Response of Wheat (Triticum aestivum L.) Plant Grown on Light Textured Soil to Copper Foliar Application Under Different Rates of Nitrogen Fertilization

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ABSTRACT

A field experiment was conducted at El-Khashaa – Balteem, Kafr El-Sheikh Governorate, Egypt during two successive growing seasons (2005/2006 and 2006/2007) to investigate the response of wheat (Triticum aestivum L.) variety Sakha 93 to copper application under different levels of nitrogen fertilization grown on copper deficient soil. The experiment was conducted in a split-split plot design with four replicates. Nitrogen fertilization with three N levels (80%, 100% and 120% of the recommended doses: R.D.), the time of Cu application (tillering stage, early boating stage and two split doses at tillering + early boating stages) and Cu foliar spray with two levels 0.5 and 1.0 kg Cu/fed. are used as the main plot, sub-plot and sub-sub-plot, respectively. The obtained results showed that wheat grains yield is high significantly increased with increasing the rate of nitrogen application up to 120% of the recommended dose (120 kg N/fed) and also with increasing the rate of copper application from 0.5 to 1.0 kg Cu /fed. The grains yield was also increased according to the application time of copper as follows: Cu applied in two split doses at tillering + early boating stages > Cu applied at early boating stage >Cu applied at tillering stage. However, the increasing of nitrogen application led to constrain the effect of copper on wheat yield. So that the mean values of the rate of yield increment has decreased with increasing the rate of N application up to 120% of the recommended dose with copper application. Application of 120 % N of R.D. and 1.0 kg Cu/ fed, in two split doses at tillering and early boating stages, resulted the highest grain yields, while the lowest grains yield was obtained in the control (zero copper application) at the lowest rate of nitrogen fertilization (80% of R.D.). However application of 100 % N of R.D. and 1.0 kg Cu/ fed in two split doses at tillering and early boating stages was superior than the application of 120% N of R. D without Cu treatment. The results also showed that wheat straw yield, plant height, spike length and tiller number have the same trend as those of wheat grain yield. Also, N, P, K and protein contents of wheat grains were increased by increasing N levels up to 120% of R. D. It is also clear that N contents of wheat grains were increased with timing of Cu applications in the order: Cu applied in two split doses at tillering + early boating stages> Cu applied at early boating stage ≥ Cu applied at tillering stage, while P and K contents haven't affected by Cu application time.In the same manner, grains N, P and K uptake followed the same trend as that of N, P, K and protein contents (%).

Keywords: Nitrogen, Copper, Application time of copper, Wheat, Protein contents.

INTRODUCTION

Wheat (Triticum aestivum L.) is the main source for bread as a diet for the Egyptian population and wheat straw is considered as an important animal fodder. The country imported about 60% of the total consumption of wheat grains. It is important to increase grains of wheat production to reduce this gap. An important technique to increase wheat production is the efficient use of nitrogen fertilization as well as Cu application.

Nitrogen is most often limiting wheat production. Adequate nitrogen fertilization is necessary to produce high yield and increase its quality (protein content of grains). High levels of protein are important for superior wheat flour milling and baking characteristics. Nitrogen availability plays a key role in determining tiller number, kernel number and kernel size in the wheat plant. Proper wheat fertilization normally have a protein content greater than 14 percent (Franzen and Goos, 1997).

Copper is an essential nutrient required for the normal growth and development of cereal crops. Chlorophyll production, protein synthesis and respiration are important plant functions that need copper. About 70 percent of the copper in plants are found in the chlorophyll. A copper deficiency can result in early aging or lowered levels of chlorophyll, which leads to yield reductions. Copper is necessary for the formation of hemoglobin and also help keep bones, blood vessels, and nerves healthy. Cereal species vary in their sensitivity to copper deficiency. The usual order of sensitivity is: winter wheat> spring wheat> barley> oats> triticale> rye (Solberg et al.,1995).Copper deficiency in cereals produces characteristic symptoms that may be similar for these species. However, crops growing on marginally copper deficient soils may have losses of 20 percent or more in grains yield while not showing visual symptoms of a deficiency. Copper deficiency should be correctly diagnosed before copper fertilizer is applied. The results of a soil test are a much better predictor of the need for Cu in a fertilizer program (Rehm and Schmitt, 1997).

