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YIELD FORMING EFFECT OF APPLICATION OF COMPOSTS CONTAINING POLYMER MATERIALS ENRICHED IN BIOCOMPONENTS

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ABSTRACT
In a pot experiment the impact of composts containing polymeric materials modified with biocomponents on the diversity of crops of oats and mustard was examined. The composts used in the study were produced in the laboratory from wheat and rape straw, and pea seed cleaning waste with 8-percent addition of chopped biopolymer materials (films) which were prepared in the Central Mining Institute (GIG) in Katowice. Three polymers differing in content of starch and density were selected for the composting. The pot experiment was conducted on three substrates: light and medium soil and on the sediment obtained after flotation of zinc and lead ores, coming from the landfill ZGH "Boleslaw" S.A. in Bukowno. The need for using such materials and substrates results from the conditions of processing some morphological fractions of municipal waste and from improving methods of reclamation. Yield enhancing effect of composts depends on the substrate on which the compost was used, cultivated plants and crop succession. Application of composts prepared with 8% of polymeric materials based on polyethylene, modified with starch as biocomponent, resulted in significantly lower yields in sandy (light) soil in case of oats and, in some cases, in medium soil. Subsequent plant yield did not differ significantly between the objects fertilized with compost.

Keywords: compost, polyethylene-based polymer, biocomponent, plant yielding.

INTRODUCTION

Management of organic matter in the field is a complex issue [3, 4] which influences a number of factors depending on and independent from the farmer. Some more important among these are: soil granulometric composition, agrotechnologies and climatic conditions. Organic matter losses from soil occur each year of vegetation. Particularly, in case of roots crops, agrotechnological measures deplete soil of humus compounds, which oxidise in result of soil translocation.

According to Wiśniowska-Kielian and Klima [6] organic matter is important in cultivation system regarding heavy metal accumulation by plants. The authors observed differences in Cd and Ni concentrations in the cultivated crops between ecological and traditional farms, which they explained, among others, by different accumulation of organic matter resulting from these systems. On the other hand, numerous authors, among them Antonkiewicz [1] or Bożym [2] having in mind reclamation and yield forming aspect of the measure, suggest application of sewage sludge for fertilizing, sometimes in combination with ash or after application of other purification methods, or as this waste treatment on the ground generating profits for agriculture or improving environment quality (recovery method R10).

More and more often a practical decision must be made concerning application as fertilizers composts of municipal waste or their selected fractions, including morphological fraction, which in its composition contains polymers with admixtures of biocomponents or preparation accelerating polymer disintegration. The basic dilemma which a farmer will face is a decision whether it is worth supplying a compost into the soil whose manufacturing was conditioned not exactly by it fertilizer value, but rather by the necessity of management of biodegradable fractions of municipal waste. Such a compost is polluted with ceramics and/or plastics, halogenated compounds and other contaminants. Also the hazard of soil contamination with heavy metals, despite their considerable binding by organic matter, should not be disregarded in practical compost application [5].

The research aimed at determining whether organic matter dilution during composting with polymer materials modified by biocomponent affects diversification of yields.

METHODS

The experiment was conducted in plastic containers with 3 kg a.d.m. of substratum. In experiment three substrata, five composts and two plant species were tested.

Two soils with diversified physicochemical properties and post-flotation sludge from "Bolesław" S.A. mining enterprise in Bukowno landfill were used as substrata. The post-flotation waste revealed an alkaline pH, the light soil neutral and the medium soil slightly acid (Table 1).

Medium soil contained from twice to thrice bigger quantities of organic C, N, P and K and only slightly bigger amounts of heavy metals in comparison with the light soil. Macroelement content in the post-floatation waste was on a very low level, reaching only from several to a dozen or so percent of their content in soils. The post-floatation waste contained very high amounts of heavy metals, particularly cadmium, lead and zinc.

