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INFLUENCE OF PROCESSED SEWAGE SLUDGE ON NITROGEN CONTENT IN PLANTS AND SOILS

The influence of vermicomposts in different stages of decomposition on the content, intake, and utilization of nitrogen by Italian ryegrass as well as the element accumulation in the soil after two years of a pot experiment was examined. The vermicomposts were produced on the basis of sewage sludge with various waste material additives and their fresh mixtures.

A total biomass yield of the grass cultivated in sand was higher if plants were fertilized with vermicomposts made of sewage sludge with other waste material additives than that of plants treated with fresh mixtures of these materials. Sludge vermicomposted for four months and sludge vermicomposted with peat and poultry droppings additives for two months proved to promote the intake of nutrients and improved the coefficient of their utilization. Fertilization with two-month-old vermicomposts led to higher nitrogen accumulation in the soil.

1. INTRODUCTION

Rendering harmless waste activated sludge with a simultaneous utilization of its nutrients, cost minimization and environmental protection is the main aim of the search for the effective methods of its processing [1], [2]. Besides the physical and chemical methods of sludge treatment, such biological methods as vermicomposting are often applied. Vermicomposting of organic waste materials and their utilization as fertilizers seem to be the optimum way for their management. Vermicomposting of sewage sludge without any additives is unfavourable, because it does not contain particles that should be ground and is characterized by too narrow C:N ratio. Vermicomposting of sewage sludge with other organic waste materials (leaves, sawdust, straw, brown coal, peat) is reasonable as it widen C:N ratio greatly and also makes heavy metals concentration lower [3], [4].

Vermicomposts produced by the earthworms (*Eisenia fetida* (Sav.)) which decompose sludges and various organic materials contain nutrients and humus [1], [5], [6].

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The fertilization value of vermicomposts and other organic fertilizers depends not only on the general content of elements, but also on the amount and form of carbon in the organic compounds, which determines the rate of mineralization and nutrient immobilization processes in the soil [7].

The aim of this research was to evaluate the influence of vermicomposts made of sewage sludge mixed with some organic materials (peat, poultry droppings) and their fresh mixtures on the content, intake, and utilization of nitrogen by Italian ryegrass as well as to assess the element accumulation in the soil after two-year experiment.

2. MATERIAL AND METHODS

The two-year pot experiment was carried out in glass-house in the years 2004–2005 in a completely randomized pattern. The pots were filled with 12 kg of soil (soil material was collected from the humus level of podzolic soil with loamy sand granulometric composition). The percentage of particular fractions was as follows: sand (2–0.05 mm) – 78%, dust (0.05–0.002 mm) – 22%, loam (<0.002 mm) – 1%, while nitrogen content was 0.63 $g \cdot kg^{-1}$.

Organic materials were applied at the rates corresponding to 2 $g N \cdot pot^{-1}$. The organic materials used to produce vermicomposts consisted of sewage sludge from mechanical-biological municipal sewage treatment plant in Siedlce, high peat, and droppings from poultry farms.

The following types of substrate were prepared:

O – soil (control);

A – soil + fresh mixture of sewage sludge (75%) and peat (25%) containing 48.8 $g N \cdot kg^{-1}$;

B – soil + vermicompost from sewage sludge (75%) and peat (25%) being vermicomposted for 2 months and containing 43.4 $g N \cdot kg^{-1}$;

C – soil + vermicompost from sewage sludge (75%) and peat (25%) being vermicomposted for 4 months and containing 33.6 $g N \cdot kg^{-1}$;

D – soil + vermicompost from sewage sludge (75%), peat (12.5%), and poultry droppings (12.5%) containing 47.6 $g N \cdot kg^{-1}$;

E – soil + vermicompost from sewage sludge (75%), peat (12.5%), and poultry droppings (12.5%) being vermicomposted for 2 months and containing 41.0 $g N \cdot kg^{-1}$;

F – soil + vermicompost from sewage sludge (75%), peat (12.5%), and poultry droppings (12.5%) being vermicomposted for 4 months and containing 28.8 $g N \cdot kg^{-1}$.

The vermicomposts used were prepared according to the patent [8]. Under laboratory conditions (at 20–25 °C), appropriate organic materials were moistened to maintain the optimum humidity of 70–75% by weight. After several days of preliminary decomposition (to remove the ammonia excess) pH of the subsoils was adjusted (using calcium carbonate) to 6.8–7.2. Earthworms (*Eisenia fetida* (Sav.)) were then introduced to thus prepared subsoils. After 2 and 4 months of vermicomposting, the earthworms were removed and vermicomposts were used for the experiments.

