EFFECT OF ORGANIC FERTILIZERS, BIOCHAR AND OTHER CONDITIONERS ON MODAL LUVISOL

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Abstract
The paper assesses changes in soil physical properties, i.e. bulk density, cone index, and implement draft, after the application of organic fertilisers, i.e. manure and compost, and manure and soil conditioners, Z'fix, NeoSol, and biochar. Biochar and traditional manure demonstrated favourable influence on soil bulk density, cone index and tillage implement draft. The manure treated by Z'fix demonstrated higher bulk density and draft, though it reached highest silage maize yields. Compost and NeoSol exhibited increased bulk density, but reduced draft on the opposite.

Key words: *cattle manure; NeoSol; Z'fix; compost; cone index; bulk density.*

INTRODUCTION

Over the past few decades, the demands on agricultural production have been growing rapidly. The pressure increases mostly due to the climate change, changes in crop rotation, decreasing area of the arable land, reduction of livestock farming. According to the Czech Statistical Office (*Sálusová, 2018*), cattle production has declined by more than half in the past 30 years. Intensification of agriculture has caused the lack of quality soil organic matter (SOM) that is on the European scale one of the staple causes of decreasing soil productivity (*Stolte et al., 2016*). This phenomenon causes a reduction in the diversity and fertility of arable land and it is associated with other soil degradation issues *(Gardi, Jeffery & Saltelli, 2013*). Besides soil fertility, SOM is associated with soil structure and other properties (*Walsh & McDonnell, 2012*). It is also known that organic matter naturally reduces soil compaction (*Chakraborty & Mistri, 2017*), which is a very serious issue. Only in Europe, even about 33 million hectares are threatened by soil compaction (*Alaoui & Diserens, 2018*). Compaction strongly affects root growth, since the conditions of water and gas transport in the soil are not optimal (*Stolte et al., 2016*). Of course, this situation often results in reduced crop yield. Soil compaction can be easily measured by cone penetrometer. Bulk density is another frequently used option for measurement (*Odey, 2018*).
Organic materials added to soil profile have a beneficial effect on reclaiming and improving the physical quality of degraded soil (*Are et al., 2017*). The application of manure or compost contributes to the increasing content of SOM (*Panagos et al., 2015*). The use of manure improves the physical, biological and chemical properties of soil (*Ludwig et al., 2007*). The manure or directly soil can be treated with so called activators or conditioners that still are not thoroughly explored. However, current studies suggest that activators improve soil properties and plant growth conditions (*Borowiak et al., 2016*). Thus when using activators, there are not only economic benefits, e.g. a reduction of the energy intensity of soil tillage (*Šařec & Žemličková, 2016*), but also a contribution to the environmental sustainability of agriculture (*Šařec & Novák, 2017*).
In recent years, biochar has gained the considerable attention. This carbon-based product of pyrolysis is made mostly of waste plant (*Mukherjee & Lal, 2013*). It is a highly porous material that affects water retention capacity (*Rasa et al., 2018*), and therefore improves soil properties. However, effect of biochar applied into the soil strongly depends on input material for the pyrolysis process and also on the pyrolysis temperature (*Lei & Zhang, 2013*).
The authors of these studies generally agree that activators and biochar should be tested on different soil types and conditions. Therefore, this study aims to determine the effect of activators, compost, and biochar for soil physical properties after one year of application.

MATERIALS AND METHODS

In 2017, experimental variants were established near the town of Větřkovice in the Moravian-Silesian Region of the Czech Republic (N 49°47.232', E 17°50.028', 501 m a. s. l.). In 2018, silage maize (LG 30.248, FAO 250) was grown on the plot, while it was sown on the 26th April 2018 and harvested on

