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VERMICOMPOSTING OF DUCKWEED (*LEMNA MINOR* L.) BIOMASS BY *EISENIA FETIDA* (SAV.) EARTHWORM

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Abstract

This work presents the dynamics of *E. fetida* (Sav.) earthworm populations during vermicomposting of duckweed (*Lemna minor* L.) biomass in small containers, and provides properties of the vermicomposts produced. An experiment was conducted under laboratory conditions (in darkness, at an average temperature 25±5°C, with substrate moisture 70-75%). Test pots (3 replications for each duckweed treatment) were filled with one litre of garden soil, into which 100 individuals of *E.fetida,* of known biomass, were introduced per pot. Duckweed was fed to earthworms regularly, in two treatments: (1) duckweed + + cattle manure (1:1), and (2) duckweed only.

Earthworm number and biomass of tested populations were determined after 4 months of vermicomposting, and it was found that an average number of *E.fetida* in containers with duckweed and manure was 121±5 ind./container with a total biomass of 25.8±1.1 g. Populations in pure duckweed were significantly smaller ($p<0.05$), with 57±6 ind./container and a total biomass of 9.8±1 g. Cocoon production was also different across treatments. Populations in duckweed alone produced 55±13 cocoons /per container, significantly less ($p<0.05$) than the 231±37 cocoones when manure was added.

Duckweed vermicomposts were odourless and had good granular structure. Chemical characteristics of both vermicompost types (with or without a manure supplement) were desirable. Content of macroelements in duckweed vermicomposts was high, whereas microelements, cadmium and lead were within the permitted levels, making these vermicomposts extremely useful in environmental reclamation, including agriculture. The manure addition was important for characteristics and chemical content of duckweed vermicomposts. The vermicomposts produced from duckweed and manure contained more ash, N, P, K, Mg, Zn, Cu, Ni, Cr, Cd and Pb.

Key words: *Eisenia fetida* (Sav.), duckweed *Lemna minor* L., vermicompost, chemical composition.

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WERMIKOMPOSTOWANIE BIOMASY RZĘSY DROBNEJ (*LEMNA MINOR* L.) Z UDZIAŁEM DŻDŻOWNICY *EISENIA FETIDA* (SAV.)

Abstrakt

W publikacji zaprezentowano stan populacji dżdżownic kompostowych *E. fetida* (Sav.) podczas wermikompotowania biomasy rzęsy drobnej *Lemna minor* L. Opisano także cechy wyprodukowanych wermikompostów. Doświadczenie prowadzono w warunkach laboratoryjnych (w ciemności, średnia temp. 25±5°C, wilgotność podłoża 70-75%). Wazony testowe (w 3 powtórzeniach dla każdej kombinacji z utylizowanej rzęsy) wypełniono ziemią ogrodową o objętości 1 dm^3. Do tych podłoży wprowadzono po 100 osobników *E. fetida* o znanej biomasie. Do utylizacji podawano regularnie biomasę rzęsy, w dwóch kombinacjach: (1) rzęsa + obornik bydlęcy (1:1), (2) rzęsa.

Liczebność i sumę biomasy testowanych populacji dżdżownic wyznaczono po 4 miesiącach wermikompostowania. W wazonach z rzęsą i obornikiem stwierdzono istotnie wyższą średnią liczebność *E.fetida* (121±5 os./wazon) i sumę biomasy (25.8±1.1 g), w porównaniu ze zredukowaną populacją w czystej rzęsie (57±6 os./wazon i 9.8±1 g biomasy). Podobne zależności stwierdzono w przypadku produkcji kokonów. Dżdżownice złożyły istotnie mniej kokonów, utylizując czystą rzęsę, bez dodatku obornika bydlęcego (odpowiednio 55±13 i 231±37 kokonów/wazon).

Dodatek obornika bydlęcego różnicował także cechy wermikompostu z rzęsy drobnej. Wermikompost z rzęsy z dodatkiem obornika bydlęcego zawierał więcej popiołu, N, P, K, Mg, Zn, Cu, Ni, Cr, Cd oraz Pb.

Słowa kluczowe: *Eisenia fetida* (Sav.), rzęsa drobna *Lemna minor* L., wermikompost, skład chemiczny.

INTRODUCTION

Presently, natural methods of sewage treatment are preferred all over the world. One possible method of communal wastewater treatment is to employ a duckweed (*Lemna minor*. L.) system, which captures nutrients present in wastewater (BONOMO et al. 1997, RIGGLE 1998, STEEN et al. 1999). *Lemna*-type systems are used mainly in natural, municipal sewage or agricultural organic waste treatment systems. Duckweed grows profusely in stagnant water, demanding hardly any agro-technical operations, but its growth is determined mainly by environmental resources (HAMID 1993). In clean water, duckweed grows slowly and contains much fiber, ash and carbohydrates, whereas in sewage-fed ponds it grows quickly and contains more protein (MIZTAR, SLINGER 1976). In a biological sewage treatment plant, duckweed acts as a natural sewage treating factor by absorbing nutrients, mainly nitrogen and phosphorus. Depending on the climatic conditions, the system works at various efficiency levels, but during the growing season a large amount of biomass is created and becomes bio-waste. Duckweed requires environmental utilization after being removed from the water.

