EFFECT OF SOIL TILLAGE AND DIGESTATE APPLICATION ON SOME SOIL PROPERTIES

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Abstract

The effect of different methods of tillage on basic physical and chemical properties of soil was tested in a pilot field experiment. The digestate was applied simultaneously and it was tested if this type of dressing did not influence soil in a negative manner. Results obtained in the Variant 2 (i.e. with the minimum tillage) indicated that, as compared with the conventional ploughing, (Variant 1) values of reduced bulk density were increased and those of soil porosity decreased. However, better values of soil humidity were recorded in Variant 2. In Variant 2, a certain trend to increasing values of C_{org}/N_t ratio was observed while in Variant 1 values of soil reaction were decreased. It was concluded that these changes could induce soil degradation processes.

Keywords: ploughing, minimum tillage, soil physical properties, soil chemical properties, digestate

Introduction

There are different opinions concerning not only methods of tillage but also the application of nutrients in the form of mineral fertilisers. One of the most important problems is the formulation of an optimum dose of supplied nutrients (Pokorný and Denešová, 1998). This problem concerns also the application of digestate.

The digestate (i.e. the waste material remaining after the anaerobic digestion of a biodegradable feedstock in biogas stations) represents one of possibilities how to apply nutrients into the soil. When defining the digestate, it is difficult to decide if it is an organic or mineral fertiliser. From the viewpoint of legislation, it is classified into the category of fertilisers of organic type (Lošák, 2010). Because digestate contains predominantly organic substances, it can be considered to be the organic fertilisers.

However, because the technology of biogas production is relatively young and new, there are no data available about effects of digestate matter application as a fertiliser on the soil environment.

If digestate doses are too high and also if it is applied into soils with existing unsuitable conditions, the soil can be excessively compacted and such a compaction can be fairly irreversible.

Materials and methods

The experimental field was situated on loamy Orthic Luvisol in a potato-growing region with the following parameters: altitude 513 m above sea level, long-term sum of precipitation 500 mm (of this, 395 mm in the course of the growing season), and average annual temperature 6.8 °C.

There were two variants of tillage: Variant 1 – conventional ploughing to the depth of 0.22 m, and Variant 2 – minimum tillage with a post-harvest crushing stubble breaking. In both variants, the digestate originating from a local biogas station was applied in the dose of 20 t ha-1 in the autumn of each experimental year. In both experimental variants only the effect of the preceding crop on soil properties was studied. The pH of the digestate was 8.9 and it contained 90.21 % of combustible substances; contents of individual elements (also expressed in % of DM) were as follows: nitrogen 5.47; phosphorus 1.18; potassium 1.53; magnesium 0.71 and calcium 1.1.

When monitoring dynamic changes in physical properties, samples of intact soil were collected by means of Kopecky cylinders. Soil samples were taken in five repetitions from three depths of soil profile (0-0.1 m, 0.1-0.2 m and 0.2-0.3 m). As far as chemical parameters were concerned, recorded were pH values and organic carbon to total nitrogen molar ratios (C_{org}/N_t). Soil texture was evaluated on the base of the coefficient of structurality (which expresses the degree of destruction of soil structure) and of the ratio between agronomical valuable (0.25-10 mm) and less valuable (>10 and <0.25 mm) structural elements. Soil samples were taken in three repetitions from two depths (0-0.15 and 0.15-0.30 m). In this paper, results obtained in years 2012 –2013 are presented.

Results concerning physical properties of soil and characterising their changes within the whole study period are presented in Tabs 1 and 2.

As one can see, in Variant 1 values of reduced bulk density of soil were always lower than in Variant 2. On the other hand, however, the content of water in soil was always higher in Variant 2. In this variant, values of soil aeration were better but only in the upper soil layer.

Table 1. Physical properties of soil – Budisov, 2012

Variants	Soil depth (m)	Bulk density (g.cm^{-3})	Total porosity (%)	Momentary content of		Maximum capillary capacity	Minimum air capacity
				water	air		
				(% vol.)		(% vol.)	
1	0-0.1	1.39	48.44	14.00	34.44	34.93	13.51
	0.1-0.2	1.38	48.88	16.88	32.00	37.11	11.77
	0.2-0.3	1.38	48.95	15.56	33.39	34.64	14.31
	Mean	1.38	48.76	15.48	33.28	35.56	13.20
2	0-0.1	1.41	49.65	15.54	34.10	34.07	15.58
	0.1-0.2	1.57	43.76	18.36	25.40	30.90	12.87
	0.2-0.3	1.53	45.27	15.94	29.33	31.48	13.79
	Mean	1.51	46.23	16.62	29.61	32.15	14.08

Table 2. Physical properties of soil – Budisov, 2013

Variants	Soil depth (m)	Bulk density (g.cm^{-3})	Total porosity (%)	Momentary content of		Maximum capillary capacity	Minimum air capacity
				water	air		
				(% vol.)		(% vol.)	
1	0-0.1	1.38	47.76	19.00	28.76	38.65	9.11
	0.1-0.2	1.41	46.89	18.14	28.76	34.83	12.06
	0.2-0.3	1.33	49.77	17.54	32.23	35.38	14.39
	Mean	1.37	48.14	18.23	29.92	36.29	11.85
2	0-0.1	1.38	48.02	22.70	25.32	35.24	12.78
	0.1-0.2	1.48	44.02	24.01	20.00	33.77	10.24
	0.2-0.3	1.46	44.99	21.11	23.88	34.88	10.10
	Mean	1.44	45.68	22.61	23.07	34.63	11.04

Results and discussion

When studying effects of tillage on physical properties of soil, individual samplings were performed always at the beginning and to the end of the growing season.

