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HEAVY METALS AND PLANT-GROWTH-YIELD AS AFFECTED BY WATER HYACINTH COMPOST APPLIED TO SANDY SOIL

The present investigation was carried out to study the effect of increasing rates of either water hyacinth compost or the mixture of sewage sludge and water hyacinth on the growth, yield and heavy metals content of corn and sesame plants. A field investigation was carried out using sandy soil mixed with 0, 5 and 10% compost of water hyacinth and/or combination of sewage sludge at three rates, namely 4, 6 and 8% with 5% water hyacinth.

The results obtained indicated that application of water hyacinth (*Eichhornia crassipes*) compost enhanced the dry matter accumulation in seed yield and stimulated the uptake of micronutrient elements. Such water hyacinth compost showed also a superior effect on the soil if compared with the compost of water hyacinth mixed with sewage sludge.

1. INTRODUCTION

As the human population has exploded during the past half century, agricultural production has been intensified through the abundant use of inorganic fertilizer, the practice of monoculture or two-crop rotations, and the liberal use of chemical pesticides. Some argue about such a system of agricultural production for being not sustainable, because it leads to degradation of the earth's environment. They offer organic farming as an alternative. Undoubtedly, human survival depends on agricultural product and the earth's environment as being sustained. Whether agriculture production will continue to exploit the present intensive system, move to organic farming, or use a mix of the two, it will have some serious implications for the billions who will occupy the earth in the next century and beyond.

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The lack of good-quality organic wastes that can be applied to land as biofertilizer and soil conditioners has necessitated an intensive investigation to develop new practices conforming to modern technology. On the other hand, aquatic weeds have a fertilizer potential; in particular, the water hyacinth. Such weeds are very prolific and hence troublesome by clogging waterways. However, they take up considerable amounts of nutrients from aquatic environment as well as certain heavy metals [1], [2].

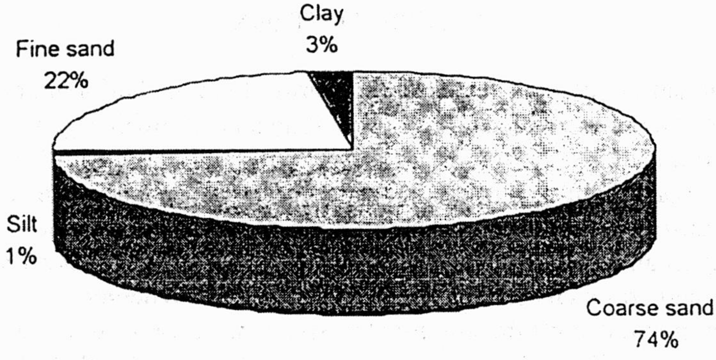
It has been reported that aquatic macrophytes, e.g. water hyacinth (*Eichhornia crassipes*), growing naturally in fresh water utilize available nutrients and produce huge amounts of biomass that can be used for some beneficial purpose [3]. According to several studies the biomass of water hyacinth can be used for feed, can serve as biological indicator of water pollution and as a compost for soil amendment [4], [5].

Meanwhile, a proper management of natural aquatic weed compost on the land is one of the best means of protecting agricultural soil against degradation process. These organic materials can markedly increase soil productivity by providing essential plant nutrients and by improving physical properties of soil.

The aim of the present study was to investigate the possible use of water hyacinth composts as an organic fertilizer of sandy soil and its impact on the growing crops.

2. MATERIALS AND METHODS

Sandy soil with poor agricultural properties (i.e. low organic matter content, poor fertility and productivity, figure) was selected for the present study. Water hyacinth plants were collected from the Nile at El-Kannater area (Cairo). Samples were dried,



Particle size distribution of the Inshas sandy soil

ground and digested for the determination of nutrient elements and heavy metals. The bulk of water hyacinth biomass collected from the Nile dirt and mud was composted for 21 days using windrow technnique [6]. Water hyacinth compost (W) at 1, 5 and

