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# The impact of diverse level of manure application on the chemical properties of the soil
(Research note)

*Witold Kazberuk, Beata Rutkowska, Wiesław Szulc*

Warsaw University of Life Sciences
Independent Department of Agricultural and Environment Chemistry
ul. Nowoursynowska 159, 02-776 Warsaw, POLAND

**Abstract.** The aim of this study was to determine the effect of various methods of introducing manure in to the soil on the chemical properties of the soil. The field experiment was carried out in the Podlasie voivodship on a sandy soil. Cattle manure was applied in a dose of 30 Mg ha$^{-1}$ and mixed with the soil using a disc harrow or plowed into the depth of 10 and 20 cm. In soil samples, the content of available forms of phosphorus, potassium, magnesium, copper, sulfur, boron, manganese, zinc, iron and the soil reaction was determined. The results confirmed the influence of depth of manure application on soil properties. As the cultivation depth increased, the content of phosphorus and organic carbon in soil increased, C/N ratio expanded, but the content of magnesium and potassium in soil decreased. No effect of the cultivation depth on the soil pH value and the content of nitrogen, boron, zinc and sulfur was found. The results of the study indicate a different rate of manure changes in soil and the related need to develop fertilizer equivalents depending on the manure application method.

**Keywords:** manure, soil, tillage, macroelements, microeleemnts

## INTRODUCTION

Organic matter in the soil is a key indicator of soil quality and plays an important role in shaping the chemical, physical and biological properties of the soil. It is not only a source of soil carbon, but also of macro- and micro-nutrients necessary for plants (Lal, 2013; Murphy, 2015). The decrease of organic matter content in arable soils is observed all over the world and is one of the main causes of their degradation (Loveland, Webb, 2003). The drop in the organic carbon content in soils is caused, among others, by the use of intensive agrotechnology, which has currently led to reducing the world's resources of soil organic matter by 25–75% compared to the original resources (Lal, 2013). At the same time, the introduction of simplified methods of farming is becoming increasingly common, the main goal of which is, among other things, to protect the resources of organic carbon in soil. The area of no-till farming is increasing all over the world. According to Holland (2004), the method of soil cultivation influences the level of soil protection. Eliminating the necessity of using a plough contributes to an increase in the content of organic carbon in the soil (Lenart, Perzanowska, 2013). However, other authors point out that simplifications in methods of soil cultivation cause a reduction in the yield of arable crops (Weber, Podolska, 2008). One can also come across research results not confirming the effect of simplified farming methods on the yield and physical properties of the soil (Piskier, 2006).

The use of natural and organic fertilizers is a common strategy for increasing the resources of soil organic matter, improving soil quality and increasing plant yield (Diacono, Montemurro, 2010; Abdulkareem et al., 2018; Zhao et al., 2019).

The use of fermented manure allows for a slow release of nutrients into the soil. This, in turn, contributes to a harvest increase through an even distribution of nutrients. It also contributes to the improvement of the natural environment (Singh et al., 2014). However, due to localized animal production, there are limitations to the large-scale application of this fertilizer (Timsina, 2018). Therefore, it is often replaced with natural fertilizers, e.g., compost (Singh et al., 2019). In the literature on the subject, the influence of organic and natural fertilizers on soil properties is well recognized, however, the research on the impact of the depth of manure application on the chemical properties of soils is lacking (Rayne, Aula, 2020).

The aim of the research was a preliminary identification of the impact of using manure on selected chemical properties of soil depending on the way of its application.

Corresponding author:
Witold Kazberuk
e-mail: kazberuk.witold@wp.pl
phone +48 85 738 83 90

## MATERIAL AND METHODS

The study lasting one year was carried out on a farm in the village of Juszkowy Gród, Michałowo commune, Białystok county, Podlaskie voivodeship in 2013. For this purpose, an experiment was launched in an arrangement of parallel strips, on soil containing 90% sand, 7% silt and 3% loam. The experiment covering an area of 1 ha included the following variants:

– control treatment (without manure) cultivated with a disc harrow to a depth of 5 cm,
– manure mixed with the soil using a disc harrow to a depth of 5 cm,
– manure ploughed to a depth of 10 cm,
– manure ploughed to a depth of 20 cm.

The experiment was performed in three replications. A dose of 30 Mg $ha^{-1}$ of cattle manure was applied in the spring.