Since composting of duckweed biomass progresses slowly, an attempt was undertaken to vermicompost it with an aid of *Eisenia fetida* (Sav.) earthworms. As described in numerous publications (BARAN et al. 1996, MAZUR et al. 1996, GĄSIOR et al. 1998, KOSTECKA et al. 1998, ZABŁOCKI, KIEPAS-KOKOT 1998, MAZUR et al. 2000, BURY et al. 2001, KALEMBASA 2001, KANIUCZAK et al. 2001), the nutrient value of vermicompost is significantly influenced by the origin, type and proportions of the (mixed) organic wastes utilized.

MATERIAL AND METHODS

Earthworms and substrates

Earthworms of the species *Eisenia fetida* (Sav.) were obtained from a culture bank (maintained since 1996) at the Institute of the Natural Basis for Agriculture, Faculty of Biology and Agriculture – now Rzeszow University.

Duckweed (*L. minor*) was taken from the municipal wastewater treatment plant located in Łąka near Rzeszow. Cattle manure, also used in the experiment, was obtained from a local farmyard and stored for several months after a high temperature treatment. Garden soil, also utilized, was characterized by pH (H_2O) of 6.6; 12.0 g N; 0.44 g P; 5.0 g K; 35.0 g Ca; 0.94 g Mg; 0.87g Na kg^{-1} determined using standard laboratory procedures (OSTROWSKA at al. 1991).

Experimental Design

Vermicomposting of duckweed biomass was conducted under laboratory conditions (in darkness, at an average temperature of 25±5°C, and a substrate moisture content of 70-75%). Ten-litre test pots (with 3 replications for each duckweed combination) were filled with garden the soil described above.

Into each pot, 100 individuals [15 adult and 85 immature of *E. fetida* of known biomass (24.1±1.1 g)] were introduced. Two treatments were established: (1) 500 ml of duckweed + cattle manure (1:1 dry weight), (2) 500 ml of duckweed (dry weight). The duckweed biomass was supplied regularly (on demand) as a feed to the earthworms.

Every month, June – October, earthworms were utilizing the same type of wastes and the state of their populations was examined. Using manual substrate segregation (with all specimens counted and weighed plus cocoons counted), average numbers and total biomasses of earthworm populations were determined. The data were expressed as means with standard deviations. The hypothesis of equal variances in both studied populations was tested using an appropriate version of Student *t*-test, at a significance level 0.05.

The composition of duckweed vermicomposts was also determined, with 10 samples of each vermicompost taken for analysis. Standard methodologies for chemical-agricultural research were used to perform the following determinations: dry mass at a temperature of 105°C, raw ash at 550°C, total organic carbon (TOC) by the wet dichromate potassium oxidation method, pH and electrical conductivity measured at a 1:5 sample/water ratio.

Total nitrogen was determined using Kiejdahl method in an automatic Kiel-Foss device, while total phosphorus was measured by the vanado-molybdate method. The total amounts of Ca, K and Na were determined by the photometric method having digested the samples in HNO_3:$HClO_4$:H_2SO_4 at a ratio of 20:5:1 in a TECATOR device, whereas the elements Mg, Fe, Mn, Cu, Zn, Co, Ni, Cr, Cd and Pb were determined by atomic absorption spectrometry (AAS). The data were expressed as means with standard deviations.

RESULTS

At the end of the experimental period an average number of *E.fetida* in containers with duckweed and manure was 121±5 ind./container with a total biomass of 25.8±1.1 g. Populations in pure duckweed were significantly smaller ($p<0.05$) with 57±6 ind./container and a total biomass of 9.8±1 g (Figures 1, 2). Cocoon production was also different across treatments. Populations in duckweed alone produced 55±13 cocoons /per container, significantly less ($p<0.05$) than the 231±37 cocoons /per container when manure was added (Figure 3). The duckweed vermicomposts produced were rich in plant nutrients (Table 1).

