The Influence of Zinc Fertilization on Bioavailable Zinc Content in Lentil

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INTRODUCTION

Zinc (Zn) is one essential nutrient that is deficient in the human diet in many developing countries where Saskatchewan lentil is marketed. Estimation of Zn in lentils and its bioavailability to humans is prerequisite for an effective biofortification program. In the past most research was focused on the role of Zn application on increasing grain yield. However, Zn-application intended for improved bioavailability of Zn in lentil grains for human consumption has not received much attention.. Zinc bioavailability can be increased by either increasing the Zn concentration or decreasing anti-nutrients, particularly the phytate concentration, in lentil grains (Hussain et al. 2012). Zinc and phytate contents in food are major determinants of Zn absorption in the human intestine and the phytate-to-zinc molar ([phytate]:[Zn]) ratio in human food is generally used to categorize the Zn bioavailability (Turnlund et al. 1984; Weaver and Kannan 2002). The amount of Zn in the grain depends on the root uptake during grain development and the amount redistributed from vegetative tissue to the grain (Garnett and Graham 2005). The amount remobilized via the phloem is mainly dependent on the phloem mobility of each element. Good Zn transport from shoot to grain has been observed in cereals such as wheat (Pearson and Rengel 1994) However Zn is a variably mobile element and its mobility is also crop/species dependant. Lentil has an excellent macro and micronutrient profile and favorable levels of mineral bioavailability enhancing factors (Thavarajah et al. 2011). However, the effect of Zn fertilization on Zn movement within the lentil plant is relatively unexplored.. The main goal of this project was to determine the variation among three market classes of lentils for Zn distribution in straw and grain and bioavailability in response to Zn fertilizer application to a Brown Chernozem soil from south-central Saskatchewan.

METHODOLOGY

Homogenized soil from 0-15 cm of a Brown Chernozem (Ardill Association) were placed in 1kg pots. The DTPA extractable Zn content of this soil was 0.25 mg Zn kg^{-1}. A basal dose of N,P and S was supplied to all pots. Zinc sulfate was used to supply Zn at a rate of 2.5 kg Zn ha^{-1}. The zinc sulfate was uniformly mixed with the soil in the pots (1000 g of soil) prior to planting to simulate a broadcast and incorporate application. Zinc was also supplied in foliar form (Zn-EDTA) at a rate of 0.246 kg Zn ha^{-1}. A popular University of Saskatchewan Crop Development Center variety of each of the three (large and small green, small red) lentil classes (Impower, Imvincble, Maxim) were grown on each soil from May to August 2013 in the University of Saskatchewan polyhouse facilities under natural light and temperature conditions. Half of the lentil plants were harvested at 30 days after seedling emergence and the remainder at maturity. Harvested plants were further separated into lower and upper shoots and analyzed for Zn concentration.

Harvested lentil grain samples were also analyzed for phytate-P content following a modified method of Gao et al. (2007). Mineral bioavailability was qualitatively estimated as [phytate]:[mineral] ratio in grains (Brown et al. 2001). Zinc bioavailability in lentil grain was also quantitatively estimated by employing the trivariate model of Zn absorption (Miller et al. 2007):

$$TAZ = 0.5 \cdot \left(A_{MAX} + TDZ + K_R \cdot \left(1 + \frac{TDP}{K_p}\right) - \sqrt{\left(A_{MAX} + TDZ + K_R \cdot \left(1 + \frac{TDP}{K_p}\right)\right)^2 - 4 \cdot A_{MAX} + TDZ} \right)$$

RESULTS AND DISCUSSION

Zinc fertilizer application influenced grain yield and biomass partitioning in lentil classes. For example, in large green lentil class (Figure 1) there was a reduction in the biomass but increase in grain yield with application of Zn. The increase in grain yield was more pronounced with foliar Zn application.

Application of foliar Zn fertilizer increased the shoot concentrations of Zn while soil application increased the grain concentration of Zn (Figure 2). Zinc is taken up over the season and eventually redistributed from the shoots to the grain.

Reduction in grain phytate-P content was observed with Zn application. A lower phytate:Zn ratio in the grain indicates greater human bioavailability of the Zn contained within the grain. A significant decrease in the phytate:Zn ratio from Zn fertilization was only observed for the treatment with foliar application of chelated Zn to small green lentil (Figure 3). The molar phytate: Zn ratio in all lentil classes was less than 15, indicating high Zn bioavailability. Quantitatively estimated Zn bioavailability using the trivariate model in all lentil classes was $\geq$3 mg Zn / 300 grams.

CONCLUSIONS

Application of Zn fertilizer increased concentration of Zn, reduced the phytate content, and in one market class (small green) increased the apparent bioavailability of the Zn in the lentil grain. Zn fertilization offers promise as a means of increasing the human nutritional value of lentil.

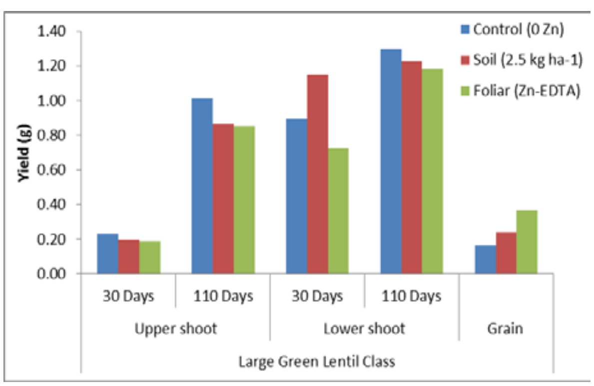

Figure 1. Influence of soil and foliar applied Zn fertilizer on straw and grain yield of Impower (large green lentil class) grown on a Brown Chernozem.
**(Plants were harvested at 30 days and maturity (110 days) and separated into lower and upper shoots*

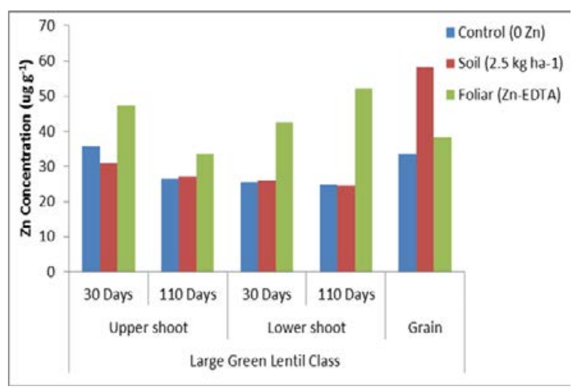

Figure 2. Influence of soil and foliar applied Zn fertilizer on zinc (Zn) concentration in straw and grain of Impower (large green lentil class) grown on a Brown Chernozem.

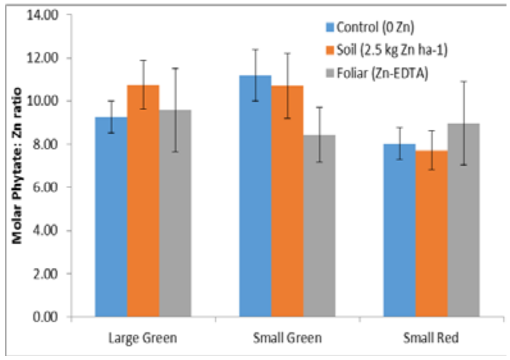

Figure 3. Influence of soil and foliar applied Zn fertilizer on molar phytate:Zn ratio in the grain of three market classes of lentil.

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