10% rate of application was thoroughly disked into the plots to the depth of 30 cm. Furthermore in other plot, the sets of compost mixtures consisting of sewage sludge mixed with 5% water hyacinth compost (B_5 + W) at the rate of 4, 6 and 8% were thoroughly disked into the plots to a depth of 30 cm according to the experimental design given in table 1. The total of seven treatments in three replications (experimental plots area = 21 m^2) were distributed completely at random. Corn (*Zea mays*) and sesame (*Sesamum indicum* L.) were planted. N-fertilizer was applied at three intervals (germination, vegetation and before flowering stages) at a rate of 50 kg N/fed.* as urea (46% N). Plots were irrigated weekly by sprinkler system. Plant samples from each plot were taken after 1, 2 months and at maturity. Corn and sesame were harvested after 3 months of planting and their yields were recorded. Three control plants were planted and NPK fertilizers were added as mentioned above without any compost application. Then samples were dried, ground and ash dried and prepared for heavy metal analysis according to CHANEY et al. [7]. Surface soil samples were collected at the same time as plant samples. The available metals were determined by DTPA extraction method [8]. All extracts were analyzed for Fe, Mn, Zn, Cu, Ni, Co, Cd and Pb using flame atomic absorption spectrometry with background correction as required for Cd, Pb and Ni.

Table 1

Experimental design of the compost addition to soil

Type of compost	Code	Compost mixture rate [%]		
		Application	W	Bs
Water hyacinth only	W	I	1%	zero
	W	II	5%	zero
	W	III	10%	zero
Water hyacinth and dry sewage sludge	Bs + W	I	5%	4%
	Bs + W	II	5%	6%
	Bs + W	III	5%	8%

W – water hyacinth compost.
Bs – dry sewage sludge.

2.1. STATISTICAL ANALYSIS

Plant and soil data were subjected to analysis of variance (ANOVA), Duncan's multiple range test was used to determine the difference in treatments at the probability level P = 0.05 whenever the analysis of variance *F*-value was significant [9]. Mean values were compared by means of the least significant differences indicators (LSD) using the statistical computer program MSTAT-PC [10].

* Feddan is an Egyptian unit of area equal to ca. 0.42 ha.

3. RESULTS AND DISCUSSION

3.1. SOIL ANALYSIS AS AFFECTED BY COMPOST APPLICATION

Table 2 shows some selected physical and chemical properties of the soil affected by compost application and its rate. Application of W-compost enhanced the per cent

Table 2

Some physical and chemical properties of soil affected by compost type and the application rates

Treatments	pH	E.C.	O.M.	Coarse sand	Fine sand	Silt	Clay
		[Mmlhos 25 °C]	[%]	[%]	[%]	[%]	[%]
Control	7.40	0.19	0.08	88.5	3.70	4.3	3.50
1% W	7.40	0.15	0.49	14.50	50.25	8.75	26.50
5% W	7.30	0.26	0.59	13.00	54.50	7.25	25.25
10% W	7.20	0.20	0.79	22.50	57.20	4.45	15.85
5% W + 4% Bs	7.10	0.30	0.89	17.50	64.50	6.00	12.00
5% W + 6% Bs	7.00	0.37	1.23	22.50	63.50	2.75	11.25
5% W + 8% Bs	6.90	0.21	1.52	15.50	71.75	2.00	10.75

W – water hyacinth compost.
Bs – dry sewage sludge.
LSD – the least significant differences.

Table 3

Levels of heavy metals in Cairo sewage sludge* compared with the worldwide** as well as maximum accepted concentrations*** (mg/kg of dry weight)

Element	Cairo ss	Worldwide	Max limit value
Cu	440–436	8.000–50	1.750–1.000
Mn	455–450	3.900–60	3.000–500
Fe	38.100–36.740	–	–
Co	30–25	260–1	150–20
Ni	165–150	5.300–6	400–300
Pb	35–20	3.600–29	1.200–750
Cd	1.8–1	3.410–1	40–20
Cr	295–275	40.600–8	1.750–1.000
Cs	1.9–1	2.90–0.45	–
Sc	8.5–8	–	–
Ba	99–86	1.004–9	–
Sn	40–30	700–40	–
Rb	15–12	–	–

