J. Elementol. 2009, 14(2): 239–247

MAGNESIUM FERTILIZATION OF SOIL CONTAMINATED WITH HEAVY METALS AND FORAGING OF SELECTED GNAWING PESTS

Janina Gospodarek

Chair of Agricultural Environment Protection
University of Agriculture in Krakow

Abstract

Magnesium fertilization of soil has been recommended as one of the ways to limit unfavourable effect of heavy metals on plants. Its effect may be connected with diminished heavy metal uptake by plants and changes in macroelement content. Therefore, the same measure may also change the host plant usability for potential herbivorous insects.

The paper contains compiled results of research on the effect of magnesium fertilization under conditions of soil contaminated with single heavy metals to level III of soil pollution according to the IUNG classification, on the foraging of *Bruchus rufimanus* Boh. and *Sitona* (*Sitona* sp.) on broad bean (*Vicia faba* L. ssp. *maior*).

It has been found that the applied fertilization level of soil contaminated with heavy metals does not affect significantly the yield of broad bean seeds, the degree of their damage due to *Bruchus rufimanus* or their germinating ability. Magnesium fertilization may slightly increase germinating energy of broad bean seeds from plants growing on cadmium contaminated soil. The effect of magnesium treatment under conditions of soil contamination with heavy metals on harmfulness of *Sitona* beetles to broad bean may be modified by atmospheric conditions in individual seasons. Magnesium fertilization of soil polluted with copper, lead, nickel and zinc to level III of soil pollution according to the IUNG classification does not lead to an increase in the degree of broad bean leaf damage by *Sitona* beetles. On the other hand, magnesium fertilization of soil contaminated with cadmium to level III of soil pollution in the IUNG classification may enhance broad bean plants' attractiveness to *Sitona*.

Key words: heavy metals, magnesium, *Sitona* sp. *Bruchus rufimanus* Boh.

dr inż. Janina Gospodarek, Chair of Agricultural Environment Protection, University of Agriculture in Krakow, Al. Mickiewicza 21, 31 – 120 Kraków. Poland

NAWOŻENIE MAGNEZOWE GLEBY SKAŻONEJ METALAMI CIĘŻKIMI A ŻEROWANIE WYBRANYCH SZKODNIKÓW GRYZĄCYCH

Abstrakt

Nawożenie magnezowe gleby jest polecane jako jeden ze sposobów na ograniczenie niekorzystnego oddziaływania metali ciężkich na rośliny. Może się to wiązać ze zmniejszeniem pobierania metali ciężkich przez rośliny i zmianami w zawartości makroskładników. Tym samym zabieg ten może również zmieniać przydatność rośliny żywicielskiej dla ewentualnych roślinożerców.

W pracy zestawiono wyniki badań nad wpływem nawożenia magnezowego w warunkach gleby zanieczyszczonej pojedynczymi metalami ciężkimi na poziomie III stopnia zanieczyszczenia wg klasyfikacji IUNG na żerowanie strąkowca bobowego (*Bruchus rufimanus* Boh.) oraz chrząszczy oprzędzików (*Sitona* sp.) na bobie (*Vicia faba* L., ssp. *maior*).

Stwierdzono, że zastosowany poziom nawożenia magnezowego gleby skażonej pojedynczymi metalami ciężkimi nie wpływa istotnie na plon nasion bobu, stopień ich uszkodzenia przez strąkowca bobowego ani też ich zdolność kiełkowania. Nawożenie magnezowe może nieco zwiększać energię kiełkowania nasion bobu pochodzących z roślin rosnących w glebie zanieczyszczonej kadmem. Wpływ nawożenia magnezowego w warunkach skażenia gleby metalami ciężkimi na szkodliwość chrząszczy oprzędzików dla bobu może być modyfikowany przez warunki atmosferyczne w danym sezonie. Nawożenie magnezowe gleby zanieczyszczonej miedzią, ołowiem, niklem i cynkiem na poziomie III stopnia zanieczyszczenia wg klasyfikacji IUNG nie powoduje wzrostu stopnia uszkodzenia liści bobu przez chrząszcze oprzędzików. Nawożenie magnezowe gleby zanieczyszczonej kadmem na poziomie III stopnia zanieczyszczenia wg klasyfikacji IUNG może natomiast przyczyniać się do wzrostu atrakcyjności roślin bobu dla oprzędzików.

