

SHORT COMMUNICATION

Effect of an industrial chemical waste on the uptake of cations by green oat

HORTENSIA RADULESCU¹, LIDIA TAUBERT^{2*}, SÁNDOR A. KISS³, ECATERINA PRINCZ² and ÉVA STEFANOVITS-BÁNYAI⁴

¹Banat's University of Agricultural Sciences and Veterinary Medicine Timisoara, Faculty of Agriculture, Calea Aradului 119, 300645-Timisoara, Romania ²Chemistry Institute Timisoara of the Romanian Academy, Inorganic Chemistry Department, Bd. M. Viteazu 24, 300223-Timisoara, P. O. Box 5/612, Romania, ³Hungarian Magnesium Society, Főfasor 73A/2, H - 6726 Szeged, Hungary and ⁴Corvinus University, Faculty of Food Science, Villányi str., Budapest, Hungary (e-mail: lidiat@acad-icht.tm.edu.ro)

(Received 10 May, revised 8 September 2006)

Abstract: Calcium carbonate, obtained as a waste in the industrial manufacture of magnesium carbonate and magnesium oxide from dolomites, can be applied in agriculture. The appreciable amounts of calcium and magnesium in this waste, together with impurities such as iron, zinc, manganese, chromium and copper compounds can be useful in soil amendment and plant nutrition. This paper presents preliminary results of the testing of several waste doses on soil, pursuing their effect on the uptake of cations by green oat (*Avena sativa* L.). The obtained results show an increase in the amount of calcium, magnesium, zinc and copper found in green oat plants, as well as a decrease of the content of iron and manganese with increasing waste dose. These results may be explained by lower absorptions of iron and manganese because of the antagonistic effect created by high amounts of calcium and magnesium, as well as by the presence of copper and zinc.

Keywords: waste doses, content of mineral elements, cation uptake.

INTRODUCTION

The carbonation process of calcined dolomites slurries generates magnesium carbonate and magnesium oxide as the main products. However, because the native composition of dolomites is double carbonates of calcium and magnesium ($\text{CaCO}_3 \cdot \text{MgCO}_3$), the mentioned process generates also calcium carbonate, but as an industrial waste.^{1,2} This waste includes in addition to precipitated calcium carbonate a considerable amount of precipitated magnesium carbonate, together with trace elements, such as iron, manganese, copper, zinc and chromium, as impurities from initial dolomites.^{3,4} Treating soil with different amounts of this waste may

* Corresponding author.

play an important role in soil amendment, as a source of mineral elements for the nutrition of plants.⁵ Magnesium plays a catalytic role in plant nutrition, participating in the photosynthesis process and facilitating the circulation of some major nutritional elements. Calcium, used by all plants in their physiological processes, promotes the development of the root system and cell division.⁶ Trace elements, such as iron, manganese, copper and zinc fulfill a catalytic function in enzymatic processes in plants. Their contents in plants are low, between 10^{-3} and 10^{-5} %, but essential.⁷

The simultaneous presence of the above-mentioned mineral elements in the nutritive medium of plants creates a balance in the uptake processes of mineral elements characterized by several antagonistic effects regarding the absorption process of some elements. The interaction of the ions in the root absorption process of plant nutrition creates an antagonistic effect when important amounts of ions (such as calcium and magnesium, in this case) diminish the uptake of other elements (such as trace elements). The ions couples between which antagonistic effects have often been established are: $\text{Ca}^{2+} : \text{Na}^{+}$; $\text{Ca}^{2+} : \text{Fe}^{2+}$; $\text{Mg}^{2+} : \text{Na}^{+}$; $\text{Mg}^{2+} : \text{Fe}^{2+}$; $\text{Mn}^{2+} : \text{Mg}^{2+}$; $\text{Mn}^{2+} : \text{Fe}^{2+}$; $\text{Zn}^{2+} : \text{Fe}^{2+}$; $\text{Cu}^{2+} : \text{Fe}^{2+}$; $\text{Cu}^{2+} : \text{Mn}^{2+}$; $\text{Zn}^{2+} : \text{Ca}^{2+}$.⁷

The main objective of this study was to present the use of this industrial waste as a soil amendment and nutritive source of mineral elements in plant nutrition. This paper reports the effects of the addition of different amounts of the waste to luvosoil on the uptake processes of mineral elements through root absorption by establishing their content in green oat plants at harvest time.

EXPERIMENTAL

Luvosoil, having a pH value of 5.8 and a rather low fertility, was collected, air-dried, crushed, mixed thoroughly and put into pots, each containing 1 kg of soil. The soil was treated with different amounts of the industrial waste, *i.e.*, 0, 180, 360, 720 and 1440 mg/kg soil. Magnesium and calcium contents in the soil samples were determined complexometrically, while contents of sodium, iron, manganese, copper, zinc, chromium were established by means of atomic absorption spectrophotometry.