The composts used for the experiment were prepared in laboratory on the basis of wheat straw, rape straw and waste from pea cleaning (Table 2). The composts mixture was prepared assuming optimal C:N ratio. The value slightly exceeding 30, which was reached at the above mentioned components proportion 1:1:0.5, was regarded as advantageous for the process. The mixture prepared in this way was supplemented with an 8% admixture (in relation to its dry mass) of crushed biopolymer materials (foils), prepared in the Central Mining Institute in Katowice. Three polymers differing in starch proportion and density were selected for the experiment. The composting was conducted in a bioreactor (V = 20 dm^3) under controlled conditions of moisture and aeration, at the temperature maintained at 35–40 ºC for 90 days and subsequently until the 180^{th} day of the process at 30 ºC.

On each substratum (in 3 replications) seven fertilizer treatments were applied: the control – without fertilization (1), mineral – NPK fertilization (2) and compost treatments (3–7). On the organic treatments the composts were applied in the amount allowing for the introduction of 0.2 g N per 1 kg of the substratum. In order to equalize the amount of phosphorus and potassium, a supplementary mineral fertilization was used to the level allowing to maintain the optimum $N:P_2O_5:K_2O$

Table 1. Physico-chemical properties of substrata used in the experiment

Parameter	Unit	Light soil	Medium soil	Sediment after flotation
pH_{KCl}	-	6.93	5.59	7.70
Organic C	[g · kg^{-1} d.m.]	12.1	25.2	2.6
N		0.98	2.99	0.11
P		0.51	1.13	0.05
K		0.73	2.29	0.27
Cd	[mg · kg^{-1} d.m.]	0.80	1.20	69.63
Cr		11.54	14.54	3.50
Cu		6.45	3.69	15.81
Ni		7.82	11.26	14.15
Pb		22.60	27.66	7500
Zn		67.35	100.32	10200

Table 2. Selected parameters of the components of a mixture of organic materials

Component of organic material	N	C	Ash	Dry mass
	[g · kg^{-1}]			
Wheat straw	5.3	406	38.4	885
Rape straw	9.9	374	81.3	882
Waste from pea cleaning	37.9	369	36.6	901

ratio (1:0.3:1.37). In the variant receiving exclusively mineral fertilizers the quantities of supplied macroelemets were half lower than on compost treatments. Mineral fertilizers were added in the form of the following salt solutions: NH_4NO_3, $Ca(H_2PO_4)_2$ H_2O, KH_2PO_4 and K_2SO_4.

The experimental design comprised the following objects:

- K1 – organic material without biopolymer foil admixture – control,
- K2 – organic material + 8% of B37 foil; Polyethylene C – 47.5%, thermoplastic corn starch – 45%, compatibilizer 7.5%,
- K3 – organic material + 8% of B36 foil, Polyethylene C – 65%, thermoplastic corn starch – 30%, compatibilizer 5%,
- K4 – organic material + 8% of B22 foil, Polyethylene – 65%, thermoplastic corn starch – 30%, compatibilizer – copolymer,
- K4+SM – organic material + 8% of B22 foil, Polyethylene – 65%, thermoplastic corn starch – 30%, compatibilizer – copolymer + microbial vaccine (SM).

The composts obtained as a result of composting revealed a relatively slight diversification of macroelements and trace elements content (Table 3). The greatest content of minerals was registered in the compost to which no polymer materials were added (K1). In the other composts, the contents of individual elements were usually on an approximate level.

When the substrata were prepared, as described earlier, oat was sown to each of the 63 pots on 14 May and harvested on 17 July after 63 days of vegetation. Subsequently, white mustard was sown as a successive crop, harvested on 27 September after 72 days of vegetation. Throughout the plant vegetation period the moisture content in the substrata was maintained (using distilled water) on the level of 50% of the maximum water capacity.

