Effect of organic amendments on heavy metals uptake by potato plants

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Abstract
Comparative research on the impact of organic soil additives (peat, compost and vermicompost) on the quantity of mobile forms of Pb, Zn, Cd and Cu and uptake of these elements by potato *(Solanum tuberosum L.)* plants was carried out. The application of soil amendments favours plant growth and development. Development and fruit yield demonstrated a stimulating effect with all amendments and this effect was best expressed after 10% compost addition. Organic amendments led to an increase of starch yield, absolute dry substance and quantity and to a decrease of reducing sugars in potatoes. Peat, compost and vermicompost application led to effective immobilization of Pb, Cu, Zn and Cd phytoaccessible forms in soil. A correlation was found between the quantity of the mobile forms and the uptake of Pb, Zn, Cu and Cd by the potato. Organic amendments led to decreased heavy metal content in potato peel and tubers, and this decrease was best expressed with 10% compost and 10% vermicompost (separately). Organic amendments were especially effective for reduction of cadmium content in potato tubers.

Key Words
Phytoremediation, heavy metals, organic amendments, potato.

Introduction

Phytoremediation can be defined as the combined use of plants, soil amendments and agronomic practices to remove pollutants from the environment or to decrease their toxicity (Salt *et al.* 1998). This technique has many advantages compared with other remediation procedures – low economic costs and the possibility of being applied to soils, causing a minimum environmental impact. Addition of organic matter amendments, such as compost, fertilizers and wastes, is a common practice for immobilization of heavy metals and soil amelioration of contaminated soils (Clemente *et al.* 2005). The effect of organic matter amendments on heavy metal bioavailability depends on the nature of the organic matter, their microbial degradability, salt content and effects on soil pH and redox potential, as well as on the particular soil type and metals concerned (Walker *et al.* 2003, 2004). The present study has the following three objectives: (i) to broaden and increase the knowledge of the effect of organic additives on the quantity of mobile forms of Pb, Zn, Cd and Cu (ii) to compare the effect of the selected additives on accumulation of heavy metals by the potato and (iii) to estimate the effect of the introduction of additives on the phytoremediation of contaminated with heavy metals soils.

Methods

The soil used in this experiment was sampled from the vicinity of the area contaminated by a copper smelter near Pirdop, Bulgaria. It is characterized by acid reaction (pH 5.5), loamy texture and a moderate content of organic matter (2.0%). The total content of Cu, Zn, Pb and Cd is high (340 mg/kg Cu, 110 mg/kg Zn, 54 mg/kg Pb and 0.4 mg/kg Cd, respectively) and exceeds the maximum permissible concentrations (60 mg/kg Cu, 90 mg/kg Zn, 50 mg/kg Pb) except for Cd (1.0 mg/kg Cd). The pot experiment was conducted on soil with organic amendments (peat, compost and vermicompost at 5.0%, 7.5% and 10.0% addition rates (calculated on soil dry weight basis). Soils were passed through a 1-cm sieve. Amendments were added and thoroughly mixed by hand. The pots were filled with 9 kg soil. All treatments were performed in triplicate. Three control pots were also set up without amendment. Pots were watered and stored in a greenhouse, where they were left to settle a minimum of 6 weeks at room temperature before planting the potato.
The potato plants were grown in a climate chamber for 56 days with regular watering and random rotation of the position of the pots. After 56 days, all plants were harvested. The plants were cleaned and washed under running water to remove stuck soil. Following drying, they were divided, with the help of a scalpel, into their constituent parts - root, potato (peel and tuber), leaves and stems, and analyzed separately. The contents of the heavy metals in the plant material were determined.

Total content of heavy metals in soils was determined in accordance with ISO 11466. The mobile heavy metals contents in soils were determined by 1 M NH_4NO_3. The plant samples were treated by the method of dry ashing. To determine the heavy metal content in the samples, inductively coupled emission spectrometer (Jobin Yvon Horiba "ULTIMA 2", France) was used.

