Relative Effectiveness of Various Cu Fertilizers in Improving Grain Yield of Wheat After Four Annual Applications on a Cu-Deficient Soil

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Abstract

The deficiency of Cu is not wide spread in Saskatchewan, but whenever it occurs it can have a serious reduction in grain yield and quality of wheat. A 4-year experiment was initiated in spring, 1999 to study the response of grain yield of wheat to Cu fertilization on a Cu-deficient soil near Porcupine Plain in northeastern Saskatchewan. Relative effectiveness of soil application of four granular Cu fertilizers (# 1, 2, 3 and 4) as soil incorporated (at 0.5 and 2.0 kg Cu ha^{-1}) and seedrow placed (at 0.25 and 1.0 kg Cu ha^{-1}); foliar application of four liquid Cu fertilizers (# 5, 6, 7 and 8 at 0.25 kg Cu ha^{-1}) at four-leaf and flag-leaf stages; and a zero-Cu check was compared in 1999, 2000, 2001 and 2002. The wheat crop showed Cu deficiency in the growing season in all the three years. In 1999, the zero-Cu check produced grain yield of 1566 kg ha^{-1}. The grain yield increased to 2709, 2571 and 2555 kg ha^{-1} with the foliar application of Cu Fertilizers 5, 6 and 7 at the flag-leaf growth stage, respectively. In 2000, the grain yield increased from 1620 kg ha^{-1} in the zero-Cu check to 2676, 2812, 2697 and 2574 kg ha^{-1} with the foliar application of Cu Fertilizers 5, 6, 7 and 8 at the flag-leaf growth stage, respectively. The Cu Fertilizer 5 also increased grain yield to 2440 kg ha^{-1} with the foliar application at 4-leaf growth stage. When incorporated into soil or placed in seedrow or foliar applied at four-leaf stage, the Cu fertilizers were not effective in correcting Cu deficiency on wheat in 1999 and 2000. In 2001, the grain yield in the zero-Cu check was 1262 kg ha^{-1}. With foliar application, the grain yield increased markedly with Cu Fertilizers 5, 6, 7 and 8 at the flag-leaf growth stage, and with Cu Fertilizers 5, 6 and 7 at the 4-leaf growth stage. With incorporation treatments, the grain yield increased with Cu Fertilizers 1, 2, 3 and 4 at 2 kg Cu ha^{-1}, and with Cu Fertilizers 1 and 2 at 0.5 kg Cu ha^{-1}. Some seedrow Cu placements (Cu Fertilizers 1 and 2 at 1 kg Cu ha^{-1}) also increased grain yield of wheat. In 2002, the grain yield in the zero-Cu check was 334 kg ha^{-1}. With foliar application, the grain yield increased significantly with Cu Fertilizers 5, 6, 7 and 8 at the flag-leaf growth stage, and with Cu Fertilizers 6 at the 4-leaf growth stage. With incorporation treatments, the grain yield increased with Cu Fertilizers 1 and 2 at 2 kg Cu ha^{-1}. Some seedrow Cu placements (Cu Fertilizers 1 at 1 kg Cu ha^{-1}) tended to increase grain yield of wheat. In summary, the results suggest that for immediate correction of Cu deficiency in wheat foliar application of some Cu fertilizers at flag-leaf growth stage can be used, but soil applications of granular Cu fertilizers may take three or more years (depending on soil-climatic conditions and management practices) to prevent any Cu deficiency in wheat on Cu-deficient soils.

Introduction

Copper (Cu) deficiency is often associated with coarse textured soils (Kruger et al. 1985). Wheat is probably the most sensitive cereal to Cu deficiency (McAndrew et al. 1984), and some cultivars of wheat are more affected by Cu deficiency than others. The deficiency of Cu is not wide spread in Saskatchewan, but it can cause a serious reduction in grain yield and quality of wheat when it occurs. Yield response of cereals to Cu fertilization has been investigated in western Canada (Karamanos et al. 1986; Malhi et al. 1989), but information is lacking on the effectiveness of different Cu sources, formulations, methods and times of application for correcting Cu deficiency on wheat.

Lack of Cu has also been associated with increased cereal diseases and wheat is often cited as the most severely affected cereal (Piening, et al. 1989). On the Canadian prairies, stem melanosis of wheat caused by the bacterium *Pseudomonas cichorii* (Swingle) Stapp has been observed (Piening, et al. 1989). Yield losses in wheat from this pathogen have been shown to be high when Cu is not available at adequate levels; and the impact of the pathogen depends on the cultivar of wheat grown. The incidence of other diseases of wheat such as take-all [*Gaeumannomyces graminis*] and powdery mildew have been reduced when copper was added to deficient soils (Wood and Robson 1984; Graham 1980).

Agronomic issues of Cu nutrition have come to the forefront due to recognition of Cu deficiency on some soils in the Prairies and availability of many Cu fertilizer products for soil or foliar application. Unfortunately, management strategies have not been well researched for the Cu fertilizer products that are commercially available. The objective of this study was to determine the relative effectiveness of various sources, formulations, methods, times and rates of Cu fertilizers on the yield, grain quality and diseases of wheat.

