Are Barley Yields on Eroded Calcareous Soils Restricted by Low Zinc Supply?

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Abstract

Calcareous knolls are often relatively unproductive locations in a field landscape. This may be attributed to lack of moisture as well as limited nutrient supplies. A growth chamber study was initiated to investigate the role of micronutrient deficiencies in yield limitations observed on calcareous knolls. Three rates of zinc (Zn) fertilizer were applied to calcareous soils collected from both an Asquith and Amulet association. In addition, macronutrients were applied in sufficient quantities as to not limit plant yields. Barley was grown in the treatments, harvested, and the treatments were compared. Results indicated a highly significant barley dry matter yield response to Zn fertilizer.

Introduction

Typical glacial till landscapes in Saskatchewan consist of undulating topography with eroded knolls. Crop yields tend to be lower on the knolls than in midslope and depressional areas (Pennock *et al*., 2000). This is due in part to water limitations as rainfall is redistributed into low-lying areas (Pennock *et al*., 2000). Organic matter content is also generally lower in the knoll positions as a result of erosion and low productivity. Subsequently, this reduced organic matter content causes nutrient limitations to exist on eroded knolls.

Larney *et al*. (2000) conducted soil excavation experiments to simulate the effects of erosion on soil productivity in southern Alberta. As topsoil was removed, crop yields declined. When amendments were applied to the treatments to restore fertility, nitrogen (N) plus phosphorus (P) fertilizer applications alone were not sufficient to restore yields to the control treatment levels. However, manure additions did compensate for yield losses where 15-20cm of topsoil was initially removed, indicating that a balanced nutrient amendment that included micronutrients was needed. Larney *et al*. (2000) also found that Zn content of spring wheat grain was significantly reduced by soil excavation treatments. Erosion of knolls can lead to higher soil pH at the soil surface as the calcareous parent material becomes mixed with the A horizon. Zn availability can be reduced at high soil pH as a result of Zn precipitation (Harter, 1983). Cowell and Schoenau (1993) found that Zn application to eroded knoll soils increased spring wheat productivity in a growth chamber experiment.

In a preliminary variable rate fertilizer experiment in 2000, it was observed that knolls well fertilized with macronutrients had spring wheat yields 10bu ac^{-1} below the field average. At the same time, these areas were heavily invaded by weed species (Russian Thistle, Kochia and Wild Buckwheat) known to have a strong ability to capture diffusion-limited nutrients such as copper (Cu) and Zn (Itoh and Barber, 1983). Analysis of the historic yield response revealed that a near 40% increase in N, P, K, and S fertility on these sites produced only a 1bu ac^{-1} yield increase. Results of post season soil analysis indicated low micronutrient supplies as a possible cause of restricted yield.

To adequately manage these knolls to achieve the highest net dollar return, the Cu and Zn responses must be quantified. As a result, a growth chamber experiment was initiated to test if low Cu and Zn supplies could be limiting yields on eroded calcareous knolls in Saskatchewan.

Materials and Methods

Soil was collected from the A horizon of two knoll positions in a southern Saskatchewan field (NW1-7-20-W2) in the fall of 2000. The soils were classified as Asquith and Amulet Orthic Regosol. The soils were air-dried, ground, and sieved.

Macronutrients as well as Cu and Zn treatments were applied to pots containing 500g soil in a band ½" below the soil surface. Blanket macronutrient applications were made to eliminate potential macronutrient deficiencies (Table 1). Zinc was applied at rates of 0, 2 and 4lb ac^{-1} in the form of chelate product "Zintrac 700" (© Phosyn Plc, Ephrata, WA) which was impregnated into the urea fertilizer prior to application to improve distribution in the soil. Copper was also impregnated into urea fertilizer as product "Coptrel 500" (© Phosyn Plc, Ephrata, WA) at rates of 0, 1 and 2lb ac^{-1}. Each treatment was replicated four times.

Table 1. Macronutrient Fertilizers Applied to Soils in the Growth Chamber Experiment Expressed in Rates of Fertilizer Product as well as Rates of Actual Nutrients.

Fertilizer Type		Asquith	Amulet
		Fertilizer Applied (lb ac^{-1})	
46-0-0-0		545.6	586.4
12-51-0-0		198.8	216.0
0-0-62-0		344.0	258.4
21-0-0-24		47.2	28.4
Actual	N	284.8	301.6
	P	101.4	110.2
	K	213.3	160.2
	S	11.3	6.8

Following fertilizer application, soil was moistened to field capacity with deionized water and equilibrated for two days. Pre-germinated barley (var. Harrington) seedlings were then placed in the fertilizer zone. Seedlings were thinned to four plants pot^{-1} after ten days. Plants were grown in a growth chamber at a temperature of 12°C, which was slowly ramped up to 20°C. The barley was harvested at boot stage, dried at 40°C, weighed, ground and analyzed for nutrient content. Total C, N and S contents were determined by combustion at 1350ºC using the CNS-2000 Element Analyzer (LECO Corporation 1994). Total P, Ca, Mg, K, Fe, Mn, Cu, Zn, B, Pb, and

Cd were determined by sulfuric acid-peroxide digestion at 360ºC for 6h. Nutrient content of the digested samples was determined via ICP analysis (Perkin Elmer Optima 3000 DV).

