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The Impact of Copper Tetramine Hydroxide Treatments on Wheat Yield

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Although much research has been carried out related to the role of trace elements in plant nutrition a lot of facts are still to be discovered. Intensive crop production and the partial replacement of nutrients often lead to nutrient imbalances and deficiencies (CSATHÓ, 1994). Nutritional anomalies frequently result in reduced yield and poor product quality. Many interactions occurring among nutrients make the question even more complex. That is the reason why the cycling and replacement requirements for the three major nutrients (N, P, K) are estimated with more or less accuracy (KÁDÁR, 1987). This estimation is more difficult in the case of trace elements where the number of interactions in plant and soil is much larger. According to national and FAO studies the available copper content of Hungarian soils is low on a considerable proportion of the arable land (SILLANPÄÄ, 1982; FEKETE & PATÓCS, 1988).

Copper, among other metal ions, plays an important role in the regulation and promotion of essential biochemical reactions taking place in plant cells. Copper requirement is especially expressed in the case of cereals (KUDUK, 1988; SZAKÁL, 1987). In lack of copper the protein synthesis, the N uptake of cereals is hindered (KÁDÁR & SHALABY, 1984, 1985; SZAKÁL & BARKÓCZY, 1988; ERCAN & VELIOGLU, 1990). The missing trace elements can be replaced through the soil or by foliar application. Although trace elements given through the soil contribute to problem solving in a more basic way, in many cases foliar application offers the only possibility for eliminating the deficiencies (SZAKÁL, 1987). GRAHAM (1976) – applying copper sulphate for copper fertilization of wheat in the form of soil and foliar treatments – experienced that foliar fertilization performed better. The best application time was at the tillering phenological phase, which was applied in our experiments too.

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Material and Methods

Three years' experimental results are reported in present publication about the effect of copper tetramine hydroxide complex on the yield of winter wheat cultivar Mv-14. The copper tetramine hydroxide was prepared from microelectronical copper waste as a secondary raw material plant nutrient (SZAKÁL & SCHMIDT, 1996; SCHMIDT et al., 2000).

The experiment was set up in randomized block design with four replications. The size of the experimental plots was 10 m² in 1991, 1992, and 12.5 m² in 1988. The experiment was carried out at the experimental site of the University of West Hungary on Danube alluvial soil in 1988 and 1992 and on peat soil in 1991. Soil samples were collected from each plot before starting the experiment. The soil could be considered homogeneous, so average soil nutrient contents are presented in Table 1. Wheat seeds were sown with a Wintersteiger plot drill and yields were harvested with a Wintersteiger plot harvester.

Treatments were applied at two phenological phases: at the end of tillering and at flowering with 0.1; 0.3; 0.5; 1.0 and 2.0 kg ha^{-1} copper doses respectively. Present publication evaluates the results of the treatments carried out at the tillering phenological phase. Spraying was done with 0.6 liter 10 m^{-2} water solution of copper amine complex, prepared according to SCHMIDT et al. (2000). The control plots were treated with the respective amount of N contained by the copper amine complex in the form of NH_4NO_3 solution. A water sprayed control was also applied. As no significant difference was found between the results measured in the water and N controls, these plots were treated uniformly as controls afterwards.

The results were evaluated by ANOVA and regression analysis.

Table 1
The nutrient content of the experimental soils

Parameter	Danube alluvial Fluvisol 1988	Peat Histosol 1991	Danube alluvial Fluvisol 1992
pH(KCl)	7.6	6.9	7.3
K_A	41.0	43.0	43.0
$CaCO_3$ %	16.0	3.4	12.5
Humus %	2.6	3.5	3.2
ALP_2O_5 mg kg^{-1}	285.0	282.0	291.0
AL-K_2O mg kg^{-1}	215.0	230.0	226.0
AL-Mg mg kg^{-1}	282.0	209.0	257.0
AL-Na mg kg^{-1}	84.0	53.0	61.0
EDTA-Zn mg kg^{-1}	4.3	2.3	3.7
EDTA-Cu mg kg^{-1}	2.1	2.5	3.4

K_A = Upper limit of plasticity according to Arany; AL = ammonium lactate extraction

Results and Discussion

Winter wheat yield

Due to the copper treatments the yield increases (Table 2) and the increase is significant at the 5% probability level (Table 3). The 2 kg ha^{-1} copper dose had a slight depressive effect and the yield decreased in all three experimental years. The coefficient of variation is slightly high, which shows the effect of environmental factors having a strong influence on yield components and yield. The treatments influenced the yield in the same way in all experimental years that is underlined by the fact that the "Treatment x Year" relationship is not significant (Table 3).