* This result is average analyses of five samples.
** Adapted from Alloway and Jackson [11].
*** Webber et al. [13] and EC [12].

share of clay, while the compost mixture (W + B) significantly reduced pH of soil and increased the per cent shares of E.C. and O.M. The level of heavy metals in the Cairo dry sewage sludge that was used in the present study is given in table 3 as average analyses of five samples. It is clear that the level of metals in such a sludge is within both the worldwide and the maximum limit value according to ALLOWAY and JACKSON [11] and WEBBER et al. [13] and EC [12].

Table 4

Total metal load due to compost application (g/plot)

Treatments	Fe [%]	Mn [g/plot]	Zn [g/plot]	Cu [g/plot]	Co [g/plot]	Ni [g/plot]	Cd [g/plot]	Pb [g/plot]
1% W	0.0010	13.4	4.2	2.1	2.45	0.35	0.10	1.45
5% W	0.0040	67	20.85	4.25	7.25	1.60	0.50	1.90
10% W	0.0085	134	43.75	9.4	14.55	2.50	1.45	3.80
4% W5+ Bs	0.0750	153	277.5	92	12.50	24.5	0.80	6.50
6% W5+ Bs	0.1100	196	405.5	135.5	15.00	36.0	1.45	9.00
8% W5+ Bs	0.1450	234	534	179.5	17.50	47.5	1.60	11.50

W – water hyacinth compost.
Bs – dry sewage sludge.
LSD – the least significant differences.

The analysis of soil samples (table 4) showed that heavy metals content in soil increased remarkably due to compost application, particularly in the case of compost mixture of W + B at any rate of application.

3.2. DRY MATTER YIELD

The general conclusion is that the yields of both dry matter and grain of the two plant species grown on organic compost combinations amending soil were significantly increased due to addition of compost. This is true in terms of the type and/or rate of the compost addition (tables 5 and 6). Results clearly indicate that compost tested stimulated the growth of corn or sesame. The order of the positive effects of the compost tested was as follows: Bs + W > W > control for both corn and sesame dry matter yields. However, the maximum yield of corn grain was obtained with W treatments, particularly 10% W which was twofold higher than control. On the contrary, Bs + W treatments tend to increase the yield of sesame seeds. The stimulation effects of the treatments being tested could be attributed to the adequate nutrients supply (table 7) as well as to the soil conditioning effects compared with the sandy soil plots (control). Several workers indicated the beneficial nutritional value of organic compost [6], [14], [15] and [16].

Table 5

Effect of organic compost being applied on dry matter and grain yield in corn and sesame plants

Treatments	Rate [%]	Corn dry matter [g/plant]		Sesame dry matter [g/plant]		Grain yield [g/plant]	
		Vegetation	Flowering	Vegetation	Flowering	Vegetation	Flowering
Control		28.4	34.4	22.4	35.3	22.8	42.8
W	I	29.10	56.30	36.0	54.3	46.3	40.1
	II	33.93	58.87	40.0	59.6	60.3	49.0
	III	60.37*	118.00*	49.9	62.8	63.3*	52.4
Bs + W	I	35.8	64.5	85.7	89.3	26.1	74.3*
	II	40.2	88.9	94.3	96.3	23.4	61.4
	III	55.8	110.7	103.3*	108.3*	28.4	52.7
LSD (5%)		1.64	12.9	2.7	3.1	–	–
Time		5.22	4.1	4.6	1.4	3.81	1.35

W – water hyacinth compost.
Bs – dry sewage sludge.
LSD – the least significant differences.

Table 6

Corn and sesame (ton/ha) yields due to application of water hyacinth compost

Treatment	Rate [%]	Corn	Sesame
Control		0.76	1.21
W	I	4.82	1.14
	II	6.77	1.39
	III	7.22	1.98
Bs + W	I	2.95	2.11
	II	3.06	1.74
	III	3.17	1.49
LSD (5%)			
Treatment		0.43	0.09
Rate		0.65	0.14

W – water hyacinth compost.
Bs – dry sewage sludge.
LSD – the least significant differences.