the 30th August 2018. Soil type of the filed was *Modal Luvisol*, and soil texture defined as loam soil. Soil properties are presented more in detail in Tab. 1. The experimental area was divided into eight smaller plots of 170 x 30 m for each variant. Fertilization management of individual variants is shown in Tab. 2. NeoSol (PRP Technologies, France) was used as the activator of biological transformation of soil organic matter. Biochar was used in the same way. Z'fix (PRP Technologies, France) was used as the activator of manure. It was applied to the bedding of cattle deep litter housing at a recommended weekly dose. These conditioners cannot be considered as fertilizers due to their low content of active components. Dosage of cattle manure was 50 $t \cdot ha^{-1}$ (2017), of NeoSol 150 $kg \cdot ha^{-1}$ (2017, 2018), of biochar 15 $t \cdot ha^{-1}$ (2017), of compost 50 $t \cdot ha^{-1}$ (2017), and of additional NPK according to crop common practice (2017, 2018). All the other field operations and material applied did not differ among variants.

Tab. 1 Soil properties of the field prior to the experiment in 2017

	Soil depth (m)	
	0.00–0.30	0.30–0.60
Soil Aggregate Stability - SAS (%)	62.9	54.7
pH/KCl	4.4	4.5
Humus content (%)	2.8	2.3
Humic Acid / Fulvic Acid ratio	1	2.1
Microbial biomass carbon - Cmic ($\mu g \cdot g^{-1}$)	3.28	2.23
C / N ratio	9.55	5.50

The registered penetrometer PEN 70 (CULS Prague) was used to determine the cone index, while ten measurements were done for each variant. Soil moisture was measured by Theta Probe (Delta-T Devices Ltd, UK). To obtain undisturbed soil samples from the depth of 0.05 to 0.10 m and subsequently soil bulk density, Kopecky cylinders with a volume of 100 cm^3 were utilized. The implement draft was measured by dynamometer with strain gauge S-38/200kN (Lukas, the Czech Republic). This device was placed between two tractors. The working tractor was John Deere 6150R (rated engine power 111.9 kW) in 2017, and Fendt 826 Vario (rated engine power 190.9 kW) in 2018. In both years, six furrow plough PHX 6-30 was used as an implement. On each variant, there were several crossings of the measuring set. First, overall draft of the pulled tractor and working implement were measured. The plough worked at a constant speed, and the tillage depth was checked after each pass. After that, the same measurements were carried out with implement not working in order to obtain only machinery rolling resistances and forces induced by potential field gradient. The system NI CompactRIO (National Instruments Corporation, USA) was used for data collection with sampling frequency of 0.1 s. Acquired data were assigned to individual variants using Trimble Business Center 2.70 (Trimble, USA). Measuring dates were 10th September 2017 and 10th October 2018. Data was processed by MS Excel (Microsoft Corp., USA) and Statistica 12 (Statsoft Inc., USA).

Tab. 2 Fertilization of individual variants and maize silage yields in 2018

Variant	Fertilization	Yield ($t \cdot ha^{-1}$)
N-1	Cattle manure with Z'Fix + NPK	44.2
N-2	Cattle manure with Z'Fix + NeoSol + NPK	43.2
N-3	Cattle manure + NPK	41.6
N-4	Cattle manure + NeoSol + NPK	42.4
N-5	NeoSol + NPK	40.2
N-6	NPK - Control	38.2
N-7	Compost + NPK	41.8
N-8	Biochar + NPK	42.8

RESULTS AND DISCUSSION

The variants attained higher silage maize yield than the control (Tab. 2). The variants with manure treated by Z'fix (N-1 and N-2) attained the highest yields, most probably due to its high nitrogen content (*Šařec, Látal & Novák, 2017*). High yield was reached also by the biochar variant (N-8), which is in accordance with the findings of *Are et al.* (2017). NeoSol (N-5) demonstrated favourable effect as well, which confirms the work of *Borowiak et al.* (2016).

All the measured values were analyzed relative to the control Variant N-6 rather than analyzing the absolute values. In this way, differing weather conditions of individual years were allowed for. Bulk density values related to the average value of respective control Variant N-6 that are displayed in Fig. 1 did not differ significantly according to the *Analysis of Variance* with regard to both factors separately, i.e. to the variant and to the measurement date, nor with regard to their combination. Nevertheless, there is a visible bulk density increase after the application of compost (N-7) and of manure treated with Z'fix (N-1 and N-2). The manure treated in such a way contains less straw that is in addition more decomposed and is therefore denser. The condition of the compost was the same case. On the other hand, bulk density slightly decreased after the biochar application (N-8). *Are et al.* (2017), *Mukherjee & Lal* (2013) and *Lei & Zhang* (2013) described also bulk density reduction after biochar application. On the contrary, *Are et al.* (2017) found bulk density reduction also after veticompost application.

