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Changes in soil properties due to the application of activators in conditions of very heavy soils

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Abstract

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This paper deals with verification of the effect of fermented manure (with and without Z'fix activators) and soil activators (PRP Sol) on a soil properties change. Their application should lead to a change in physical, physical-chemical and biological properties of soil, along with ecological material fixation, improved water retention and infiltration, reduction of soil susceptibility to water erosion and decreased soil tillage energy requirements. Field trial was established in Slovec in Central Bohemia in the year 2014. The experiment was divided into several variants and was designed as multiannual. Z›fix activator was used as a biological transformation activator of manure. PRP Sol was used as a soil activator. In order to verify the effect, soil infiltration, cone index, bulk density and draft of tillage implement were measured. Measurements have shown a beneficial effect of the activators with regard to the decomposition of organic matter. Consequently, changes in soil properties and a reduction of draft at tillage operations developed. Finally, the effect should evolve gradually with a prolonged activator treatment.

Keywords: bio-activator; energy requirement; soil properties; transformation of organic matter

The main quality problems of usable agricultural land in the Czech Republic are threats of water erosion, technogenic compaction and recently also loss of organic carbon in the soil (Kroulík et al. 2009). The organic matter may be applied in various forms. Manure or compost is commonly used, but it is possible to use also other forms (Wang et al. 2015). Especially on heavy and decarburized soils, there is a problem with the decomposition of applied organic matter (Fontaine et al. 2003). It remains in the soil without decomposition and does not affect positively other properties of the soil, e.g. the physical and chemical ones (Steinbeiss, Gleixner 2005). On numerous locations, negative effects are underestimated and their interaction causes irreversible damage to soil fertility (Wilhelm et al. 2007). As a result, there is also a decrease in biomass yield of crops and grasslands (Shahzad et al. 2012). Of course, the problem of soil organic carbon loss may be stopped by applying sufficient quantities of organic matter (Johnson et al. 2006). Manure (or other forms of organic matter) can be supplemented by activators of biological transformation (Šařec, Novák 2016). The use of activators for the decomposition of organic matter was also recommended by Parr et al. (1986). In their case, activators were applied within the composting. Barzegar et al. (2002) confirmed a positive impact of the compost treatment of as well, i.e. increased wheat yields

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and improved soil physical properties. The aim of this work was to verify the effect of manure and activator application on physical properties of soil and on the value of tillage implement draft.

MATERIAL AND METHODS

A long-term field experiment was established in Slovec̆ in 2014 to verify the technology of transformation of organic matter using activators of biological transformation in order to improve and stabilize the soil environment. Mainly heavy black soils are typical in this area. The content of particles < 0.002 mm was 48% (depth of 0.00 to 0.3 m), and according to the USDA soil structure, it was a clay. A trial plot was divided into individual 0.6 ha variants (45 × 150 m), where the application of fertilizers was conducted in accordance with the plan. The field was cultivated using reduced-tillage technology. The following fertilizers were applied: manure (cattle), NPK 15-15-15 (Lovofert; Lovochemie, Czech Republic). PRP Sol (PRP Technologies, France) was used as an activator of soil. PRP Sol is a matrix of calcium carbonate with magnesium added and it was applied directly onto soil surface. Z'fix (PRP Technologies) was used as an activator of organic matter. Z'fix is a granular mixture of mineral salts and carbonates and it was applied directly into the straw bedding of the cow housing. A weekly dose of Z'fix was set at 0.7 kg per one livestock unit (1 LU = 500 kg live weight) with respect to the body weight of cows. Removal of fresh dung was done in 6–8 week intervals according to the condition of bedding. Variants differed with fertilizer, activators and with their combination applied (Table 1). Dosing was as follows: manure 50 t/ha (years 2014 and 2016), NPK 200 kg/ha (each production year) and PRP Sol 200 kg/ha (each production year). The activators should not be understood as a fertilizer. Their application is meant to improve the conditions for the transformation of organic matter.