Table 7

Total and available index (AI) of heavy metals
in the compost applied (ppm)

Type	Fe	Mn	Zn	Cu	Co	Ni	Cd	Pb
	Total element							
W	1648	268	84	42	29	7	2	9.1
Bs + W	18197	369	669	221	30	59	1.9	30
	Available element							
W	3.5	1.9	4.6	0.89	0.26	0.59	0.05	0.32
Bs + W	11.5	2.7	10.4	3.4	0.53	0.93	0.10	3.1
	Availability index [%]							
W	0.21	0.71	5.5	2.1	0.90	0.43	2.5	3.5
Bs + W	0.06	0.73	1.6	1.5	1.77	1.58	5.3	10.3

W – water hyacinth compost.
Bs – dry sewage sludge.
LSD – the least significant differences.

3.3. HEAVY METALS CONCENTRATION IN CORN AND SESAME PLANTS

Application of compost significantly increased the concentration of heavy metals in shoots (table 8) and seeds (grains) of both plant species (table 9). The results obtained indicated that such an increase in the level of metals varied, depending on the plant species as well as on the part of plant (shoot or root). For instance, corn shoots accumulated higher concentrations of Fe, Cu, Co, and Pb, while sesame shoots showed higher Mn, Ni and Cd concentrations. In the case of corn grains, Co, Ni and Cd concentrations were always higher compared to sesame that accumulated more Fe, Mn, Zn, and Cu.

This selectivity in metal accumulation may be attributed to a plant affinity to nutrients and other available elements that compete and interfere with each other. In the mean time, no phytotoxicity symptoms were observed which might suggest that both corn an sesame could tolerate the increasing levels of heavy metals. It is worth mentioning here that the concentration of metals in shoots or seeds never exceeds the permissible levels in foodstuff (tables 8 and 9). This is in a good agreement with the finding of O'CONNOR et al. [17] who indicate that food chains is protected from many trace elements in land.

It is worth noting that the value of availability index (AI) differed remarkably, depending on the kind of treatment. For example, (W) treatments showed higher AI-values in the case of Fe, Zn and Cu. On the contrary, the AI-values for Mn, Co, Ni, Cd and Pb were higher in the case of (W + Bs) treatment (table 7). The variation in the

Table 8

Concentrations of heavy metals in corn shoots due to addition of compost
(μg/g as dry weight)

Type	Rate [%]	Fe	Mn	Zn	Cu	Co	Ni	Cd	Pb
Corn									
Control		210	45.4	23.5	26.0	3.0	7.9	2.7	15.9
W	I	449	43.4	38.0	19.9	4.7	6.5	4.5	61.7
	II	599	26.7	38.7	17.9	5.6	6.9	4.6	68.7
	III	727	38.4	50.0	16.0	6.5	6.5	4.0	70.0
Bs + W	I	302	42.0	51.0	20.9	6.0	4.5	3.9	57.0
	II	267	38.4	50.0	20.4	5.4	3.4	4.0	66.7
	III	248	47.2	51.5	20.9	4.9	3.2	4.0	64.7
LSD (5%)									
Treatment		30.6	3.44	5.06	1.96	0.52	0.62	0.17	3.2
Rate		35.4	4.00	5.85	2.27	0.59	0.70	0.20	3.7
Sesame									
Control		84	56.2	25.5	10.5	2.5	11.2	3.1	14.8
W	I	112	65.2	22.1	3.7	2.9	14.3	3.7	10.9
	II	118	64.8	24.2	7.7	4.7	16.7	4.6	10.1
	III	119	72.9	28.0	10.8	5.2	29.2	4.5	10.9
Bs + W	I	128	55.7	59.9	11.9	2.5	12.5	4.1	11.8
	II	133	56.3	61.6	13.2	2.6	17.0	4.6	12.1
	III	149	58.6	63.7	14.6	2.8	21.5	5.35	13.77
LSD (5%)									
Treatment		12.4	2.09	4.9	1.04	0.42	1.95	0.23	3.79
Rate		47.6	4.70	4.8	2.47	0.82	1.13	0.38	3.67

W – water hyacinth compost.
Bs – dry sewage sludge.
LSD – the least significant differences.

uptake of metals by plants may again be attributed to the variation in the break-down of organic compost applied as well as the interaction changes of the (compost: soil) with the prolonged time. It has been proved that such changes in interaction can alter the availability of metals to plant [18].