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On Cu-deficient soils, symptoms generally occur in irregular patches. Deficiency is often first noticed on wheat as "stem melanosis". This is a browning discoloration of wheat associated with reduced yields and ergot infestations (Solberg et al., 1995). In order to correct Cu deficiency, copper-containing fertilizers have to be applied either to the soil or directly to the plants as foliar spray. Foliar spray is more effective than soil application, particularly under low rainfall condition.Application of high nitrogen levels delays the translocation of copper from older leaves to the growing points (i.e., head development), significantly enhancing copper deficiency. High levels of phosphorous, zinc, iron, manganese and aluminum may also restrict copper absorption by cereal roots (Srivastava and Gupta, 1996).Yield responses to copper application have been thought to be mostly associated with organic soils (Kubota and Alloway, 1972). Canadian research on barley and spring wheat showed yield responses with copper application on mineral soils, mostly with low organic matter content (Karamanos et al., 1986). Because many soils in Egypt fit into this category, the current study aimed to investigate the response of wheat grains grown on light textured soil to copper foliar fertilization under different levels of nitrogen fertilization.

MATERIALS AND METHODS

Experimental layout

A field experiment was conducted, at El-Khashaa – Balteem, Kafr El-Sheikh Governorate, Egypt during two successive seasons 2005/2006 and 2006/2007. The experimental layout was a split-split plot design with four replicates. The main plot was assigned to N fertilization with three N levels: 80%, 100% and 120% of the recommended dose (120 kg N/fed), while the subplot was the time of Cu application (the tillering stage: T_1, early boating stage: T_2 and two split doses at tillering + early boating stages: T_3) and the sub-sub plot was Cu foliar spray with two levels of applied copper as copper sulfate ($CuSO_4.5H_2O$) at a rate of 0.5 and 1.0 kg/fed as Cu1 and Cu2, respectively. The copper treatment contained less than 0.4 Kg/fed. sulfur as a companion ion. Crop responses to applied sulfur are not seen until sulfur rates exceed 4 Kg/fed., It was, therefore, not necessary to include a sulfur application to the check plots. The area of each plot was 5 X 8 square meter.

Wheat grains (Triticum aestivum L.) Sakha 93. at a rate of 60 kg/fed were sown. Other agricultural practices were applied according to recommendation of Ministry of Agriculture and Land Reclamation. The grain and straw were collected after maturity from each and their weights were measured at 15% moisture content. Grain samples were washed by tap water then by distilled water, oven dried at 70^0C for 48 hours ground in a stainless steel mill and then wet digested according to the method described by Jackson (1967).

Total nitrogen in the digests was determined using the MicroKjeldahl method as described by Jackson (1967). Phosphorus was determined using the calorimetric method (Jackson, 1967). Potassium was determined by using flame photometer (Jackson, 1967).

Soil samples (0-30 cm) were taken from the experimental site and analyzed before planting. Electrical Conductivity (EC) was determined according to Chapman and Pratt (1961) Soil reaction (pH), total calcium carbonate and organic matter were determined according to Cottenie et al. (1982a). Mechanical analysis was carried out by Pipette method (Piper, 1950). Available phosphorus was extracted using sodium bicarbonate according to Olsen et al. (1954) and then colorimetrically determined using Spectrophotometer (Jackson (1967). Available potassium was determined by using flame photometer in the ammonium acetate extract, (Jackson, 1967). Available copper was determined using Atomic Absorption Spectrometry in the DTPA extract, according to Lindsay and Norvell (1978). The soil analysis data for the experimental site are presented in Table (1). The data obtained were statically analyzed according to Cochran and Cox (1962).

RESULTS AND DISCUSSION

Table(1) showed that the organic matter content of the soil of the experiment was low (1.1 %)and the soil is considered copper deficient whereas the level of Cu in the soil was 0.48 ppm and critical level of soil Cu deficiency using 0.005 M DTPA (pH 7.3) extractant fall

Table1. Some chemical and physical properties of the soil surface layer (0-30 cm) before planting

pH* 1:2.5	EC** dS/m/25^{0}C	O.M %	Total Carbonate %	Available nutrients mg/kg				Clay %	Silt %	Sand %	Texture
				N	P	K	Cu				
7.9	1.85	1.1	1.54	10	15	518	0.48	18.3	35.8	45.9	Sandy loam

* Measured in 1 : 2.5 soil water suspension, ** Measured in soil saturated water extract.

in the range of 0.40 - 0.66 ppm as cited by Karamanos et al. (1986) and Sakal et al. (1984a).