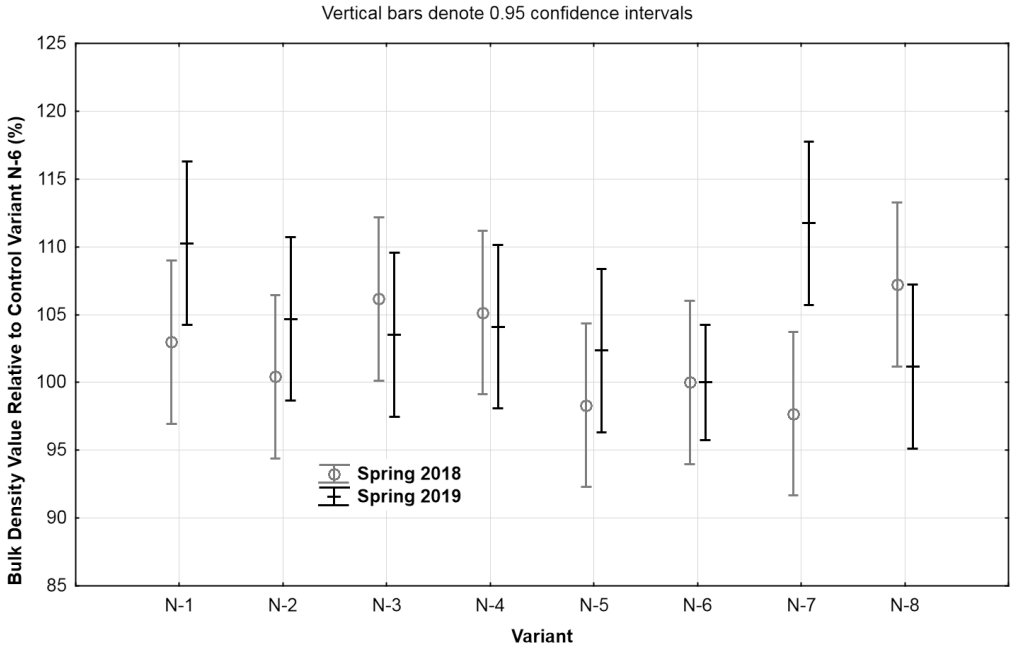

Fig. 1 Graph comparing relative differences of bulk density values from the depth of 0.05 to 0.10 m in spring 2018 and 2019 for individual variants (Variant N-6 as 100%)

Since cone index values depend strongly on soil moisture, they were measured also in spring, i.e. on 22nd April 2018 and on 23rd April 2019, when soil moisture was more likely to be homogenous. Cone index values were again analyzed relative to the control Variant N-6, as is presented in Fig. 2. The *Analysis of Variance* did not prove statistically significant differences for the combination of all the factors in question, i.e. measurement date, variant and depth. Considered separately though, factors' average cone index differences were statistically significant. For the variants with manure application, i.e. N-1 to N-4, cone index values decreased at shallow depths to up to 20 cm. This corresponds with the findings of *Celik et al.* (2010) and *Šařec & Žemličková* (2016). Deeper on the other hand, the values generally slightly increased for the mentioned variants. Since the manure application had taken place before the first measurement was carried out, the increased cone index values below tilled profile cannot be assigned to the additional pass of a manure spreader. The variants with NeoSol and compost used, i.e. N-5 and N-7, demonstrated no evident pattern except for the increased cone index average at the depth of 24 cm. The application of biochar (N-8) decreased cone index values at shallower depths without having increased them deeper.