Table 9

Concentrations of heavy metals in corn and sesame grains due to compost addition (µg/g as dry weight)

Type	Rate %	Fe	Mn	Zn	Cu	Co	Ni	Cd	Pb
Corn									
Control #		64.2	27.0	53.3	12.50	13.7	28.0	2.50	N.D.
W	I	39.4	27.5	41.2	6.35	11.9	27.4	6.50	N.D.
	II	71.2	29.2	42.0	7.50	14.9	30.5	7.20	N.D.
	III	78.5	30.9	40.0	10.00	13.9	28.0	7.90	N.D.
Bs + W	I	52.2	27.0	54.7	15.20	11.7	31.2	4.00	N.D.
	II	55.6	27.5	55.0	16.40	11.9	33.3	4.30	N.D.
	III	57.5	28.3	56.7	18.90	13.3	35.7	4.80	N.D.
LSD (5%)									
Treatment		24.5	1.40	4.92	1.60	1.32	2.28	0.80	N.D.
Rate		16.0	2.71	4.99	1.97	1.82	3.73	1.13	N.D.
Sesame									
Control #		62.5	31.7	44.1	16.0	9.15	20.6	2.70	1.90
W	I	84.2	29.7	50.8	16.7	9.70	19.0	0.90	2.30
	II	102.0	33.1	53.2	17.8	9.95	21.2	3.70	3.52
	III	196.0	43.1	55.5	18.4	11.4	23.7	4.10	4.80
Bs + W	I	113	33.5	65.3	16.3	10.9	23.7	1.30	2.50
	II	171	35.2	71.3	22.8	11.2	25.1	1.90	7.80
	III	229	38.8	81.8	33.8	11.9	28.1	2.50	8.20
LSD (5%)									
Treatment		13.4	1.83	3.79	2.88	1.23	1.98	0.46	1.59
Rate		9.65	2.91	5.28	2.97	1.57	2.03	0.97	1.87

W – water hyacinth compost.
Bs – dry sewage sludge.
LSD – the least significant differences.

4. CONCLUSION

The results indicate that the application of a water hyacinth-based compost is a feasible disposal method and a valuable recycling technique in desert sandy soil. Therefore, the biomass of water hyacinth collected from fresh-water channels could be used as a rich green manure or compost that can be incorporated into sandy soil. Thus, improvement in the physical properties and enrichment of the chemical characteristics of such a soil can be achieved.

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WPŁYW KOMPOSTU Z HIACYNTÓW WODNYCH STOSOWANEGO NA PIASZCZYSTEJ GLEBIE NA ZAWARTOŚĆ METALI CIĘŻKICH W ROŚLINACH ORAZ NA ICH WZROST I PLONOWANIE

Badano wpływ wzrastających dawek albo kompostu z wodnych hiacyntów, albo mieszaniny osadu ściekowego z wodnym hiacyntem na wzrost, plon i zawartość metali ciężkich w roślinach kukurydzy i sezamu. Do badań terenowych użyto piaszczystej gleby zmieszanej z 0, 5 i 10%-owym kompostem

z wodnego hiacynta i/lub kombinację osadu ściekowego w trzech dawkach 4, 6 i 8%-owych z 5%-ową zawartością hiacynta.

Otrzymane wyniki świadczą, że kompost z wodnego hiacynta (*Eichhornia crassipes*) stymuluje powstawanie suchej masy nasion i pobieranie mikroelementów. Kompost z hiacyntów wpływa też lepiej na glebę w porównaniu z mieszaniną takiego kompostu z osadem ściekowym.