The plant grown in the course of the experiment was a maize Dumka cultivar, harvested for silage. Winter rye was the forecrop. After the rye harvest, tillage was performed to the depth of 30 cm in the autumn. No mineral fertilization or chemical protection was used at any of the treatments.

### Chemical analysis of the soil

The soil samples for tests were collected before the application of manure and after harvesting maize from the depth of 0-20 cm. Fifteen sub-samples were collected from each plot and mixed forming a composite sample. The collected soil was dried at room temperature and passed through a sieve with 2 mm mesh (PN-ISO 11464: 1999). Chemical analyses of soil samples included determination of the content/value of:

– available phosphorus and potassium using the Egner-Riehm method (PN-R-04023: 1996; PN-R-04022: 1996),
– total nitrogen content using the Kjeldahl method (PN-ISO 11261: 2002),
– pH in KCl solution with a concentration of 1 mol $dm^{-3}$ – using the potentiometric method (PN-ISO 10390: 1997)
– organic carbon content using the Tiurin method (PN-ISO 14235: 2003),
– available magnesium using the Schachtschabel method (PN-R-04020: 1994),
– available sulphur with the nephelometric method (using barium chloride) after extraction with ammonium acetate and acetic acid,
– boron by colorimetric method with 1-1 diantrimid after extraction using HCl with a concentration of 1 mol $dm^{-3}$ (PN-R-04018: 1993),
– manganese, copper, zinc, iron after extraction in HCl with a concentration of 1 mol $dm^{-3}$ – by atomic absorption spectrometry (ASA) (Ostrowska et al., 1991).

Table 1. Soil properties before establishing the experiment.

| Parameter | Unit | Average value ±standard deviation |
|---|---|---|
| pH | - | 4.25 ±0.17 |
| Nog. | g·$kg^{-1}$ DM | 0.11 ±0.01 |
| Corg. | | 1.54 ±0.20 |
| C/N | - | 14.62 ±0.21 |
| P | mg·$kg^{-1}$ DM | 62.68 ±12.53 |
| K | | 69.55 ±7.01 |
| Mg | | 13.33 ±2.98 |
| S-$SO_4$ | | 0.65 ±0.14 |
| B | | 0.50 ±0.00 |
| Mn | | 207.40 ±36.73 |
| Cu | | 1.71 ±0.33 |
| Zn | | 5.56 ±0.77 |
| Fe | | 1329.25 ±156.81 |

### Chemical analysis of the manure

The manure sample was collected in accordance with the Polish Standard (PN-R-04006: 2000). The following content was determined in the manure:

– dry weight with the oven-dry method,
– total nitrogen with the Kjeldahl method,
– phosphorus with the vanadate-molybdate method,
– potassium, calcium and magnesium with the method of atomic absorption spectrometry after mineralization of the sample in a mixture of $HNO_3$ and $HClO_4$ acids in proportion 4:1.

Table 2. Nutrient content in the manure.

| N | P | K | Mg | Ca | Dry matter (DM) [%] |
|---|---|---|---|---|---|
| g $kg^{-1}$ DM | | | | | |
| 5.30 | 0.90 | 5.90 | 1.40 | 2.90 | 20.20 |

### Statistical analysis

Statistical analysis was performed using one-way analysis of variance (ANOVA) and comparisons were made using Fisher procedure with significance level = 0.05, using Statistica ver. 13.3 software.

## RESULTS

The conducted research demonstrated a significant influence of the varied depth of manure application on some chemical properties of the soil. It was found that the method of manure application did not significantly affect the soil reaction, which was very acidic in all of the tested sites (Table 3). In comparison to the control site, tillage cultivation caused an increase while cultivation with a disc har-

Table 3. Effect of diverse level of manure application on content pH, nitrogen, organic carbon, C/N rate in soil.

| Treatment | pH | N total | C org. total | C/N ratio |
|---|---|---|---|---|
| | | $g \cdot kg^{-1}$ DM | | |
| Control | 4.3 a | 1.20 a | 1.44 a | 12.00 a |
| Disc harrow | 4.4 a | 1.10 a | 1.37 a | 12.45 a |
| 10 cm plowing | 4.2 a | 1.11 a | 1.53 b | 13.91 b |
| 20 cm plowing | 4.2 a | 1.10 a | 1.54 b | 14.00 b |

a, b – values that do not differ significantly at the significance level α=0.05 in individual columns are marked with the same letters

Table 4. Effect of manure application on content of available forms of phosphorus, potassium, magnesium and $S\text{-}SO_4$ in soil.

