Zinc nano-chelate foliar and soil application on maize (*Zea mays* L.) physiological response at different growth stages

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Abstract

In order to investigate the effect of zinc nano-chelate foliar and soil application on physiological characteristics of maize (*Zea mays* L.), an experiment was conducted in the factorial form based on Completely Randomized Block Design with three replications during growing seasons of 2013-2014. Treatments were nano-chelate zinc application in four levels: a\(_1\): soil application, a\(_2\): foliar application, a\(_3\): soil application + foliar application, a\(_4\): control and different growth stage in three levels contain b\(_1\): 8-10-leaves stage, b\(_2\): taselling and b\(_3\): SA grain filling stage. The analysis of variance showed significant effect of nano-chelate Zn application on grain filling rate, grain filling duration, seed yield (p<0.05) and ear yield (p<0.01). The detailed results of the study showed that soil application of nano-chelate Zn had 37% and 12% more grain filling rate and duration. Moreover, foliar application of nano-chelate Zn had 24%, 64% and 68% more dry matter weight, ear yield and seed yield per m\(^2\), respectively.

Keywords: Foliar application, nano-chelate zinc, maize, soil application and *Zea mays* L.

Introduction

Maize (*Zea mays* L.) is an important crop worldwide. Zinc (Zn) is an essential micronutrient that plays many important roles in various physiological and metabolic processes in plants. Agricultural systems are the main pathway from which nutrients, including Zn enter the human food chain. Therefore, Zn malnutrition must be directly dependant on the inability of cropping systems to deliver enough Zn to the food crops (Welch, 2008). Nanotechnology as a new powerful technology has the ability to create a great revolution and transformation in the food supply system in a global scope (Andreta, 2003 and Sharma *et al.*, 2005). Nanomaterials are classified as materials with at least one dimension less than 100 nm (Wiesner *et al.*, 2006). Thus, nanomaterials between ions and macroscopic materials (Banifield and Zhang, 2001), and mat contain 20-15000 atoms (Liu, 2006). Nonmaterial could to be applied in designing more soluble and diffusible sources of Zn fertilizer for increased plant productivity. The smaller size, higher specific surface area and reactivity of nanoparticulate Zn may affect Zn solubility, diffusion and hence availability to plants. The effect of zinc fertilization was conducted on growth and yield of many plants such as wheat, maize, barley and cotton were investigated in numerous researches and observed increasing in yield with zinc application (Galavi *et al.*, 2011; Xi-Wen *et al.*, 2011; Efe and Yarpuz, 2011). Deficiencies of zinc occur in many parts of the world on a wide range of soil types but semi-arid areas with calcareous soils, tropical regions with highly weathered soils and sandy-textured soils in several different climatic zones tend to be the most seriously affected (Alloway,
This reduces the ability of nutrient uptake by plants and naturally plants requirement increases to these elements (Alloway, 2008). The aim of this study was to investigate the effects of zinc nano-chelate foliar and soil application on the physiological characteristics of maize at different growth stages.

Materials and Methods

The field experiment was carried out in factorial form by completely randomized block design with three replicates at the Research Station of the Islamic Azad University, Tabriz Branch, north-western Iran, during the 2013 - 2014. The first factor was nano-chelate zinc application in four levels: a1: soil application, a2: foliar application, a3: soil application + foliar application and a4: control. The second factor was different growth stage in three levels [b1: 8-10-leaves stage, b2: taselling, b3: SA grain filling stage. Each plot consists of 4 rows, 75 cm row spacing and 25 cm plant interval. There were 2-5 seeds beside each other and they were thinned at three leaves stage to obtain plant density of 5 plants per m². On the basis of the soil test (Table - 1), 1 in 1000 foliar application and 4 Kg ha⁻¹ were determined. Taking into account the size of the plots and in order to ease foliar application and to increase the delicacy of the spraying, a hand sprayer was used. In order to have an even and efficient spraying, 50 cm distance from the plants seemed reasonable. The spraying was carried out thoroughly until the foliar was dropping from the plants. Furthermore, Tween80 was used as surfactant to have the leaves absorb nutrient mineral. The control plots were water sprayed consistently to avoid the effects of foliar application used for experimental plots.