TABLE I. Composition of the industrial waste

Ca/%	Mg/%	Na/%	Fe/mg g ⁻¹	Mn/mg g ⁻¹	Cu/mg g ⁻¹	Zn/mg g ⁻¹	Cr/mg g ⁻¹
28	7	0.77	1.93	0.14	0.042	0.16	0.054

TABLE II. Waste amounts and mineral content of the experimental soils

Parameter	Experimental soils			
	V ₁	V ₂	V ₃	V ₄
Waste amount/mg kg ⁻¹ soil	180	360	720	1440
Calcium content/mg kg ⁻¹ soil	50	101	202	403
Magnesium content/mg kg ⁻¹ soil	13	25	50	101
Sodium content/mg kg ⁻¹ soil	1.39	2.76	5.52	11.03

TABLE II. Continued

Parameter	Experimental soils			
	V ₁	V ₂	V ₃	V ₄
Iron content/mg kg ⁻¹ soil	0.347	0.695	1.390	2.780
Manganese content/mg kg ⁻¹ soil	0.025	0.050	0.101	0.202
Copper content/mg kg ⁻¹ soil	0.007	0.015	0.030	0.060
Zinc content/mg kg ⁻¹ soil	0.029	0.058	0.115	0.230
Chromium content/mg kg ⁻¹ soil	0.010	0.019	0.039	0.078

All experiments were done in triplicate in pots placed near a window. The pots were sown with fifteen oat grains (*Avena sativa* L.). After a vegetation period of 8 weeks the uptakes of the mineral elements present in the industrial wastes were established by measuring their content in the green oat samples at harvest time.

The content of the studied elements in green oat plants were determined according to the following method: The plants were dried at 105 °C, then they were crushed in an agate mortar. The samples were digested with concentrated nitric acid in a Berghof B type microwave apparatus. The obtained solution was analysed by means of a Yobin Yvon 24 sequential ICP instrument.⁸

RESULTS AND DISCUSSION

The composition of the employed industrial waste is given in Table I. The compositions of the soil samples after addition of different amounts of the waste material are given in Table II, together with the amount of waste added. Table III shows the influence of the soil treatment with 4 different amounts of waste (V₀ 0 mg; V₁, 180 mg; V₂, 360 mg; V₃, 720 mg; V₄, 1440 mg) on the contents of essential and trace elements in green oat at harvest time.

TABLE III. Mineral content (essential and trace elements) in green oat at harvest time

Parameter		Experimental alternative				
		V ₀	V ₁	V ₂	V ₃	V ₄
Calcium	mg/kg	4002	4723	5450	6517	8672
	content %	100	118	136	163	217
Magnesium	mg/kg	2117	2410	3175	3412	3645
	content %	100	114	150	161	172
Sodium	mg/kg	6247	7447	11759	10970	9480
	content %	100	119	188	176	152
Iron content	µg/g	192	154	128	118	129
	content %	100	80	67	61	67
Manganese	µg/g	76.5	61.4	65.8	43.9	26.3
	content %	100	80	86	57	34
Copper	µg/g	4.63	4.79	5.88	6.39	6.96
	content %	100	103	127	138	150
Zinc content	µg/g	25.3	28.7	33.0	38.8	42.2
	content %	100	113	130	153	167

TABLE III. Continued

Parameter		Experimental alternative				
		V ₀	V ₁	V ₂	V ₃	V ₄
Chromium	µg/g	1.45	1.56	1.58	2.28	2.76
content	%	100	108	109	157	190

Treating the soil with higher amounts of waste increased the uptake of calcium and magnesium by the plant. The increase of the calcium concentration in green oat plants was proportional to the administered amount of waste. The highest amount of waste (V₄) resulted in increase of 117 % of the calcium concentration in the plant at harvest time. For the same dose, the increase of magnesium content was 72 %, because of the lower concentration of magnesium in the waste. For the other amounts of added waste (V₁, V₂, V₃) the % increases of uptake of calcium and magnesium by the plant were similar. Due to presence of sodium in the waste, the contents of sodium in the plant were higher when waste had been added than in the control, without the addition of waste. However, with increasing amount of added waste, the uptake of sodium by the plant decreased because of the antagonistic effects existing between the ion couples Ca²⁺ : Na⁺ and Mg²⁺ : Na⁺. The contents of iron and manganese in the plant decreased with increasing amount of added waste dose. This effect can be explained by the high concentration of calcium and magnesium in the experimental soils and their antagonistic effects on iron uptake by oat plants (Ca²⁺ : Fe²⁺; Mg²⁺ : Fe²⁺). Increasing amounts of copper registered with increasing amount of added waste had an antagonistic effect on the absorption of iron and manganese (Cu²⁺ : Fe²⁺; Cu²⁺ : Mn²⁺). As a result, both the iron and manganese content in the plants decreased with increasing amount of added waste. The zinc and chromium uptake by the oat plants rose with increasing amount of added waste.