Results

Effect of soil amendments on the mobile forms of Pb, Zn, Cu and Cd

In many plants there is direct relation between the content of microelements in the soil solution and their uptake by the plants. This relation is most evident with cadmium and less evident with zinc and lead (Kabata Pendias, 2001). The soil amendments used for phytostabilization may have a significant effect on the mobile forms of Pb, Zn, Cu and Cd as a result of sedimentation, absorption and change in the degree of oxidation. The quantity of mobile forms of Pb, Zn, Cu and Cd depended on the soil amendments and the treatment (type and rate). The results presented in Figure 1 showed that the impact of soil amendments on mobile forms of Pb, Zn, Cu and Cd was explicitly expressed and led to their effective immobilization.

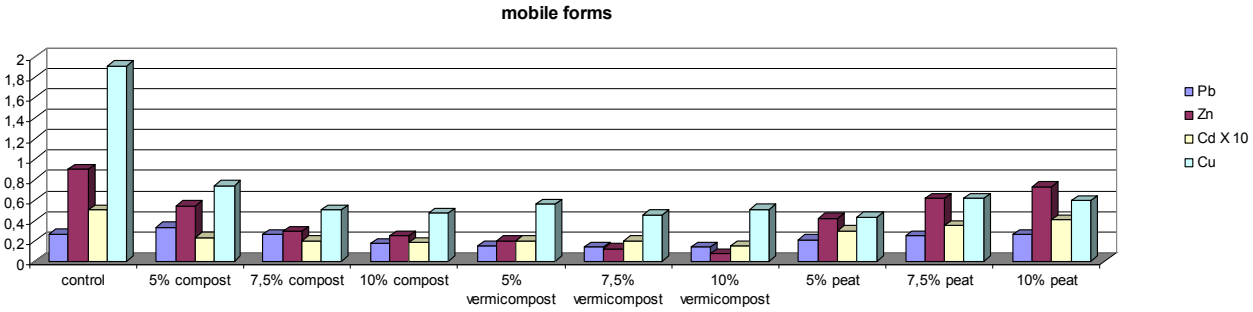

Figure 1. Effect of the soil amendments on the quantity of the mobile forms of Pb, Zn, Cd and Cu.

Effect of organic amendments on the Pb, Zn, Cu and Cd accumulation in potato plants

Impact of soil amendments on plant biological and physiological reactions

The application of soil amendments favours plant growth and development. Development and fruit yielding were stimulated with all amendments and this effect was best expressed after 10% compost addition. Organic amendments led to an increase of starch yield, absolute dry substance and quantity and to a decrease of reducing sugars in potatoes in comparison to those in the control samples.

Accumulation of Pb, Zn, Cu and Cd by potato plants

The results for the influence of the organic additives on the accumulation and distribution of Pb, Zn, Cu and Cd in the potatoes are presented in Figure 2. The contamination of the potatoes was due mainly to the presence in the soil of heavy metals, which entered the plants through their root system, as well as by diffusion through the peel. The movement and the accumulation of the heavy metals in the vegetative organs of the potato plants differed considerably. Their quantity in the stems and leaves of the plants of potato was considerably higher compared to the root system. Probably via the conductive system the heavy metals moved to above-ground parts and predominantly accumulated there. The peel played the role of a selective filter for the heavy metals preventing them from moving into the tuber. The content of Pb in the tuber in plants without amendments reached to 0.38 mg/kg, Zn – 3.7 mg/kg, Cu - 2.7 mg/kg and Cd – 0.04 mg/kg. Pb, Zn and Cu content in the potato tuber were below the proposed guideline values for vegetable plants (0.5 mg/kg Pb, 10 mg/kg Cu and 10 mg/kg Zn). In the tuber of potato, Cd accumulated in quantities considerably above the proposed guideline value for vegetable plants (0.03 mg/kg).