Table 1. Fertilization of individual variants

	Variants of fertilization
1	Manure + Z'fix + NPK
2	Manure + Z'fix + PRP Sol + NPK
3	Manure + NPK
4	Control: only NPK

In the 2015 season, maize was grown in the trial field. In the next season, spring barley followed. Crop rotation was the same for all the variants. In May 2015, after germination of maize, soil samples were taken (after BBCH 10). There were three basic methods of measurement. Firstly, soil infiltration capacities were measured using a circular infiltrometer (0.15 m diameter). The method applied was "simplified falling-head". According to this method, infiltration is converted to the saturated hydraulic conductivity. A known amount of water was poured into the infiltrometer (in this case 0.5 dm^3), and infiltration time and soil moisture of the surface layer were measured. Ten repetitions were carried out within each treatment. Secondly, cone index was measured by a registration penetrometer PN-10, which was developed at the Czech Agricultural University (CULS) Prague. Penetrometer was equipped with a tip according to the ASABE standards with a cone angle of 30°, and its area was 100 mm^2. Cone index measurements were carried out again in ten repetitions. Thirdly, soil physical properties were evaluated using the Kopecky cylinders with a volume of 100 cm^3 and then analysed in the CULS laboratories. Volumetric soil moisture was measured by a Theta Probe (Delta Devices, United Kingdom). Data were processed using MS Excel (Microsoft Corp., USA) and Statistica 12 (Statsoft Inc., USA). Furthermore, after harvest tillage implement draft was measured using the draught dynamometer with a strain gauge load cell S-38/200 kN/ (LUKAS, Czech Republic) mounted between two tractors (Fig. 1).

The implements used were a chisel plough or a tine cultivator. Data was collected and stored using

Fig. 1. Measurements of the draft of a tine cultivator Köckerling Vario 480 in Slovec̆ in autumn 2015

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the logger NI CompactRIO (National Instruments Corporation, USA) with a sample rate set at 0.1 s. Several passes were done with a constant working speed and depth. Depth of the tillage was checked by a measurement for each pass. Furthermore, passes without tillage implement working were made in order to detect rolling resistance of machinery and possible impact of slope. This resistance was subtracted from the total resistance with respect to the direction of passing, and thus the draft of the machine was found. Trimble Business Center Software 2.70 (Trimble, USA) was used for sorting the measurement data to individual variants.

RESULTS AND DISCUSSION

Bulk density measurement results

Undisturbed soil samples were taken each year. The graph in Fig. 2 shows the bulk density attained during the three seasons. Favourable trend was observed in the 2015 season, which is well illustrated by the bar graph in Fig. 2. Measurement in 2016 did not confirm the trend, but it was probably affected by other factors. At the time, stubble of spring barley was in the field. An increased bulk density may have been caused by technogenic impacts by very dry August 2016, and vice versa moist conditions of the previous months. That would explain the increased values for all variants in 2016 compared to the previous season. Nevertheless, the changes in values of bulk density are relatively small. Values are also significantly influenced by soil environment. At the beginning, the variants with lower sequence number showed heavier and more compact soil and were thus disadvantaged. Generally, the beneficial effects of activators can be perceived in a decreasing variability of values that leads to a more uniform soil environment, which influences the conditions for plant growth and also environmental soil properties.

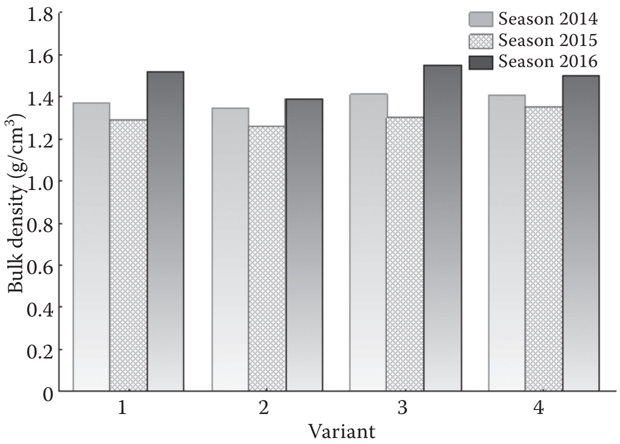

Fig. 2. Average bulk density values obtained from undisturbed soil samples in Sloveč

Cone index measurement results

Values of cone index suggest a beneficial effect of bio activators used together with manure. As shown in Fig. 3, especially Variant 4 (control) showed a negative trend compared to other variants with manure application. This situation was evident particularly in the measurement period of August 2015. In the 2016 season, major differences between the variants were