In order to assess mineral component concentrations, samples of organic materials were "dry" mineralized in a muffle furnace at 450 ºC for 12 hours. After cooling, ash of the aboveground parts and roots was digested in HCl (1:1) and HNO_3 acids (1:2), whereas the substrata were dissolved in concentrated HNO_3 and $HClO_4$ acids mixed in 1:2 (*v*/*v*) ratio and after their evaporating in the hydrochloric acid (1:1). In the prepared filtrates the mineral content was assessed by atomic emission spectrometer with inductively coupled plasma (ICP-OES). Total nitrogen concentrations were determined using Kjeldahl's method. Besides, the following soil properties were determined: granulometric composition using Bouyoucose-Casagrande method in Prószyński's modification, pH by potentiometer in 1 mol · dm^{-3} KCl solution and organic C content by Tiurin's method.

Table 3. The content of selected mineral components in composts used in the experiment

Component	K1	K2	K3	K4	K4+SM
	[g · kg^{-1} d.m.]				
N	8.8	5.8	5.3	7.0	8.5
P	3.9	3.3	3.5	2.9	3.2
K	14.6	12.2	12.2	9.6	10.0
[mg · kg^{-1} d.m.]					
Cd	2.0	1.1	1.0	0.8	0.8
Cr	14.3	13.0	12.7	10.9	11.0
Cu	17.6	7.4	5.6	5.4	5.6
Ni	8.6	6.8	6.7	5.8	6.0
Pb	4.2	2.7	2.3	2.2	2.8
Zn	175.8	148.9	138.0	117.0	118.4

The results of the yields were subjected to two-way ANOVA analyses regarding fertilization and substrata. The computations were made using Statistica w.10PL programme.

RESULTS

The quantities of harvested oat biomass (Table 4) differed significantly not only in respect of applied fertilization but also the substratum used for the experiment (light soil, medium soil and post-floatation sludge).

Post-floatation sludge used for the experiment proved the worst with respect to the amount of harvested oat biomass. Applied fertilization, including composts with polymer material admixtures was of a secondary importance and did not alleviate unfavourable, particularly physical and chemical, properties of this substratum. Two soil materials used for the experiment differed considerably by their granulometric composition and contents of components available to plants. Notwithstanding, the quantities of gathered biomass of both oat aboveground parts and roots generally did not differ significantly between analogous objects. Beside the post-floatation waste, oat biomass yield was most beneficently affected by fertilization with chemically pure mineral salts, which should be associated with NPK components availability. Irrespectively of the polymer supplement, adding composts to the post-floatation sludge influenced growth and development of oat aboveground parts more positively than on the control or the mineral salts treatment. However, statistically significantly bigger amount of oat aboveground parts was harvested from the object where compost was applied without admixtures (control) or compost with 8% admixture of B22 foil+microbial vaccine. No similar dependence was observed for oat roots. A beneficial effect of applied composts on oat biomass increments in comparison with the control (0) should be connected not only with supplying nutrients to plants, but also with an improvement of the post-floatation sludge physical properties, improvement of water-air and chemical conditions - immobilization of mobile forms of toxic heavy metals in result of binding them by organic matter.

Table 4. The amount of oats biomass collected in the pot experiment (g d.m. · pot^{-1} ± SD)

Treatments	Tops	Roots
	light soil	
I. „0"	7.00^{c} ± 1.41	1.83^{de} ± 0.52
II. NPK	29.83^{h} ± 1.31	3.67^{h} ± 0.26
III. K1	27.17^{efg} ± 0.85	3.39^{gh} ± 0.37
IV. K2	26.00^{def} ± 0.41	2.85^{fg} ± 0.09
V. K3	27.67^{fg} ± 0.62	2.35^{ef} ± 0.15
VI. K4	25.33^{de} ± 2.09	3.40^{gh} ± 0.36
VII. K4+SM	24.67^{d} ± 1.25	3.34^{gh} ± 0.38
	medium soil	
I. „0"	7.50^{c} ± 0.71	1.50^{cd} ± 0.13
II. NPK	29.83^{h} ± 0.62	3.61^{gh} ± 0.43
III. K1	28.83^{gh} ± 1.93	3.04^{fgh} ± 0.19
IV. K2	25.50^{def} ± 1.08	3.46^{gh} ± 0.41
V. K3	27.50^{efg} ± 0.71	2.90^{fgh} ± 0.24
VI. K4	26.90^{efg} ± 1.02	3.19^{gh} ± 0.62
VII. K4+SM	24.63^{d} ± 0.87	4.37^{i} ± 0.76
	post-floatation sludge	
I. „0"	0.00^{a}	0.00^{a}
II. NPK	1.04^{ab} ± 0.02	0.98^{bc} ± 0.13
III. K1	2.44^{b} ± 0.64	0.82^{bc} ± 0.17
IV. K2	1.99^{ab} ± 0.42	0.82^{bc} ± 0.26
V. K3	2.10^{ab} ± 0.21	0.68^{bc} ± 0.22
VI. K4	1.97^{ab} ± 0.47	0.74^{bc} ± 0.30
VII. K4+SM	2.45^{b} ± 0.15	1.02^{bc} ± 0.18