Słowa kluczowe: metale ciężkie, magnez, *Sitona* sp. *Bruchus rufimanus* Boh.

INTRODUCTION

Magnesium fertilization of soils contaminated with heavy metals is recommended as one of the measures for reducing the uptake of these metals by plants (CURZYDŁO 1988). It may also improve the condition and growth of plants growing on polluted soil (JAWORSKA, GOSPODAREK 2003). Typically, gnawing insects less eagerly attack plants from polluted areas (BOCZEK, SZLENDAK 1992). Therefore, improvement of plant growth as a result of magnesium treatment may enhance attractiveness of these plants to this pest group.

The goal of the paper has been to compile the results of investigations on the effect of magnesium fertilization of soil contaminated with single heavy metals to level III of pollution according to the IUNG classification on harmfulness of *Sitona* sp. and bean beetle *Bruchus rufimanus* Boh. to broad bean *Vicia faba* L., ssp. *maior*.

MATERIAL AND METHODS

The experiments were conducted in field conditions in Zagaje Stradowskie, a village in Świętokrzyskie Province. Observations were conducted on broad bean (*Vicia faba* L., ssp. *maior)*, cv. White Windsor, cultivated on the following objects: unpolluted soil with natural heavy metal content (Control); unpolluted soil with natural heavy metal content receiving mineral fertilization (control+NPK); soil polluted with 4 $mg \cdot kg^{-1}$ d.m. of cadmium; soil polluted with a dose of 530 $mg \cdot kg^{-1}$ d.m. of lead; soil polluted with copper dosed at 85 $mg \cdot kg^{-1}$ d.m.; soil contaminated with a dose of 1.000 $mg \cdot kg^{-1}$ d.m. of zinc and soil polluted with 110 $mg \cdot kg^{-1}$ d.m. of nickel. The established level of soil pollution corresponded to a moderate pollution level in the IUNG classification. Identical magnesium fertilization was applied to all the objects: 20.4 mg $Mg \cdot kg^{-1}$ d.m.

Harmfulness of bean beetle was assessed on the basis of the weight of damaged seeds in relation to total seed mass. The assessment of broad bean seed germination energy and ability was conducted in laboratory conditions, following the generally accepted standards.

Harmfulness of *Sitona* sp. beetles was determined by measuring the leaf area loss, the consumed area and by counting injured and non-injured leaves. The damage was analysed twice (on 21.05.05 and 2.06.05). The significance of differences between means was established by means of one-way ANOVA. The means were differentiated by Duncan test at the significance level p=0.05.

Plant samples for chemical analyses were collected at the seed milk maturity stage. Because the experiment also assessed harmfulness of *Aphis fabae* Scop. aphid, which is the most serious broad bean pest, the sampling date was set to match its feeding period. Chemical analysis of the plant material comprised determining the content of heavy metals (cadmium, lead, zinc, copper and nickel). Detailed description of the methods applied was presented in other papers (Gospodarek, Nadgórska-Socha 2007, Gospodarek 2008a).

RESULTS AND DISCUSSION

The applied magnesium fertilization caused 2-5 fold decline in the content of the analysed heavy metals in broad bean underground parts (Table 1). On the other hand, in the aerial parts a reduction of the metal content in resulting from the application of magnesium fertilization occurred in the case of zinc (Table 2). A similar effect of magnesium fertilization in relation to this element was noted in Italian ryegrass (Gorlach et al. 1980).

Table 1

The mean content of heavy metals in dry mass of roots of broad bean cultivated on soil with natural heavy metal content, soil contaminated with heavy metals and after application magnesium treatment (% in relation to control + NPK)

Objects	Content of heavy metals (% in relation to control + NPK)				
	Cd	Cu	Pb	Zn	Ni
Control	109 *a*	151 *a*	81 *a*	134 *a*	164 *a*
Control+Mg	46 *a*	62 *a*	79 *a*	114 *a*	166 *a*
Control+NPK	100 *a*	100 *a*	100 *a*	100 *a*	100 *a*
Control+NPK+Mg	41 *a*	51 *a*	72 *a*	101 *a*	420 *a*
Cd	1838 c	-	-	-	-
Cd+Mg	705 *b*	-	-	-	-
Cu	-	1890 c	-	-	-
Cu+Mg	-	485 *b*	-	-	-
Pb	-	-	3397 c	-	-
Pb+Mg	-	-	1005 *b*	-	-
Zn	-	-	-	46766 *c*	-
Zn+Mg	-	-	-	23831 *b*	-
Ni	-	-	-	-	16810 *c*
Ni+Mg	-	-	-	-	3362 *b*