The pot experiment was carried out in three replications on Italian ryegrass (*Lolium multiflorum* (Lam.)). During the two-year experiment, we got four crops a year at 30-day intervals (eight crops in total).

Total nitrogen content was determined both in soil samples collected after the first and second years of experiment and in grass samples collected during each of eight swathes by means of their digestion in concentrated sulfuric acid(VI) and ammonia distillation (the Kjeldahl method).

The grass biomass and nitrogen content allowed the nitrogen intake by plants to be estimated. The value of utilization coefficient was calculated by means of a differential method. The significance of the differences was estimated by applying the variance analysis (Fisher–Snedecor's test) and LSD values were calculated using Tukey's test.

3. RESULTS AND DISCUSSION

The crop of Italian ryegrass biomass ($g \cdot pot^{-1}$) cultivated in a two-year pot experiment with vermicomposts made on the basis of sewage sludge with waste materials in various decomposition stage as well as with fresh organic mixtures varied, depending on the fertilization after every swatche in the first and second years, which was confirmed by LSD values (table 1). The biomass crop was higher in the first year of the experiment (32.5 $g \cdot pot^{-1}$) than in the second one (18.4 $g \cdot pot^{-1}$): the highest crop was collected in the 2nd swatche of the 1st year (13.8 $g \cdot pot^{-1}$), and in the 1st swatche of the 2nd year (7.22 $g \cdot pot^{-1}$), while the lowest in the 4th swatche of both years (2.85 and 2.52 $g \cdot pot^{-1}$, respectively).

Table 1

Crop of Italian ryegrass dry matter ($g \cdot pot^{-1}$) in first and second years of pot experiment

Type of substrate	Dry matter crop ($g \cdot pot^{-1}$)										
	Swatches in first year of experiment					Swatches in second year of experiment					Total for two years
	I	II	III	IV	Total	I	II	III	IV	Total	
O	7.40	8.50	1.40	0.80	18.1	8.20	4.20	2.70	2.40	18.1	36.2
A	9.80	14.5	5.20	3.00	32.5	7.20	4.50	3.50	2.40	17.6	50.1
B	11.2	14.5	7.60	4.20	37.5	8.20	5.80	4.00	3.00	21.0	58.5
C	11.4	16.9	6.30	2.90	37.5	5.70	4.70	3.20	2.70	16.3	53.8
D	9.60	14.3	5.10	3.50	32.5	7.20	5.20	2.60	2.40	17.4	49.9
E	12.4	14.5	5.70	2.60	35.2	6.70	7.40	3.30	2.60	20.0	55.2
F	12.6	13.6	5.20	3.00	34.4	7.40	5.30	3.90	2.20	18.8	53.2
Mean	9.34	13.8	5.21	2.85	32.5	7.22	5.30	3.31	2.52	18.4	50.9
$LSD_{0.05}$	0.51	0.24	0.26	0.57		0.32	0.57	0.36	0.43		

Vermicomposting the sewage sludge with peat (B and C) as well as with peat and poultry droppings (E and F) affected the increase of grass biomass compared to that of plants grown in fresh mixtures (A and D). Longer (4 months) vermicomposting of these mixtures had negative effect on the grass crop. Gathering the harvests at regular intervals enabled the examination of the nitrogen mineralization and its biological sorption in the soil. A much lower crop of the ryegrass biomass in the second year was probably the result of depleting the nitrogen resources in the subsoil. These resources were used by plants in the first year of the experiment. In the second year, no mineral fertilization was intentionally applied in order not to exert the influence on the organic material mineralization processes in the soil.

Nitrogen content in the Italian ryegrass biomass of all swatches varied, depending on the type of substrate (table 2). The grass in the first year of experiment accumulated higher concentration (26.5 $g \cdot kg^{-1}$) of this nutrient than in the second one (20.1 $g \cdot kg^{-1}$); a nitrogen content in the plants fertilized with vermicomposts made of sewage sludge with other waste materials mixtures (B, C, E) was higher than that of the grass grown on fresh organic mixtures (A, D), except for the substrate F. In the second year, the nitrogen content was slightly higher in the ryegrass grown on the substrates fertilized with vermicomposts (B, C, E, F) compared with that of plants fertilized with fresh mixtures (A, D).