I) Effect of N fertilization on wheat yield and its components:

Table(2) showed that the wheat yield and its components: (grains and straw yield, plant height, spike length and tillers number) are high significantly increased with increasing the rate of nitrogen applied up to 120% of the recommended dose (R.D.) during the two growing seasons.The increment rates of grains yield under 120% N of (R.D.) were 12.95% and 12.17% compared to 100% N of (R.D.) in the first and second growing seasons, respectively. However, the corresponding values of the rates of grain yield decrement under 80% N of (R.D.) are 20.80% and 21.77% % compared to 100% N of (R.D.) in the first and second growing seasons, respectively. These result agreed with those obtained by Sabry et al. (1999), El-Desouqi (2000) Muhammad (2001), Maqsood et al. (2002) and Megahed. (2005).

II) Effect of application time of copper:

Table(2) showed that wheat yield and its components are highly significantly affected by the application time of copper. These are increased in the following order: Cu applied in two split doses at tillering and early boating stages> Cu applied at early boating stage≥ Cu applied at tillering stage, at both the two rates of Cu application (0.5, 1.0 kg Cu /fed.). This points out that the critical period in copper-deficient plants is the early booting stage (Marschner, 1997). These results agree with those reported by Grundon (1980).

III) Effect of copper application on wheat yield and its components:

Table(2) showed that wheat yield and its components are highly significantly increased as the rate of copper application was increased up to 1 kg Cu /fed. This could be attributer to that copper had enhanced chlorophyll synthesis, which led to yield increase (Solberg et al.,1995). The grains yields in the first season increased by 14.58 and 24.94 % as compared with the control (zero Cu kg/fed.) for 0.5 and 1.0 kg Cu/fed. application, respectively. The corresponding values were 15.95% and 28.47% in the second season. These results were agreed with those of Grundon (1980).

IV) Interactions effect between different treatment on wheat grains yield:

Table(3) showed that application of 120 % N of R.D. and 1kg Cu/ fed. in two split doses at tillering and early boating stages resulted in the highest grains yields (21.31 & 21.63 ardab/fed. in the 1st and 2nd seasons, respectively). However, the lowest grains yields (11.20 & 11.05 ardab/fed. for the two seasons, respectively) were obtained in the control (zero cu) and at the lowest rate of nitrogen fertilization (80% of R.D.).

Table(3) illustrates that increasing the rate of nitrogen application led to decrease the stimulating effect of copper application on grains yield. In other words, the mean values of the relative yield increment are decreased with increasing the rate of N application up to 120% of R.D. This could be attributed to that, application of high nitrogen levels accentuates Cu deficiency in plants because of increasing the plant growth increased plant requirements for Cu (Srivastava and Gupta, 1996). This can be also due to that high application of nitrogen would delay the translocation of copper from older leaves to the growing points (i.e., head development) by promoting the organic N compound levels in leaves that may bind Cu and also by delaying senescence of older leaves, which could significantly enhancing copper deficiency (Srivastava and Gupta, 1996).

Table(3) showed that application of 100% N of R.D. and 1 Kg Cu/fed. in two split doses at tillering and early boating stages was superior to the application of 120% N of R.D. without Cu by about 14.98% and 16.11% in the two seasons, respectively.

IV) Effect of N and Cu application on N, P, K and protein contents (%) and N, P & K uptakes of wheat grains (kg/fed.):

Table(4) showed that N, P, K and protein contents of wheat grains are increased by increasing N application up to 120% of R.D. These results agree with those reported by Mohammadi et al. (1991), El-Sherbieny et al. (1999), El-Beyli et al. (2000), Staggenborg et al. (2003) and Megahed (2005). Moreover, N and protein contents are affected by timing of Cu application where they are increased in the following order: Cu applied in two split doses at tillering and early boating stages> Cu applied at early boating stag ≥ Cu applied at tillering stage> Cu 0, within each treatment. However, P and K contents were not affected by Cu time of application. Grains uptake of N, P and K followed the same trend as those of N, P, K and protein contents.