In the second experimental year, values of reduced bulk density of soil were generally lower (above all in Variant 2). Different methods of soil management and of application of any kinds of organic fertilisers influence and change physical properties of soil.

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When using a new form of fertiliser (i.e. the so-called digestate), it is necessary to define not only its doses but also the method of its application.

Table 3. Statistical evaluation of Bulk density

Source	SS	df	MS	F	p	sign.
Intercept	244.0294	1	244.0294	28585.36	0.000000	*
Year	0.0413	1	0.0413	4.84	0.029824	*
Variante	0.2658	1	0.2658	31.13	0.000000	***
Season	0.0473	1	0.0473	5.54	0.020247	*
Depth	0.1001	2	0.0500	5.86	0.003773	**
Error	0.9732	114	0.0085			

*** P = 0.001; **P = 0.01; *P = 0.05

Table 4. Statistical evaluation of Water content

Source	SS	Degr. of	MS	F	p	sign
Intercept	39884.69	1	39884.69	6250.222	0.000000	***
Year	572.43	1	572.43	89.703	0.000000	***
Variante	228.28	1	228.28	35.773	0.000000	***
Season	3534.61	1	3534.61	553.898	0.000000	***
Depth	76.25	2	38.12	5.974	0.003408	**
Error	727.47	114	6.38			

*** P = 0.001; **P = 0.01; *P = 0.05

The term digestate is used as a name of the waste material remaining after the anaerobic digestion of a biodegradable feedstock in biogas stations. There are different kinds of digestate and that can be classified from different points of view, e.g. with regard to biodegraded raw materials, according to the method of their use or on the base of the content of dry matter (Marada et al., 2008). In contrast to well examined and exactly known kinds of biomass (e.g. well fermented sludge and compost), properties of digestate are not known in detail and also the methods of its use in agriculture still remain to be unexplored (Ferri et al., 2010; Tampone et al., 2010). In Table 3 and 4 is statistical evaluation of Bulk density and Content of water. The results are statistically significant between variants, years and depths Values of the coefficient of structurality are presented in Tab. 5. These values indicated that in Variant 1 there was a tendency to improving soil texture. In 2013, parameters of soil texture were generally better than in 2012.

Table 5. Coefficient of structurality (Budisov 2012, 2013)

Variants	Soil depth (m)	2012		2013	
		spring	autumn	spring	autumn
1	0-0.15	1.87	1.97	3.42	3.05
	0.15-0.30	1.90	2.49	2.62	3.87
	Mean	1.88	2.21	2.98	3.42
2	0-0.15	2.01	1.87	1.08	2.08
	0.15-0.30	1.82	1.88	1.14	2.96
	Mean	1.91	1.88	1.11	2.46

It was possible that the application of the fore crop straw into the soil performed in 2012 contributed to this improvement of soil structure.

Table 6. Statistical evaluation of Structure

Source	SS	Degr. of	MS	F	p
Intercept	81.10104	1	81.10104	234.5237	0.000000
Year	1.21034	1	1.21034	3.5000	0.088191
Variante	2.51817	1	2.51817	7.2819	0.020712
Season	1.16006	1	1.16006	3.3546	0.094209
Depth	0.11358	1	0.11358	0.3284	0.578106
Error	3.80393	11	0.34581		

Differences between variants weren't statistically significant (Tab.6). The C_{org}/N_t ratios calculated for both variants of tillage are presented in Tab. 7. On the one hand, a well-balanced carbon-to-nitrogen ratio is important for the decomposition of organic matter contained in soil while on the other it is also closely associated with the reduced bulk density. As it is well-known that the rate of organic matter decomposition is dependent on the C_{org}/N_t ratio, organic compounds with the C_{org}/N_t below 10:1 are decomposed very quickly (and are very easily available for soil microorganisms) while those with the C_{org}/N_t ratio above 50:1 are decomposed very slowly (Váňa, 1994). Results obtained within the framework of our experiments indicated that the rate of organic matter decomposition was nearly the same in both variants of tillage. In 2013, a slightly increased C_{org}/N_t ratio was recorded in deeper soil layers in Variant 2. Properties of the digestate are dependent on the quality and parameters of materials used for anaerobic digestion. Contents of other elements are usually different and depend on the properties of the fermented feedstock (Dostál, Richter, 2008). It was found, that values of soil reaction in year 2013 were decreased in Variant 1. This process is associated with the decomposition of organic matter to mineral that are for plants more available (Pokorný et al., 1998). It is therefore probable that the digestate caused an acidification of soil in ploughed Variant 1.

Table 7. C_{org}/N_t ratio in variants with different methods of tillage and digestate application (Budisov 2012, 2013)

Variants	Soil depth (m)	2012		2013	
		spring	autumn	spring	autumn
1	0-0.15	10	10	10	10
	0.15-0.30	13	11	9	9
	Mean	12	11	10	10
2	0-0.15	12	10	12	12
	0.15-0.30	13	13	16	13
	Mean	13	12	14	13

Conclusions

Results of a two-year monitoring of physical and also some chemical properties of soil in different variants of tillage and application of digestate indicate that basic physical properties of soil and its texture were influenced above all by the method of tillage.

In Variant with minimum tillage, the C_{org}/N_t, ratio was increased in the second experimental year. This means that in this variant the content of C organic substances was higher than in Variant with ploughing.

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