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Possible Use of Renewable Industrial By-products in Environmentally-Friendly Agricultural Production

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Abstract. The aim of our study is to provide on overview of selected wastes (sewage sludge, lime sludge, compost) on the physiological parameters of sunflower (*Helianthus annus L. cvs. Arena*). The filtrates of the examined materials were added to a nutrient solution. The dry matter accumulation of the shoots and roots, the relative chlorophyll contents and the contents of elements were measured of plants that were grown on a nutrient solution. We concluded that the examined wastes may have dangerous effects on the ecosystem, because they contain several harmful elements for plant development.

Keywords: crop production, environmental protection, industrial by-products

1. Introduction

While worldwide data on emission of heavy metals from natural sources are particularly scarce, a summary of a literature survey has been prepared. Windblown dusts and volcanic eruptions are of particular relevance to ecosystem inventories and budgets of heavy metals. Marine aerosols and forest fires also exert a major influence on many environments. While the long-range transport of dust particles, particularly from the Sahara, has recently received considerable attention [1] the transport of dust particles originating in Asia and elsewhere to the Pacific, Arctic and Antarctic has also been investigated [2].

Climate change may bring about increased aridity to large areas of Europe. Higher temperatures, larges water deficits and high light stress are likely to occur in conjunction with elevated levels of CO_2. These changes raise the question whether a high CO_2 concentration in the atmosphere can compensate for the decrease in carbon gain under water-stressed conditions. The processes which determine dry matter production and the ways they are affected by soil water deficits are discussed. It is now well established that in most species and under most circumstances stomata is the main limiting factor to carbon uptake under water deficit; the photosynthetic machinery being highly resistant to dehydration. However, when other stresses are superimposed, a decline in photosynthetic capacity may be observed. In the short term, under drought conditions, an increase in CO_2 in the atmosphere may diminish the importance of stomata limitation for carbon assimilation inhibiting photorespiration, which might otherwise result in significant losses in plant production under stress conditions. However, in the longer term though, a negative acclimation of photosynthesis appears to occur in many species, an explanation for which still needs to be clearly identified. Similarly, the effects of extended exposure to elevated CO_2 under arid conditions are not known. Plant production is more closely related to the integral of photosynthesis over time and total foliage area than to the instantaneous rates of the photosynthetic process. Water deficits result in a decrease in foliage area biomass and, therefore, in productivity. On the other hand, the increase in air temperature may result in more

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respiratory losses. Neverthless, experimental as well as stimulatory evidence suggests that doubling CO_2 concentration in the air may improve carbon assimilation and compensate partially for the negative effects of water stress even if we assume a down-regulation of the photosynthetic process as a result of acclimation to elevated CO_2.

2. Material and methods

Sunflower seeds *(Helianthus annus L. cvs. Arena)* were used in the experiments. The test plants were growing on a continuously aerated nutrient solution, composed as follows: 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 $MnSO_4$, 1µM $ZnSO_4$, 0.25 µM $CuSO_4$, 0.01 µM $(NH_4)_6Mo_7O_{24}$, 10^{-4}M Fe(III)-EDTA. The filtrates of the examined industrial wastes were added to the nutrient solution in different quantities. The solubility of examined materials differed: therefore, to obtain the same concentration the filtrates were given to the nutrient solution in different amounts, as follows: compost 91 ml dm^{-3}, sewage sludge 66 ml dm^{-3} and lime sludge 100 ml dm^{-3}. The seedlings were grown under controlled environmental conditions (light/dark regime 10/14 h at 24/20°C, relative humidity of 65–70% and a photosynthetic photon flux of 300 µmol $m^{-2}s^{-1}$. Three repetitions were made using each type of combination. The contents of elements were measured with ICP, the relative chlorophyll contents with of 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 Cº, the dry matter of shoots and roots of 12 plants was measured

The lime sludge originated from the Ore, Mineral and Waste Recycling Works of Borsod Private Company Limited by Shares (BÉM Zrt.) (Northern Hungary), and the sewage sludge and compost came from the Alkaloida Chemicals Co. Ltd. (East Hungary).

3. Results and discussion

The examined matters were supplied in large quantity by the above-named companies. These materials contain lots of harmful elements for plants (e.g. chromium, aluminium, etc.) (Table 1).

Table 1. Contents of some elements (Cu, Fe, K, Mg, Na, P, Zn) in the examined wastes (compost, sewage sludge, lime sludge) (mg kg^{-1})

Elements	Compost	Sewage sludge	Lime sludge
Al	7,227.00	17,349.00	3,440.00
Cr	25.50	41.30	169.00
Li	3.18	4.21	4.70
Mn	337.00	496.00	1,983.00
Pb	41.30	70.10	80.70
Sr	102.00	195.00	157.00
Ti	41.70	87.20	132.00

The plants can absorb these elements, which may cause different effects on the development and growth. The up-taken elements are shown in Tables 2-3.

Of the seventeen plant-essential elements, eight (iron, manganese, zinc, copper, boron, molybdenum, cobalt and chlorine) are required in small quantities and are thus called trace elements [3]. Of these eight, iron, manganese, zinc, copper and molybdenum are sometimes referred to as heavy metals. Yet, the term heavy metals does not distinguish between those metals that are toxic to plants at levels encountered in some natural systems [4]. Accordingly, the terms trace metal, heavy metal and descriptions of an element's necessity to plants must be considered carefully when used.

Table 2. Concentration of examined elements (Al, Cr, Li, Mn, Sr, Ti) in the shoots of sunflower seedlings (mg kg^{-1}) effecting by compost, sewage sludge, lime sludge.