Explanation: Means marked by the same letters did not differ significantly at $\alpha < 0.05$ according to the Duncan test, factors: fertilization × substrate.

Amounts of harvested white mustard biomass (Table 5) did not differ significantly, either in respect of applied fertilization, or due to the substratum used in the experiment (light soil, medium soil or post-floatation sludge). Because of the order of cultivation (after oat) mustard plants had different conditions considering availability of nutrients. A clear diversification was observed in the quantity of mustard biomass cultivated on the soils and post-floatation waste. Applied fertilization, including composts with polymer materials admixture, was not in any obvious way important for the amount of plant biomass cultivated on the soils (light and medium). Two soil materials used for the experiment differed considerably with their granulometric composition and the content of components bioavailable to plants. Nevertheless, the amounts of gathered biomass of both mustard aboveground parts and roots generally did not differ significantly between the analogous objects. The post-floatation sludge proved a markedly better substratum in case of both soils considering the amount of harvested mustard biomass. Significantly the greatest biomass quantities were

Table 5. The amount of white mustard biomass collected in the pot experiment [g d.m. · pot^{-1} ± SD]

Treatments	Tops	Roots
	light soil	
I. „0”	1.51 ^{bc} ± 0.48	0.34 ^{bcde} ±0.04
II. NPK	1.62 ^{bc} ± 0.19	0.29 ^{bcde} ± 0.01
III. K1	2.66 ^{de} ± 0.26	0.49 ^{ef} ± 0.02
IV. K2	2.21 ^{cd} ± 0.53	0.41 ^{def} ± 0.02
V. K3	2.19 ^{cd} ± 0.17	0.40 ^{def} ± 0.06
VI. K4	1.81 ^{cd} ± 0.39	0.36 ^{cde} ± 0.04
VII. K4+SM	1.98 ^{cd} ± 0.19	0.39 ^{def} ± 0.08
	medium soil	
I. „0”	1.53 ^{bc} ± 0.09	0.23 ^{bcd} ± 0.06
II. NPK	0.67 ^{ab} ± 0.01	0.14 ^{ab} ± 0.02
III. K1	1.46 ^{bc} ± 0.45	0.29 ^{bcde} ± 0.07
IV. K2	2.21 ^{cd} ± 0.29	0.29 ^{bcde} ± 0.04
V. K3	1.56 ^{bc} ± 0.07	0.31 ^{bcde} ± 0.03
VI. K4	1.51 ^{bc} ± 0.08	0.35 ^{cde} ± 0.05
VII. K4+SM	1.57 ^{bc} ± 0.06	0.22 ^{abcd} ± 0.05
	post-floatation sludge	
I. „0”	0.05 ^{a} ± 0.01	0.02 ^{a} ± 0.01
II. NPK	0.25 ^{a} ± 0.17	0.18 ^{abc} ± 0.05
III. K1	4.49 ^{gh} ± 0.56	0.81 ^{hi} ± 0.10
IV. K2	4.21 ^{fg} ± 0.66	0.57 ^{fg} ± 0.22
V. K3	5.18 ^{h} ± 0.30	0.77 ^{hi} ± 0.07
VI. K4	3.44 ^{ef} ± 0.79	0.70 ^{gh} ± 0.13
VII. K4+SM	4.48 ^{gh} ± 1.22	0.91 ^{i} ± 0.23