Values in columns marked with different letters are statistically different at $p = 0.05$

Broad bean cultivated on soil contaminated by an aggregated dose of the analysed heavy metals, at an elevated content level in the IUNG classification, was found to have a reduced uptake of Pb, Cd and Ni by roots and Zn uptake by roots, leaves and pods under magnesium fertilization combined with liming (JAWORSKA, GOSPODAREK 2005). In the case of copper and cadmium, magnesium treatment did not significantly affect the content of these elements in broad bean aerial parts, whereas for lead and nickel a slight increase in their content was observed on contaminated soil subjected to magnesium fertilization (GOSPODAREK, NADGÓRSKA-SOCHA 2007) – Table 2. In the author's former investigations, reduced content of cadmium and nickel in broad bean pods was noted under the influence of magnesium fertilization applied to soil contaminated with an aggregate dose of heavy metals (Cu, Cd, Ni, Zn and Pb) to the level of elevated content (JAWORSKA, GOSPODAREK 2005).

Magnesium fertilization of soil contaminated with the analysed elements did not affect significantly the degree of leaf injuries due to *Sitona* sp. at an early stage of the plant development (1st date – 2nd decade of May) – Table 3, Figure 1 (GOSPODAREK 2008b). However, later (2nd date – 1st decade

Table 2

The mean content of heavy metals in dry mass of aerial plant parts of broad bean cultivated on soil with natural heavy metal content, soil contaminated with heavy metals and after application magnesium treatment (% in relation to control + NPK)

Objects	Content of heavy metals (% in relation to control + NPK)				
	Cd	Cu	Pb	Zn	Ni
Control	148 *b*	91 b	117 *b*	96 *a*	129 *a*
Control+Mg	58 *a*	131 *c*	98 *b*	106 *a*	138 *a*
Control+NPK	100 *b*	100 *b*	100 *b*	100 *a*	100 *a*
Control+NPK+Mg	53 *a*	72 *a*	98 *b*	91 *a*	104 *a*
Cd	438 *c*	-	-	-	-
Cd+Mg	453 *c*	-	-	-	-
Cu	-	226 *d*	-	-	-
Cu+Mg	-	215 *d*	-	-	-
Pb	-	-	1310 *d*	-	-
Pb+Mg	-	-	1960 *e*	-	-
Zn	-	-	-	24263 *c*	-
Zn+Mg	-	-	-	19104 *b*	-
Ni	-	-	-	-	11798 *b*
Ni+Mg	-	-	-	-	13138 *c*

Values in columns marked with different letters are statistically different at $p = 0.05$

of June), under the conditions of cadmium contaminated soil, a slight increase in the area damaged by *Sitona* sp. was noted following magnesium treatment (Table 3). Also, per cent loss of leaf blade was slightly higher in this object (Figure 1). No considerable effect of soil magnesium treatment on the degree of broad bean plant damage due to this pest occurred on soil contaminated with copper, lead and nickel. Plants growing on soil contaminated with zinc and subjected to magnesium fertilization were characterized by a considerably worse growth but were not injured by *Sitona* beetles. In the former research, magnesium fertilization of soil with elevated levels of heavy metals applied jointly did not cause any increase in the degree of broad bean damage caused by *Sitona* beetles (Jaworska, Gospodarek 2003).

Magnesium fertilization of soil contaminated with cadmium, copper and lead did not affect significantly the seed yield or the degree of seed injuries due to bean beetle (Table 4). The seed germination energy test revealed beneficial effect of magnesium treatment under the conditions of cadmium contaminated soil – Table 4 (Gospodarek 2008a). Plants growing on soil contaminated with zinc and nickel did not form seeds.