Table 2

The yield of winter wheat (kg m^{-2}) in the copper treatments

Treatment Cu kg ha^{-1}	1988	1991	1992	Average	CV%
0	0.75	0.52	0.62	0.63	18.31
0.1	0.76	0.55	0.62	0.64	16.62
0.3	0.78	0.59	0.60	0.66	16.28
0.5	0.81	0.60	0.63	0.68	16.70
1	0.82	0.61	0.64	0.69	16.46
2	0.73	0.57	0.61	0.64	13.08
$LSD_{5\%}$	0.092	0.035	0.047	0.04	

Table 3

Table of variance (Yield)

Source	SQ	dF	Mean squares	F	Sign
Total	0.1466	17			
Year	0.1337	2			
Treatment	0.0088	5	0.0018	4.35	*
Treatment x year	0.0041	10	0.0004	0.93	NS
Error	-	45	0.0004		

A regression analysis was carried out to determine the relationship between copper doses and yield. The changes in yield due to the application of copper can be described by a quadratic equation that is significant at 5% probability level (Figure 1). The curve also displays that the 2 kg ha^{-1} copper dose already had a yield reducing effect. The calculated maximum of the curve is at 1.04 kg ha^{-1} copper dose with 0.692 kg m^{-1} yield.

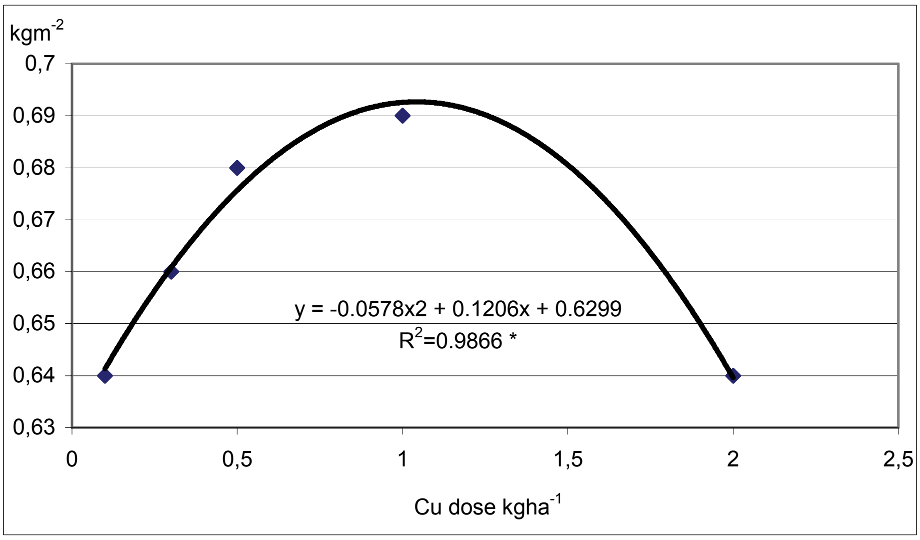

Figure 1
The relationship between the yield of winter wheat and the copper doses, three years' average

Kernel weight

Kernel weight also increases due to the application of the copper complex (Table 4). It seems to be a general rule that the 2 kg ha^{-1} copper dose has a slightly depressive effect and decreases kernel weight, too. In terms of this parameter, it can also be established that there is a marked variation between the experimental years. The variation of coefficient values (CV%) shows a balanced effect with the exception of the 2 kg ha^{-1} copper dose. That is why we carried out the analysis of variance by both including and omitting the 2 kg ha^{-1} copper dose. The differences can be seen in Tables 5 and 6, indicating that when the 2 kg ha^{-1} treatment is included the effect is non-significant, but a sig-

Table 4
The 1000 kernel weight of winter wheat (g) in the copper treatments

Treatment Cu kg ha^{-1}	1988	1991	1992	Average	CV%
0	33.00	37.46	43.20	37.89	13.50
0.1	33.08	37.88	43.93	38.30	14.20
0.3	34.00	37.37	44.28	38.55	13.59
0.5	34.30	38.00	44.30	38.87	13.01
1	34.40	37.95	44.30	38.88	12.90
2	29.20	36.75	43.75	36.57	19.90
$LSD_{5\%}$	1.09	1.04	1.23	1.87	

nificant difference was proven in the "Treatment x Year" interaction. When the evaluation is carried out without the 2 kg ha^{-1} copper dose the "Treatment x Year" interaction is not significant but there is an effect proven at 5% probability level regarding the treatments.

