor wheat seeds, after six months of storage, on Zn transport efficiency. *UFPel*, Pelotas, RS, 2015. *Coating: $ZnSO_4$ + fungicide + polymer + water. A) high vigor batch; B) low vigor batch

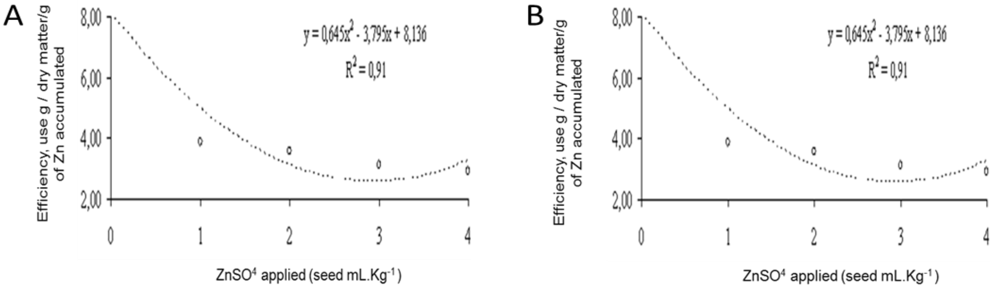

Fig3. Effect of different $ZnSO_4$ doses in high and low vigor wheat seeds, after six months of storage, on Zn use efficiency. *UFPel*, Pelotas, RS, 2015. *Coating: $ZnSO_4$ + fungicide + polymer + water. A) high vigor batch; B) low vigor batch

They were watered whenever needed. The plantlets were removed from the plastic cups 20 days after sowing, when the aerial parts presented an average length of 10-15 cm. They were washed in running water and dipped in EDTA 10 g l^{-1} solution for 15 minutes in order to remove the ions on the plantlets surface, and then washed again in running water for 2 minutes. The plantlets were cut and the aerial parts separated from the root system. Then the material placed in paper bags and kept in a forced convection oven, at 65 ºC for 96 hours (Nakagawa, 1994).

Conduction of experiment

The samples were solubilized via nitric perchloric digestion. A 0.2 g of ground dry material weighed and transferred into tubes. 5 ml of nitric acid (HNO_3) were added to each tube. After resting for 1 hour, the tubes were heated (100 ºC) for 4 hrs and 30 min in a digester. Then 2 mL of perchloric acid ($HClO_4$) was added for 6 to 8 hrs, followed by digestion until the dissipation of values emanating from the tubes. Subsequently, 10 ml of distilled water was added to the mineralized sample. This was followed by mineral determination, using the methodology adapted from Bataglia et al. (1983). After digestion, the zinc was calculated using the extract obtained via atomic absorption spectrometry (Malavolta et al., 1997).

Traits measured

The following ratios were calculated based on the plant dry material and nutrient content:
(a) Efficiency of Absorption = (total plant nutrient content) / (root dry material), in accordance with Swiader et al. (1994);

(b) Efficiency of Transport = (nutrient content in the aerial part) / (total plant nutrient content) x 100, in accordance with Li et al. (1991); and
(c) Efficiency of Use = (total dry material produced)^2/(total plant nutrient content) in accordance with Siddiqi and Glass (1981).

Statistical analysis

For each batch of seeds, a trial was carried out using an entirely randomized design with four repetitions, in which the treatments were composed of the five doses of $ZnSO_4$. After variance analysis, regression analysis was carried out.

Conclusion

Applying $ZnSO_4$ to seeds resulted in greater Zn absorption efficiency. When doses of Zn were increased it caused a quadratic response. Applying Zn via seed treatment is viable for supplying plantlet needs during their development and seed production.

Acknowledgements

The authors thank the Higher Education Personnel Improvement Coordination (CAPES) for project financing and the granting of the first author's doctoral fellowship.

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