© 2012 Triveni Enterprises
Vikas Nagar, Lucknow, INDIA
editor@jeb.co.in
Full paper available on: www.jeb.co.in

J. Environ. Biol.
33, 425-429 (2012)
ISSN: 0254-8704
CODEN: JEBIDP

Industrial side-products as possible soil-amendments

Author Details

Brigitta Toth (*Corresponding author*) — Division of Agricultural Botany and Crop Physiology, Institute of Crop Sciences, Centre for Agricultural and Applied Economics Sciences, University of Debrecen, Debrecen, 4032, Hungary
e-mail: btoth@agr.unideb.hu

Szilvia Veres — Division of Agricultural Botany and Crop Physiology, Institute of Crop Sciences, Centre for Agricultural and Applied Economics Sciences, University of Debrecen, Debrecen, 4032, Hungary

Nora Bakonyi — Division of Agricultural Botany and Crop Physiology, Institute of Crop Sciences, Centre for Agricultural and Applied Economics Sciences, University of Debrecen, Debrecen, 4032, Hungary

Eva Gajdos — Division of Agricultural Botany and Crop Physiology, Institute of Crop Sciences, Centre for Agricultural and Applied Economics Sciences, University of Debrecen, Debrecen, 4032, Hungary

Marianna Marozsan — Nyírerdõ Nyírségi Forestry Corporation, Nyíregyháza, 4400, Hungary

Laszlo Levai — Division of Agricultural Botany and Crop Physiolohógy, Institute of Crop Sciences, Centre for Agricultural and Applied Economics Sciences, University of Debrecen, Debrecen, 4032, Hungary

Publication Data

Paper received:
05 November 2010

Revised received:
08 July 2011

Accepted:
30 July 2011

Abstract

The protection of our environment is a common task. All pollution that expose our soils, plants or in the narrower and wider sense environment will appear sooner or later in the food chain and in human beings who are at the top of the food-chain pyramid. The aim of our work is to give a brief overview about the effects of some industrial wastes on the physiological parameters of plants. Compost, black soot, sewage sludge and lime sludge dust was examined. Sunflower seeds were used in the experiments. The filtrates of examined materials were added to the nutrient solution in different quantities because of different solubility.The contents of sample elements and uptake of the element were measured by ICP, the relative chlorophyll contents by SPAD 502. Disadvantageous and advantageous physiological effects of compost, black soot, sewage sludge and lime sludge were proved. Larger concentrations of aluminium were measured in the roots than in the shoots. The concentrations of chrome were below the control value in the shoots when black soot, compost, lime sludge and sewage sludge were added to the nutrient solution. The concentrations of zinc, phosphorous, magnesium and copper were very low when black soot was used, and it was lower than the control. The dry matter of shoots increased when compost and sewage sludge was used, but the growth of roots remained under the control level.

Key words

Compost, Black soot, Sewage sludge, Soil amendments

Introduction

The world's population is rapidly increasing. It is estimated to be 8 billion in the next decade. The food production must be doubled on the presently used land to meet the demand (James and Krattiger, 1996). The large enhancements in use of fertilizers and improvements of soil fertility are indispensable approaches (Cakmak, 2001). Nowadays, the degradation of ecosystem is caused by poor soil fertility, low levels of available mineral nutrients in soil and unsuitable nutrient management.

The challenge of present agriculture is that the productivity should be increased, especially in the developing countries. However, recent trends indicate that the growth rate in crop production has begun to slow down in the past 10 years.

Special Issue - **Environment and Geography in the Mediterranean**
Guest Editors - **Dr. Recep Efe, Dr. Munir Ozturk and Dr. Sumati Gaumat**

Over-application of fertilizers in poorly managed cropping systems can result with serious environmental problems, such as pollution of groundwater and eutrophication of surface waters (Socolow, 1999). Tremendous requirements for food are more important problems than the environmental pollution in many developing countries (Gruhn *et al.*, 1996). Reduced soil fertility caused by continuous production with low nutrient supply is a major threat both to food production and the ecosystem viability (Pinstrup-Andersen *et al.*, 1999). As a result of declining soil fertility, together with increasing population to marginal lands and forested areas there is a considerable increase what are leading to harmful ecosystem destruction (Tillman, 1999).