Organic additives impact

According to the literature the content of organic substance in soil has a significant impact on absorption and translocation of heavy metals in soil and their uptake by plants. Cu, Zn, Pb and Cd are adsorbed on organic matter, which generate stable forms and lead to their accumulation in organic horizons of soil and peat (Kabata Pendias, 2001). The results obtained by us showed that Pb, Zn, Cu and Cd uptake by potato depended on the soil amendments and treatment (type and rate). Compost, vermicompost and peat addition led to increased Pb and Cu content in potato roots, stems and leaves, and this increase was better expressed with 10% compost, 10% vermicompost or 5% peat. Organic amendments led to decreased Pb and Cu content in the potato peel and tubers, and this decrease was best expressed with 10% compost or 10% vermicompost.

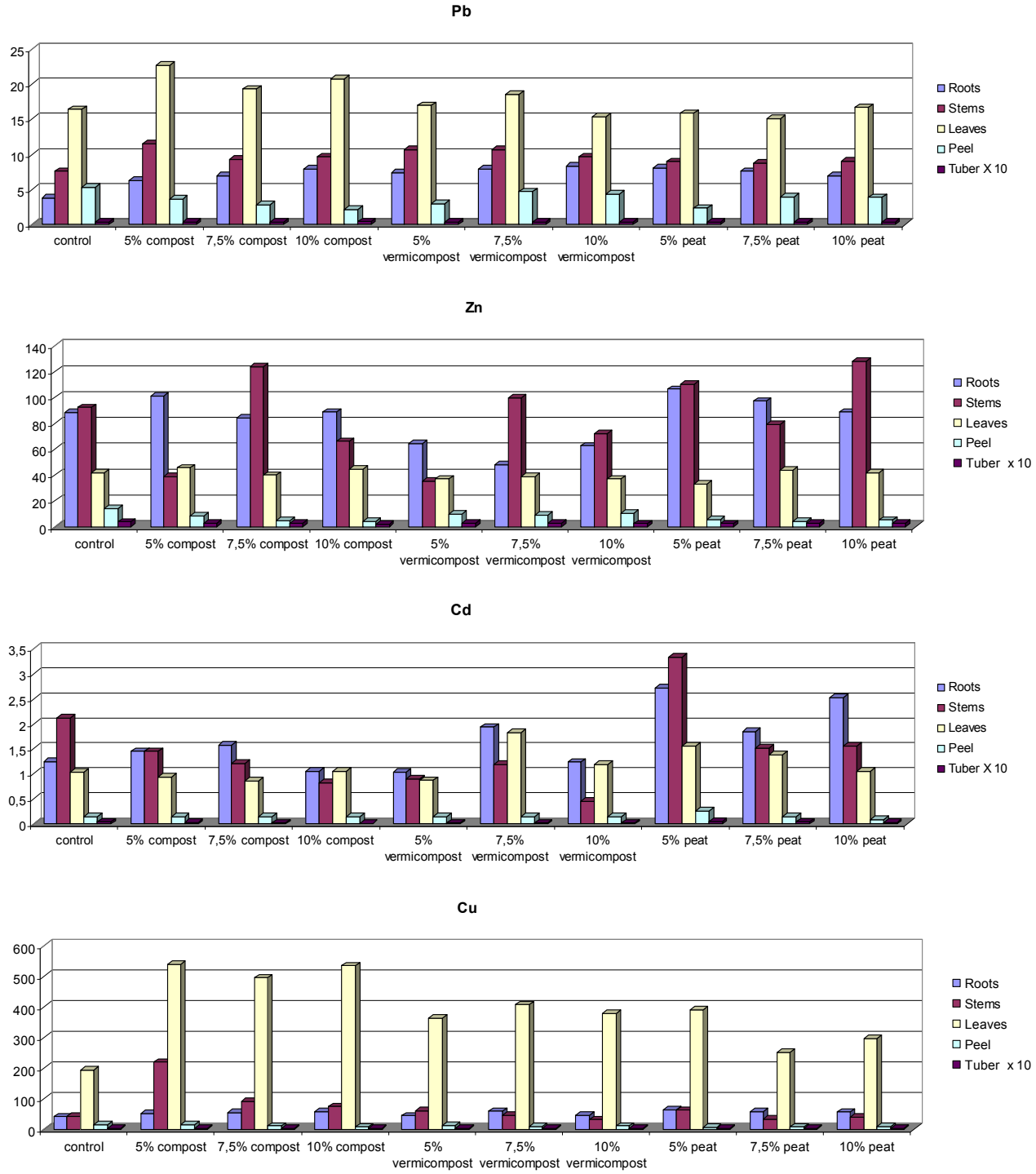

Figure 2. Effect of the organic amendments on the quantity of Pb, Zn, Cd and Cu (mg/kg) in potato plants.

Impact of organic amendments on Pb accumulation in potato peel depended significantly on their quantity. Increase of compost quantity led to a decrease of the Pb content in potato tubers: the concentration of Pb with compost was 0.34 mg/kg. When the soil was treated with vermicompost, Pb content remained practically unchanged (0.38 mg/kg). When the soil was treated with peat, Pb concentration decreased from 0.36 to 0.33 mg/kg. Cu showed similar tendency. Increase in the quantity of compost and vermicompost led to a decrease of Cu content in tubers and concentrations were 1.6 and 1.7 mg/kg, respectively. Increase in the quantity of peat led to an increase in Cu from 1.7 to 2.0 mg/kg. Changes in Cd and Zn content in potato organs were rather complex. Zn content in roots and stems increased in the plants treated with compost and peat amendments and decreased with vermicompost amendment. Zn in leaves showed a similar, but less obvious tendency. Organic amendments led to decreased Zn content in the potato peel and tubers, and this decrease was best expressed with 10% compost, 10% vermicompost and 5% peat.