Materials and Methods

A 4-year field experiment was initiated in 1999 on a Cu-deficient soil (0.5 mg Cu kg^{-1}) near Porcupine Plain in northeastern Saskatchewan. As wheat had shown severe Cu deficiency in the summer of 1998 at this site, response to Cu application was expected. Each treatment was replicated four times in a RCBD. Individual plots were 1.8 m or 3.6 m x 7.5 m. The test crop was Hard Red spring wheat (cv. AC Barrie). Crop received a blanket annual application of 135 kg N, 50 kg P_2O_5, 25 kg K_2O and 20 kg S ha^{-1}. All the Cu treatments received annual application of Cu fertilizers in 1999, 2000 and 2001.

The treatments included various combinations of Cu fertilizers types (Cu Fert 1 – Cu chelate, granular; Cu Fert 2 – Cu sulphate, granular; Cu Fert 3 – Cu oxysulphate I, granular; Cu Fert 4 – Cu oxysulphate II, granular; Cu Fert 5 – Cu chelate-EDTA, liquid; Cu Fert 6 – Cu sequestered I, liquid; Cu Fert 7 – Cu sulphate/chelate, granular dissolvable; Cu Fert 8 – Cu sequestered II, liquid), formulations (granular, liquid), methods (incorporated, seed-placed, foliar), times (prior to seeding, at seeding, 4-leaf growth stage and flag-leaf growth stage) and rates (0.25, 0.50, 1.00 and 2.00 kg Cu ha^{-1}) of application. In total there were 25 treatments.

Data were recorded on grain yield and disease severity. Disease severity of foliar diseases was determined on 50 plants of each plot using a scale for stem melanosis based on degree of melanism and area of foliage affected (Piening et al. 1989). The grain samples are being analyzed for protein content and total Cu content. The data were subjected to the GLM in SAS and $LSD_{0.05}$ was used to separate the means.

Results and Discussion

In 1999, the wheat crop showed Cu deficiency in the growing season. The grain yield of 1566 kg ha^{-1} was produced in the zero-Cu treatment (Table 1). Substantial and significant increase in grain yield was observed with foliar application of 0.25 kg Cu ha^{-1} at the flag leaf stage as Cu Fert 5, 6 and 7. The grain yield was increased by 73, 64 and 63% from the foliar-flag-leaf stage application of Cu Fert 5, 6 and 7, respectively. Substantial response of wheat grain yield to the three foliar-flag-leaf stage treatments indicated that the crop benefited from Cu application. Lack of response by most soil applied treatments was apparently due the non availability of applied Cu at the time needed by the crop. Lack of yield response to foliar-4leaf-stage was considered due to most fertilizer not being sprayed on the crop but being sprayed on the soil surface from where it may have not been used by the crop.

In 2000, the wheat crop again showed Cu deficiency in the growing season. The grain yield of 1620 kg ha^{-1} was produced in the zero-Cu treatment (Table 2). Substantial and significant increase in grain yield was observed with foliar application of 0.25 kg Cu ha^{-1} at the flag leaf stage as Cu Fert 5, 6, 7 and 8. The grain yield was increased by 65, 74, 66 and 59% from the foliar-flag-leaf stage application of Cu Fert 5, 6, 7 and 8, respectively. Substantial response of wheat grain yield to the four foliar-flag-leaf stage Cu fertilizer treatments indicated that the crop benefited from Cu application. The grain yield also increased with foliar application at 4-leaf growth stage with Cu Fert 5 (not statistically significant), and tended to increase with Cu Fert 6 and 7. Incorporation of Cu Fert 1 at 2.0 kg Cu/ha increased grain yield moderately, but it was not statistically significant. Lack of response by most soil applied treatments was apparently due the non availability of applied Cu at the time needed by the crop.

In 2001, the wheat crop again showed Cu deficiency in the growing season. The grain yield of 1262 kg ha^{-1} was produced in the zero-Cu treatment (Table 3). Significant increase in grain yield was observed with foliar application of 0.25 kg Cu ha^{-1} at the flag leaf stage with Cu Fert 5, 6, 7 and 8. The grain yield was increased by 109, 98, 72 and 92% from the foliar-flag-leaf stage application of Cu Fert 5, 6, 7 and 8, respectively. Marked response of wheat grain yield to the four foliar-flag-leaf stage Cu fertilizer treatments indicated that the crop benefited from Cu application. The grain yield also increased substantially with foliar application at 4-leaf growth stage with Cu Fert 5, 6 and 7. Incorporation of Cu Fert 1 and 2 at 2.0 kg Cu/ha also increased grain yield considerably. The grain yield increased moderately when Cu Fert 1 and 2 were incorporated at 0.5 kg Cu/ha or seedrow placed at 1.0 kg/ha rate. Lack of yield response by many soil applied treatments was apparently due the non availability of applied Cu at the time needed by the crop.