The produce of fertilizer needs lots of energy and cost. Plenty of harmful gases get out during the produce procedure. Recommended the reuse of wastes and side-products which contain lots of organic matter, micro and macro elements and have got not harmful effect to environment. To use these side products the CO_2 emission could also be reduced. The land application of sewage sludge is a common agricultural practice worldwide. It effectively disposes of a waste product while recycling valuable nutrient into the soil - plant system. We have to try to reuse more and more waste and side-products.

Materials and Methods

Sunflower *(Helianthus annus* L.*)* was used in the experiments. The seeds were sterilized with 18% hydrogen peroxide, and then washed in distilled water. Then they were germinated on moistened filter paper at 25 °C. The seedlings were transferred to continuously aerated nutrient solution of the following composition: 2.0 mM $Ca(NO_3)_2$, 0.7 mM K_2SO_4, 0.5 mM $MgSO_4$, 0.1 mM KH_2PO_4, 0.1 mM KCl, 1µM H_3BO_3, 1µM $MnSO_4$, 0.25 µM $CuSO_4$, 0.01 µM $(NH_4)_6Mo_7O_{24}$. Iron was added to the nutrient solution as Fe-EDTA at a concentration of 10^{-4}M. The filtrates of black soot, compost, lime sludge and sewage sludge were added to the nutrient solution. The solubility of examined materials was different, therefore to obtain the same concentration the filtrates were given in different amounts to the nutrient solution as follows: black soot 94 ml dm^{-3}, compost 91 ml dm^{-3}, sewage sludge 66 ml dm^{-3} and lime sludge 100 ml dm^{-3}. The filtrates were made from 17 g examined materials and 170 ml distilled water. This was shaked for 2 hrs, and after that it was vacuum filtrated. The seedlings, 12 for each basic treatment, were grown under controlled environmental conditions (light/dark regime 10/14 hr at 24/20 °C, relative humidity of 65–70 % and a photosynthetic photon flux of 300 µmol $m^{-2}s^{-1}$). There were three replications for each treatment. The contents of elements were measured with ICP, the relative chlorophyll contents with SPAD 502 (Minolta). The number of laboratory readings for ICP was the mean of three samples, and SPAD 502 was 60. The samples were dried at 85 ºC, the dry matter of shoots and roots of 12 plants was measured. For each used industrial side-product, germination test using mustard (*Sinapsis alba L.*) plants has been conducted for raw materials and its filtrate. The amounts of examined materials were 10g per perti dishes. The black soot dust originated from Hajdu Komm Environmental Protection Ltd. (Eastern Hungary), the sewage sludge and compost came from Alkaloida Chemicals Co. Ltd. (East Hungary) and the lime sludge originated from the Ore, Mineral and Waste Recycling Works of Borsod Private Company Limited by Shares (BÉM Zrt.).

Results and Discussion

The examined side products were supplied in large quantities by the above-mentioned companies. These materials contain lots of useful elements for plants (e.g. Fe, K, Zn, Mg, etc.) and some harmful elements in addition (e.g. aluminum, chrome) (Table 1). The selected elements have environmental relevance and have important role in plant life. The content of cu was approximately 10 times higher in the lime sludge than in the black soot. The quantity of Fe was highest in the lime sludge. This value was 203 times higher than in black soot. The large amount of Fe, Cr and Pb originated from the produce of lime sludge because it was made from metallurgy melted wastes mixed with lime. The concentration of P, Zn and Al was the highest in the sewage sludge. The concentrations of 25 elements were measured, for further examination the elements of highest concentrations were selected.

A germination test on the examined physiological parameters with mustard plants showed differences in the effects of raw materials and those of their filtrates. Moistured with distilled water, filter paper was used as control. The germination percentage was higher when filtrates were used. The differences originate from the low solubility of materials that can be found in the side-products. The black soot retarded the germination: there was no germinated seed at all and the germination percentage was very low in the lime sludge (Table 2).

Application of the filtrate of the black soot, compost and lime sludge increased the germination percentage. The germination rate was higher for the compost and lime sludge than the control on the second, third, fourth and fifth day when filtrates were used. There was lower germination rate observed when black soot was examined (Table 3).

