Spring Wheat Response to Zinc and Copper Applied to Eroded Soils

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ABSTRACT

A response to added N and P was not observed in a growth chamber experiment using soils sampled from eroded knolls. Subsequent soil tests indicated very low levels of available copper and zinc in some of the soils. A second growth chamber experiment was set up to determine if micronutrient deficiencies may have limited yield. Soil was collected from a number of eroded knolls in a farm field near Lanigan, and wheat yield response to added zinc and copper was measured. There was little response to copper, but earlier maturity and increased yield was observed on several of the soils where zinc had been applied.

INTRODUCTION

Soil erosion may reduce potential crop yield due to lower water holding capacity, poor seedbed structural quality and a direct loss of nutrients. Where the main effect of erosion is nutrient loss, application of fertilizer will improve yield. Deficiencies of N and P on eroded knolls in Saskatchewan have been recognized, and crop grain yields improved by fertilizer application (de Jong and Rennie, 1969; Cowell and de Jong, 1990; Elliott et al, 1991). Requirements for micronutrients on eroded knolls have not been documented. This project examined the possible development of zinc or copper deficiencies in eroded soils sampled from the knolls of a field near Lanigan, Saskatchewan.

Both zinc and copper have been recognized as possible nutrient deficiencies in Saskatchewan. Copper fertilizer is often required for cereal crop growth on organic soils and leached sandy Luvisols (Karamanos et al, 1985, 1986; Kruger et al, 1985; Saskatchewan Agriculture, 1987). Zinc is suspected to be deficient in certain calcareous soils, especially where soil leveling for irrigation has been done, but field trials have often failed to measure a crop yield increase due to zinc addition (Tomasiewicz and Stewart, 1982; Stewart and Tahir, 1971; Tomasiewicz et al, 1989).

There is reason to suspect copper and zinc deficiency in eroded soils. The availability of both copper and zinc decreases as soil pH increases and soil organic matter decreases (Haby and Sims, 1979; Singh et al, 1985, 1987; Liang et al, 1990). Eroded knolls typically have lost a large portion of their organic matter and calcareous subsoil is often exposed or at least mixed with the cultivated surface soil. Erosion therefore leads to the direct loss of zinc and copper and the remaining portion becomes less available. Zinc nutrition is most severely affected; much lower levels of available zinc has been found in subsoils relative to topsoil in field experiments in both Montana and Saskatchewan (Haby and Sims, 1978; Singh et al, 1985).

SITE DESCRIPTION

Site Description

Large composite samples of topsoil (0-15 cm) were collected for growth chamber studies from the shoulders of eroded knolls in a field owned by Mr. J. Kresse near Lanigan, Saskatchewan. The soil characteristics of this field have been described in previous studies (Pennock and Anderson, 1992). In summary, over 50% of the soil organic matter has been lost from the shoulder positions, and soil pH has increased slightly from 7.4 to 7.6 over the course of 80 years of cultivation. The soil-landscape is a typical thin Black Chernozem (Oxbow association) developed on hummocky glacial till.

Preliminary Studies

A requirement for both N and P had been established in field fertilization experiments at this and similar sites (Elliott and de Jong, 1992). A continued field trial in 1992 was established to compare N and P requirements at various slope positions. Crop yield increases were measured for additions of both N and P fertilizer (data not shown).

A parallel experiment was carried out to compare the potential use of anion and cation exchange membranes (ACEM) for predicting N and P availability in a field environment. The ACEM technique had been proven to accurately predict uptake of N and P in previous growth chamber experiments with Saskatchewan soils (Shoenau and Huang, 1991; Qian and Schoenau, 1992). Membranes were buried at various slope positions at the Lanigan site, and nutrient availability was subsequently measured. Soil was collected from the same sites for a growth chamber experiment. Exchange membranes were again buried in the collected soil to determine available N and P levels. A simple growth chamber experiment was then carried out with treatments of Control, +N, and +P applied to the soils from the various slope positions. Background additions of K and S were applied to prevent these deficiencies. Micronutrients were not added, on the assumption that these deficiencies were not likely a factor for these soils. Spring wheat was then grown to maturity in the growth chamber. On the soils collected from the shoulder positions of the knolls, plant yield was very low and maturity was delayed, despite additions of N or P. A second growth chamber experiment was then set up to determine if zinc or copper deficiencies may have limited yield.

Growth Chamber Experiment

Soil was collected from four shoulder positions and two backslope positions for the experiment. Available cationic micronutrients were measured using traditional extraction techniques (DTPA), as well as an ACEM soil-water suspension extraction. Available N and P were measured with traditional methods; $CaCl_2$ for nitrogen, and $NaHCO_3$ for phosphorus.

Five hundred grams of each soil was added to pots. Treatments included 'Control' (no added zinc or copper), +Zn (5 μg zinc as $ZnCl_2$ per g soil), and +Cu (2 μg copper as $CuCl_2$ per g soil). Background levels of 125 μg N , 40 μg P, 75 μg K, and 25 μg S per g of soil were also applied to each pot. Three replicates were used per treatment for each soil in a completely randomized design. Spring wheat (var. Katepwa) was grown to maturity, the plants were dried, and the total and grain weights were measured. The grain and straw from the three replicates of each treatment was combined, then ground, and total copper and zinc was determined. Yield and maturity data was compared in ANOVA tables.