Table 5

Table of variance of the kernel weight (2 kg ha^{-1} copper dose included)

Source	SQ	dF	Mean square	F	Sign.
Total	385.0988	17			
Year	363.8964	2			
Treatment	11.4163	5	2.2833	2.33	NS
Treatment x year	9.7861	10	0.9786	7.04	***
Error	-	45	0.1390		

Table 6

Table of variance of the kernel weight (2 kg ha^{-1} copper dose not included)

Source	SQ	dF	Mean square	F	Sign.
Total	269.8849	14			
Year	266.8367	2			
Treatment	2.1041	4	0.5260	4.46	*
Treatment x year	0.9442	8	0.1180	0.85	NS
Error	-	45	0.1390		

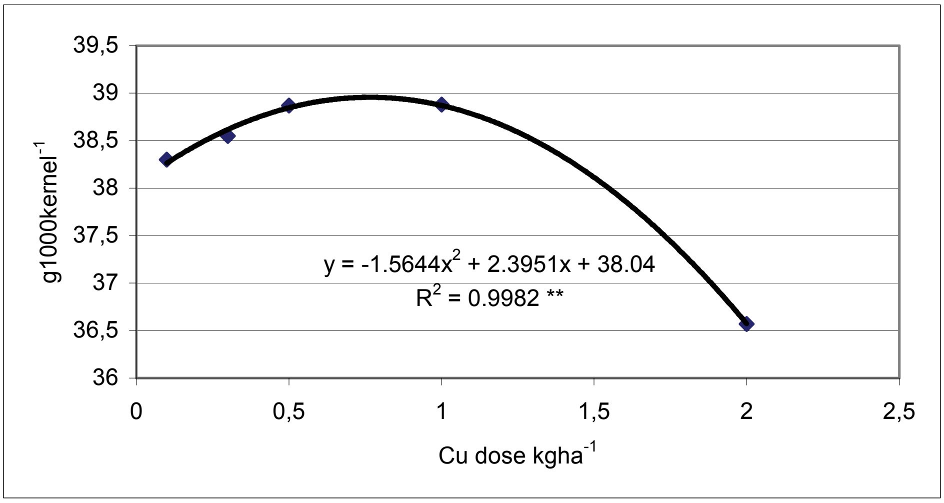

Figure 2

The relationship between kernel weight and copper treatments, three years' average (the 2 kg ha^{-1} copper dose included)

A regression analysis was also made to examine the relationship between copper application and the changes in the 1000 kernel weight (Figures 2 and 3). The curves look a bit different, depending on the inclusion or exclusion of the 2 kg ha^{-1} copper dose. In spite of the different appearance of the curves the calculated values are almost the same. The calculated maximum is at the 0.77 kg ha^{-1} (Figure 2) and at the 0.79 kg ha^{-1} (Figure 3) copper dose, respectively. There is practically no difference in the calculated maximum 1000 kernel weight values: 38.95 g (Figure 2) and 38.947 g (Figure 3), respectively.

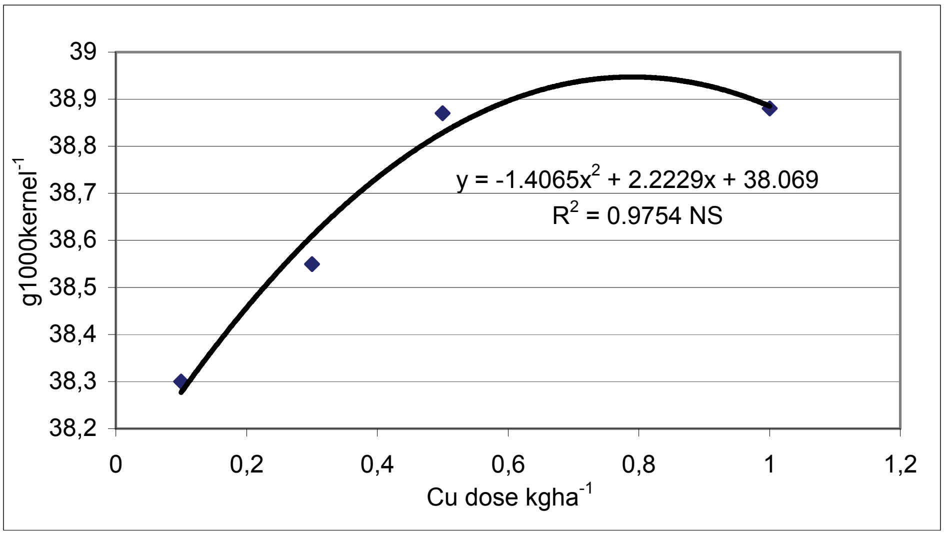

Figure 3
The relationship between kernel weight and copper treatments, three years' average (the 2 $kgha^{-1}$ copper dose not included)