| Treatment | P | K | Mg | $S\text{-}SO_4$ |
|---|---|---|---|---|
| | $mg \cdot kg^{-1}$ DM | | | |
| Control | 57.67a | 37.35a | 9.62a | 0.50a |
| Disc harrow | 55.36a | 62.31b | 18.17c | 0.50a |
| 10 cm plowing | 66.32b | 57.35b | 13.93b | 0.51a |
| 20 cm plowing | 64.56b | 39.87a | 10.92a | 0.50a |

a, b – values that do not differ significantly at the significance level α=0.05 in individual columns are marked with the same letters

Table 5. Effect of manure application on content of boron, manganese, cooper and iron in soil.

| Treatment | B | Mn | Cu | Zn | Fe |
|---|---|---|---|---|---|
| | $mg \cdot kg^{-1}$ DM | | | | |
| Control | 0.51 a | 165.61 a | 1.50 a | 5.17 a | 1236 a |
| Disc harrow | 0.52 a | 163.01 a | 1.57 a | 5.24 a | 1233 a |
| 10 cm plowing | 0.51 a | 183.22 b | 1.84 b | 5.64 a | 1359 b |
| 20 cm plowing | 0.50 a | 175.23 ab | 1.64 ab | 5.55 a | 1299 ab |

a, b – values that do not differ significantly at the significance level α=0.05 in individual columns are marked with the same letters

row caused a decrease in the content of soil organic carbon. No impact of the varying depth of manure deposition on the soil nitrogen content was observed for any of the fertilising combinations. Tillage cultivation resulted in the extension of the C/N ratio compared to the simplified cultivation with the use of a disc harrow and the control site (Table 3).

The manure used in the experiment increased the content of the available forms of phosphorus, potassium and magnesium in the soil (Table 4) compared to the control site. Regardless of the depth of manure application, the $S\text{-}SO_4$ content remained at the same level in all analysed combinations. The use of the tillage system, compared to the simplified cultivation, caused a significant increase in the absorbable phosphorus content in comparison to the control site. In turn, with the increase in the depth of the application, the content of the absorbable forms of K and Mg in the soil decreased, however, it was higher than in the control site.

The depth of manure application did not affect the boron or zinc content in the soil, whereas the content of manganese, copper and iron were the highest after ploughing to a depth of 10 cm. It was always significantly higher than after the application of a disc harrow (Table 5.).

## DISCUSSION

Manure is a valuable source of nitrogen for plants, but it also poses a threat to the environment (Zhang et al., 2017). The greatest losses of nitrogen occur during the first day after application, therefore it should be mixed with the soil as soon as possible (Marcinkowski, Pietrzak, 2006). Since disc harrows are characterised by high efficiency at work, they can be used to quickly mix natural fertilizers with the soil in order to reduce the volatilization of $NH_3$ (Huijsmans et al., 2003; Upadhyay, Raheman, 2018). Some experiment results demonstrate that ploughing leads to a reduction in nitrogen content in the topsoil (0-20 cm) compared to direct sowing (Lenart, Sławiński, 2010). In the experiment, the method of manure application was not found to affect the nitrogen content in the soil, while as a result of ploughing the C/N ratio was enlarged, which stemmed from an increase in the soil organic carbon content. The research conducted by Ren et al. (2014) did not prove a significant increase in the amount of organic matter in the soil fertilized with manure having a low C/N ratio, and an appropriately high organic carbon content in manure may limit nitrogen leaching. According to a common opinion, simplifications in soil cultivation may lead to an increase in the soil humus content (Haddaway et. al. 2017). However, intensive cultivation leads to a reduction of organic carbon in the soil (Cudzik et al., 2011; Pecio, Niedźwiecki, 2007). De Mastro et al. (2020) claimed that the farming system had no effect on the soil organic carbon content. According to Alcántra et al. (2016) deep ploughing increases the reserves of organic matter in agricultural soil. As demonstrated in the authors' own research, soil organic carbon content was higher in the tillage cultivation system than in the simplified system. Surface application of manure increases $CO_2$ emissions to the atmosphere, and its deeper application slows down the rate of mineralization (Altikat et al., 2018). Since, according to Jurczuk (2012), mineralization has a large impact on the rate of organic matter changes, it is important to determine the appropriate depth of manure application. In the future, it will become even more important in connection with the global warming of the climate and the increased rate of organic matter mineralization by microorganisms (Crowther et al., 2016; Caitlin et al., 2017).

