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UPTAKE OF MAJOR AND TRACE ELEMENTS BY GRASS BIOMASS AFTER AMELIORATION OF DEGRADED SOIL

Benkova M.*, L. Dimova, T. Simeonova

Nikola Poushkarov Institute of Soil Science – 7 Shosse Bankya Str., 1080 Sofia, Bulgaria

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Summary. This research aimed to study the uptake of major elements (N, K, Na, Ca and Mg) and trace elements (Cu and Zn) by grass as influenced of amended polluted acid soil. A pot experiment with a grass mixture grown on heavy metal polluted acidic soil (Dystric Fluvisols) from the region of Zlatitza was carried out. To improve the soil properties five kinds of ameliorative mixtures – CaO (LM), peat (P), coal powder (C), iron hydroxide (Fe) and zeolite (Z) in different treatments were tested. Three biomass cuts within two year were made. Concentrations of the following major elements N, K, Na, Ca, Mg in the biomass were analyzed. The uptake of Cu and Zn by the biomass was calculated. The results showed that amendments (except application of zeolit as a single ameliorant) can improve plant growth both quantitatively and qualitatively. Biomass increased significantly compared to the control except for the zeolite treatment. All rates of peat and lime in two components (LM_2P, LM_2P_2 and LM_2P_3) and three – component mixture (LM_2P_2Z) increased the uptake of macronutrients (Ca, Mg, and K) by plants. The application of the organic mixtures ($LM_2P_{1,2,3}$ and LM_2CFe) resulted in increased Cu and Zn uptake by plants. The higher Cu and Zn uptake may be related to the formation of soluble organic-metal complexes. Higher soil pH resulting from amendments likely increased the dissolved organic matter (DOC) in soil and as a result of this complexion affinity DOC enhanced the solubility of certain metals.

Key words: major elements, copper and zink uptake, amedments, biomass, acid soil.

Abbreviatios: LM – lime material; P – peat; C – coal powder; Z – zeolite; Fe – iron hydroxide; DOC – dissolved organic matter.

INTRODUCTION

Chemical remediation techniques involve addition of some chemical materials (lime material, organic matter, iron hydroxides, zeolite, etc.) to polluted soils in order to immobilize heavy metals, so that they cannot be taken up

*Corresponding author: majaben@abv.bg

by plants (Mench et al., 1994; Chlopecka and Adriano, 1997). It is known that on acid polluted soils the nutrition of plants becomes more difficult because of lack of balance in nutrients and possible toxicity problems. The application of such materials can reduce the concentration of heavy metals and serve to enhance fertility of soil in which the bioavailability of trace elements limits plant growth (Ludwig et al., 2002; Tyler and Olsson, 2001).

This research aims to study the uptake of major nutrients and trace elements by grass as influenced by amended polluted soil.

MATERIALS AND METHODS

Research was carried out on heavy metal polluted (Cu 845 $mg.kg^{-1}$, Zn -130 $mg.kg^{-1}$) acid (pH_{H2O} - 4.00) soil (Dystric Fluvisols). Amendments as CaO (LM), peat (P), coal powder (C), iron hydroxide (Fe -containing adsorbent) and zeolite (Z) in different treatments were applied. The amount of lime material in organo-mineral mixtures was evaluated based on a modified formula for the liming rate of acid soils (Ganev, 1990). The amounts of peat and coal applied were calculated according to the optimal rate for organo-mineral mixture (Raychev et al., 2002). Three grass biomass cuts within a two-year period were taken. Total grass yield and content of major and trace elements in plants were measured. Total content of N in biomass was determined by the method of Kjeldahl, K, Na, Ca and Mg by ash analysis (Peterburskii, 1986). Plant material was digested using concentrated HNO_3 and H_2O_2 (Methods of soil analysis, 1982). The metal concentration was determined by ICP-AES. Results were processed statistically using the correlation analysis and one-way ANOVA analysis. A STATGRAPHICS Centurion XV program was used.

RESULTS AND DISCUSSION

Application of organic amendments to soils can be beneficial because they can provide nitrogen and other nutrients and improve the structure of degraded soils. The most effective amelioration was shown in variant 11 (LM_2P_2Z) where biomass increased by about 68% compared to control (untreated soil). Values of variant 7 (LM_2P_3) were not statistically different ($P<0.05$) from variant 11 (LM_2P_2Z) regardless of their high variation in the replicates. In both variants crop biomass increased by about three times. Variant 10 (Z) was characterized with the lowest amount of biomass and the least variation in variants. A significant correlation ($P<0.05$, positive r = 0. 84) between soil solution pH (data are not shown) and plant biomass was found. The amount of plant production increased with increasing the reaction of the soil solution. It is well known that application of amendments (lime, organic matter) may neutralize toxic exchange acidity for plants.

Uptake of major elements by biomass

Macroelements (N, K, Na, Ca and Mg) in total biomass were analyzed. Our results (Table 1) showed that N content in plants ranged from 1.33% (LM_1) to 2.14% (LM_3). A sufficient amount of Ca in the soil can help plants to use as a source of nitrogen, ammonium cations, whose toxicity in the presence of calcium is removed. This was confirmed by the fact

Table 1. Total dry weight of biomass [g/pot] for the experimental period and content of N, K_2O, Na, Ca and Mg [% DW] in plants.

