CHANGES IN SELECTED SOIL PROPERTIES DEPENDING ON THE APPLIED FERTILIZER

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Abstract

The current world energy policy envisages the expansion of alternative electricity production. Bio-gas plants are one of the energy sources which fulfil this assumption with the digestate by-product which is often applied as a fertilizer for farmland. Impact of this fertilizing method is not well known. This paper evaluates the changes of selected soil properties of corn crop production depending on applied fertilizer (manure, mineral fertilizer and digestate) of the growing season 2014 and 2015. The results show the influence of selected fertilizers on the physical condition of the soil.

Key words: *physical soil properties, manure, mineral fertilizer, digestate, corn*

1. INTRODUCTION

The current world energy policy supports so-called renewable energy resources. Bio-gas plants are one of these sources. The input material is transformed by fermentation process into the digestate which is used as an agricultural fertilizer not only in the Czech Republic. The Czech legislation classifies the by-products of biogas plants among organic fertilizer (must meet limit content min. 25% of combustible fuel component and 0.6% nitrogen).

Some scientific papers highlight the positive impact of organic fertilizer on different soil properties (Celik et al. 2004, Leroy et al. 2008). Organic fertilizers increase the soil organic matter content and improve physical soil properties. For example, aggregation, field capacity, hydraulic conductivity or bulk density (Franzluebbers 2002, Quin et al. 2014, Zebarth et al. 1999).

Digestate, the semi-solid residue obtained after biomass extraction in anaerobic digestion, is considered as a vital source of organic matter and nutrients, nitrogen in particular (Tiwary et al. 2015). Dealing with digestate is currently gaining great importance as it has certain amount of plant nutrients and organic matter and can be used as organic fertilizer or soil conditioner (Massaaccesi et al. 2013).

Despite these advantages, one major problem arises. Fertilizer, with unknown potential negative consequences, is applied to the soil. Long-term monitoring and in-depth analysis of the fertility of soils that are amended with digestates are required (Bachmann et al. 2014). The literature with digestate is focused on impact at nutrients, fate of N, soil organic matter (Bachmann 2014, Galvez et al. 2012, Grigatti et al. 2015, Walsh et al. 2012). But, the literature about the digestate impact on physical soil properties is few (Beni et al. 2012).

The influence of vegetation covers on soil properties were mentioned in a number of papers (Bochet et al. 1999, Liu et al. 2015, Quing et al. 2015). The latest finding indicates that the vegetation cover primarily affects the physical properties of soil (Trabaquini et al. 2015).

The maize, which is one of the major components for bio-gas production, is now the part of current cropping posts and its cultivation for several consecutive years is no exception. Monoculture growing of maize brings some negative effects like increased incidence of root rot (Govaerts et al. 2007), yield affecting (Govaerts et al. 2006) and slowing down of decomposition process of crop residues (McDaniel et al. 2014). Monoculture growing may also adversely affect the water quality by phosphorus release and increase the silting of watercourses caused by water erosion (Mbonimpa et al. 2014). Neimetz and Kettl (2012) point out that the monoculture growing (e.g. maize) is harmful for the soil management.

In our investigation, the field trial was focused on obtaining of physical soil properties changes (bulk density, field capacity, maximum capillary water capacity and minimum air capacity). The applied fertilizers were manure, mineral fertilizer and digestate. The impact of fertilizer management was observed at vegetation season end of years 2014 and 2015. The vegetation cover was corn in both years. The described depths were 0.05 and 0.15 m.

2. MATERIAL AND METHODS

2.1 Experimental locality

The small-plot experiment was located at Bohemia-Moravian Highlands (Czech Republic) at the Research Forage Production Station in Vatin (49° 31´N and 15° 58´E). The altitude is 540 m a. s. l. The site is situated on a plane surface without a gradient. The mean annual air temperature is 7.5 – 8.5 °C with mean annual precipitation is 700 – 900 mm and probability of dry growing season of 0 – 10 % (e-Agri 2015).

The soil type is Dystric Cambisol Loamic, parent material is gneiss (Šimečková 2015). Cambisol is the most widespread soil reference soil group in the Czech Republic (Tomášek 2007). These soils are developed in humid environments. Chemical and physical properties are varied. This is affected by soil organic matter content. (Němeček 2011).

Soil properties of the small-plot experiment are presented in Table 1.

Table 1. Selected soil properties of small-plot experiment in Vatin before the start, 2013, the depth scale from 0 to 0.20 m

Soil properties	Value
Particle sice distribution	
Clay (<2 µm, %)	11.69
Silt (50 – 2 µm, %)	34.87
Sand (2 000 - 50 µm, %)	53.44
Bulk density (kg.cm^{-3})	1197.12
Porosity (%)	54.36
Field capacity (%)	29.34
Maximum capillary water capacity (%)	39.87
Minimum air capacity (%)	14.49
Oxidizable carbon (%)	1.8
pH/H_2O	5.79

Note: Values shown for individual properties are averaged from all of the samplings taken from a research plot.