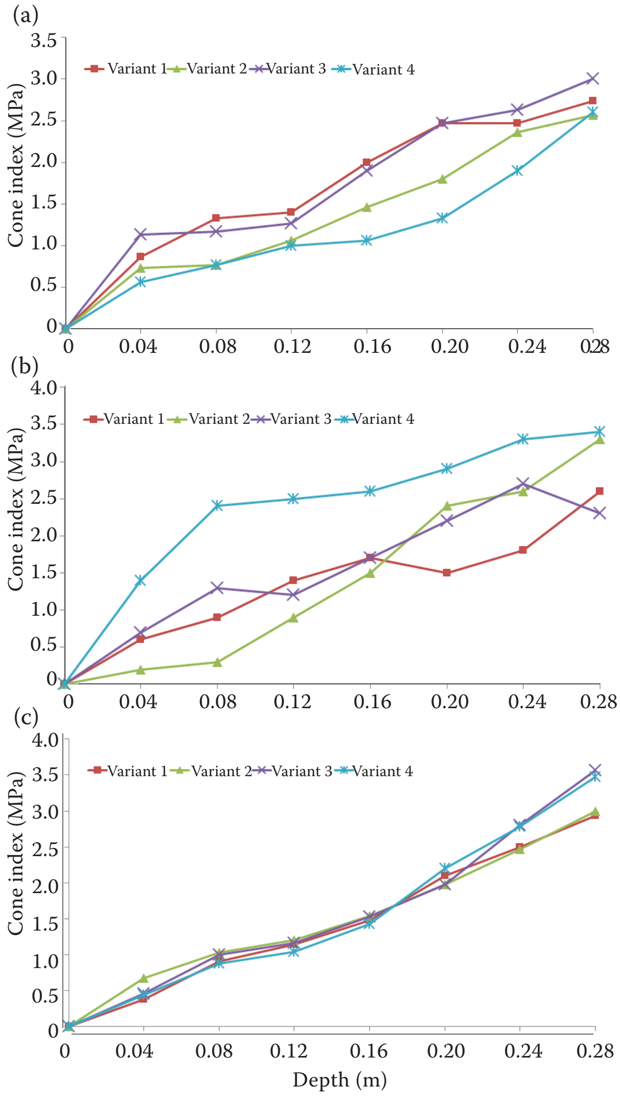

Fig. 3. Average cone index values of individual variants in Sloveč in the season 2014 (a), 2015 (b), and 2016 (c)

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not possible to observe. This result, however, confirmed the previous trend and indicated also the improved homogeneity of soil environment. Moreover, the trend was more evident in the shallower depths where the outcome of manure and activator application was more substantial due to properties of soil tillage and incorporation of organic matter. Even though cone index belongs to indirect indicators of soil state, the effect of activators and bio-mineralized organic matter was apparently favourable in terms of soil environment with all its consequences.

Water infiltration measurement results

Water infiltration into the soil is another indicator of the activators effect. It directly affects moisture conditions of soil or plant growth, but also environmental hazards (water erosion, surface runoff, etc.). From the viewpoint of infiltration, two seasons – 2015 and 2016 – were observed. Due to the measurement technique, graphs in Fig. 4 demonstrate saturated hydraulic conductivity that is however fully comparable to direct infiltration in this case. Both measurements were made shortly after germination of respective crops, i.e. maize in 2015 and spring barley in 2016. All measurements showed a relatively high variability, but the trend of measurements clearly show a positive impact of the application of manure and activators. In the 2015 season, measurements had an interesting outcome when Variant 3 had the largest ability of water retention. This may be plausibly explained by a smaller disintegration of pieces of manure that, in terms of micro-location measurements, significantly accelerated water infiltration into the soil. Infiltration was thus conducted by incorporated macro particles of non-mineralized organic matter. In terms of soil environment this phenomenon is however not favourable. The presence of macro particles of manure could be observed by a naked eye in Variant 3 during the measurements in the 2015 season. On the contrary, in Variant 2, where high levels of infiltration could be also discerned, a positive effect developed probably due to the mineralization of most manure macroparticles by both activators during the winter 2014/2015. This confirms the helpful impact of the technology. Data were treated by the Tukey's test. The test results show that the differences between the variants are below the threshold of statistical significance at the 0.05 level of statistical significance. High variability of the measured values was a possible cause.