The plants can uptake the measured elements and may cause different effects on the development and growth of plants. The uptaken elements are shown in the Table 4 and 5.

Larger concentrations of Al were measured in the roots than in the shoots. We suppose that Al accumulated in the roots and the root- to- shoot transfer is retarded. The Al concentrations was highest in the roots of treated plants. This observation is in contradiction with the increased growth of shoots and roots of treated plants. The concentration of Al was about 7 times higher in shoots and 761 times higher with treated black soot than that of control. This concentration was 22 times higher in the roots treated with compost, 13 times higher in the lime sludge and about 10 times higher in the sewage sludge. The toxic effects of Al are primarily root-related (Taylor, 1988). The root system becomes

Table - 1: Contents of some elements (Cu, Fe, K, Mg, Na, P, Zn, Al, Cr, Pb) in the examined wastes (black soot, compost, sewage sludge, lime sludge) (mg kg^{-1}). Essentiality is marked as essential or beneficial$_a$ and toxic$_b$.

Elements	Black soot	Compost	Lime sludge	Sewage sludge
Cu_a	17.90± 2.51	53.00± 8.99	109.00± 4.41	185.00± 6.60
Fe_a	583.00± 11.33	9.883.00± 63.63	21,098.00± 213.33	118,500.00± 633.31
K_a	542.00± 9.36	1.485.00± 234.45	2,878.00± 135.45	1,010.00± 52.10
Mg_a	842.00± 12.21	3,693.00± 125.54	5,548.00± 121.02	5,055.00± 170.04
Na_{ab}	4,738.00± 80.02	1,475.00± 210.33	2,163.00± 99.33	5,419.00± 184.61
P_a	185.00± 9.50	10,063.00± 351.93	21,289.00± 120.36	162.00± 6.39
Zn_a	116.00± 4.21	251.00± 21.54	473.00± 21.94	106.00± 4.45
Al_b	2,549.00± 24.50	7,227.00± 123,66	17,349.00± 645.37	3,440.00± 123.45
Cr_b	6.07± 0.33	25.50± 1.32	41.30± 2.52	169.00± 5.52
Pb_b	22.50± 6.33	41.30± 6.54	70.10± 10.21	80.70± 13.33

Values are mean of three replicates ± S. E.

Table - 2: The effects of different matters (black soot, compost, sewage sludge, lime sludge) on the germination (%) of mustard (n=3±S.E.) Significant difference as compared to control

Days	Control	Black soot	Compost	Sewage sludge	Lime sludge
2.	25.67± 8.74	0.00± 0.00**	25.00± 16.64	63.67± 1.53**	3.67± 1.15*
3.	56.00± 6.66	0.00± 0.00**	57.67± 8.74	84.34± 2.52	3.67± 0.00**
4.	68.33± 7.02	0.00± 0.00**	65.34± 3.21	86.67± 1.53	3.67± 0.00*
5.	79.00± 8.62	0.00± 0.00**	70.01± 3.06	89.00± 1.53	5.00± 0.58

Values are mean of three replicates ± S. E.; *p<0.05; **p<0.01

Table - 3: The effects of the filtrate of the examined substances (black soot, compost, sewage sludge, lime sludge) on the germination (%) (n=3±S.E.) Significant difference as compared to the control

Days	Control	Black soot	Compost	Sewage sludge	Lime sludge
2.	19.00± 16.64	3.67± 3.79	20.67± 11.02	11.67± 5.51	32.67± 2.52
3.	31.33± 9.24	9.00± 1.53*	38.67± 3.61	19.67± 0.00**	50.00± 3.06
4.	52.33± 2.00	17.00± 6.93	61.67± 7.55	30.34± 2.31	66.67± 5.03
5.	65.33± 4.16	22.00± 1.73	68.34± 4.93	37.37± 0.00	74.34± 4.04
6.	73.66± 6.43	28.00± 4.00	75.01± 4.93	52.37± 8.66	79.67± 4.16

Values are mean of three replicates ± S. E.; *p<0.05; **p<0.01

Table - 4: Concentration of examined elements (Al, Cr, Cu, Fe, K, Mg, Na, P, Zn) in the shoots of sunflower seedlings (mg kg^{-1}) treated with black soot, compost, sewage sludge and lime sludge