2.2 Experimental design

The trial plot was established in autumn 2013 (agrotechnical adjustment of the plots and application of manure). The trial plot was divided in three variants. Each variant had different fertilizer management. The fertilizer management was: manure, mineral fertilizer and digestate. The dose of nitrogen for each fertilizer management was 150 kg of N · ha^{-1}. The size of the small plot was 10 m^2 (1.25 x 8 m). The vegetation cover of the small plots was corn (*Zea mays)* during both years.

The full dose of manure was applied in the autumn. The mineral fertilizer and the digestate were applied during the vegetation season in divided doses – the first dose was in the second half

of April (it was 60% of total delivered N) and the second dose was at the turn of June and July (it was 40% of total delivered N).

The mineral fertilizer was applied as Calcium Ammonium Nitrate with Single Superphosphate and Muriate of Potash. The digestate was from biogas plant Nove Mesto in Moravia (years 2014 and 2015). The material, used in this biogas plant, was bovine manure, farmyard manure, grass silage, maize silage. The manure is from a nearby farm.

The parcel was agriculturally processed as follows - stubble cultivation in depth of 0.16 m after the harvest in the autumn followed by rotavator tillage in the spring for seedbed preparation.

Manure applications were carried out always in the autumn. Appropriate amount of manure, determined from the nitrogen content calculations, was stratified uniformly over the parcel and subsequently incorporated during the stubble cultivation.

First dose of digestate and mineral fertilizer was applied during the spring on cultivated parcel before the maize sowing. Digestate was applied into the furrow and mineral fertilize on the parcel with subsequent covering by soil. Second dose was applied between the row spacing into the furrow with approximate depth of 10 cm.

2.3 Cuts and analyses

The undistributed soil samples were taken in October of both years, after the maize harvest. The samples were sampled into the Kopecky rollers (volume 100 cm^3). The depths of samplings were 0.05 m and 0.15 m (the middle of rollers). Sampling depth selection described the root zone. Soil samples were taken in row spacing within 5 repetitions for each fertilizer management. Samples were processed according to the methodology of the Central Institute for Supervising and Testing in Agriculture (Zbíra et al. 2010).

The laboratory results identified the following physical properties of soil: bulk density, total porosity, field capacity, maximum capillary water capacity and minimum air capacity. These physical soil properties are used to evaluate the physical condition of the soil in the Czech Republic. The limit values for the evaluation are shown in Table 2.

Table 2. Limits for evaluation of physical soil properties – favourable assessment parameters of sandy loam soil

Soil properties	Limit
Bulk density ($kg.cm^{-3}$)	< 1.55
Total porosity (sandy loamy) (%)	> 42
Maximum capillary water capacity (%)	< 36
Minimum air capacity (%)	> 10

2.4 Statistical analyses

Results of each physical soil properties obtained from the years of 2014 and 2015 were statistically compared. The depths were compared separately. Parametric data were analysed using the t-test and the nonparametric data were analyzed using the Wilcoxon paired test with the usage of STATISTICA Cz 12 software (StatSoft, Inc., USA).

3. RESULTS AND DISCUSSION

Most of the physical properties changes did not showed the statistically significant difference. Not even in the case of 0.05 m depth, even though certain trends in the soil properties changes are observed. In case of mineral fertilizer and digestate application within 0.15 m depth, the statistically significant differences of soil properties changes were found.

3.1 Physical soil properties – depth 0.05 m

Application of the manure and digestate in 0.05 m depth had a positive effect on soil properties. Mean values of observed parameters are listed in Table 3. Field capacity had a positive trend in case of mineral fertilizer application but negative trend in case of digestate and manure.

Parameters of maximum capillary capacity decreased due to all fertilizers application which is evaluated as a positive effect. In case of manure and digestate maximum capillary capacity decreased below the critical value. Mineral fertilizer caused decrease of maximum capillary capacity directly on the limit value. The smallest decline was reached by application of manure. Same trend had a variant with digestate and mineral fertilizer. Changes were not statistically significant.

Application of the fertilizer had a positive effect on bulk density, porosity and minimal air capacity, especially application of the digestate and manure. There was a positive trend in change of soil properties but unfortunately a statistically significant difference was not found. Neither after the application of mineral fertilizer statistically significant changes were not found. The impact of the mineral fertilizer application on soil properties was classified as a negative.

The positive aspect of the fertilizer application was that the minimal air capacity remained on the limit value in all cases. In addition, after the digestate and manure application the value of minimal air capacity increased. Unfortunately, none of the monitored soil properties changes were statistically significant.

In the terms of physical condition comparisons were all specific soil properties in the compliance with the reference values. Excepting the maximum capillary capacity during the mineral fertilizer application where the compared values remained on the limit reference value.

Application of the digestate over the years of experiments brought the highest changes in the physical soil properties in comparisons to other fertilizers. Conversely the deterioration of the soil properties by application of various fertilizers in case of digestate had the lowest influence.