Fig. 4b is a graph of hydraulic conductivity in the 2016 season. These results confirm the conclusions drawn from the previous season. The lowest values were reported in Variant 4 (control). Conversely, a sharp improvement in the infiltration abilities of Variant 1 was attained. This probably indicates a beneficial effect of organic matter and of activators.

Data were again processed using the Tukey´s test. The results show that the differences between the variants are again below the threshold of statistical significance at the level of 0.05. The causes were similar to the previous year. In general, it appears to be a disadvantage of the used measurement method that has high variance of values.

Measurement results of the tensile force (draft) of implements for soil tillage

Energy requirements at soil tillage are an important indicator of economic benefit. The graph in Fig. 5a

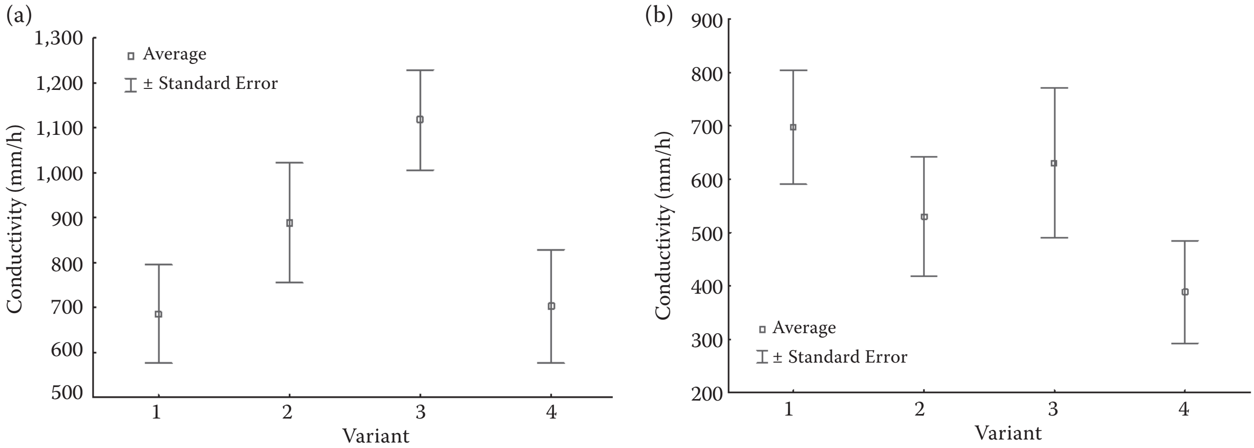

Fig. 4. Saturated hydraulic conductivity in 2015 (a) and 2016 (b)

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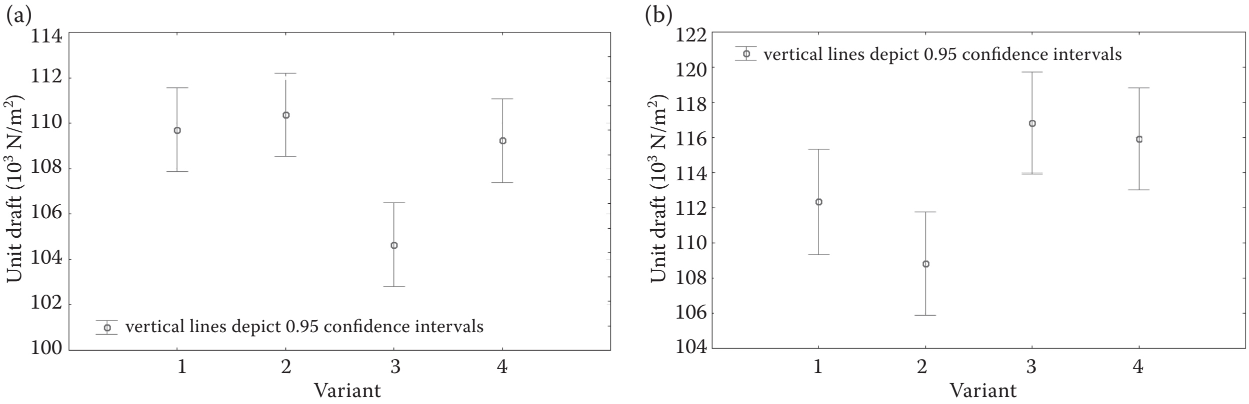

Fig. 5. Unit draft of individual variants at the initial (a) and final (b) state of the experiment

shows the initial state, when a significantly lower draft was exhibited by Variant 3 where untreated manure was applied later on. This difference was statistically significant at the 0.05 level of significance (Tukey's test).