Elements	Control	Black soot	Compost	Sewage sludge	Lime sludge
Al	7.25± 1.57	50.90± 5.61	12.74± 2.11	7.44± 1.47	16.53± 1.69
Cr	1.20± 0.37	0.41± 0.03	0.72± 0.03	0.49± 0.03	0.77± 0.01
Cu	5.87± 1.23	3.56± 0.33	7.91± 2.02	5.01± 0.81	5.65± 0.09
Fe	117.33± 18.67	35.33± 9.35	129.66± 7.55	111.00± 15.21	164.00± 6.54
K	44,366.33± 4,629.33	35,665.33± 3,421.33	51,177.067± 5.749.87	38,632.00± 3,369.21	40,078.00± 3,857.31
Mg	3,788.33± 321.23	2,422.33± 212.97	4,194.00± 368.94	3,356.00± 300.21	3,927.00± 312.29
Na	204.00± 63.39	3,184.66± 387.12	339.00± 38.65	202.33± 12.21	339.00± 40.91
P	4,455.00± 368.07	1,031.00± 102.21	5,152.66± 421.33	4,202.67± 354.39	4,945.00± 215.33
Zn	27.76± 3.39	10.21± 1.29	34.20± 5.87	24.66± 3.85	23.93± 0.21

Values are mean of three replicates ± S. E.

stubby as a result of inhibition of elongation of the main axis and lateral roots (Klotz and Horst, 1988). The severity of inhibition of root growth is a suitable indicator of genotypic differences in aluminium toxicity (Foy *et al*., 1967). Aluminium toxicity is, therefore, often expressed simultaneously in two ways, namely induced deficiency of mineral nutrients, such as Mg, and inhibition in root elongation (Tan *et al*., 1992). The concentrations of chrome was below the control value in the shoots when black soot, compost, lime sludge and sewage sludge were added to the nutrient solution. In contrast, the concentrations of chrome in roots were higher when compost, lime sludge and sewage sludge were examined. This elements also was measured.

Table - 5: Concentration of examined elements (Al, Cr, Cu, Fe, K, Mg, Na, P, Zn) in the roots of sunflower seedlings (mg kg^{-1}) treated with black soot, compost, sewage sludge and lime sludge

Elements	Control	Black soot	Compost	Sewage sludge	Lime sludge
Al	34.80± 2.11	25,890.67± 521.33	780.33± 56.99	368.33± 33.39	437.33± 32.33
Cr	1.22± 0.12	1.01± 0.00	2.57± 0.02	1.57± 0.02	20.03± 2.12
Cu	19.00± 1.21	6.99± 0.04	22.03± 2.21	15.46± 1.02	19.00± 1.01
Fe	454.33± 62.93	1,240.00± 100.33	1,147.33± 121.34	887.33± 54.55	798.33± 69.31
K	58,219.67± 5,822.05	45,498.33± 4,314.33	42,299.67± 4,123.44	43,415.00± 4,213.87	54,876.67± 5,312.06
Mg	2,953.00± 227.46	1,506.66± 121.31	6,373.33± 569.33	5,672.00± 521.06	3,610.00± 312.36
Na	3,686.33± 259.91	14,580.33± 1213.33	8,013.00± 758.99	5,503.67± 455.03	8,119.67± 791.62
P	7,148.33± 450.39	3,442.00± 321.64	6,104.67± 549.07	6,324.67± 568.I09	7,625.00± 635.33
Zn	44.50± 4.21	16.76± 1.06	55.83± 4.55	45.90± 4.93	46.96± 4.09

Values are mean of three replicates ± S. E.

concentration was under control in the black soot. The quantity of Na was 15 times higher in the shoots and 4 times higher in roots when black soot was added to the nutrient solution. The concentration of Fe was lower in the shoots when we treated with black soot, but was about 3 times higher in the roots when we used black soot and 2.5 times higher when we added compost to the nutrient solution. The concentration of Zn, P, Mg and Cu was very low when black soot was used, and it was lower than control. Differences were observed also in dry matter accumulation of sunflower seedlings during the experiment. The results are shown in Table 6.