Raw protein

The application of copper markedly increased the raw protein content of winter wheat (Table 7). The effect is significant at the 0.1% probability level (Table 8). Due to environmental factors the raw protein content varies according to years, but the CV values still indicate a quite balanced effect. The 2 kg ha^{-1} copper dose, in a variable extent, but decreased the raw protein content of wheat.

The relationship between copper doses and the raw protein content of wheat can be described by a quadratic regression curve (Figure 4). The calculated maximum of the regression curve is at the 1.12 kg ha^{-1} copper dose and equals 13.28 % raw protein content.

Table 7
The raw protein content of winter wheat (%) due to the copper treatments

Treatment Cu kg ha^{-1}	1988	1991	1992	Average	CV%
0	13.20	11.00	12.85	12.35	9.57
0.1	13.43	11.20	12.95	12.53	9.37
0.3	13.60	11.35	13.53	12.83	9.97
0.5	13.93	11.60	13.58	13.04	9.64
1	14.13	11.90	13.73	13.25	8.97
2	13.49	11.18	13.58	12.75	10.67
$LSD_{5\%}$	0.65	0.54	0.4	0.25	

Table 8
Table of variance of the raw protein content

Source	SQ	dF	Mean square	F	Sign.
Total	20,1337	17	17		
Year	18,3220	2	2		
Treatment	1,6242	5	5	17,33	***
Treatment x year	0,1875	10	10	0,58	NS
Error	-	45	45		

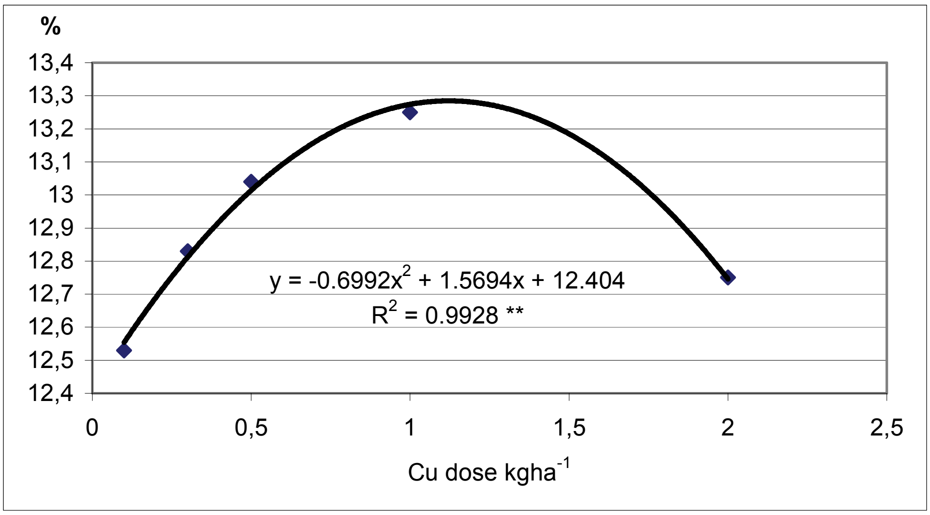

Figure 4
The relationship between the raw protein content of winter wheat and copper treatments, three years' average

Summary

Authors studied the effect of copper nutrition on the yield, kernel weight and raw protein content of winter wheat. Copper was applied in the form of copper tetramine hydroxide that was produced from a clean copper containing waste originating from microelectronical industry. After suitable chemical transformation this waste can be used as an excellent secondary raw material for the preparation of copper fertilizer. The foliar application of copper tetramine hydroxide complex at the phenological phase of tillering significantly increased the yield, kernel weight and raw protein content of winter wheat. The calculated copper doses that gave the maximum yield, raw protein content and kernel weight were 1.04, 1.12 and 0.77 kg ha^{-1} respectively.

Key words: winter wheat, copper, yield, kernel weight, raw protein content

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