Fertilization of lentils with zinc on Saskatchewan soils to increase yield, grain zinc content and marketability

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SPG Contributions	Project Status	Duration/Timeline of Project (Year to Year)	Co-funders	Total Project Cost
$81,523.50	Completed	April 2012 – March 2016	Saskatchewan Minsitry of Agriculture – Agriculture Development Fund; Natural Sciences and Engineering Research Council of Canada	$192,431.50

Project Description

To determine the grain yield and zinc concentration response in selected genotypes of three different market classes of lentil to application of zinc sulfate fertilizer on Saskatchewan soils; to assess the effect of the zinc sulfate application to lentil on the yield and zinc concentration in hard red spring wheat that is grown following the lentil; to determine an optimum rate and mode of Zn application in order to increase lentil yield, Zn content and bioavailability within lentil grain classes, the variation in Zn concentrations and phytate in lentil plant parts and consumed lentil grains, the phytate to zinc molar ratios, and the bioavailable Zn in lentil grains using the trivariate model.

In the export market for prairie lentil, especially in south and central Asia where human deficiency of Zn is relatively common, an extra edge over other countries may be gained by improving the quality of lentil. This can be achieved by improving the content of essential but deficient nutrients in the human diet such as Zn. Although industry is beginning to recognize that there may be potential gains from considering Zn in the lentil fertility package, there has not been enough research conducted to clearly identify what rates, lentil genotypes, and soil types Zn fertilization is most likely to produce a yield or quality response. The study specifically examines Zn fertilization as a potential strategy to promote a greater accumulation and human bioavailability of Zn in lentil grain. Since lentils are typically grown in rotation with a cereal like wheat, the fate of Zn applied to lentil in influencing the yield, and Zn content of wheat is also examined in this study.

The body of research conducted in this project tested the following hypotheses:
(i) Broadcast and incorporated ZnSO4 fertilizer will improve yield and grain Zn concentration of lentil in Saskatchewan soils
(ii) Differences in response to Zn fertilization will exist between soils and lentil cultivars
(iii) Yield and grain Zn concentration will be influenced by the method of application (soil, foliar) and form (inorganic salt, natural or synthetic chelate) of Zn fertilizer applied
(iv) Zinc fertilization will improve the bioavailability of Zn in lentil grain
(v) In-season application of Zn fertilizer will have residual effects for spring wheat yield grown the subsequent year

A set of controlled environment, polyhouse and field studies were conducted on soils from the lentil growing region of southern Saskatchewan to evaluate the response of three lentil classes (large and small green, red) to zinc fertilization at rates as high as 5 kg Zn/ha using various Zn sources (sulfate salt, organic and synthetic chelate) and application method.

The effect of broadcast and incorporate application of zinc sulfate (ZnSO4) fertilizer at rates of 0, 2.5 and 5 kg Zn/ha on lentil yield, zinc content and human bioavailability of zinc was evaluated in the field at Central Butte and Saskatoon, and in 10 Saskatchewan soils collected from across the lentil growing region of Saskatchewan. Soil analyses for residual Zn forms in the soil was completed. An economic cost-benefit analyses of fertilization of lentil with Zn was conducted using the results of the 2013 field studies.

The effects of the lentil Zn fertilization treatments on hard red spring wheat was assessed in polyhouse and field studies in which wheat was grown on the lentil stubble. Wheat grain and straw yield and Zn concentrations were determined in response to residual soil Zn left behind after the lentil crop.

The optimum rate and mode of Zn application to increase lentil yield, Zn content and bioavailability was accomplished by measuring phytate in lentil grain from all the experiments, and using the phytate:zinc molar ratios along with the trivariate model to qualitatively and quantitatively assess how Zn fertilization practice influenced human Zn bioavailability.

Outcome

The results of this project indicate that addition of Zn fertilizer as soil applied zinc sulphate was not particularly effective in increasing the yield, grain Zn content or human bioavailability of Zn based on results from several greenhouse and field experiments with soils from the lentil growing region of Saskatchewan.