The measurement results of the draft after application of manure and biological activators are shown in the graph of Fig. 5b. Generally, higher absolute values compared to the initial state were primarily caused due to the implement used, the working depth and soil moisture. The absolute values of the individual measurements of tensile resistance are not as important as the ratio related to the control Variant 4 that points out a possible effect of different treatments of individual variants. The draft of Variant 1 and 2 with the applied manure treated with activator Z'fix and potentially PPR Sol decreased considerably compared to the control Variant 4. This probably indicates a positive impact of mineralization of treated organic matter and of soil activators on draught force. On the opposite, Variant 3 with untreated manure demonstrated a relative increase of the specific draught force. This increase was likely caused by non-mineralized organic matter macro particles which increased functional resistance to implement working tools.

Table 2 shows the results of the Tukey´s test, depicting a statistically significant difference between Variant 2 (treatment with activators Z'fix and PRP Sol) and control Variant 4 at the significance level 0.05. Variants 1 and 2 with the application of manure treated with activator Z'fix formed a homogeneous group.

Table 2. Tukey's test – values of a unit draft at the final state of experiment - homogenous groups

Variant	Average unit draft (N/m^2)	Homogenous groups	
2	108.8		****
1	112.3	****	****
4	115.9	****	
3	116.8	****	

The graph in Fig. 6 illustrates a relative decrease in specific draught force of the two mentioned Variants 1 and 2, which formed a homogeneous group, relative to the control Variant 4. At the initial state, the average of unit draft of Variants 1 and 2 was by 0.79% higher than the one of the control Variant 4. After the application of the manure and the activators, the average value decreased by 4.21% lower than that of the control. The overall difference thus amounted to 5.00% and was statistically significant at the level of 0.5 (p = 0.001065).

The effect of reduced variability of soil environment in terms of the physical properties of soil was observed. It confirms the hypothesis on a positive impact of activators. It is consistent with the study by Šařec and Novák (2016) testing a different soil type. Golchin et al. (1994) affirmed a need to support the microbial activity in the soil for organic matter decomposition. In addition, a beneficial effect of

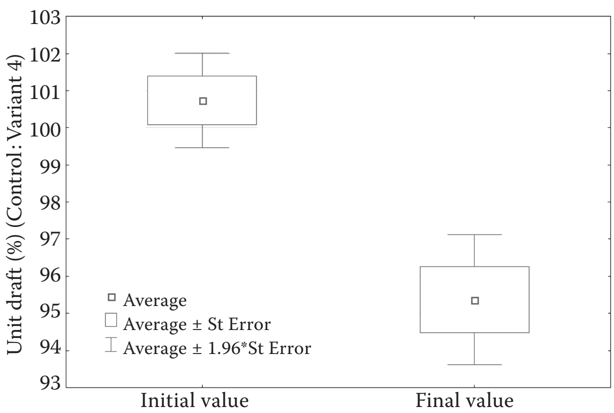

Fig. 6. Relative unit draft of variants treated with Z'fix (Variants 1 and 2) related to the control (Variant 4)

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application of organic matter treated with Z'fix and of PRP Sol activator on cone index values and on draft of tillage implements was observed, thus confirming the previous statements. Balesdent et al. (2000) also implied these results. The average value of the unit draft of variants with the application of manure treated with Z'fix activator and optional application of PRP Sol activator, i.e. Variants 1 and 2, decreased by 5.00% compared with the control variant. Peltre et al. (2015) showed similar results when using treated and untreated fertilizers of organic origin. Six et al. (1999) also stressed the tillage method for decomposition of organic matter in the soil. This reduction, verified for tillage by stubble tine cultivator on heavy soil, suggested a decrease in energy requirements of tillage operations.

CONCLUSION

Use of an activator technology should ensure better conditions for decomposition of organic matter in the soil, subsequent reduction in energy requirements of soil tillage operations, and should favourably affect soil properties. These desired results can be attained by applying organic matter together with activators of biological transformation, in particular those for multiple uses, in order to achieve a long-term corrective effect. When meeting these prerequisites, an overall improvement in soil conditions with a consequent positive effect on economy of agricultural production can be anticipated with a simultaneous reduction of environmental risks.

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