Antagonistic Effect of Copper and Zinc in Spring Wheat Under Low Phosphorus Soil Conditions

Noabur Rahman & Jeff Schoenau

Department of Soil Science, University of Saskatchewan, Saskatoon, SK. Canada

INTRODUCTION

- Copper (Cu) deficiency is the most common micronutrient deficiency on the prairies. Lack of zinc (Zn) can also be a factor in certain soils. Growers may consider applying both Cu and Zn for wheat production (Kruger et al., 1985; Singh et al., 1987).
- Cu and Zn may interact in the plant uptake and redistribution process. There can be strong competition between Cu and Zn for adsorption sites (Cu > Zn). Cu will redistribute Zn to soil solution and plant roots (Alloway, 2008).
- It is purported that insoluble precipitates can result from reactions with P: e.g. insoluble Zn phosphates (Loneragan and Webb, 1993).

OBJECTIVE

- ✓ To assess and understand possible interactions that are involved in "induced deficiency" of micro and macro nutrients as related to fertilization.

MATERIALS AND METHODS

Experimental Approach: *Controlled Environment and Field Studies*

- Three soils in which HRS wheat (Waskada) was grown under controlled environment conditions:
  - Levine Series GLCU.R
  - Waskada Series O.BLC
  - Tisdale association O.DGC

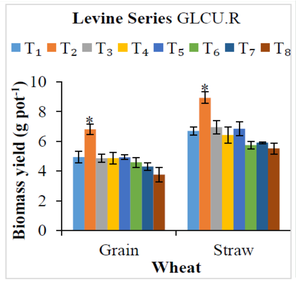
- Field site in south central Saskatchewan:
  - Echo B.SS

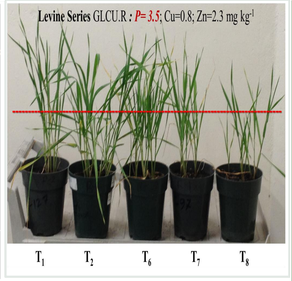
Treatments:

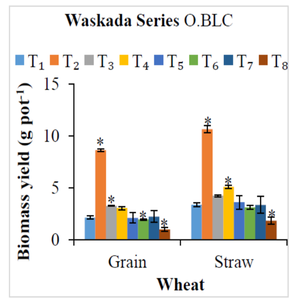
T_1: Control (no micronutrient and no P)
T_2: Control (no micronutrient, but P added to confirm P deficiency)
T_3: Cu @ 2.5 kg ha^{-1}
T_4: Zn @ 2.5 kg ha^{-1}
T_5: Cu+Zn each @ 2.5 kg ha^{-1}
T_6: Cu @ 5 kg ha^{-1}
T_7: Zn @ 5 kg ha^{-1}
T_8: Cu+Zn each @ 5 kg ha^{-1}.

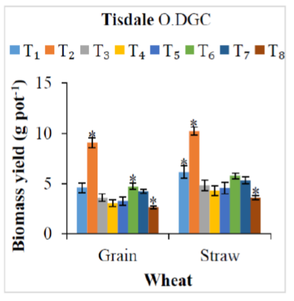
- ➢ Cu & Zn (sulphate salts) solution were applied in soil as band at time of seeding.
- ➢ Experimental design was CRD in phytotron and RCBD at field site. Each treatment was replicated 4 times.

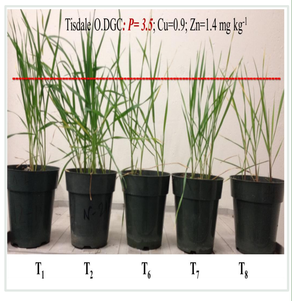
RESULTS AND DISCUSSION











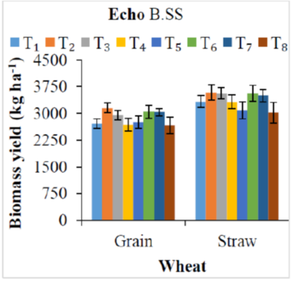


Fig. 1. Effect of Cu and Zn fertilization on wheat grown in soils with low available P. MK-extractable P and DTPA extractable Cu and Zn for each soil are provided at top of photo. Treatment bars with an asterisk (*) for grain or straw yield are significantly different ($p < 0.05$). Error bar represents standard error of mean.