Table 2. Effect of copper application on wheat yield and its components under different levels of nitrogen fertilization in the two seasons

Treatment			Grains yield (ardab/fed)		Staw yield (ton/fed)		Plant height (cm)		Spike length (cm)		Tiller number	
			1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
N % of R.D.	**N1**		12.942	13.021	2.421	2.369	89.649	88.278	9.681	9.778	8.00	7.917
	N2		16.341	16.644	2.866	2.874	98.322	98.181	10.861	10.917	10.028	10.028
	N3		18.457	18.670	3.283	3.235	103.667	103.417	11.444	11.458	10.861	10.906
	F-test		**	**	**	**	**	**	**	**	**	**
	LSD	**0.05**	0.193	0.162	0.059	0.048	0.337	0.322	0.211	0.206	0.401	0.279
		0.01	0.293	0.246	0.089	0.073	0.511	0.488	0.319	0.312	0.608	0.423
Timing (T)	**T1**		15.441	15.593	2.743	2.699	95.771	95.458	10.236	10.319	9.194	9.139
	T2		15.645	15.948	2.782	2.773	96.769	96.208	10.556	10.583	9.389	9.306
	T3		16.653	16.794	3.044	3.006	99.097	98.208	11.194	11.250	10.306	10.306
	F-test		**	**	**	**	**	**	**	**	**	**
	LSD	**0.05**	0.136	0.110	0.037	0.026	0.268	0.257	0.116	0.139	0.196	0.170
		0.01	0.187	0.150	0.051	0.036	0.367	0.352	0.159	0.190	0.269	0.232
Copper (Cu)	**Cu0**		14.061	14.034	2.528	2.498	91.280	90.306	8.833	8.792	7.417	7.667
	Cu1		16.111	16.272	2.866	2.834	98.165	97.569	10.958	11.069	10.250	10.111
	Cu2		17.568	18.029	3.176	3.146	102.192	102.625	12.194	12.292	11.222	10.972
	F-test		**	**	**	**	**	**	**	**	**	**
	LSD	**0.05**	0.161	0.151	0.034	0.037	0.326	0.308	0.167	0.188	0.236	0.232
		0.01	0.214	0.201	0.045	0.049	0.434	0.410	0.223	0.251	0.315	0.309
Interaction	**N X Cu**		**	**	**	**	**	**	ns	ns	ns	*
	N X T		ns	ns	ns	**	ns	**	ns	ns	ns	*
	Cu X T		**	**	**	**	**	**	**	**	**	**
	N X Cu X T		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

N1: 80% N of the recommended dose (R.D.). **T1:** Tillering stage. **Cu0:** 0 kg Cu /fed.

N2: 100% N of the recommended dose (R.D.). **T2:** early boating stage. **Cu1:** 0.5 kg Cu /fed.

N1: 120% N of the recommended dose (R.D.). **T3:** Tillering + early boating stages. **Cu2:** 1 kg Cu /fed.

Table 3. Effect of copper application on wheat grains yield (ardab/fed.) under different levels of nitrogen fertilization (two seasons)

N % of R.D.	Application time	Copper treatment	First season		Second season	
			Grains yield (ardab/fed.)	Relative increase %	Grains yield (ardab/fed.)	Relative increase %
80 %	Tillering	Cu0	11.20	00.00	11.05	00.00
		Cu1	12.77	14.02	12.81	15.93
		Cu2	13.72	22.50	13.82	25.07
	Early boating	Cu1	13.08	16.79	13.21	19.55
		Cu2	13.74	22.68	14.23	28.78
	Tillering+ early boating	Cu1	14.10	25.89	14.12	27.78
		Cu2	15.53	38.66	15.85	43.44
	Mean		13.45	20.08	13.58	22.93
100 %	Tillering	Cu0	14.31	00.00	14.40	00.00
		Cu1	15.80	10.41	16.15	12.15
		Cu2	17.47	22.08	18.08	25.56
	Early boating	Cu1	16.06	12.23	16.34	13.47
		Cu2	17.73	23.90	18.68	29.72
	Tillering+ early boating	Cu1	17.48	22.15	17.50	21.53
		Cu2	19.62	37.11	19.86	37.92
	Mean		16.92	18.27	17.29	20.05
120 %	Tillering	Cu0	16.68	00.00	16.66	00.00
		Cu1	17.84	06.95	17.80	06.84
		Cu2	19.19	15.05	19.58	17.53
	Early boating	Cu1	18.22	9.23	18.43	10.62
		Cu2	19.81	18.76	20.54	23.29
	Tillering+ early boating	Cu1	19.71	18.17	20.09	20.59
		Cu2	21.31	27.76	21.63	29.83
	Mean		18.97	13.70	19.25	15.53

