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Original Research Article

THE EVALUATION OF THE FERTILIZING AND YIELD POTENTIAL OF STRAW AND CELLULOSE MANURE

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Abstract

The objective of the study was to determine the physicochemical properties as well as the fertilizing and crop-yielding value of straw and cellulose manure after a 6-month storage period. Before field application pH value and contents of dry matter, TC, $C_{org.}$ and N in cellulose manure were higher than in straw manure. The application of cellulose manure caused an increase in pH and the contents of P and K in the soil. The contents of DM, TC, C_{org}., as well as N and P in the rye grain collected from a field with cellulose manure were higher than in the rye grain collected from a field with straw manure. It follows that the soil fertilized with the cellulose manure was more conducive to the mineralization and sorption of macroelements assimilable by plants. The cellulose manure demonstrated better fertilizing value than the straw manure and increased the yield potential of the soil.

Keywords: manure, straw, cellulose, yield, fertilizing value, yield potential

1. INTRODUCTION

Sustainable agriculture is a system of management in which economic, social and ethical principles are correlated with ecological safety [1, 3, 6]. A particular responsibility for environmental protection is laid on agriculture, whose production has an impact on the soil, water and air properties as well as

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contributes to changes in biodiversity [2, 21]. Over 90% of soils in Poland are based on acid sedimentary rock and therefore the share of soils with pH below 5.5 exceeds 60% of all agricultural land [7]. Soil pH is one of the more important indicators of soil fertility. Acidic environment reduces the assimilability of nutrients, especially phosphorus and magnesium, and increases the mobility of dangerous elements, especially heavy metals and aluminum. Soil acidification also contributes to the decrease in microorganism activity and the occurrence of elements in forms less assimilable by plants (f. ex. phosphorus) [5]. 40% of soils in Poland are light, not very fertile and require heavy fertilizing [7]. However, acid and light soil exhibits very average sorptive properties and is characterized by low nutrient retention; nutrients find their way to groundwater or escape into the air and are irretrievably lost [9, 12]. The application of organic substances and plant nutrients impacts the soil's physical properties, enriches its sorption complex and increases its biological activity [19].

The dissimilation of organic substance is a natural process and one can only limit its speed and distribution in time [15]. An excessive speed of mineralization may result in the pollution or even contamination of water and soil ecosystems.

It is very common in agriculture in Poland to fertilize fields with organic and natural fertilizers. The aim of using fertilizers it to help plants with availability of nutrients during the whole vegetation period. Within the balanced fertilization scheme, the manure has to be stored at least six months.

It is therefore essential that the introduced manure should undergo a slow process of dissimilation and improve the sorption properties of soil [13].

The physicochemical properties of the applied manure depend i.a. on the composition of the manure mass and the processes taking place during the storage period. The speed and direction of the process of mineralization are largely dependent on the properties of the bedding material, which also determine the degree of sorption of the end products of organic matter decomposition [4, 16]. Therefore for the development of sustainable agriculture the choice of bedding material is of importance.

The objective of the study was to determine the physicochemical properties as well as the fertilizing and crop-yielding value of straw and cellulose manure after a 6-month storage period in field conditions. Cellulose is an organic compound (polysaccharide) of natural origin, non-toxic, odourless; when in the manure, it improves its sorptive properties and serves as an additional source of organic carbon for microorganisms.

2. MATERIALS AND METHODS

The study material came from a livestock building - a turkey house.

In our research we have used two types of manure: the cellulose manure and the straw manure. This type of material was obtained from our research in poultry houses, and this was a reason for selecting them in this study [17, 18]. After the production cycle had been finished, the manure obtained from two bedding materials - straw (OS - control) and cellulose (OC) - was stored in field conditions. At the beginning of September, after a 6-month storage period in piles, the manure in the amount of 3 $kg \cdot m^{-2}$ was applied on two 1.5 ha plots which had not been either fertilized or limed for 3 years. In the last decade of September the fields were sown with the Dańkowskie Złote rye. In July of the following year the yield was harvested.

In the manure and the harvested yield of the grain, the contents of the following were determined according to IUNG [8] guidelines for pH, moisture acc. [25], ash acc. [24], nitrogen (the Kjedahl method) acc. [22], calcium and potassium (flame emission spectroscopy) and phosphorus (colorymetric method with molydbenum-sulphuric acid) acc. [23]. The contents of carbon were determined with the SHIMADZU SSM – 5000 carbon analyzer.

The soil samples for pH marking and determining the contents of P, K and Mg were collected [10] directly before the application of the manure on the field and after the yield had been harvested. In the collected soil samples the following were determined: pH in KCl, the contents of phosphorus and potassium (the Egner-Riehm method) and magnesium (the Schachtschabel method). The earth samples were taken form six places of each field. Chemical analysis was performed four times of each sample. The plant material was taken from six places of each field. Every plant sample was subjected to chemical analysis four times [8].