Table. 1. Effect of Cu and Zn fertilization on grain yield of wheat grown on a field catena with a phosphorus fertility gradient (low P: upper slope ⟶ high P: low slope.

Treatment	Block I (upper slope)	Block II (mid slope)	Block III (mid slope)	Block IV (low slope)	Average
	grain yield (kg ha^{-1})				
T_1 (cont.)	2393abc	3068ab	2817a	2608ab	2721a
T_2 (cont. + P)	2692abc	3757a	2950a	3409a	3192a
T_3 (Cu@2.5)	3128a	2481b	3410a	2769ab	2947a
T_4 (Zn@2.5)	3513a	2256b	2870a	2043b	2671a
T_5 (Cu+Zn@2.5)	1967bc	3173ab	3118a	2740ab	2750a
T_6 (Cu@5)	2834b	3103ab	3715a	2522ab	3044a
T_7 (Zn@5)	2762abc	2909ab	3129a	3250a	3013a
T_8 (Cu+Zn@5)	1734c	2223b	3638a	3063ab	2665a
p values	0.0004	0.0025	0.1351	0.0077	0.0621

Table 2. Effect of Cu and Zn fertilization on concentration of Cu, Zn, and P in grain and straw tissue, respectively.

Treatment	*Crop growth condition and Soil type*								
	Control environment						Field		
	Waskada Series O.BLC			Tisdale O.DGC			Echo B.SS		
	Cu	Zn	P	Cu	Zn	P	Cu	Zn	P
	concentration in grain (mg kg^{-1})								
T_1 (cont.)	3.41ab	47.0cd	1795b	4.66b	47.34bc	1770bcd	4.77a	39.3c	4965a
T_2 (cont. + P)	3.07b	39.6d	2165b	4.62b	35.56d	2527a	4.70a	38.3c	5192a
T_3 (Cu@2.5)	4.07ab	74.9ab	2075b	5.51ab	46.86c	1782bc	4.84a	41.4bc	5064a
T_4 (Zn@2.5)	3.31ab	72.4ab	2035b	4.60b	48.65bc	1569cd	4.52a	46.1a	5154a
T_5 (Cu+Zn@2.5)	3.50ab	71.5ab	1935b	5.23ab	49.12bc	1528d	4.55a	45.0ab	4962a
T_6 (Cu@5)	4.02ab	60.2bc	1715b	5.99a	65.80a	1893b	4.73a	37.9c	4917a
T_7 (Zn@5)	3.42ab	75.9ab	1987b	5.46ab	64.05a	1739bcd	4.70a	47.5a	4919a
T_8 (Cu+Zn@5)	4.25a	89.0a	3200a	5.05ab	51.66b	1601cd	4.80a	48.3a	5107a
p values	0.014	<.0001	<.0001	0.0004	<.0001	<.0001	0.053	<.0001	0.214
	concentration in straw (mg kg^{-1})								
T_1 (cont.)	2.25ab	21.8cd	93.5b	4.14a	14.39c	99abc	2.29ab	9.30de	749a
T_2 (cont. + P)	1.79b	8.0d	121.2b	3.90a	2.54d	111ab	2.25ab	8.25e	869a
T_3 (Cu@2.5)	2.64a	61.8ab	103.2b	4.24a	14.90c	72bc	2.48a	11.28cde	852a
T_4 (Zn@2.5)	2.58ab	55.4abc	127.7b	3.30a	17.22bc	72bc	2.42a	17.20ab	937a
T_5 (Cu+Zn@2.5)	2.65a	57.4abc	122.1b	5.25a	22.70bc	65c	2.19ab	16.54abc	845a
T_6 (Cu@5)	2.53ab	27.8bcd	65.7b	4.46a	27.73ab	114a	2.21ab	9.91de	800a
T_7 (Zn@5)	2.27ab	85.4a	121.8b	4.66a	35.72a	92abc	2.00b	13.73bcd	704a
T_8 (Cu+Zn@5)	2.49ab	77.2a	265.5a	5.04a	20.21bc	70bc	2.24ab	19.04a	812a
p values	0.0404	<.0001	<.0001	0.2720	<.0001	0.0016	0.0002	<.0001	0.1749

Table. 3. Effect of Cu and Zn fertilization on Cu, Zn, and P uptake by wheat.