Table 3

Injuries caused by Sitona beetles on broad bean growing on natural soil (control, control + NPK), soil polluted with individual heavy metals and after application magnesium treatment (% in relation to control + NPK)

Objects	Leaves injured by *Sitona* sp. (% in relation to control+ +NPK) First date	Leaves injured by *Sitona* sp. (% in relation to control+ +NPK) Second date	Total consumed area per plant (% in relation to control+ +NPK) First date	Total consumed area per plant (% in relation to control+ +NPK) Second date
Cd	123 *a*	112 *e-g*	265 *a*	79 *c-e*
Cd+Mg	190 *a*	125 *g*	258 *a*	191 *g*
Cu	101 *a*	95 *d-g*	200 *a*	66 *a-e*
Cu+Mg	31 *a*	100 *d-g*	61 *a*	54 *a-d*
Control	90 *a*	114 *e-g*	229 *a*	88 *c-f*
Control+Mg	0 *a*	61 *bc*	0 *a*	52 *a-d*
Ni	*81 a*	99 *d-g*	145 *a*	30 a-d
Ni+Mg	16 *a*	94 *d-g*	58 *a*	47 *a-d*
Control+NPK	100 *a*	100 *d-g*	100 *a*	100 *d-f*
Control+NPK+Mg	19 *a*	80 *b-e*	26 *a*	76 *c-e*
Pb	103 *a*	109 *e-g*	113 *a*	125 *e-f*
Pb+Mg	16 *a*	121 *g*	3 *a*	87 *c-f*
Zn	0 *a*	52 *b*	0 *a*	6 *ab*
Zn+Mg	0 *a*	0 *a*	0 *a*	0 *a*

Means in columns marked with the same letter do not differ at $p = 0.055$

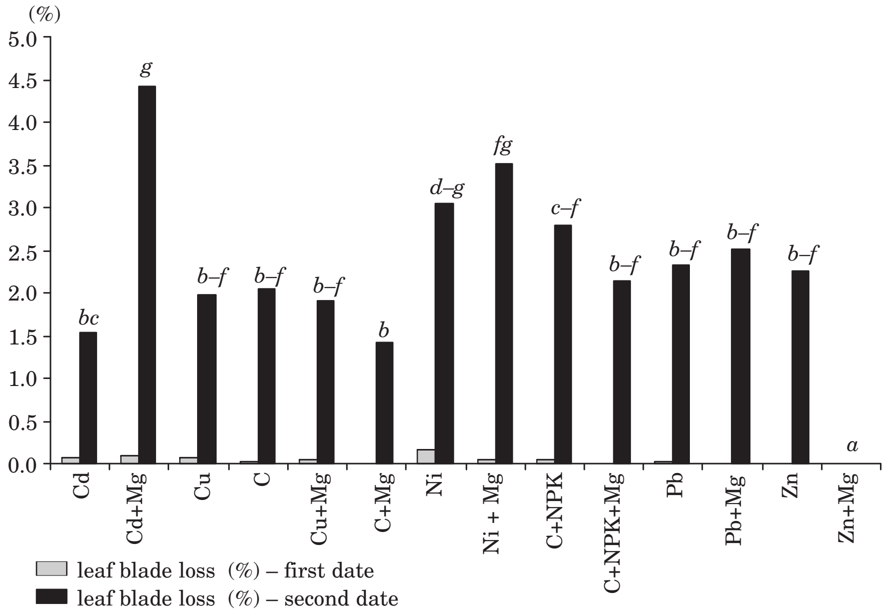

Fig. 1. Leaf blade loss due to *Sitona* beetle feeding (% of total leaf area) in broad bean growing on natural soil (control – C, control + NPK), soil polluted with individual heavy metals and after application of magnesium fertilization. Means marked with the same letter do not differ at p = 0,05. Assessments were presented only when statistical differentiation between means existed

Table 4

Injuries caused by *Bruchus rufimanus* Boh. beetles on broad bean growing on natural soil (control, control+NPK), on soil polluted with individual heavy metals and after application magnesium treatment. Germination energy and ability of broad bean seeds