Literature is ambiguous in defining the effect of manure on soil acidity. Manure fertilization may cause an increase in soil pH due to the presence of bicarbonates and organic acids in manure (Whalen et al., 2000). Other authors believe that manure can induce a decrease in soil pH. This effect is explained by the acidifying effect of nitrification. During the transformation of the ion $NH_4^+$ to $NO_3^-$, hydrogen ions that lower soil pH are released (O'Hallorans et al., 1993). The change in pH value after manure application may also be influenced by the type of soil where fertilizer experiments are established. In acidic soil after manure application, Ano and Ubochi (2007) found an increase while in calcareous soil, Yan et al. (2018) found a decrease in pH. In our study, we did not observe any effect of tillage system on soil pH, even though soils from plow tillage usually tend to have higher pH (Blecharczyk et al., 2007). Also, Ozlu et al. (2018) observed that perennial application of manure maintains soil pH at a similar level as opposed to mineral fertilization, which lowers it.

Manure application through its positive effect on physical properties increases nutrient availability to plants (Diacono, Montemurro, 2010). Deeper mixing of manure reduces soil bulk density and increases soil water content (Shaker et al., 2017). Reports in the literature regarding the effect of manure fertilization on available phosphorus content in the soil are inconclusive. According to Rutkowska et al. (2002), manure fertilization increases the concentration of phosphorus in the soil solution, while according to other authors manure does not significantly increase the available phosphorus in the soil (Stępień et al., 2002). In our study, we found a simultaneous increase in available phosphorus and soil organic carbon with increasing manure application depth. Organic fertilization increases P content in the soil solution, due to increase in microbial biomass and phosphatase activity (Meena, Biswas, 2011). Plough tillage compared to reduced tillage has been shown to decrease the content of available forms of potassium and magnesium in soil probably released from cattle manure. Tillage simplifications contribute to the concentration of nutrients in the topsoil. This may have a negative impact on the environment, as nutrients can leach into surface waters during heavy rainfall. As a result, the macro- and micronutrient contents of the soil are reduced (Włodek et al., 2009).

Sulfur release from manure to soil is higher under aerobic conditions than under anaerobic conditions (Islam et al., 2021). There was no increase in sulfur content under manure fertilization because the experiment was set up on a light, sandy soil from which sulfate ions are very easily leached (Wielebski, Wójtowicz, 2000). The type of manure used in the experiment may also have influenced the outcome of the study. Cattle manure has lower sulfur content than swine manure and manure from broilers and layers (Kuziemska et al., 2017).

A long-term study found no effect of cattle manure on soil boron content (Benke et al., 2008). Also in our study, the application of manure, irrespective of the depth of its application, did not affect the boron content. This could have been influenced by setting up the experiment on sandy soil. The content of available forms of this element is strongly dependent on soil physical and chemical properties. From light sandy soils, ions $BO_3^-$ are easily leached deep into the soil profile (Brdar-Jokanović, 2020). The vast majority of soils in Poland are deficient in boron (Lipiński, 2019). As indicated by the studies of other authors, the content of micronutrients in soil increases under the influence of manure application, but this relationship is not always observed in the case of zinc (Trawczyński, 2015; Filipek-Mazur, Tabak, 2016; Dhaliwal et al., 2019). According to Chaudhary and Narwal (2005), the content of micronutrients increases under manure fertilization and their increase in content is higher in the surface layer of the soil. In the study conducted, the plough system had a beneficial effect on the content of micronutrients in the soil. Also, Kwiatkowski et al. (2020) came to similar conclusions.

## CONCLUSIONS

1. Differing rates of manure decomposition associated with different depth of placement in the soil can affect the interpretation of results. Conducted research should be continued in long-term experiments to better recognize the problem.
2. The application of farmyard manure increased the content of available phosphorus, potassium and magnesium and slightly increased the content of iron, manganese and copper, while it did not affect the pH value or the content of nitrogen, sulphur, zinc and boron in the soil.
3. Plough tillage caused an increase in soil organic carbon content and a widening of the C/N ratio in comparison with tillage with a disc harrow.

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| Author | ORCID |
| --- | --- |
| Witold Kazberuk | 0000-0002-5907-0746 |
| Beata Rutkowska | 0000-0003-4563-0156 |
| Wiesław Szulc | 0000-0001-8505-0514 |

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