Cu0: 0 kg Cu /fed. Cu1: 0.5 kg Cu /fed. Cu2: 1 kg Cu /fed.

Table 4. Effect of copper application under different rates of N application on N, P and K contents and protein content of wheat grains (After the second season)

N % of R.D.	Application time	Copper treatment	N content %	Grains uptake of N (kg/fed)	Protein content %	P content %	Grains uptake of P (kg/fed)	K content %	Grains uptake of K (kg/fed)
80 %		Cu0	1.00	16.58	6.25	0.32	5.30	0.54	8.95
	Tillering	Cu1	1.21	23.25	7.56	0.30	5.76	0.52	9.99
		Cu2	1.26	26.12	7.88	0.31	6.43	0.42	8.71
	Early boating	Cu1	1.22	24.17	7.63	0.31	6.14	0.50	9.91
		Cu2	1.30	27.75	8.13	0.30	6.40	0.51	10.89
	Tillering+ early boating	Cu1	1.33	28.17	8.31	0.30	6.35	0.42	8.90
		Cu2	1.36	32.33	8.50	0.31	7.37	0.49	11.65
	Mean		1.24	25.48	7.75	0.31	6.25	0.49	9.86
100 %		Cu0	1.39	30.02	8.69	0.38	8.21	0.63	13.61
	Tillering	Cu1	1.51	36.58	9.44	0.41	9.93	0.62	15.02
		Cu2	1.59	43.12	9.94	0.43	11.66	0.63	17.09
	Early boating	Cu1	1.52	37.26	9.50	0.37	9.07	0.65	15.93
		Cu2	1.62	45.39	10.13	0.42	11.77	0.67	18.77
	Tillering+ early boating	Cu1	1.62	42.53	10.13	0.40	10.50	0.66	17.33
		Cu2	1.81	53.92	11.31	0.40	11.92	0.67	19.96
	Mean		1.58	41.26	9.88	0.40	10.44	0.65	16.81
120 %		Cu0	1.83	45.73	11.44	0.46	11.50	0.79	19.74
	Tillering	Cu1	1.92	51.26	12.00	0.49	13.08	0.78	20.83
		Cu2	1.99	58.45	12.44	0.50	14.69	0.75	22.03
	Early boating	Cu1	2.08	57.50	13.00	0.48	13.27	0.79	21.84
		Cu2	2.16	66.55	13.50	0.47	14.48	0.74	22.80
	Tillering+ early boating	Cu1	2.31	69.61	14.44	0.47	14.16	0.83	25.01
		Cu2	2.37	76.89	14.81	0.49	15.90	0.88	28.55
	Mean		2.09	60.86	13.09	0.48	13.87	0.79	22.97

Cu0: 0 kg Cu /fed. Cu1: 0.5 kg Cu /fed. Cu2: 1 kg Cu /fed.

CONCLUSION

Foliar application of 1 kg/fed. of copper as $CuSO_4.5H_2O$ into two split doses, at tillering and early boating stages of wheat plants grown on copper deficient soils increased the over all yield under efficient use of nitrogen fertilization. Also, with foliar application of cupper, the nitrogen application rate could be decreased by about 20% without significant decrease in grains yield.