Soil nutrient supply rates were measured via 24 hour in-lab burial of PRS™-probes (Western Ag Innovations, Saskatoon, SK) in soil moistened to field capacity (Schoenau *et al.*, 1993). Soil pH and E.C. were determined with a pH meter (Oakton pH/Con 10 series) in 1:1 water:soil mixtures.

Statistics were performed using balanced analysis of variance ($\alpha = 0.05$)(Minitab, 1998).

Results and Discussion

The pH of both soils was relatively high (Table 2), indicating that Zn availability could be restricted by Zn precipitation. Soil pH and EC were determined on samples collected from the field prior to grinding, therefore values are lower than would be measured using ground soils. Supply rates of N, P and K indicated that the soils would be responsive to fertilizer application however any potential macronutrient deficiencies should have been eliminated by fertilizer application. Supply rates of micronutrients were low, particularly for the Amulet soil.

Table 2. Characteristics of the Soils Collected for the Growth Chamber Experiment.

Soil Properties	Asquith	Amulet
pH	7.5	7.4
E.C. (mS/cm)	0.3	0.4
F.C. (%)	15	24
	PRS™ Supply Rate (µg $10cm^{-2}$ $24h^{-1}$)	
(NO_3+NH_4)-N	13	5
P	1.4	0.6
K	68	92
S	46	58
Ca	2558	1579
Mg	156	159
Fe	5.4	1.8
Mn	12.0	6.0
Cu	1.0	0.2
Zn	0.6	0.4

Although Cowell and Schoenau (1993) found increased Cu uptake by spring wheat with Cu application to eroded knolls, no significant effect of Cu application to barley was detected in this experiment. Results and discussion are therefore limited to the Zn treatments.

There was a signficant difference in barley dry matter yields among Zn treatments applied to the Amulet soil (Table 3). A similar trend was seen on the Asquith soil, however the differences were not significant. Dry matter yields were lower overall in the Asquith soil. It is possible that the high rates of urea reduced soil pH enough to cause $CaCO_3$ to dissociate and temporarily tie up fertilizer P.

Zinc concentration in barley tissue tended to increase with Zn application to both soils. Zinc uptake was significantly increased by application of 2lb Zn ac^{-1} to the Amulet soil and 4lb Zn ac^{-1} to the Asquith soil. Phosphorus uptake was also significantly increased by application of Zn to the Amulet soil as a result of increased dry matter yield and therefore demand for P.

Table 3. Dry Matter Yield, Zn Concentration, Zn and P Uptake by Barley Grown in Pots Amended with Three Rates of Zn Fertilizer.

Soil	Zn Rate lb. ac^{-1}	Dry Matter Yield g pot^{-1}	Zn Conc. µg g^{-1}	Zn Uptake µg pot^{-1}	P Uptake mg pot^{-1}
Asquith	0	1.98 c	8.48	16.9 c	2.55 c
	2	2.24 c	10.04	21.8 c	2.83 c
	4	2.30 c	12.57	28.2 b	2.82 c
Amulet	0	3.87 b	8.02	31.7 b	4.62 b
	2	4.35 a	9.06	39.3 a	5.47 a
	4	4.26 a	10.33	43.8 a	5.48 a
LSD$_{(0.05)}$		0.36	-	5.6	0.61

Barley responded to Zn fertilizer application to these soils, due in part to a high Zn demand relative to other crops. For this reason, a similar response may not have occurred had a lower Zn demanding crop, such as spring wheat, been planted. However, other researchers have shown spring wheat response to Zn application to soils collected from Oxbow association eroded knolls (Cowell and Schoenau, 1993).

Conclusions

Barley responded to Zn fertilizer application under the controlled conditions of this experiment. By overcoming water and macronutrient limitations, it was shown that applications of Zn fertilizer to these soils could significantly increase dry matter yields as well as Zn uptake. Further research is required to determine if a Zn response would also occur under field conditions. Producers wishing to increase the productivity of eroded calcareous knolls should inspect plants growing on knolls for micronutrient deficiency symptoms. Micronutrient application should be considered after reviewing soil nutrient supplies, moisture availability, potential crop demand, and economics. Micronutrients are used most efficiently when applied in balance with appropriate levels of macronutrients and when well distributed in the soil to maximize root access while minizing cost. This may be achieved by impregnating macronutrient fertilizers with liquid micronutrient chelate fertilizers.

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