The polyhouse experiment showed that overall Zn fertilizer application was not required for all soil associations for obtaining high grain yield and Zn concentration. Of the ten, only two were consistently responsive, and these soils were identifiable by their measured low contents of plant available zinc. There were no significant differences in yield or Zn accumulation in either lentil grain or straw among Zn fertilizer treatments and differences in Zn uptake were a factor of a significant cultivar effect as opposed to a fertilizer response. However, foliar applications of chelated Zn were more effective than soil applied salts in increasing the human bioavailability of Zn in lentil.

In the field trials, the application of ZnSO4 fertilizer through broadcast and incorporation of intact granules was not effective for increasing yield, grain Zn concentration or human bioavailability of the Zn in lentil. The impacts of soil Zn fixation were confirmed in a subsequent field experiment that examined the residual value of ZnSO4 fertilizer applied to lentil in 2013 on the yield and nutrient content of a rotational crop of hard red spring wheat grown in 2014. No significant differences in grain or straw

yield among any rates of the previously applied fertilizer Zn were detected at either Saskatoon or Central Butte site locations. The economic analysis showed that no economic benefit was realized from the addition of the zinc sulfate to the lentil, nor was there a benefit to the following wheat crop. Unless a crop deficiency is clearly established, producers should not apply Zn fertilizer at the expense of other field operations that have more reliable agronomic efficacy.

Application of $ZnSO_4$ had no significant effect on any of the lentil grain Zn bioavailability assessments in the field trials at the two sites. However, the effect of cultivar was significant, with CDC Imvincible had the highest concentrations of phytate in the grain at either site which resulted in higher phytate:Zn molar ratios and lower levels of estimated bioavailable Zn compared to other lentil cultivars. Results from this study indicate that phytate accumulation in lentil grain is influenced by Zn fertility, lentil genotype differences, and environmental conditions during the growing season. Zinc reduces the P uptake by lentil and decreases the accumulation of grain phytate.

The processing of whole lentil seed to create footballs, splits and seed coat fractions revealed that the footballs and splits did not significantly differ in Zn concentration from the whole seed, but that the seed-coat did have significantly lower Zn concentration. Overall, processing appears to have relatively little impact on the Zn concentration in the lentil processing product used for human consumption.

Overall, this project revealed that the addition of Zn fertilizer would not be beneficial for increasing economic yield of lentil in most instances for prairie farmers. Lentil Zn content is more influenced by soil conditions, especially the native Zn content and by genetics than it is affected by fertilization, although it does appear to be possible to increase the human bioavailability of the Zn in the lentil by foliar addition of chelated Zn fertilizer forms.

An improved understanding of the response of lentils to fertilization with Zn has been obtained that will contribute to more accurate fertilizer micronutrient recommendations for lentil growers. Specific forms and application methods that are more efficacious have been identified. Economic analysis of the field data for Zn response showed that Zn fertilization did not demonstrably increase economic return, due to the lack of statistically significant yield responses to the Zn fertilizer applied. Yield response of lentil to Zn fertilization is too variable to allow much confidence in a consistent positive economic return on fertilizer investment. Unless a crop deficiency is clearly established, producers should not apply Zn fertilizer at the expense of other field operations that have more reliable agronomic efficacy.

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Research Objective

OBJECTIVE 1
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OBJECTIVE 2
To assess the effect of the zinc sulfate application to lentil on the yield and zinc concentration in hard red spring wheat that is grown following the lentil.

OBJECTIVE 3
To determine an optimum rate and mode of Zn application in order to increase lentil yield, Zn content and bioavailability within lentil grain classes, the variation in Zn concentrations and phytate in lentil plant parts and consumed lentil grains, the phytate to zinc molar ratios, and the bioavailable Zn in lentil grains using the trivariate model.