In order to evaluate the weight increase process of dry grain in the grain filling rate and duration, the sampling was done after pollination and grain formation with 7 - day intervals. In each sampling, two plants were randomly selected from every plot. Corn grains were drawn out carefully from four rows of upper, middle, and the lower part of earning and dried in an electrical oven under 70°C for 48 h. Then the dried weight of the grain was determined and divided to the number of rows in cob and the average weight per grain was calculated. To calculate grain filling rate and duration, the following formulas were used (Khalilvand Behrouzyar et al., 2012):

Grain filling rate = \[ \frac{\sum_{x} x y - \left(\frac{\sum_{x} x \left(\sum_{y} y\right)}{n}\right)}{\sum_{x} x^2 - \left(\frac{\left(\sum_{x} x\right)^2}{n}\right)} \]

Grain filling dyration = weight of grain / grain filling rate

In these formulas, the abbreviations stand for the following factors: x: day number from pollination to physiological maturation, y: weight of grain and n: day number from the start to physiological maturation.

Statistical analysis

In order to check the normality of data, analysis of variance, and mean comparison MSTAT-C software were used. The means of the treatments were compared using the Duncan’s test at P<0.05.

Results and Discussion

The analysis of variance showed significant effect of nano-chelate Zn application on grain filling rate, grain filling duration, seed yield (p<0.05) and ear yield (p<0/01), (Table -2).

### Table -1. Physical and chemical analysis of soil

<table>
<thead>
<tr>
<th>pH</th>
<th>Ec * 10^3</th>
<th>N (％)</th>
<th>Mn (ava) ppm</th>
<th>Zn (ava) ppm</th>
<th>P (ava) ppm</th>
<th>K (ava) ppm</th>
<th>Sand (％)</th>
<th>Silt (％)</th>
<th>Clay (％)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/25</td>
<td>1/76</td>
<td>0/056</td>
<td>0/84</td>
<td>1/08</td>
<td>0/8</td>
<td>168</td>
<td>76</td>
<td>14</td>
<td>10</td>
</tr>
</tbody>
</table>
Grain filling rate

Results showed that nano-chelate Zn soil application and control had the highest (0.0022 g day\(^{-1}\)) and lowest (0.0016 g day\(^{-1}\)) grain filling rate, respectively (Table - 3). Meanwhile, this treatment had 37% more grain filling rate than the control treatment. Gebeyehou et al., (2002) stated that there is a strong correlation between final grain weight and grain filling period. Munier-Jolian et al., (1998) reported that the rate of dry grain substance gathering is affected by nitrogen rate available for plant during the grain filling period. It seems that process of grain filling has ascended during the growth period, but its stability and filling rate depends on environmental resources. Egli (2004) proposed that lengthening the seed filling period is the most promising avenue to higher yield in a given seed filling rate.

Grain filling duration

Zn soil application (70/16 day) and control (68/31 day) had the highest (which had an average 12% increase compared with the control) and lowest grain filling duration, respectively (Table - 3). Grain filling duration seems to be more affected by environmental factors rather than by the grain filling rate (Royo et al., 2000). Genetic variation for the duration of grain filling has been reported for corn (Cross, 1975), wheat (Bruckner and Frohberg, 1987) and barley (Rasmusson et al., 1979).

Biomass dry weight

Based on the results, the highest (2844 g m\(^{-2}\)) and the lowest (2287 g m\(^{-2}\)) dry matter weight were related to Zn-foliar application and control (Table - 3). Total biomass or crop dry weight (CDW) is the result of these two processes. Harvest index (HI) is the ratio of grain yield to biological yield, i.e., a measure of the efficiency of the plant when accumulating assimilates in the organs of economic significance (Moragues et al., 2006). Significant relationships between yield and biomass at anthesis or during grain filling have been reported in bread wheat (Turner, 1997) and durum wheat (Ramdani, 2004).

Ear yield

Foliar application of Zn-nano chelate and control treatment had the highest (176/11 g/ plant) and lowest (106/77 g/ plant) ear yield (Table - 3). This treatment had 64% more ear yield than without Zn application treatment.
Seed yield

Our results also showed that the highest seed yield was related to nano-chelate Zn foliar application (852 \/ 62 g m$^{-2}$). Also, control (without application) had the lowest seed yield per plant (505/34 g m$^{-2}$), (Table -3). Nanoparticles (NPs) with small size and large surface area are expected to be the ideal material for use as a Zn fertilizer in plants. It is because of that when materials are transformed to a nanoscale, they change their physical, chemical and biological characteristics as well as catalytic properties and even more increase the chemical and biological activities (Mazaherinia et al., 2006). Prasad et al. (2012) studied the effect of nanoscale zinc oxide on the germination, growth and yield of peanut and observed significantly more growth and yield. Reynolds (2002) demonstrated that micronutrients in the form of NPs can be used in crop production to increase yield.

Conclusion

It could be concluded that, use of nano-chelate zinc application had positive effect on Morpho-physiological characteristics of maize. Based on the results, soil application of nano-chelate zinc had the grain filling rate and duration. Also, dry matter weight, ear yield and seed yield were found by foliar nano-chelate zinc application.

References


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