RESULTS AND DISCUSSION

Available Soil Nutrients

Available zinc was lowest on the shoulder sites, based on both resin and DTPA extractions (Table 1). Current guidelines for DTPA extractions consider 0.50 μg Zn and 0.50 μg Cu per g soil deficient (Saskatchewan Soil Testing Laboratory, 1990). Accordingly, 5 of 6 sites were Zn deficient, while 2 of 6 sites were marginally Cu deficient. Available N and P were quite uniform between sites, and both deficient for plant growth.

Table 1. Available nutrients in growth chamber soils.

		Available nutrients (μg g soil^{-1})					
				DTPA		Resin	
Site	Slope	N	P	Cu	Zn	Cu	Zn
K1	Shoulder	2.6	6.3	1.2	0.33	0.40	0.18
K2	Shoulder	2.6	6.8	0.85	0.24	0.26	0.09
K3	Shoulder	2.4	4.8	1.2	0.21	0.39	0.10
K4	Shoulder	2.8	3.8	1.2	0.21	0.46	0.09
K5	Backslope	1.8	6.4	0.64	0.77	0.24	0.16
K6	Backslope	2.0	6.5	1.1	0.44	0.31	0.12

Plant Growth

Zinc addition reduced the days to plant heading on four of six soils by an average 5.5 days (Table 2). Plant maturity was also hastened by zinc addition on four soils, by an average of 3.5 days. Copper addition had little effect on plant maturity, with increased days to heading on one soil, and decreased days to maturity on a different soil (Table 2).

Total plant weight was not detectably affected by copper or zinc addition in any case. However, zinc addition increased grain yield by an average 17% on four of the soils (Table 2). Other than the effect of zinc on maturity and grain yield, no visible deficiency symptoms were noted in any of the pots. Copper did not increase grain on any site.

Plant response to added zinc on soils collected from shoulder positions corresponded to low levels of available zinc (Table 1).

Table 2. Plant growth response to added copper and zinc.

	Days to head			Days to mature			Grain Weight (g/pot)		
Site	Ck	Cu	Zn	Ck	Cu	Zn	Ck	Cu	Zn
K1	---NS---			68	68	65**	---NS---		
K2	39	42*	37**	---NS---			1.7	1.7	2.1**
K3	42	44	35***	70	70	65***	1.6	1.5	1.8*
K4	42	43	35*	69	69	66**	1.6	1.9	1.9*
K5	---NS---			---NS---			---NS---		
K6	39	40	34**	69	66**	66**	1.7	1.7	1.9*

Significant difference from check (Ck) treatment at; * $P < 0.10$; ** $P < 0.05$; *** $P < 0.01$

Plant Nutrient Uptake

Zinc uptake by the wheat plants increased markedly when zinc was added to all of the soils, though the effect was largest for soils K2, K3, and K4 (Table 3). These soils also had the lowest levels of available zinc, and the largest grain yield response to added zinc (Table 1 and 2). Plant uptake of copper also increased with copper addition (Table 3). The largest percentage increase in copper uptake was for the K2 and K5 soils, which were also marginally copper deficient (Table 1). Although a plant growth response to copper was not measured within the limits of this experiment, it is apparent that the soil tests were capable of discerning the most copper deficient soils.

Table 3. Total plant (grain + straw) content of zinc and copper at maturity.

	Copper (μg/pot)		Zinc (μg/pot)	
Site	Ck	+Cu	Ck	+Zn
K1	21.8	28.1	32.8	56.6
K2	19.8	37.2	32.0	71.6
K3	27.1	26.4	26.7	59.8
K4	23.5	29.5	28.1	74.9
K5	16.5	22.9	52.4	79.5
K6	22.0	22.5	39.9	75.1

Many research projects have indicated a negative relationship between plant uptake of zinc and phosphorus (Racz and Haluschak, 1974; McKenzie and Soper, 1983; Singh et al, 1986, 1988). Phosphorus concentration of the wheat seeds did decrease when zinc was added to four of the soils, but total phosphorus uptake was actually increased in many cases (data not shown). A consistent interactive relationship between zinc and phosphorus uptake was not distinguishable within this experiment. The small amount of phosphorus added (40 μg P per g soil) to supplement low soil phosphorus levels was unlikely to induce any zinc deficiency.

CONCLUSIONS

A response to zinc was measured for plants grown on soils collected from eroded knolls in a farm field. Plant maturity was hastened and grain yield increased in four of six soils. A consistent response to added copper was not measured. Soil tests provided a good indicator of plant growth response and total uptake of both zinc and copper.

This simple experiment establishes the potential development of micronutrient deficiencies on eroded soils. The soils used in the experiment were not originally selected for the purpose of detecting these deficiencies. It therefor seems likely that a significant portion of eroded knolls in the prairie environment may respond to micronutrient fertilization, and particularly to zinc. Correction of these deficiencies may provide a significant yield increase in some cases, and also slow the continued spread of erosion from these sensitive areas. Simple soil tests and field trials could quickly establish potential micronutrient responses for specific field conditions. However, micronutrient fertilization should only be part of a rational approach to management of eroded soils, in addition to application of organic matter and macronutrients, as required.

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