The chemical analyses determining the contents of macroelements in the manure, soil and grain were performed at the LODR Laboratory in Kalsk, and the carbon contents were determined at the Laboratory of the Institute of Environmental Engineering, University of Zielona Gora.

The obtained results were subject to statistical analysis to determine the statistical significance of the mean difference of macroelement contents in the studied types of manure, in the soil before manure application, in the soil after the yield harvest and in the grain harvested from the fields. The analysis of mean difference was based on the Student's t-test [14].

3. RESULTS

In Table 1 are presented the results of the laboratory analysis of manure before field application.

Table 1. The physical parameters and contents of macroelements in the cellulose and straw manure before field application [$g \cdot kg^{-1}$ of manure directly in the sample]

Tested parameter	Cellulose manure (OC)	Straw manure (OS)
pH [-]	8.6	8.2
Moisture (RH) [%]	48.4	66.0
DM	522.5	339.8
Total Carbon (TC)	181.2	122.6
Organic Carbon ($C_{org.}$)	180.5	122.3
General Nitrogen (N)	24.2	19.8
General Phosphorus (P)	10.8	12.3
General Potassium (K)	14.6	14.8
Calcium (Ca)	15.8	15.9
Ash	92.3	101.0
C:N/Ratio [-]	7	6
C:P/Ratio [-]	17	10

Source: autor's calculations

The results of the laboratory analysis showed that before field application OC was characterized by a slightly higher pH value than OS; the difference was 0.4. The moisture of the cellulose litter was by 17.6 percentage points lower than the straw litter. The lower moisture content of OC than OS resulted in a higher by 182.7 $g \cdot kg^{-1}$ content of dry matter. Such differentiation of moisture and DM content in the studied manure types is caused by better water absorbency of cellulose than straw [11].

The high moisture content of OS caused the inhibition of the aerobic decomposition of organic matter, as indicated by TC and Corg. levels - higher in OC than OS by 58.6 g kg^{-1} and 58.2 g $kg^{-1}$of manure respectively. Organic carbon constituted a similar percentage of general carbon in both OC and OS (99.6% and 99.7%). The cellulose manure as compared with the straw manure was characterized by higher contents of N – by 4.4 g kg-^{1}of manure. The P and ash contents were lower in OC than in OS by 1.5 g kg^{-1} and 8.7 g $kg^{-1}$of manure respectively. The levels of K contents in both types of manure were similar (the difference of 0.2 g $kg^{-1}$of manure) and so was it in the case of Ca contents (the difference of 0.1 g $kg^{-1}$of manure). In both types of the studied manure the C:N ratio was similar (1-point difference), whereas the C:P ratio was higher in OC than in OS (7-point difference). The lower content of ash in the cellulose manure than in the straw manure, can indicate that there is lower amount of minerals in the cellulose manure. The ratio of C:N and C:P also confirms the thesis that the mineralization processes are slower in the cellulose manure [20].

The statistical analysis of the obtained results showed that the differences between the average contents of DM, moisture, TC and $C_{org.}$ in OC and OS were statistically significant at $p<0.01$ and $p<0.05$. As regards the other characteristics studied (pH, NPK, Ca and ash), despite the differences in average values, the high *sd* (especially in OS) precluded the significance of differences.

As the data in Table 2 show, the application of both manure types increased the pH of soil; however it was higher after OC than OS application, by 0.5 and 0.1 respectively. The most likely cause of such changes was the higher pH value of the applied OC as compared to the pH value of OS. The TC and $C_{org.}$ levels in the soil increased after the application of both types of manure respectively by 1.0 and 1.1 $g \cdot kg^{-1}$ DM of soil after OC application, and by 3.1 and 2,9 $g \cdot kg^{-1}$ DM after OS application.

Table 2. The physical parameters and contents of macroelements in the soil before the application of OC and OS manure and after yield harvest

Tested parameter	Soil		Soil	
	Before OC application	After yield harvest	Before OS application	After yield harvest
pH [-]	6.2	6.7	5.5	5.6
Total Carbon (TC) [$g \cdot kg^{-1}$ DM]	28.4	29.4	14.4	17.5
Organic Carbon ($C_{org.}$) [$g \cdot kg^{-1}$ DM]	25.7	26.8	11.8	14.7
General Phosphorus (P) [$mg \cdot 100g^{-1}$ of the soil]	2.7	19.3	10.0	15.5
General Potassium (K) [$mg \cdot 100g^{-1}$ of the soil]	6.9	10.3	6.2	7.2
Magnesium (Mg) [$mg \cdot 100g^{-1}$ of the soil]	5.4	5.7	3.2	4.0

Source: autor's calculations

After OC and OS application the P contents in soil increased by 16.6 and 5.5 $mg \cdot 100g^{-1}$ of soil respectively. The levels of K in soil increased after the application of both types of manure, by 3.4 $mg \cdot 100g^{-1}$ after OC application and by 1.0 $mg \cdot 100g^{-1}$ of soil after OS application. The increase in Mg contents after OC and after OS was similar and was 0.3 and 0.8 $mg \cdot 100g^{-1}$ of soil respectively. The higher change in P and K in soil after OC application points to the increase in the soil's richness whereas the higher change in TC and $C_{org.}$ in soil after OS application indicates either a slower process of the mineralization of organic matter or nitrogen robbery. The analysis of the average values of the studied soil parameters before manure application and after the yield harvest shows that the soil fertilized with OC was more conducive to the mineralization of organic matter and to the cumulation of assimilable macroelement forms than the soil fertilized with OS.