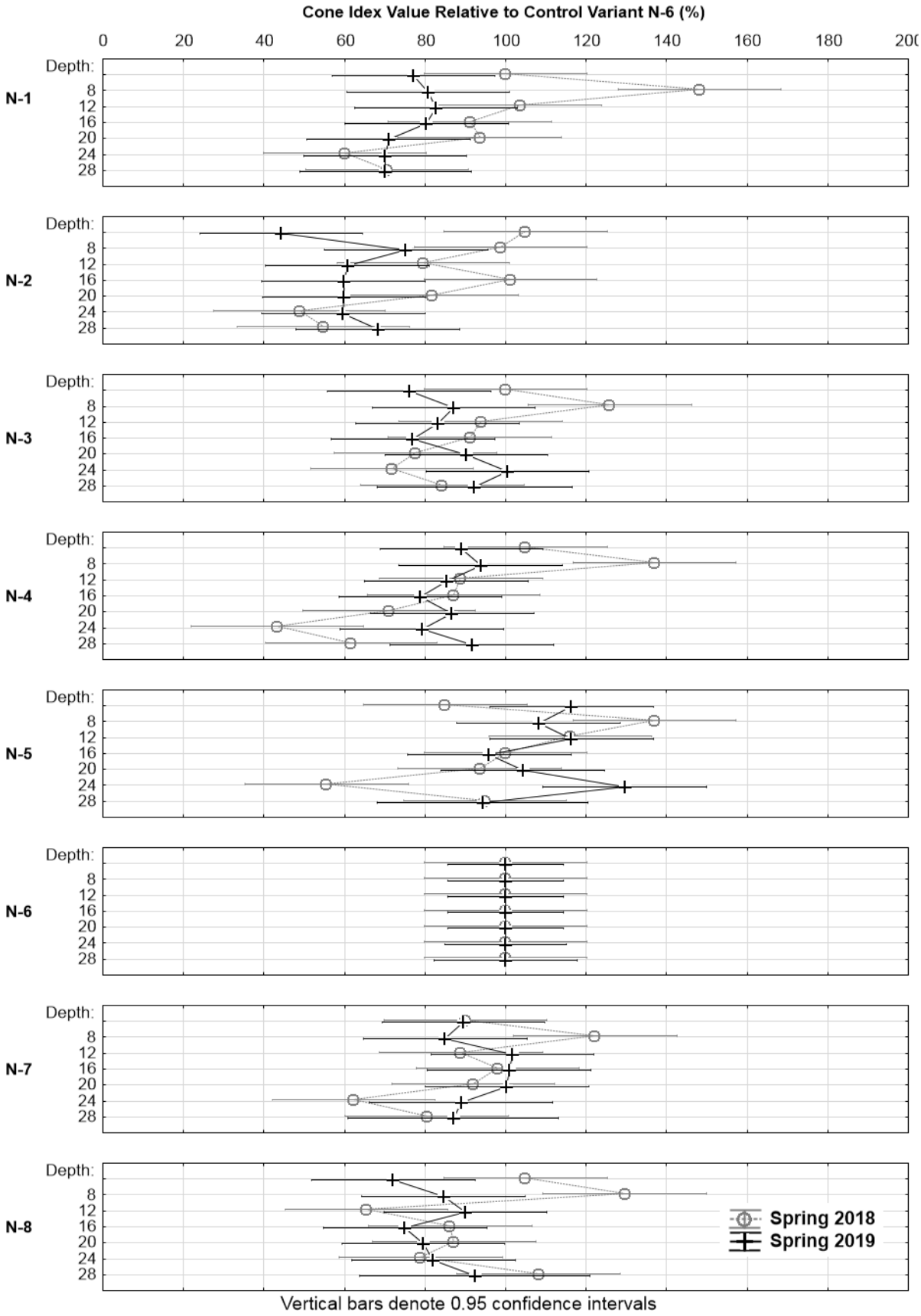

Fig. 2 Graphs comparing relative differences of soil cone index values in spring 2018 and 2019 for individual variants (Variant N-6 as 100%)