In 2002, there was Cu deficiency observed on the wheat crop in the growing season. The grain yield of 334 kg ha^{-1} was produced in the zero-Cu treatment (Table 4). Because of the drought, grain yields were low in 2002. But, there was significant increase in grain yield with foliar application of 0.25 kg Cu ha^{-1} at the flag leaf stage with Cu Fert 5, 6, 7 and 8. The grain yield was increased by 98, 80, 58 and 99% from the foliar-flag-leaf stage application of Cu Fert 5, 6, 7 and 8, respectively. Marked response of wheat grain yield to the four foliar-flag-leaf stage Cu fertilizer treatments indicated that the crop benefited from Cu application. The grain yield also increased with foliar application at 4-leaf growth stage with Cu Fert 6 and incorporation of Cu Fert 1 and 2 at 2.0 kg Cu/ha. Incorporation of Cu Fert 4 and seedrow placed Cu Fert 1 at 1.0 kg/ha tended to increase grain yield. Lack of yield response by many soil applied treatments was apparently due the non availability of applied Cu at the time needed by the crop.

In summary, the results suggest that for immediate correction of Cu deficiency in wheat foliar application of some Cu fertilizers at flag-leaf growth stage can be used, but soil applications of granular Cu fertilizers may take three or more years (depending on soil-climatic conditions and management practices) to prevent any Cu deficiency in wheat on Cu-deficient soils.

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Table 1. Grain yield of wheat with different sources, rates, times and methods of Cu fertilizer application at Porcupine Plain in 1999 (first year results)

Method of application	Rate of Cu (kg Cu ha^{-1})	Grain yield with different Cu fertilizer treatments (kg ha^{-1})			
		Cu Fert 1	**Cu Fert 2**	**Cu Fert 3**	**Cu Fert 4**
Incorporated	0.5	1567	1680	1523	1467
Incorporated	2.0	1821	1591	1655	1453
Seedrow	0.25	865	1347	1271	1886
Seedrow	1.00	1588	1831	1441	1348
		Cu Fert 5	**Cu Fert 6**	**Cu Fert 7**	**Cu Fert 8**
Foliar - 4-leaf	0.25	1844	1849	1572	1522
Foliar – Flag-leaf	0.25	2709	2571	2555	1343
Control	0	1566			
$LSD_{0.05}$		684			

Table 2. Grain yield of wheat with different sources, rates, times and methods of Cu fertilizer application at Porcupine Plain in 2000 (after two annual applications - second year results)

Method of application	Rate of Cu (kg Cu ha^{-1})	Grain yield with different Cu fertilizer treatments (kg ha^{-1})			
		Cu Fert 1	**Cu Fert 2**	**Cu Fert 3**	**Cu Fert 4**
Incorporated	0.5	1770	1914	1211	1264
Incorporated	2.0	2236	1958	1651	1758
Seedrow	0.25	804	1250	1602	1800
Seedrow	1.00	1801	1898	1252	1424
		Cu Fert 5	**Cu Fert 6**	**Cu Fert 7**	**Cu Fert 8**
Foliar - 4-leaf	0.25	2440	2062	2131	1742
Foliar – Flag-leaf	0.25	2676	2812	2697	2574
Control	0	1620			
$LSD_{0.05}$		959			

Table 3. Grain yield of wheat with different sources, rates, times and methods of Cu fertilizer application at Porcupine Plain in 2001 (after three annual applications - third year results)

Method of application	Rate of Cu (kg Cu ha^{-1})	Grain yield with different Cu fertilizer treatments (kg ha^{-1})			
		Cu Fert 1	**Cu Fert 2**	**Cu Fert 3**	**Cu Fert 4**
Incorporated	0.5	2076	2188	1248	1345
Incorporated	2.0	2724	2823	2049	2299
Seedrow	0.25	815	1336	1404	1838
Seedrow	1.00	2162	2324	1380	1641
		Cu Fert 5	**Cu Fert 6**	**Cu Fert 7**	**Cu Fert 8**
Foliar - 4-leaf	0.25	3016	2861	3003	1866
Foliar – Flag-leaf	0.25	2641	2492	2165	2417
Control	0	1262			
$LSD_{0.05}$		860			

Table 4. Grain yield of wheat with different sources, rates, times and methods of Cu fertilizer application at Porcupine Plain in 2002 (after four annual applications - fourth year results)

Method of application	Rate of Cu (kg Cu ha^{-1})	Grain yield with different Cu fertilizer treatments (kg ha^{-1})			
		Cu Fert 1	**Cu Fert 2**	**Cu Fert 3**	**Cu Fert 4**
Incorporated	0.5	286	362	228	275
Incorporated	2.0	564	601	416	517
Seedrow	0.25	156	220	282	342
Seedrow	1.00	515	419	251	234
		Cu Fert 5	**Cu Fert 6**	**Cu Fert 7**	**Cu Fert 8**
Foliar - 4-leaf	0.25	430	624	450	375
Foliar – Flag-leaf	0.25	663	602	527	664
Control	0	334			
$LSD_{0.05}$		269			