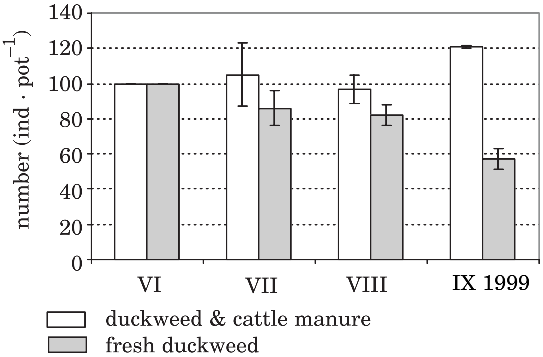

Fig. 1. Mean number (± SD) of *E. fetida* within given vermicomposting treatments

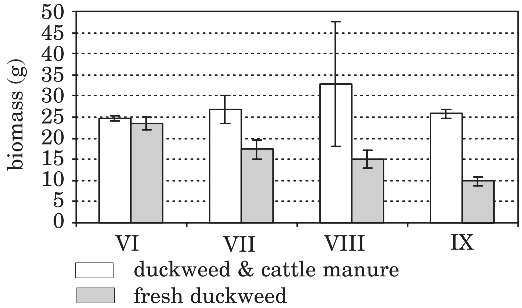

Fig. 2. Mean total biomass (± SD) of *E. fetida* within given vermicomposting treatments

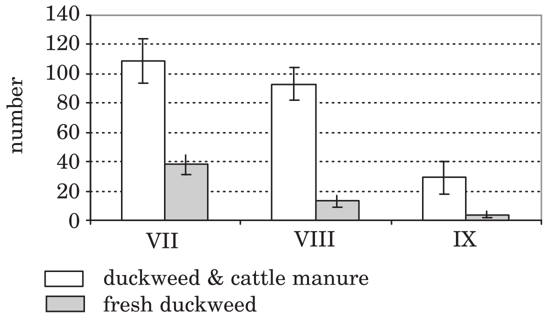

Fig. 3. Cocoon production (mean ± SD) of *E. fetida* within given vermicomposting treatments

DISCUSSION

Vermiculture biotechnology functions efficiently and quickly when density of earthworm is high (approximately 100 ind.$\cdot$dm^{-3}) (Gaddie, Douglas 1977). It can be used to utilize different type of organic wastes (Edwards 1988, Edwards, Bohlen 1996, Elvira et al 1997, 1999, Nogales et al. 1999), and vermicompost thus produced can be useful and effective as a plant growth promoter (Buckerfield et al. 1999, Kostecka, Błażej 2000). As soils in many countries worldwide lose fertility and the amount of organic carbon and other minerals they contain is decreasing, we should use every opportunity to utilize organic waste to improve soil conditions.

Vermicomposting of duckweed caused a swift and odourless transformation of the substrate, which acquired characteristics, such as granular structure and content of nutrients, suitable for plants. Duckweed, nevertheless, was not a substrate that allowed populations of *E. fetida* to reproduce and grow to maximum levels. After four months of duckweed vermicomposting,

Table 1

Characteristics and chemical content of duckweed vermicomposts

Type of vermicompost		Produced from fresh duck-weed + cattle manure				Produced from fresh duck-weed			
Properties		average	SD	min	max	average	SD	min	max
%	ash	38.1	0.7	37.2	39.0	36.1	0.8	35	37
	TOC	36.5	0.3	36.0	36.8	37.6	0.5	37.1	38.3
pH in H_2O		-	-	5.5	6.0	-	-	4.3	4.6
$g \cdot kg^{-1}$ of dry mass	N	26.8	1.1	25	28	24.5	1.2	23	26
	P	5.7	0.2	5.4	6.0	4.4	0.4	4.0	4.8
	K	15.2	2.2	12.0	17.5	4.2	0.5	3.5	4.7
	Ca	2.3	0.2	2.0	2.5	2.9	0.2	2.6	3.1
	Mg	4.7	0.5	4.1	5.3	2.7	0.2	2.4	3.0
$mg \cdot kg^{-1}$ of dry mass	Na	844	214	600	1111	715	207	540	1055
	Fe	2463	423	2000	3000	2862	223	2600	3200
	Mn	638	34	600	680	665	35	635	726
	Zn	106	13	90	120	82	9.3	70	92
	Cu	52	8	40	60	45	17	22.5	65.0
	Ni	6.5	0.5	6.0	7.2	5.9	0.8	5.0	6.9
	Cr	5.3	1.3	4.0	7.0	3.84	1.11	2.55	5.02
	Co	0.87	0.14	0.7	1.05	1.6	0.5	1.20	2.34
	Cd	0.56	0.25	0.25	0.90	0.33	0.10	0.20	0.45
	Pb	8.9	0.9	7.8	10.0	7.97	0.85	7.02	9.27

the initial number and biomass had decreased by approximately 50%. This could have been a result of high earthworm density under experimental conditions. A reduction in the reproductive capacity of earthworm populations in vermicomposting beds and small containers has previously been recorded (MEYER, LOOTS 1999).