Treatments	Biomass [g/pot, DW]	N [%]	K_2O [%]	Na [%]	Ca [%]	Mg [%]
1. K	20.73	1.59	2.86	0.022	0.49	0.65
2. LM_1	34.10	1.33	2.44	0.013	0.47	0.51
3. LM_2	48.05	1.68	2.43	0.018	0.58	0.46
4. LM_3	37.04	2.14	2.71	0.076	1.13	0.57
5. LM_2P_1	45.54	1.85	3.18	0.024	1.02	0.76
6. LM_2P_2	44.37	1.83	3.10	0.063	1.09	0.80
7. LM_2P_3	58.62	1.60	2.89	0.023	0.99	0.72
8. LM_2C	45.60	1.51	3.04	0.021	0.57	0.56
9. LM_2CFe	41.57	1.62	3.47	0.045	0.79	0.75
10. Z	13.65	1.44	3.28	0.044	0.68	0.53
11. LM_2P_2Z	65.82	1.49	3.45	0.016	0.46	0.44
LSD 5%	13.3					

that the highest concentration of nitrogen in plant biomass was observed in the variant with a maximum dose of calcium oxide (LM_3). Data showed that potassium in plant biomass ranged from 2.43% to 3.45%. There was some reduction in the concentration of this element in variants LM_1 and LM_2, which were statistically different ($P < 0.05$) from variants LM_2CFe and LM_2P_2Z. The uptake of potassium may be expected to decrease by liming, because of ion competition with Ca and increasing CEC of the soil matrix. The content of Na ranged within narrow limits: 0.01 – 0.08 %, as Na values were the lowest in variants $LM_{1,2}$. The content of K and Na are known to decrease as a result of liming (Tyler, 2000). As regards the content of Ca, the lowest values were measured in the control (0.49) and variants LM_1 (0.46) and LM_2P_2Z, while the highest values were found in variants with application of the maximum dose of calcium oxide and in the three variants with the application of a mixture of calcium oxide and peat. Magnesium generally occurs in dry matter at a lower concentration than calcium (0.2 – 0.56%). In our study, the content of Mg ranged from 0.44 % to 0.80 % in the dry weight. Our data showed a slight variation between different variants. There was a good correlation between the content of Ca and Mg in plant biomass (r = 0.79) and also a weaker correlation between Ca and N (r = 0.68).

Uptake of trace elements by biomass

Essential trace elements such as Cu and Zn can have toxic effects on plants when applied at higher concentrations. Both trace elements showed a higher concentration in biomass compared to control of the same treatment (Fig. 1). Data showed that there was not statistically significant differences (P<0.05) between mean copper and zinc concentrations in dry matter from one level of variant to another. There was the same trend of the copper and zinc uptake by biomass in the treatments. In fact treatments including peat with lime and amendment of three components (lime, coal and iron hydroxide) resulted in an increase in the uptake of both Cu and Zn. Many researchers have attributed increased metal mobility in

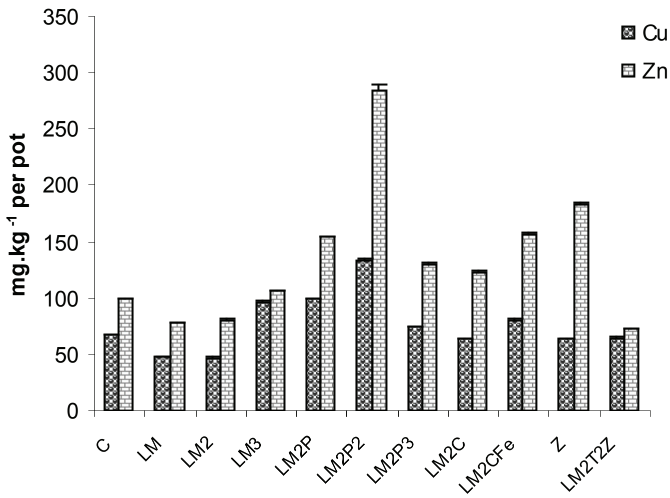

Figure 1. Copper and zink concentrations (mg.kg^{-1} per pot).

amended soils to complexes with DOC (McBride et al., 1997; Zhou and Wong, 2001). Hartley et al. (2004) have reported that the application of lime and iron sulphate to soil increases the fraction of available Zn, but none of the treatments is efficient for Cu stabilization. Some amendments are ineffective for very high contamination levels (Mench et al., 1994) as in our study where the concentration of copper was over 800 mg/kg and its phytotoxicity could not be overcome. Our results showed that amendments (except application of zeolit as a single ameliorant) could improve plant growth both quantitatively and qualitatively. Biomass increased significantly compared to the respective controls except for zeolit treatment. All rates of peat and lime in the two-component (LM_2P, LM_2P_2 and LM_2P_3) and three – component mixtures (LM_2P_2Z) increased plant uptake of macronutrients (Ca, Mg, and K). The application of the organic mixtures ($LMP_{1,2,3}$ and LM_2CFe) resulted in increased Cu and Zn uptake. High Cu and Zn uptake may be related to the formation of soluble organic - metal complexes. Higher soil pH likely increased dissolved organic carbon (DOC) in soil and as a result of this complexion affinity DOC could enhance the solubility of certain metals.

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