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الملخص العربي

استجابة القمح النامي في ارض خفيفة القوام لإضافة النحاس رشاً تحت معدلات مختلفة من التسميد النيتروجيني

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أقيمت تجربة حقلية بمنطقة الخاشعة - بلطيم بمحافظة كفر الشيخ – مصر خلال الموسمين الزراعيين 2006/2007- 2005/2006 علي محصول القمح (*Triticum aestivum L.*) صنف سخا 93 لدراسة استجابته للرش بالنحاس تحت مستويات مختلفة من التسميد النيتروجيني. و قد أجريت التجربة باستخدام تصميم القطع المنشقة ثنائيا في أربع مكررات. وكانت المعاملات المستخدمة هي التسميد النيتروجيني بثلاثة مستويات(80%و100%و120%) من الجرعة الموصى بها وهى 120 كجم /فدان بالنسبة للأراضي خفيفة القوام), وميعاد رش النحاس في ثلاثة مواعيد (في مرحلة التفريع، مرحلة ما قبل طرد السنابل ثم على دفعتين في مرحلتي التفريع و ما قبل طرد السنابل) ثم إضافة النحاس رشا بمستويين (0.5و1.0كجم نحاس/فدان). وزعت المعاملات علي القطع الرئيسية والمنشقة والمنشقة ثنائيا علي الترتيب.

من أهم النتائج المتحصل عليها:

زاد محصول الحبوب زيادة معنوية بزيادة معدلات التسميد النيتروجيني حتى 120% من الموصي به و كذلك بزيادة إضافة النحاس رشا من 0.5 إلى 1 كجم/فدان. أيضا زاد محصول الحبوب زيادة معنوية طبقا لميعاد إضافة النحاس حسب الترتيب التالي: إضافة عنصر النحاس على دفعتين في مرحلتي التفريع و ما قبل طرد السنابل > مرحلة ما قبل طرد السنابل > مرحلة التفريع. بينما أدت إضافة معدلات عالية من التسميد النيتروجيني إلى تقييد التأثير المحفز للنحاس على زيادة المحصول، بمعني أن متوسط قيم معدلات زيادة محصول القمح نتيجة إضافة النحاس كانت أقل عند المستويات العالية من التسميد النيتروجين.

أدت إضافة 120% من التسميد النيتروجينى الموصى به ورش 1كجم/فدان من النحاس على دفعتين في مرحلتي التفريع وما قبل طرد السنابل إلى الحصول على اعلي محصول من الحبوب بنما كانت اقل قيمة للمحصول عند إضافة 80% نيتروجين الموصى به بدون إضافة نحاس. تفوق إنتاج الحبوب تحت إضافة100% نتروجين من الموصى به ورش 1كجم/فدان من النحاس على دفعتين في مرحلتي التفريع وما قبل طرد السنابل على إضافة120%نيتروجين من الموصى به بدون نحاس. اخذ محصول القش وطول النبات وطول السنبلة وعدد الأفرع نفس اتجاه محصول القمح في تأثره بالمعاملات المختلفة. أيضا زاد محتوي النبات من النتروجين والفسفور والبوتاسيوم والبروتين زيادة معنوية بزيادة معدلات التسميد النيتروجيني حتى 120%من الموصي به. ومن الملاحظ زيادة تركيز النتروجين في الحبوب طبقا لميعاد إضافة النحاس حسب الترتيب التالي: إضافة عنصر النحاس على دفعتين في مرحلتي التفريع و ما قبل طرد السنابل > مرحلة ما قبل طرد السنابل ≤ مرحلة التفريع بينما لم يتأثر تركيز عنصري الفسفور والبوتاسيوم. اخذ محتوى النبات من النيتروجين والفوسفور والبوتاسيوم نفس اتجاه تركيز النيتروجين والفوسفور والبوتاسيوم في الحبوب.

الخلاصة: يمكن الحصول على اعلى انتاج من محصول الحبوب برش النحاس في صورة كبريتات نحاس بمعدل 1كجم للفدان على دفعتين في مرحلتي التفريع وما قبل طرد السنابل لنبات القمح المنزرع في تربة خفيفة القوام فقيرة في النحاس مع اضافة الموصى بة من التسميد النتروجينى. يمكن تقليل20% من النيتروجين باضافة النحاس رشا دون أن يحدث نقص معنوي في محصول الحبوب.