In nearly all the cases, the values were found around control value, except the black soot, where the values were under the control figures. The dry matter of shoots increased when compost and sewage sludge was used, but the growth of roots remained under the control level. The dry matter accumulations of shoots and roots were lower than the control when black soot was used, and the values were higher in treatments with lime sludge. The dry matter accumulation of shoots and roots reduced significantly when

Table - 6: Effects of different matters (black soot, compost, sewage sludge, lime sludge,) on the dry matter accumulation of shoots and roots of sunflower seedlings (g $plant^{-1}$) Significant difference comparison to the control

Treatments	Shoots	Roots
Control	0.96± 0.16***	0.21± 0.04***
Black soot	0.37± 0.14***	0.07± 0.09***
Compost	1.13± 0.16**	0.22± 0.14***
Sewage sludge	1.03± 0.36***	0.21± 0.21***
Lime sludge	0.88± 0.22***	0.18± 0.01**

Values are mean of three replicates ± S. E.; *p<0.05; **p<0.01

Table - 7: Effect of the examined materials (black soot, compost, lime sludge, sewage sludge) on the relative chlorophyll contents of sunflower leaves (Spad units) Significant difference comparison to the control

Treatments	10^{th} days	13^{th} days	15^{th} days
Control	47.57± 1.93	50.63± 1.34	50.33± 0.40
Black soot	43.29± 1.30***	41.46± 1.39***	39.34± 1.43***
Compost	46.78± 1.34	49.87± 0.64	50.02± 1.28
Sewage sludge	46.71± 3.09	48.36± 0.95***	48.88± 0.11
Lime sludge	44.45± 0.68***	45.54± 0.47***	46.35± 1.43***

Values are mean of three replicates ± S. E.; *p<0.05; **p<0.01

black soot was applied and dry matter accumulation of roots when lime sludge was given to the nutrient solution. These results suggest the potential application of compost and sewage sludge as microelement fertilizers.

Low chlorophyll contents affect photosynthetic activities. The decreasing dry matter accumulation can be explained by the lower level of the chlorophyll contents (Table 7). The relative chlorophyll content decreased significantly on the 10^{th}, 13^{th} and 15^{th} days at all treatments, as well as on the 13^{th} days when sewage sludge was added to the nutrient solution. The relative chlorophyll content decreased with about 1 Spad unit in the compost treatment on the 10^{th} and 13^{th} day and the decline was not considerable on the 15^{th} day. These values decreased with 1 Spad unit on the 10^{th} and about 2 units on the 13^{th} day and 1.5 units on the 15^{th} day.

When plants are grown under controlled conditions, 80% of the Fe is localized in the chloroplasts in rapidly growing leaves, regardless of iron nutritional status. Fe can be stored in plant cells in the stroma of plastids as phytoferritin (Seckbach, 1982). Its content is high in dark-grown leaves (up to 50% of the total Fe), but rapidly disappears during regreening (Mark *et al.*, 1981), and remains very low in green leaves. After resuppyling the Fe to deficient plants, however, the uptake rate is exceptionally high and the phytoferritin leaf content may transiently increase dramatically (Lobreaux *et al.*, 1992), and make up as much as 30% of the total leaf Fe (Van der Mark *et.al.*, 1982; Platt- Aloia *et al.*, 1983). The localization of phytoferritin is not confined to chloroplasts: it can also be detected in the xylem and phloem (Smith, 1984). The chlorophyll contents depend on Fe content (Machold, 1968) and the relative low chlorophyll content in sunflower can be co-related to low iron content (583 mg kg^{-3}) in black soot material.

The investigated materials contain lots of elements. The largest concentration of Cu, Fe, Na, Cr and Pb were measured in the lime sludge than in black soot, compost or sewage sludge. The highest contents of K, Mg , P, Zn and Al were measured in the compost. This result originated from the materials of produce. The lime sludge also contained lot of metals.

The plants up take these elements which may cause different effects of their growth and development. The amount of uptaken

Larger concentration was measured in the roots than in the shoots from the examined elements. We suppose that these elements are accumulated in the roots and the root-to-shoot transfer is retarded. It is advantageous in case of crop production because we especially use the shoots of crop plants. The dry matter production – which is the main aim of crop production - depends on nutrient supply.