An addition of manure to the duckweed substrate supported maintenance of biomass and number of *E. fetida* populations (it also improved cocoon production). The presence of manure in the substrate also improved the characteristics of the vermicompost produced (larger amounts of N, P, K, Mg and Na than those produced with duckweed only). Manure also caused an increase in the pH of the vermicompost.

All vermicomposts produced with duckweed were characterized by large amounts of dry mass, including organic carbon and ash. However, these vermicomposts still included less ash than the ones produced with manure

(Gąsior et al. 1998) and household organic waste (Kostecka et al. 1999), sewage sludge, tannery waste plus straw (Mazur et al. 2000), duckweed plus sewage sludge 1:1 (Kaniuczak et al. 2001). The total amount of organic carbon (TOC) in these vermicomposts was higher than in the ones produced with manure (Gąsior et al. 1998), household organic wastes (Kostecka et al. 1999) and cattle manure (Nogales et al. 1999), sewage sludge (Baran et al. 1996), sewage sludge, tannery waste plus straw (Mazur et al. 2000), and lower than in vermicomposts produced with other wastes such as dry olive cake + cattle manure, olive cake + municipal biosolids, and dry olive cake + cattle manure + municipal biosolids (Nogales et al. 1999). Vermicomposting improves the quality of organic wastes, particularly through an increase in humic components which bind with heavy metals, making them less available to other organisms in the food chain. Stability of these organic and metallic complexes is highest at pH levels around 5, which are characteristic of many vermicomposts (Baran et al. 1996).

The pH level of all duckweed vermicomposts was lower than that of manure vermicomposts (Gąsior et al. 1998), household organic waste (Kostecka et al. 1999) and other wastes (Nogales et al. 1999).

Fresh duckweed is characterized by high amounts of nitrogen and phosphorus (Wo•niak, Zawora 1999) and vermicomposts made from it generally contain higher amounts of these elements than other vermicomposts (Gąsior et al. 1998, Kostecka et al. 1999, Nogales et al. 1999). It is important to stress that duckweed vermicomposts examined here contained more nitrogen, potassium and sometimes magnesium and sodium compared with vermicomposts produced by Mazur et al. (2000), or more nitrogen and potassium compared with vermicomposts produced by Bury et al. (2001) and Kalembasa (2001). These vermicomposts contained more nitrogen, phosphorus, potassium, magnesium and sodium compared with vermicomposts from duckweed and sewage sludge (Kaniuczak et al. 2001). The duckweed vermicomposts had a low ratio of C/N, so in order to avoid nitrogen loss to soils, carbohydrates should be provided (straw, cellulose, etc.). Vermicomposts produced from duckweed contained more microelements compared with household organic waste vermicomposts (Kostecka et al. 1999). The vermicomposts produced here, from duckweed and manure, contained more magnesium than vermicomposts from sewage sludge and tannery waste plus straw (Mazur et al. 2000), and also compared with vermicomposts produced from sewage sludge and sawdust (Zabłocki, Kiepas-Kokot 1998). Chemical analyses of our vermicomposts showed more magnesium and copper than found in vermicomposts produced from sewage sludge and additions: peat, sawdust, peat plus sawdust (Kalembasa 2001). Levels of iron, magnesium, zinc, copper and nickel were lower than in vermicomposts from sewage sludge plus additions: straw, hay, waste paper and leaves (Bury et al. 2001). Duckweed + + cattle manure vermicompost contained more zinc, copper, nickel, chromium, cadmium and lead and less iron and manganese than vermicomposts produced from pure duckweed. Vermicomposts produced from duckweed and duckweed plus manure contained less lead, cadmium and chromium than vermicomposts described by other authors (ZABLOCKI, KIEPAS-KOKOT 1998, MAZUR et al. 2000, BURY et al. 2001, KALEMBASA 2001). They also contained less cobalt, nickel, cadmium, chromium and lead compared with vermicomposts from duckweed plus sewage sludge (KANIUCZAK et al. 2001) and vermicomposts produced from sewage sludge and sawdust (ZABLOCKI, KIEPAS-KOKOT 1998). The levels of zinc, copper, nickel, chromium, lead and cadmium in duckweed vermicomposts was within the legal requirements for soil fertility improvement products (Rozp. Min. Roln. i Rozw. Wsi, 2001).

CONCLUSIONS

1. The earthworm *E. fetida* utilized duckweed biomass from a *Lemna*-type biological sewage treatment plant but had better population characteristics when cattle manure was added.

2. Duckweed vermicomposts were odourless and had good granular structure. Chemical characteristics of both vermicompost types (with or without a manure supplement) were desirable.

3. Content of macroelements in duckweed vermicomposts was high, whereas microelements, cadmium and lead were within permitted levels, thus making these vermicomposts extremely useful in environmental reclamation, including agriculture.

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