Elements	Control	Compost	Sewage sludge	Lime sludge

Al	7.22	12.74	7.44	16.53
Cr	1.20	0.72	0.49	0.77
Li	0.14	0.25	0.15	0.16
Mn	34.43	45.33	36.13	64.33
Sr	17.73	26.36	18.40	19.36
Ti	0.27	0.42	0.25	0.54

Table 3. Concentration of examined elements (Al, Cr, Li, Mn, Sr, Ti) in the roots of sunflower seedlings (mg kg^{-1}) effecting by compost, sewage sludge, lime sludge.

Elements	Control	Compost	Sewage sludge	Lime sludge
Al	34.80	780.00	7.44	437.33
Cr	1.22	2.57	1.57	20.03
Li	0.22	0.62	0.34	0.73
Mn	19.63	58.96	48.70	59.30
Sr	9.17	11.61	9.25	9.64
Ti	0.33	2.37	1.35	8.55

Larger concentrations of aluminium were measured in the roots than in the shoots in all of the cases. We suppose that the Al were accumulated in the roots and the root- to- shoot transfer is retarded. The Al concentrations were highest in the roots of treated plants, and as a consequence the observed growth of the shoots and roots were higher than for the control. The concentrations of Al were about 18 times higher than the control. The toxic effects of aluminium are primarily root-related [5]. The root system becomes stubby as a result of the inhibition of elongation of the main axis and lateral roots [6]. The severity of inhibition of root growth is a suitable indicator of genotypic differences in aluminium toxicity [7]. Aluminium toxicity is therefore often expressed simultaneously in two ways, namely induced deficiency of mineral nutrients, such as magnesium, and inhibition in root elongation [8]. The concentration of chromium was higher in the roots than in the shoots. These values were approx. 3 or 3.5 times higher when compost and sewage sludge were used and 26 times higher in plants treated by lime sludge. The concentration of lithium was also higher in the roots than in the shoots. The content of manganese was higher in the roots than in the shoots, except for the case of lime sludge, where this concentration was higher by 1%. Manganese deficiency is abundant in plants growing in soils derived from parent material inherently low in manganese and in highly leached tropical soils. It is also common on soils of high pH containing free carbonates, particularly when combined with large organic matter content [9]. The critical deficiency contents of manganese in plants are similar, varying between 10 and 20 mg Mn kg-1 dry weight in fully expanded leaves, regardless of plant species or cultivar or prevailing environmental conditions. Below the critical deficiency content, dry matter production [10], net photosynthesis, and chlorophyll contents decline rapidly, whereas rates of respiration and transpiration remain unaffected [11]. Differences were observed in dry matter contents during the experiment. The results are shown in Table 4.

Table 4. Effects of different matters (compost, sewage sludge, lime sludge) on the dry matter accumulation of shoots and roots of sunflower seedlings n=12± s.e. (plant g^{-1}) Significant difference comparison to the control: *p<0.05; **p<0.01;***p<0.001.

	Dry matter of sunflower (plant g^{-1})	
Treatments	Shoots	Roots
Control	0.96± 0.16	0.21± 0.04
Compost	1.13± 0.16**	0.22± 0.14
Sewage sludge	1.03± 0.36	0.21± 0.12
Lime sludge	0.88± 0.22	0.18± 0.01**

In nearly all the cases, the values were around those of the control. The dry matter of shoots increased when compost and sewage sludge were applied. Dry matter of shoots increased significantly when compost was used. The dry matter accumulation of shoots and roots are below that of the control, when lime sludge was introduced to the nutrient solution. The dry matter accumulation of roots decreased significantly when plants were treated by lime sludge.

Low chlorophyll contents affect photosynthetic activities. The decreasing dry matter accumulation can be explained by the lower level of the chlorophyll contents (Table 5).

Table 5. Effects of the examined materials (compost, sewage sludge, lime sludge) on the relative chlorophyll contents of sunflower leaves on the 10th, 13th and 15th days of measurement (Spad units) n=75± s.e. Significant difference comparison to the control: *p<0.05; **p<0.01;***p<0.001.

Relative chlorophyll contents of 1st leaf of sunflower (Spad Units)

Treatments	10th days	13th days	15th days
Control	47.57± 1.93	50.63± 1.34	50.33± 0.40
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***

When plants are grown under controlled conditions, cc. 80% of the iron is localized in the chloroplasts in rapidly growing leaves, regardless of iron nutritional status. Iron can be stored in plant cells in the stroma of plastids as phytoferritin [12]. Its content is high in dark-grown leaves (up to 50% of the total iron), but rapidly disappears during re-greening [13] and remains very low in green leaves. The chlorophyll contents will be larger due to the larger iron contents [14].

The compost, sewage sludge and lime sludge contain some iron (contain of iron in compost: 9,883 mg kg^{-1}; content of iron in sewage sludge is 21,098 mg kg^{-1}; and this value is 118,500 mg kg^{-1} in the lime sludge).The relative chlorophyll contents did not change between the 13rdand 15th days. The relative chlorophyll content decreased significantly when lime sludge was applied, and on the 13th day when sewage sludge was used.

4. Conclusions

The investigated materials contain some harmful elements. The plants can absorb these elements and may cause different effects on the development and growth of plants. Most of these elements are localized in the roots and not transferred into the shoots. The dry matter of shoots increased when compost and sewage sludge were applied. Dry matter of shoots increased significantly when compost was used. The dry matter accumulation of shoots and roots are below the control, when lime sludge was introduced to the nutrient solution. The dry matter accumulation of roots decreased significantly when plants were treated using lime sludge.

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