Table 2

Nitrogen content ($g \cdot kg^{-1}$ DM) in Italian ryegrass crop in first and second years of pot experiment

Type of substrate	Nitrogen content ($g \cdot kg^{-1}$ DM)										
	Swatches in first year of experiment					Swatches in second year of experiment					Mean for two years
	I	II	III	IV	Mean	I	II	III	IV	Total	
O	24.5	19.2	21.0	28.0	23.2	17.1	22.7	21.0	24.5	21.3	22..2
A	24.5	19.2	24.5	29.7	24.4	17.5	15.7	21.5	19.2	18.5	21.5
B	29.0	19.2	25.7	31.5	26.3	17.0	14.0	21.7	26.2	19.7	22.8
C	38.5	24.5	25.3	31.8	30.0	17.3	14.5	24.5	28.0	21.1	25.5
D	28.0	21.0	28.0	32.6	27.4	16.8	19.2	21.0	21.3	19.6	23.5
E	31.5	21.0	29.7	33.2	28.8	17.8	21.0	22.7	21.0	20.6	24.7
F	21.0	19.2	29.1	31.5	25.2	17.3	17.5	21.3	22.7	19.7	22.4
Mean	28.1	20.5	26.2	31.2	26.5	17.3	17.8	21.9	23.3	20.1	23.4
$LSD_{0.05}$	1.51	0.85	1.41	1.42		n.s.	1.39	n.s.	1.53		

n.s. – not significiant.

The significance of the differences in nitrogen content between the substrates tested was found in all swatches of the first year of experiment as well as in the second and the fourth swatches of the second year, which was proven by LSD values.

Mean two-year effect of one gram of nitrogen introduced into the soil in fresh organic mixtures and vermicomposts (expressed as grams of grass dry matter) varied (table 3), ranging from 5.80 to 11.1 g. The strongest effect of one gram of nitrogen was observed in the plants grown on the two-month vermicompost made of sewage sludge and peat (B – 11.1 g), whereas the weakest in the grass fertilized with 4-month vermicompost made of sludge and peat (C – 5.80 g). Vermicomposting of both organic mixtures for four months contributed to a certain reduction of this effect. The highest amount of nitrogen was assimilated by Italian ryegrass fertilized with four-month vermicompost made of sewage sludge with peat (C – 0.65 $g \cdot pot^{-1}$). The ryegrass grown on two-month vermicompost made of sludge, peat, and poultry droppings assimilated slightly less ammonium (E – 0.61 $g \cdot pot^{-1}$), and that on fresh sewage sludge with peat mixture – the smallest amount of this nutrient (A – 0.21 $g \cdot pot^{-1}$). The nitrogen assimilation by the test plant during two-year experiment (table 3) was the highest when the grass was fertilized with 4-month vermicompost made of sewage sludge with peat (C – 31.7%), slightly lower in plants treated with 2-month vermicomposts made of sewage sludge and peat as well as peat and poultry droppings (B and E) (28.4% and 29.8%, respectively), and the lowest in those grown on the fresh mixture of sewage sludge and peat (A – 14.4%). Mean value of nitrogen utilization coefficient for all the organic materials studied was 21.7%.

Table 3

Effect of one gram of nitrogen, nitrogen assimilation and its utilization coefficient after two years of pot experiment

Type of substrate	One gram of nitrogen effect (g)	Nitrogen assimilation ($g \cdot pot^{-1}$)	Nitrogen utilization coefficient [%]
A	6.95	0.21	14.4
B	11.1	0.44	28.4
C	5.80	0.65	31.7
D	6.85	0.36	18.1
E	9.30	0.61	29.8
F	8.50	0.36	18.0
Mean	8.08	0.44	21.7

The largest nitrogen accumulation was found in loamy sand fertilized with 4-month vermicompost from sludge, peat, and poultry droppings mixture (F – 46.0%), whereas the smallest one in soil fertilized with 4-month vermicompost form sludge with peat mixture (C – 6.50%) (table 4). On an average the amount of accumulated nitrogen was 29.7% for all experimental substrates. Prolonging the time of vermicomposting the mixture of sludge, peat, and droppings increased the nitrogen amount retained in the soil, and prolonging the vermicomposting of the sludge and droppings up to 4 months contributed to a significant decrease of the nutrient concentration. The total quantity of nitrogen taken by plants and retained in the soil was 41.0% (in relation to the total amount of introduced nitrogen assumed as 100%).