Implement draft was measured in autumn, i.e. on 10th October 2017 prior to the application of manure and other substances, and on 10th September 2018. Tillage depth attained in average 0.210 m in 2017 and 0.206 m in 2018. Soil moisture differed statistically significantly ($p = 4.89504643598622 \cdot 10^{-23}$) having been 27.6% vol. in 2017 and 13.1% vol. in 2018. The decreased moisture caused an increase in overall unit implement draft across all variants, i.e. from 63960.88 $N \cdot m^{-2}$ in 2017 to 65929.05 $N \cdot m^{-2}$ in 2018. The difference was highly significant ($p = 0.000845$), although the implement used was the same for both years. Draft values were therefore assessed relative to the control Variant N-6, as is shown in Fig. 3. The *Analysis of Variance* confirmed statistically significant differences with respect to the variants, but measurement date and the combination of both factors proved insignificant. Generally, average implement draft values decreased relative to the control, with the exception of the manure treated by Z'fix (N-1 and N-2), which was denser than the untreated one as mentioned above.

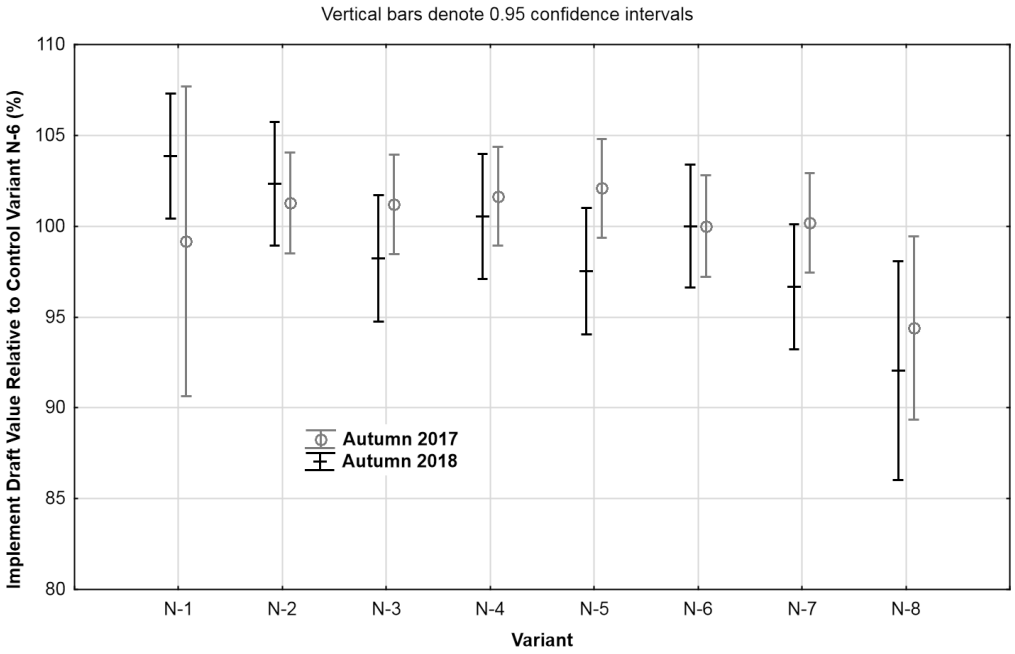

Fig. 3 Graph comparing relative differences of implement unit draft values in autumn 2017 and 2018 for individual variants (Variant N-6 as 100%)

CONCLUSIONS

The experiment focused on the effect of organic fertilizers and conditioners on soil physical properties was conducted. Biochar demonstrated favourable influence on soil bulk density, cone index and tillage implement draft. The same can be to some extent stated on the effect of traditional manure. The manure treated by Z'fix demonstrated higher bulk density and draft, though it reached highest silage maize yields. Compost and NeoSol exhibited increased bulk density, but reduced draft on the opposite. It is necessary to carry on with the research for a prolonged period, so that changes can manifest themselves.

ACKNOWLEDGMENT

This study was supported by the Technology Agency of the Czech Republic in the project no. TH02030169, and by the Faculty of Engineering, Czech University of Life Sciences Prague under internal grant IGA 2018: 31180/1312/3116.

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