Table 3. Obtained values of physical properties of the soil depending on fertilization management – depth 0.05 m

Soil properties	Fertilizer management					
	Manure		Mineral fertilizer		Digestate	
	2014	2015	2014	2015	2014	2015
Bulk density ($kg \cdot cm^{-3}$)	1191.64	1182.06	1165.04	1265.34	1164.96	1145.62
Total porosity (%)	54.34	55.39	55.19	52.43	55.02	56.44
Field capacity (%)	28.94	28.02	29.80	30.30	30.72	28.75
Maximum capillary water capacity (%)	35.45	33.93	38.71	35.95	35.71	33.00
Minimum air capacity (%)	18.85	21.46	17.38	16.48	19.31	23.44

Note: Values shown for individual properties are averaged from all of the samplings taken from a research plot.

3.2 The physical soil properties – depth 0.15 m

Effect of digestate application in the depth of 0.15 m is not convincing like in case of depth 0.05 m. Mean values of specific physical properties are listed in Table 4. In comparison of digestate application effect on soil properties within 0.05 m depth, the trend is not so positive. Parameter of bulk density increased due to digestate application. Mean values of porosity and minimum air capacity were conversely decreased. Field capacity was dependant on the fertilizer application. The level of maximal capillary capacity increased which is classified as deterioration.

Changes of field capacity were impacted by fertilizer treatment. Application of the manure resulted in field capacity stagnation. Mineral fertilizer decreased the observed soil property. The most positive effect had an application of the digestate which brought increase of water retention capacity. This change was confirmed as statistically significant. Increasing field capacity has got a positive effect in the terms of water erosion prevention.

Inverse trend was found during the maximal capillary water capacity observation which showed deterioration of this parameter compared to the year 2014. Application of mineral fertilizer showed a statistically significant difference of negative change. This fertilizer treatment led to the highest increase within the years and it reached highest value of maximal capillary capacity compared to the all of observed methods of fertilization.

The positive change of bulk density decrease was found only in case of manure application. Mineral fertilizer and digestate fertilization had a statistically significant increase of bulk density. Greater negative change was observed in case of digestate application. Same trend was found also in total porosity and minimum air capacity change. Decline was found in both cases but more significant changes were found in case of digestate fertilization. Statistically significant decrease of maximal air capacity was found both digestate and mineral fertilizer application. Damning trend of total porosity drop was found only in case of digestate dosage. The use of manure led to the total porosity increase.

Negative progress of soil properties change in the depth of 0.15 m with digestate application could be caused by its shallow application. However, in the year 2014 deep harrowing was performed which led to the digestate deeper burying resulting in a significant influence on the physical properties of the soil.

In the terms of physical condition of the soil assessing to the reference values, the negative changes were found in some cases. The variants with the manure and mineral fertilization application brought the best results. Reference value was exceeded only in case of maximum capillary water capacity. Conversely the digestate application led to the deterioration of observed soli properties, especially in the case of maximum air capillarity and minimal air capacity. Significant changes of bulk density were reached even though that the reference values were not exceeded.

Regarding the magnitude of changes within two growing seasons and comparison of applied fertilizers among themselves, the trend is not as clear as in case of 0.05 m depth. In case of bulk density, total porosity and minimum air capacity were the most significant changes observed for digestate application. In other cases, the most significant changes were observed for mineral fertilizer fertilization.

It is worth mentioning that the smallest negative change of water retention capacity was found within the digestate application.

The long-term monitoring and Indech analysis of the fertility of soils that are amended with digestates are required (Bachmann et al. 2014). But the assessment of a digestate application is not so easy to observe because each digestate sample shows different composition (Grigatti et al. 2015).

Table 4. Obtained values of physical properties of the soil depending on fertilization management – depth 0.15 m

Soil properties	Fertilizer management					
	Manure		Mineral fertilizer		Digestate	
	2014	2015	2014	2015	2014	2015
Bulk density (kg·cm^{-3})	1269.56	1218.20	**1221.86**	**1276.36**	**1183.42**	**1370.92**
Total porosity (%)	51.54	53.68	52.82	51.84	**54.48**	**47.47**
Field capacity (%)	31.68	31.50	30.45	28.46	**31.36**	**33.72**
Maximum capillary water capacity (%)	36.94	37.89	**35.34**	**38.52**	36.36	37.89
Minimum air capacity (%)	14.60	15.79	**17.49**	**13.32**	**18.12**	**9.59**

Note: Values shown for individual properties are averaged from all of the samplings taken from a research plot. Statistically significant differences within the years are highlighted in red colour.

4. CONCLUSION

Main aim of the field experiments was to observe the impact of the digestate application on the physical properties of the soil. Former research did not confirmed whether positive or negative influence of this treatment. Obtained results show mainly positive trend of soil properties changes within depth of 0.05 m. Inconsistent influence of soil properties changes was observed in depth of 0.15 m.

Results also confirmed the fact, that the mineral fertilizers application has got negative effect on soil properties changes. This type of fertilizer is intended only for plant nutrition. It is necessary to apply the mineral fertilizers with additional fertilizers or enhancing substances for maintaining of the physical condition in soil environment.

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