Table 4

Nitrogen balance in soil after two years of Italian ryegrass cultivation in pot experiment

Type of substrate	Nitrogen assimilation along with crop	Nitrogen accumulation in soil	Total	Amount of nitrogen introduced	Nitrogen utilization and accumulation in soil	Nitrogen losses
	$(g \cdot pot^{-1})$					(%)
A	0.29	0.62 31.0*	0.92	2.00	48.8	51.2
B	0.55	1.09 54.5	1.64	2.00	83.5	16.5
C	0.63	0.13 6.50	0.76	2.00	42.9	57.1
D	0.37	0.62 31.0	0.99	2.00	51.9	48.1
E	0.60	0.75 37.5	1.35	2.00	68.7	31.3
F	0.36	0.92 46.0	1.28	2.00	65.7	34.3
Mean	0.50	0.68 29.7	1.16	2.00	60.3	31.1
%	25.0	34.0	41.0	100	–	–
$LSD_{0.05}$	n.s.	n.s.	n.s.		0.20	0.18

* per cent of nitrogen introduced.
n.s. – not significiant.

The percentage of nitrogen used by plants and retained in the soil was the highest for the substrate fertilized with 2-month vermicompost made of sewage sludge and peat mixture (B – 83.5%), while the lowest for the substrate fertilized with 4-month vermicompost made of the same mixture (C – 42.9%). In the substrates C and A, nitrogen losses (probably of gaseous nature) were the largest (57.1% and 51.2%, respectively).

The discussion about the value of vermicomposts, especially in grass cultivation, is very difficult, because there is a small number of research devoted to that issue in scientific literature. The experiment carried out by PATORCZYK-PYTLIK et al. [9] revealed that corn crops did not vary on light soil fertilized with manure, vermicompost made of manure or sewage sludge and vermicompost made of that sludge.

Corn crops from the soil treated with vermicompost made of sewage sludge were recorded to be higher than those from soil fertilized with sewage sludge and manure (BARAN et al. [10]).

4. CONCLUSIONS

1. Sewage sludge can be utilized as the waste without any additives or after its processing, e.g. by vermicomposting or adding waste organic substances, which allows their use as fertilizers in agriculture.

2. During the two-year pot experiment, the total crop of Italian ryegrass grown on loamy sand was higher in plants fertilized with vermicompost from sewage sludge mixed with other organic waste materials than in plants treated with fresh mixtures of those materials.

3. More nitrogen was accumulated in grass biomass in the first year of cultivation than in the second one; this phenomenon can be explained by the fact that vermicomposts are responsible for higher nitrogen concentration in plants than fresh mixtures of sewage sludge with peat, or with peat and poultry droppings.

4. Nitrogen assimilation and its utilization coefficient in the test plant testify to a positive effect of vermicomposting of sewage sludge and peat for 4 months, and that with peat and poultry droppings additives for 2 months.

5. Balancing the soil nitrogen in the present experiment revealed that fertilization with 2-month vermicomposts caused greater accumulation of that nutrient in the soil.

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ODDZIAŁYWANIE PRZETWORZONEGO OSADU ŚCIEKOWEGO
NA ZAWARTOŚĆ AZOTU W ROŚLINIE I GLEBIE

Badano wpływ wermikompostów o różnym stopniu rozkładu, wytworzonych na bazie osadu ściekowego z dodatkiem różnych materiałów odpadowych, oraz ich świeżych mieszanin na zawartość, pobranie i wykorzystanie azotu przez życicę wielokwiatową, a także na akumulację tego pierwiastka w glebie po dwóch latach doświadczenia wazonowego.

Sumaryczny plon biomasy trawy uprawianej na piasku był wyższy, gdy rośliny nawożono wermikompostem z osadu ściekowego z dodatkiem innych materiałów odpadowych, niż gdy nawożono je świeżymi mieszaninami tych materiałów. Stwierdzono, że wermikompostowanie osadów ściekowych przez cztery, a z dodatkiem torfu i kurzeńca przez dwa miesiące wpływa korzystnie na pobranie azotu oraz wartość współczynnika jego wykorzystania przez uprawianą trawę. Lepszą akumulację azotu w glebie spowodowało nawożenie dwumiesięcznymi wermikompostami.