Explanation: Means marked by the same letters did not differ significantly at α< 0.05 according to the Duncan test, factors: fertilization × substrate.

produced in the objects where composts were applied. A beneficial effect of composts on mustard biomass increments, in comparison with the control (0) and NPK treatment should be connected not only with nutrient release to plants in result of mineralization, but most probably with the improvement of physical properties of post-floatation sludge – improvement of water-air conditions. It should be also emphasized that on the mineral salt treatments, irrespectively of the substratum, the amounts of mustard biomass (aboveground parts and roots) were markedly lower than gathered from the objects receiving compost fertilization.

A confirmation of a diverse response of the plant yield to the substratum conditions is the analysis of variance for this factor, considering homogenous groups. Average oat dry matter yield on post-floatation sludge was 1.71a g d.m. · pot^{-1} and differed significantly from mean yields obtained on light soil (23.95b g d.m. · pot^{-1}) and on medium soil (24.39b g d.m. · pot^{-1}).

Three homogenous groups were revealed for mustard yield. The aboveground part yield from this plant was the lowest on medium soil (1.45a g d.m. · pot^{-1}). On light soil on average 1.99b g d.m. · pot^{-1} was gathered and on post-floatation sludge 3.16c g d.m. · pot^{-1}. Homogenous groups of average yields for substrata did not change even after elimination from the analysis of the objects without fertilization and receiving mineral fertilizers. It indicates a considerable importance of substratum choice (Figure 1) regarding the results which

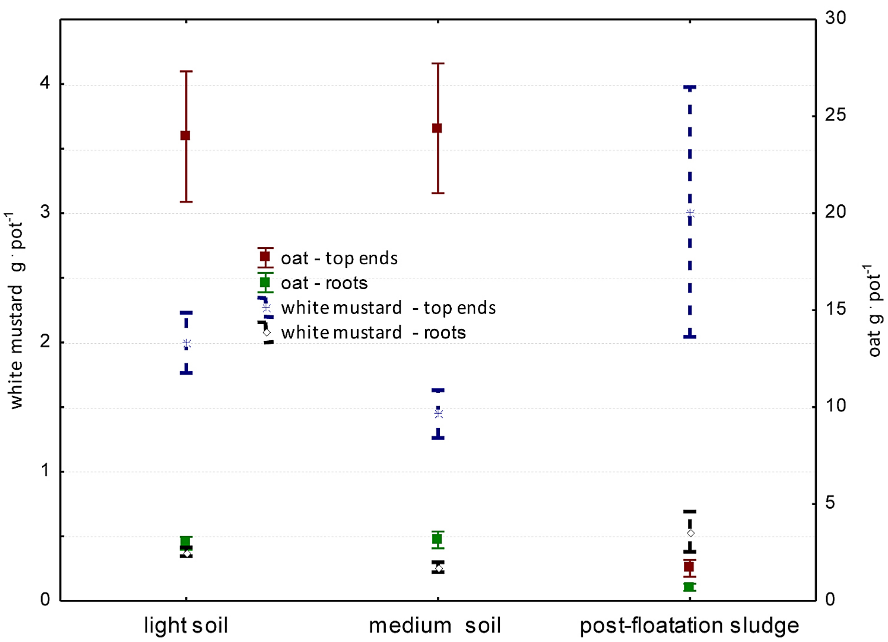

Figure 1. Yield [g · pot^{-1}] of top ends and roots of test plants obtained on three substrata

one plans to achieve when using composts. The selection of plant allowing for optimum utilization of components is no less important.

CONCLUSION

1. Yield forming effect of compost application depends on the substratum to which the compost was used and its decomposition time.
2. Composts prepared with 8% admixture of polymer materials on the basis of polyethylene modified with starch as biocomponent led to a lower oat yield, particularly on light soil.
3. Mustard, a successive plant yield was not significantly diversified among the objects fertilized with composts.
4. No unanimous effect of the kind of polymer used in composting on plant yield was noted.

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