Different dry matter accumulation of shoots was observed. It was 17% when compost, 7% when sewage sludge was added to the nutrient solution. The dry matter accumulation of roots increased by 4% due to the compost treatement and there was no difference in dry matter of roots when sewage sludge was used. These results suggest the potential application of sewage sludge and especially compost as nutrient supplementary materials in crop production among controlled circumstances. Further examinations are needed to examine the potential application in the fields.

Acknowledgements

We would like to say many thanks to those companies for their help that have made the examined materials available for us: Ore, Mineral and Waste Recycling Works of Borsod Private Company Limited by Shares, Hajdu Komm Environmental Protection Ltd., Alkaloida Chemicals Co. Ltd.

References

Cakmak I.: Plant nutrition research: Priorities to meet human needs for food in sustainable ways. In Plant nutrition- Food security and sustainability of agro-ecosystem. Kluwer Academic Publishers. pp. 4-7 (2001).

Fov, C.D., A.L. Fleming and W.H. Armiger: Characterization of differential aluminium tolerance among varieties of wheat and barley. *Soil Sci. Soc. Am. Proc*., **31**, 513-521 (1967).

Gruhn, P., F. Goletti and M. Yudelman: Integrated nutrient management, soil fertility, and sustainable agriculture: Current issues and future challenges. Washington DC. International Food Policy Research Institute. Food, Agriculture and Environment Discussion Paper 32. (2000).

James, C. and A.F. Krattiger.: Global Review of the Field Testing and Commercialization of Transgenic Plants, 1986 to 1995: The First Decade of Crop Biotechnology. ISAAA Briefs No.1. ISAAA: Ithaca, **31**, (1996).

Klotz, F. and W.J. Horst: Genotypic differences in aluminium tolerance of soybean (*Glycine max*.L.) as affected by ammonium and nitrate-nitrogen nutrition. *J. Plant Physiol.,* **132**, 702-707. (1988).

Lobreaux, S., O. Massene and J.F. Briat: Iron induces ferritin synthesis in maize plantlets. *Plant Mol. Biol.,* **19**, 563-575 (1992).

Machold, O.: Einfluss der Ernährugsbedingungen auf den Zustand des Eisens in den Blättern, den Chlorophyllgehalt und die Katalase- souie Peroxydaseaktivität. Flora (Jena), Abt. A. **159**, 1-25 (1968).

Mark, F.van der, Lange T. de and H.F. Bienfait: The role of ferritin in developing primary bean leaves under various light conditions. *Planta* **153**, 338-342 (1981).

Pinstrup-Andersen, P., R. Pandya-Lorch and M.W. Rosegrant: World Food Prospects: Critical Issues for the Early Twenty – First Century. 2020 Vision Food Policy Report. Washington, DC: IFPRI (1999).

Platt-Aloia, K.A., W.W. Thomson and N. Terry: Change in plastid ultrastructure during iron nutrition-mediated chloroplast development. *Protoplasma,* **114**, 85-92 (1983).

Seckback J.: Ferreting out the secrets of plant ferritin - A review. *J. Plant Nutr.,* **5**, 369-394 (1982).

Smith B.N.: Iron in higher plants: Storage and metabolic rate. *J. Plant Nutr.,* **7**, 759-766 (1984).

Socolow R.H.: Nitrogen management and the future of food: Lessons from the management of energy and carbon. *Proc. Nat. Acad. Sci. USA,* **96**, 6001-6008 (1999).

Tan, K., W.G. Keltjens and G.R. Findenegg: Aluminium toxicity with sorghum genotypes in nutrient solutions and its amelioration by magnesium. *Z. Pflanzenernähr. Bodenk.*, **155**, 81-86 (1992).

Taylor, G.J.: The physiology of aluminium phytotoxicity. *In*: Metal Ions in Biological Systems (*Eds*.: H. Sigel and A. Sigel). Marcel Dekker Inc. New York, **24**, 123-163 (1988).

Tilman, D.: Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. In Proceedings of the National Academy of Sciences of the United States of America, **96**, 5995-6000 (1999).

Van der Mark, F., M.L. van den Briel, J.W.A.M. Van Oers and H.F. Bienfait: Ferritin in bean leaves with constant and changing iron status. *Planta,* **156**, 341-344 (1982).