Objects	Average seed weight per plant (g)	Seeds injured by *Bruchus rufimanus* Boh. (%)	Germination energy (%)		Germination ability (%)	
			uninjured seeds	injured seeds	uninjured seeds	injured seeds
Cd	7.501 *ab*	63.50 *ab*	0.011 *a*	0.000 *a*	81.02 *a*	58.03 *ab*
Cd+Mg	8.210 *ab*	72.31 *ab*	20.03 *b*	33.31 *b*	73.31 *a*	60.05 *ab*
Cu	6.340 *ab*	61.40 *ab*	6.732 *ab*	13.42 *ab*	93.31 *a*	46.71 *ab*
Cu+Mg	4.733 *ab*	76.32 *ab*	0.000 *a*	0.000 *a*	87.54 *a*	60.03 *ab*
Control	6.215 *ab*	89.53 *ab*	0.000 *a*	0.000 *a*	89.02 *a*	60.04 *ab*
Control+Mg	*2.803 a*	86.04 *ab*	0.000 *a*	0.000 *a*	72.01 *a*	45.01 *a*
Control+ +NPK	5.421 *ab*	55.53 *a*	0.000 *a*	0.000 *a*	87.03 *a*	47.02 *ab*
Control+ +NPK+Mg	6.324 *ab*	90.51 *ab*	20.52 *b*	6.712 *ab*	85.04 *a*	73.10 *b*
Pb	7.501 *ab*	92.83 *ab*	0.000 *a*	20.03 *ab*	75.02 *a*	73.32 *b*
Pb+Mg	9.323 *b*	98.12 *b*	0.000 *a*	13.31 *ab*	81.06 *a*	51.71 *ab*

Means in columns marked with the same letter do not differ at $p = 0.055$

CONCLUSIONS

1. Magnesium fertilization of soil contaminated with copper, lead, nickel and zinc to pollution level III according to the IUNG classification does not cause any increase in the degree of broad bean injuries by gnawing insects, such as *Sitona* and bean beetle.

2. Magnesium treatment may have a beneficial effect, increasing broad bean seed germination from plants growing on soil contaminated with cadmium.

3. Magnesium fertilization of soil contaminated with cadmium to pollution level III in the IUNG classification may contribute to improved attractiveness of broad bean plants for *Sitona* beetles.

REFERENCES

BOCZEK J., SZLENDAK E. 1992. *Wpływ stresów roślinnych na porażenie roślin przez szkodniki [Effect of plant stresses on plant infestation by pests].* Post. Nauk Rol., 2: 4-16.

CURZYDŁO J. 1988. *Ołów i cynk w roślinach i glebach w sąsiedztwie drogowych szlaków komunikacyjnych [Lead and zon in plants and soils near roads].* Zesz. Nauk. AR w Krakowie, Rozpr. habil. nr 127.

GORLACH E., GORLACH K., STĘPIEŃ S. 1980. *Wpływ wapnowania na wzrost życicy wielokwiatowej oraz zawartość mikroelementów w roślinach i ich form rozpuszczalnych w glebie [Effect of liming on Italian ryegrass growth and content of micronutrients and their solule forms in soil].* Acta Agr. Silv., 19: 31-45.

GOSPODAREK J., NADGÓRSKA-SOCHA A. 2007. *Effect of soil liming and magnesium fertilization on heavy metal concentrations in broad bean plants (Vicia faba L., ssp. maior) growing in heavy metal polluted soil.* Ecolog. Chem. Engineer., 14 (9): 966-974.

GOSPODAREK J. 2008 a. *The effect of magnesium treatment in conditions of soil contamination with heavy metals on bean beetle (Bruchus rufimanus Boh.) feeding on broad bean (Vicia faba L. ssp. maior).* Ecolog. Chem. Engineer. (in press).

GOSPODAREK J. 2008 b. *Comparison of the effect of liming and magnesium treatment in conditions of soil heavy metal pollution on Sitona sp. harmfulness on broad bean bean (Vicia faba* L. ssp. *maior).* Ecolog. Chem. Engineer. (in press).

JAWORSKA M., GOSPODAREK J. 2003. *Effect of liming and magnesium treatment of the soil contaminated with heavy metal on the chewing pests of broad bean (Vicia faba L., ssp. maior)*, Acta Agroph., 1 (4): 653-659

JAWORSKA M., GOSPODAREK J. 2005 *Effect of liming soil contaminated with heavy metals on chemical composition of broad beans (Vicia faba L., ssp. maior).* Ecolog. Chem. Engineer., 12 (8): 803-809.