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Effects of long term application of chicken manure and spent mushroom substrate on organic matter and storage of water in sandy soils

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Soil organic matter (SOM) is a key resource base for agriculture. It affects soil structure, water storage and supply essential plant nutrients. Soil organic matter can retain hold up to twenty times their weight in water. However, its content in cultivated soils decreases due to intensive soil disturbance by tillage practices. Almost half of European agricultural soils have low (0–2%) organic matter content). Hence, the decline in SOM is a large current environmental threat and a soil degradation component (EASAC, 2018). The effects of SOM on water storage are of particular importance in sandy soils that exhibit low water holding capacity and are highly prone to droughts (Lipiec and Usowicz, 2018). They cover about 900 mln ha world-wide. Increasing organic matter content in such soils can allow farmers to reduce reliance on low and uneven precipitation and high-price mineral fertilizers. To increase soil organic matter content application of exogenous (recycled) organic materials is recommended. Therefore, the aim of the work was to examine the effects of long term (20 years) application of chicken manure and waste spent mushroom substrate on coarsely textured soils.

Object and methods

Coarse-textured (632–741 mg kg^{-1}of sand), acidic (~ pH 4.2) with low organic matter podzol soils (Table 1) were enriched with chicken manure (10 Mg ha^{-1}) or waste spent mushroom substrate (20 Mg ha^{-1}) (Photo 1) from local farms (Lublin region, Poland). Both amendments have high pH (>7.5) and provide valuable plant nutrients. They were applied every year during 20 years.

Photo 1 Mushroom farm in Trzebieszów-Kolonia (Poland)

Measurements in control and organic amended soil included:

* top soil organic matter content (0–20 cm) using Turin's method,
* soil water retention curve with pressure plates at six suctions (from saturation to 1500 kPa) and then used to calculate contents of transmission pores (>50 µm), storage pores (50–0.5 µm) and residual pores and bonding space (<0.5 µm) at depths 0–20, 20–40 cm and 40–60 cm,
* saturated hydraulic conductivity (SHC) on undisturbed soil samples in metal Kopecky rings of 100 cm^3,
* penetration resistance of soil using the soil penetrometer (penetrologger – Eijkelkamp).

Results

Long-term application of chicken manure and spent mushroom substrate appreciably increased initial organic matter in the top soil (0–20 cm) (Table 1). Visual soil assessment showed that addition of both organic amendments decreased number of firm clods (>20 mm) (ex. on Photo 2) and increased proportion of friable, fine aggregates.

Table 1. Textural composition, organic matter and penetration resistance of soils. Standard errors are in brackets.

Treatments	Texture, g kg^{-1}			Organic	Penetration
	Clay	Silt	sand	matter, %	resist., MPa
Control (no chicken manure)	20.5	270.4	709.1	1.34	1.87 (0.11)
Chicken manure	21.6	345.9	632.5	3.50	1.88 (0.09)
Control (no spent mushroom substr.)	18.0	240.9	741.1	0.87	2.76 (0.10)
Spent mushroom substrate	19.4	269.1	711.5	4.71	1.63 (0.09)

Photo 2. General view of field soil structure in control (left) and spent mushroom substrate (right) amended soils.

As can be seen from Table 2 the addition of both chicken manure and spent mushroom substrate decreased content of transmission pores (>50 µm) and increased content of residual pores (<0.5 µm) and field water capacity at all three soil depths. This effect with regard to the transmission pores was more pronounced in chicken manure than spent mushroom substrate amended plots. The decrease in content of the transmission pores at depths of 0–20 and 20–40 cm was reflected in decrease of saturated hydraulic conductivities. As to storage pores, the differences between control and organic amended plots were relatively low and not consistent at all depths. The response of pore size distribution can be attributed with large specific surface (SSA) area of the organic amendments when incorporated to the coarse textured soil of low SSA (<8 m^2 g^{-1}).

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Table 2. Pore size distribution, bulk density and saturated hydraulic conductivity of soils. Standard deviations are in brackets.

Treatments	Depth (cm)	Porosity (% v/v) Transmission pores >50 µm	Storage pores 50–0.5 µm	Residual pores and bonding space <0.5 µm	Field water capacity %, v/v	Saturated hydraulic conductivity m/day
Control (no chicken manure)	0–20	22.8 (1.26)	8.4 (1.27)	8.4 (1.50)	13.6 (1.04)	15.8 (4.51)
	20–40	8.5 (1.48)	13.0 (2.16)	9.4 (1.27)	18.5 (1.10)	7.8 (3.80)
	40–60	14.3 (2.7)	10.9 (0.79)	7.0 (2.86)	13.2 (4.86)	9.2 (4.02)
Chicken manure	0–20	4.4 (1.25)	11.4 (2.53)	22.9 (1.03)	31.8 (2.14)	4.7 (2.18)
	20–40	4.3 (2.33)	14.1 (4.29)	17.9 (1.92)	27.8 (1.72)	2.4 (0.73)
	40–60	4.3 (1.59)	10.2 (1.00)	16.0 (2.41)	23.3 (2.77)	8.5 (4.63)
Control (no spent mushroom substrate	0–20	13.8 (1.05)	13.1 (0.21)	8.9 (0.72)	17.7 (1.13)	5.7 (1.86)
	20–40	8.6 (0.74)	17.7 (1.24)	5.7 (2.07)	17.6 (2.78)	2.6 (0.23)
	40–60	9.5 (0.43)	17.6 (1.33)	7.3 (2.76)	20.7 (1.79)	1.8 (0.71)
Spent mushroom substrate	0–20	12.0 (1.5)	13.6 (0.8)	18.1 (1.44)	27.2 (1.32)	4.7 (1.03)
	20–40	8.9 (2.03)	13.2 (1.64)	18.2 (2.30)	27.0 (1.96)	0.78 (0.20)
	40–60	7.9 (0.98)	16.4 (1.11)	9.5 (0.65)	20.6 (0.30)	4.4 (0.83)

Application of the spent mushroom substrate caused several-fold increase in the electrical conductivity and contents of total N and extractable P and K (Table 3). The initial soil pH (4.2) increased by more than 50%. The addition of the spent mushroom substrate influenced relatively more the soil chemical properties than pore size distribution and available water content.

Table 3. Selected soil chemical properties in control and pent mushroom substrate amended soil

Treatments	pH $CaCl_2$	[1]EC	Total N	Extractable P	Extractable K
		dS m^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}
Control (no spent mushroom substr.)	4.22	0.13	800	104.4	107.9
Spent mushroom substrate	6.76	0.99	2800	639.5	367.4

[1]EC=Electrical conductivity

Conclusions

The study showed that long term (20 years) application of chicken manure and spent mushroom substrate appreciably increased topsoil (0–20 cm) organic matter content. Both types of organic amendments decreased content of transmission pores (>50 µm) and saturated hydraulic conductivity and increased content of residual pores and bonding space (<0.5 µm) at depths of 0–20 and 20–40 cm. The addition of spent mushroom substrate increased topsoil pH (from 4.2 to 6.8) and contents of total N (from 800 to 2800 mg kg^{-1}) and extractable P (from 104 to 639 mg kg^{-1}) and K (from 108 to 367 mg kg^{-1}). Our results indicate that chicken manure and spent mushroom substrate left after growing the mushrooms can be friendly and economical viable soil management practices to increase quality of coarse-textured soils.

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