Cadmium content in roots increased with all amendments used in the experiments. Cadmium content tended to decrease in stems and leaves when treated with the amendments. The only exception was the case where 5% peat amendment was applied, in which case Cd content in stems and leaves increased by 58% and 33%, respectively. Cadmium content in the peel remained practically unchanged in plants treated with compost and vermicompost. Organic amendment addition was especially effective for the reduction of Cd content in potato tubers. Increase of compost, vermicompost and peat doses led to a decrease of Cd content in potato tubers by up to 0.011 mg/kg (10% compost), 0.016 mg/kg (10% vermicompost) and 0.029 mg/kg (10% peat) and these concentrations were below the allowable concentration. The results agreed with those obtained by Chlopecka and Adriano (1997) who found that amendments were more efficient when Cd concentrations in soil were low, probably because at higher Cd concentrations in the soil the amount of amendment added was not sufficient to immobilize all available Cd.

Conclusion

1. The application of soil amendments favours plant growth and development. Development and fruit yielding were stimulated effect with all amendments and this effect was best expressed after 10% compost addition. Organic amendments led to an increase of starch yield, absolute dry substance and quantity and to a decrease of reducing sugars in potatoes.
2. Organic amendment application led to an effective immobilization of Pb, Cu, Zn and Cd phytoaccessible forms in soil. A correlation was found between the quantity of the mobile forms and the uptake of Pb, Zn, Cu and Cd by the potato.
3. Organic amendments led to decreased heavy metal content in the potato peel and tubers, and this decrease was best expressed with 10% compost or 10% vermicompost. Organic amendments were especially effective for reduction of the Cd content in potato tubers.
4. The organic amendments are of great interest for the purpose of phytostabilization. Evaluation of their potential, however, requires further study of the effect of organic amendments on a wider range of agricultural crops.

Acknowledgement

This work is supported by Bulgarian Ministry of Education, Project DO-02-87/08 and NSFB project GAMA DO 02-70 11/12/2008.

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