CONCLUSIONS

The obtained experimental results confirmed that the employed waste represents an important source of mineral elements for soil amendment and plant nutrition.

Soil treatment with four different amounts of this waste had a stimulating effect on the root absorption process of essential and trace elements involved in plant nutrition.

Due to the waste composition, high amounts of calcium and magnesium were available for plant nutrition. The simultaneous presence of essential and trace elements in the nutrition medium of the plant had an important influence on the root absorption process and uptake of cations.

The high amounts of calcium and magnesium, as well as the presence of copper and zinc, in the waste diminished the uptake of cations such as sodium, iron and

manganese. The explanation lies in the decrease of the absorption process for some cations because of the antagonistic effect established between well-known ions couples, such as $\text{Ca}^{2+} : \text{Na}^+$; $\text{Ca}^{2+} : \text{Fe}^{2+}$; $\text{Mg}^{2+} : \text{Na}^+$; $\text{Mg}^{2+} : \text{Fe}^{2+}$; $\text{Zn}^{2+} : \text{Fe}^{2+}$; $\text{Cu}^{2+} : \text{Fe}^{2+}$; $\text{Cu}^{2+} : \text{Mn}^{2+}$.⁷

ИЗВОД

УТИЦАЈ ИНДУСТРИЈСКОГ ХЕМИЈСКОГ ОТПАДА НА УНОС КАТЈОНА У
ЗЕЛЕНИ ОВАС

HORTENSIA RADULESCU¹, LIDIA TAUBERT², SÁNDOR A. KISS³, ECATERINA PRINCZ² и ÉVA STEFANOVITS-BÁNYAI⁴

¹Banat's University of Agricultural Sciences and Veterinary Medicine Timisoara, Faculty of Agriculture, Calea Aradului 119, 300645-Timisoara, Romania ²Chemistry Institute Timisoara of the Romanian Academy, Inorganic Chemistry Department, Bd. M. Viteazu 24, 300223-Timisoara, P. O. Box 5/612, Romania, ³Hungarian Magnesium Society, Föfasor 73A/2, H-6726 Szeged, Hungary и ⁴Corvinus University, Faculty of Food Science, Villányi str., Budapest, Hungary

Калцијум-карбонат, добијен као отпад у индустријским процесима за производњу магнезијум-карбоната и магнезијум-оксида из доломита, може бити искоришћен у пољопривреди. Знатне количине калцијума и магнезијума у овом отпаду, заједно са нечистоћама, као што су компоненте гвожђа, цинка, мангана, хрома и бакра могу бити корисне у побољшању земљишта и исхране биљака. Овај рад представља прелиминарно тестирање неколико доза отпада на земљиште с циљем да се процени утицај на унос катјона у зелени овас (*Avena sativa* L.). Добијени резултати показују пораст садржаја калцијума, магнезијума, цинка и бакра у зеленом овсу, али и смањење садржаја гвожђа и мангана са повећањем дозе отпада. Ови резултати могу се објаснити мањом апсорпцијом гвожђа и мангана због супротних ефеката проузрокованих великим количинама калцијума и магнезијума као и због присуства бакра и цинка.

(Примљено 10. маја, ревидирано 8. септембра 2006)

REFERENCES

1. D. Kohn, L. Taubert, S. Policec, E. Romanu, *Filtr. Sep.* **12** (1988) 161
2. L. Taubert, S. Policec, D. Kohn, *Proceedings of the IVth International Symposium "Regional Multidisciplinary Research"*, Timisoara, Romania, 1998, p. 521
3. L. Taubert, *Proceedings of the 12th Romanian International Conference on Chemistry and Chemical Engineering*, Bucharest, Romania, 2001, p. 201
4. L. Taubert, *Proceedings of the 9th Symposium on Analytical and Environmental Problems*, Szeged, Hungary, 2002, p. 41
5. H. Radulescu, S. A. Kiss, L. Taubert, E. Princz, *Proceedings of the 12th Symposium on Analytical and Environmental Problems*, Szeged, Hungary, 2005, p. 467
6. G. Lixandru, C. Caramete, G. Hera, N. Marin, Z. Borlan, L. Calancea, M. Goian, C. Rauta, *Agrochemistry, Didactica si Pedagogica*, Bucuresti, Romania, 1990, p. 21 (in Romanian)
7. I. Avarvarei, D. Davidescu, R. Mocanu, M. Goian, C. Caramete, M. Rusu, *Agrochemistry, Sitech*, Craiova, Romania, 1997, p. 48 (in Romanian)
8. A. Czikkell-Szolnoki, *Proceedings of the XXXVIII Hungarian Spectroscopic Conference*, Paks, Hungary, 1995, p. 51.