In Table 3 are summarized the physicochemical parameters of the grain yield from fields fertilized with cellulose and straw manure.

Table 3. The physical parameters and contents of macroelements in the harvested yield according to the type of manure applied

Tested parameter	Yield from field after application of cellulose manure	Yield from field after application of straw manure
MTZ[1] [g]	25.8	25.7
RH [%]	12.7	13.1
DM [g·kg^{-1}]	873.5	869.0
Total Carbon (TC) [g·kg^{-1} directly in the sample]	402.9	401.1
Organic Carbon ($C_{org.}$) [g·kg^{-1} directly in the sample]	400.6	398.8
General Nitrogen (N) [g·kg^{-1} directly in the sample]	18.0	14.8
Generał Phosphorus (P) [g·kg^{-1} directly in the sample]	4.2	4.0
General Potassium (K) [g·kg^{-1} directly in the sample]	4.2	4.3
Ash [g·kg^{-1} directly in the sample]	18.6	18.0

[1]MTZ - the weight of one thousand grains

Source: autor's calculations

The weight of one thousand grains (MTZ) of plants harvested from the field fertilized with OC was a little higher than of those from the field fertilized with OS, the difference being 0.1 g. The grain harvested from the OC-fertilized field was characterized by lower moisture than that from the OS-fertilized field, the difference being 0.4 percentage point. Most probably, the higher moisture value of grain harvested from the OS-fertilized field was the cause of the increased MTZ. The dry matter content was higher by 4.5 g·kg^{-1} for grain from the OC field than that from the OS field. The analysis of chemical composition of the crop showed that the grain from the OC field contained higher amounts of TC and $C_{org.}$ as well as N, P and ash than the grain from the OS field by 1.8, 1.8, 3.2, 0.2 and 0.6 g·kg^{-1} respectively. The amount of K in grain from the OC field was a little lower than in grain from the OS field, the difference being 0.1 g·kg^{-1}.

The observed differences between the average values of the studied parameters in the harvested grain were:

- statistically highly diverse at $p<0.001$ for N;
- statistically significant at $p<0.01$ for RH, DM and ash;
- statistically significant $p<0.05$ for P.

4. CONCLUSIONS

1. Before field application the values of most of the studied parameters were higher in the cellulose manure than in the straw manure (the differences were statistically significant for DM, RH, total and organic carbon).
2. The application of the cellulose manure resulted in a statistically significant increase in pH of the soil as compared to the pH of the soil fertilized with straw manure (the difference was statistically significant at $p<0.05$).
3. The soil fertilized with the cellulose manure was more conducive to mineralization and the sorption of macroelements.
4. The cellulose manure enriched the soil with phosphorus and potassium to a higher degree than the straw manure and thus increased its richness.
5. The more beneficial chemical composition of grain harvested from the field fertilized with the cellulose manure than the straw manure (statistically significant differences for: moisture, dry matter and ash at $p<0.01$; nitrogen at $p<0.001$; phosphorus at $p<0.05$) points to a higher yield potential of the cellulose manure.
6. The cellulose manure was characterized by higher fertilizing value than the straw manure.

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OCENA PRZYDATNOŚCI NAWOZOWEJ OBORNIKA SŁOMIASTEGO I CELULOZOWEGO

S t r e s z c z e n i e

Przeprowadzone badania miały na celu określenie właściwości fizykochemicznych, przydatności nawozowej i plonotwórczej obornika słomiastego oraz celulozowego po okresie 6. miesięcznego składowania. Przed aplikacją na pole wartość pH oraz zawartość suchej masy, TC, C_{org}. i N w oborniku celulozowym były wyższe, niż w oborniku słomiastym. Aplikacja obornika celulozowego spowodowała wzrost pH oraz zawartości P i K w glebie. Zawartość suchej masy, TC, Corg., N i P w ziarnie żyta zebranego z pola po oborniku celulozowym była wyższa, niż w ziarnie zabranym po oborniku słomiastym. Wynika z tego, że w glebie nawiezionej obornikiem celulozowym panowały bardziej korzystne warunki mineralizacji i sorpcji makroelementów przyswajalnych przez rośliny. Obornik celulozowy posiadał lepszą przydatność nawozową, niż obornik słomiasty, a zaaplikowany do gleby podwyższył jej zdolność plonotwórczą.

Słowa kluczowe: obornik, słoma, celuloza, plon, przydatność nawozowa

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