Treatment	*Crop growth condition and Soil type*								
	Control environment						Field		
	Waskada Series O.BLC			Tisdale O.DGC			Echo B.SS		
	Cu (μg pot^{-1})	Zn (μg pot^{-1})	P (μg pot^{-1})	Cu (μg pot^{-1})	Zn (μg pot^{-1})	P (μg pot^{-1})	Cu (g ha^{-1})	Zn (g ha^{-1})	P (kg ha^{-1})
	grain uptake								
T_1 (cont.)	7.3cd	99d	3781bc	21.4bc	209bc	8120bc	13.1a	106b	13.4b
T_2 (cont. + P)	26.4a	342a	18673a	41.7a	321a	22811a	14.8a	121ab	16.3a
T_3 (Cu@2.5)	13.2b	244ab	6754b	19.6bc	168c	6336bcd	14.2a	121ab	14.9ab
T_4 (Zn@2.5)	10.6bc	221bc	6468bc	13.9c	140c	4832d	12.2a	123ab	13.8ab
T_5 (Cu+Zn@2.5)	7.7cd	149bcd	3986bc	17.0c	161c	5021cd	12.3a	121ab	13.8ab
T_6 (Cu@5)	7.8bcd	117cd	3312c	28.3b	319a	8934b	14.4a	112b	15.0ab
T_7 (Zn@5)	9.4bcd	179bcd	4639bc	22.3bc	271ab	7366bcd	14.3a	144a	15.0ab
T_8 (Cu+Zn@5)	4.2d	83d	3093c	13.3c	135c	4209d	12.7a	129ab	13.7ab
p values	<.0001	0.0003	<.0001	<.0001	<.0001	<.0001	0.0529	0.0028	0.0274
	straw uptake								
T_1 (cont.)	7.6cd	73b	314bc	24.9ab	92bcd	749b	7.60ab	30.2bc	2.47a
T_2 (cont. + P)	19.0a	84b	1284a	39.4a	25d	1130a	7.94ab	28.9c	3.02a
T_3 (Cu@2.5)	11.2bc	260ab	437bc	20.6b	71cd	353cd	8.79a	41.5abc	3.13a
T_4 (Zn@2.5)	14.0ab	275ab	649b	14.1b	72cd	308cd	7.99ab	55.2a	3.06a
T_5 (Cu+Zn@2.5)	9.7bcd	209ab	429bc	23.2b	103bc	297cd	6.64b	48.6ab	2.65a
T_6 (Cu@5)	7.8cd	87b	204c	26.1ab	162ab	632bc	7.85ab	29.9bc	2.85a
T_7 (Zn@5)	7.5cd	315a	447bc	24.7ab	190a	495bcd	6.97ab	46.9abc	2.39a
T_8 (Cu+Zn@5)	4.5d	138ab	470bc	17.6b	72cd	253d	6.22b	56.8a	2.37a
p values	<.0001	0.0010	<.0001	0.0017	<.0001	<.0001	0.0011	<.0001	0.0838

- ❖ Significantly higher grain yield of wheat was obtained with P fertilization of the three soils in the controlled environment study (Fig. 1), confirming P deficiency in the soils.
- ❖ Compared to the unfertilized control, there was no significant response to Cu or Zn added alone. However, yield was often lowest where both Cu and Zn were applied together in phytotron soils and in the upper slope positions in the field soil (Fig. 1, Table 1).
- ❖ Adding P fertilizer reduced tissue Zn concentration (Table 2). Cu addition tended to increase plant Zn concentration and uptake (Tables 2 and 3)
- ❖ Apparent antagonistic effect on the growth and yield of wheat from the addition of Cu and Zn without P on low P soils could be explained by reaction of micronutrient with P to form insoluble precipitates. Physiological imbalance of P and Zn in plant tissue is also reported to be associated with disturbance of enzyme function, and might contribute to impaired crop growth and yield (Wissuwa et al., 2006).

CONCLUSION

An observed negative response of wheat to combined addition of copper and zinc under highly P deficient conditions suggests that P limitations should be addressed when addition of these micronutrients is considered. Chemical and spectroscopic speciation analyses is underway to identify possible micronutrient-P reaction products forming in the soils.

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Contact: noabur@gmail.com