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The effect of different tillage systems under organic management on soil quality indicators

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Abstract: The aim of this study was to adapt reduced tillage to organic farming. The effect of tillage by plough (TP) versus tillage by chisel (TS) on selected soil quality indicators was quantified. The experiment was initiated in 2006 on a loam degraded Chernozem on loess in Borovce (near Piešťany) in the western part of the Slovak Republic. The report focuses on the conversion period and investigates changes during the years 2007 and 2008 while tillage intensity was reduced. Soil samples were taken from the depth of 0–30 cm and analysed for soil reaction (pH), soil organic carbon (C_{org}), total nitrogen (N_t), microbial biomass (C_{mic}), number of cellulolytic bacteria, earthworm density and biomass. All measured parameters increased in both tillage systems between 2007 and 2008, except C_{mic} in the TP system. The increase for all parameters was the strongest in the TS system. However only for C_{mic} ($*P < 0.05$), earthworm density and biomass ($**P < 0.01$) the differences between TP and TS were significant.

Key words: organic management, different tillage systems, soil quality indicators

INTRODUCTION

There is a modern alternative to conventional tillage called conservation or reduced tillage (CT). Literature indicates various benefits of CT. CT leaves an organic mulch at the soil surface, which reduces run-off, increases the surface soil organic matter (SOM) promoting greater aggregate stability which restricts soil erosion (Franzluebbers, 2002). Other beneficial aspects of conservation tillage are soil moisture preservation, increase of soil biodiversity (Holland, 2004) and reduction in fuel consumption (Balla, 2004). Ideally, organic farming systems (OFS) follow a 'whole-farm' approach to manage a (mixed) farm as far as possible as a nearly closed and integrated system (Köpke, 1995). OFS depend more on specific site conditions and are therefore forced to combine the best adapted elements in a holistic approach. OFS must always be environmentally sound, locally adapted and individually site-specific. This is also valid for target-oriented soil cultivation (Köpke, 2008). Conservation tillage systems could provide new opportunities in organic farming as well, but they have been developed under conventional farming systems involving the use of agrochemicals (Pekrun & Claupein, 1998). Few experiments have been conducted to investigate conservation tillage under organic farming conditions (Pekrun et al., 2003; Hampl, 2005; Kainz et al., 2005). In most of the experiments there were problems with weeds (Hampl, 1999; Zwerger, 1996), slugs (Jourdan et al., 1997) and a delay in soil

nitrogen mineralization in spring. Hence reduced tillage systems need to be developed further under organic management.

The aim of our study was to adapt reduced tillage to organic farming. We quantified the effect of tillage by plough versus chisel on selected soil quality indicators. The experiment was initiated in 2006 on a loam degraded Chernozem on loess in Borovce (near Piešťany) in the western part of the Slovak Republic. The report focuses on the conversion period and investigates changes during the years 2007 and 2008 while tillage intensity was reduced. Soil samples were taken from a depth of 0–30 cm and analysed for soil reaction (pH), soil organic carbon (C_{org}), total nitrogen (N_t), microbial biomass (C_{mic}), number of cellulolytic bacteria, earthworm density and biomass.

MATERIALS AND METHODS

The stationary field experiment was established in the experimental station of the Research Institute of Plant Production Piešťany in Borovce in the year 2006 (since this date the whole experiment is under organic management). The field experiment was located on Luvi-Haplic Chernozem on loess. It was situated in an area with a moderate continental climate (average temperature per year: 9.2°C, per vegetation period: 15.5 °C, precipitation depth per year: 593 mm, per vegetation period: 358 mm).

The experimental design consisted of a split plot arrangement in a randomised complete block with three replications. Agro technical operations were carried out in accordance with the law NR SR about organic farming valid for the Slovak Republic.
There were two tillage variants used. The conventional tillage system was a treatment with a mouldboard plough to a depth of 0.20 m followed by a surface treatment and seed-bed preparation (rototiller and harrow). In the reduced system, the chisel plough was used to loosen the soil to a depth of 0.15 m and a rototiller was used for the seedbed preparation. Seedbed preparation was done at the same time in both tillage systems. Composted cow manure was applied to potatoes (20 t ha^{-1}), to rye (10 t ha^{-1}) and to maize for silage (15 t ha^{-1}).

Soil samples were taken four times during the vegetation period, from a depth of 0.02–0.2 m. The air dried soil samples were used for chemical analysis (pH/KCl, C_{org}). The biological properties were measured in fresh soil samples. Used methods: pH/KCl measured by Ion Analyser (JENWAY, VB), C_{org} measured by analyser CNS-2000 (LECO, Corp. St. Joseph, MI, USA), and microbial biomass C_{mic} defined by fumigation – extraction method. To investigate earthworm numbers, the method of hand sorting was used, the sampling unit was 0.30 x 0.30 m per experimental plot to a soil depth of 30 cm. Earthworm biomass was assessed in the laboratory (VIPER SW 1.5). The data were statistically evaluated by one way ANOVA.

RESULTS AND DISCUSSION

The objective of this field experiment was to elucidate the changes in selected soil quality indicators provoked by conventional and reduced tillage in the conversion period. Even after a short period of two years, C_{org} increased by 8.89% (Table 1) under reduced tillage although the differences were not statistically significant. The relatively

hight content of C_{org} in reduced tillage might be explained by the high amount of plant residues left on the field plots, supplemented by composted manure inputs.

There was no significant difference between the systems in soil pH (Table 1). Nevertheless, the soil pH increased by 0.07 units in conventional versus reduced tillage plots. Our results are not in line with Pronin (2003) and Berner et al. (2008), who observed lower pH values with the accumulation of organic acids in the organic matter in the superficial soil layerrs in no-till soils or soils under reduced tillage management. Similarly, for C_{org} and pH, there were no statistically significant diffferences in N_t content between the systems. A positive correlation was observed between N_t and C_{org} in the experiment (Table 2).

The quantity of soil organic matter (SOM) in the whole topsoil varies due to the interacting influences of climate, topography, soil type and crop management history (fertilizer use, tillage, rotation and time) (Kay & VandenBygaart, 2002). In conservation tillage, SOM and microbiological activity are stratified in the soil profile, according to the burial depth of crop residues and manures (Needelman et al., 1999; Franzluebbers, 2002).

The microbial biomass is related to the most labile pools of organic matter and it serves as an important reservoir of plant nutrients (Marumoto et al., 1982). Soil microbial biomass was significantly higher under reduced tillage than under conventional tillage (**$P < 0.05$). This enrichment was generally related to soil organic matter content. We calculated the C_{mic} to C_{org} ratio, which is suggested as an indicator of biological soil fertility (Sparling, 1992; Stockfisch et al., 1999; Weber & Emmerling, 2005). In our tillage experiment, the ratio C_{mic}-to-C_{org} was 3.315% higher (**$P < 0.05$) under reduced tillage due to the addition of organic plant biomass to the soil surface.

The number of earthworms and their activity increased in conservation compared with conventional tillage (Table 1). Ploughing disrupts earthworms and exposes them to predation and desiccation. Tillage in the autumn period harmed the earthworm populations. Earthworms are often referred to as ecosystem engineers due to their ability to alter the soil environment. Since they influence a wide range of critical chemical and physical soil properties it is important to understand how their populations are affected by soil management. The number of earthworms and their biomass was significantly affected by tillage (**$P < 0.01$) in our experiment. Earthworm number was 148% higher (**$P < 0.01$) under reduced tillage compared to conventional tillage. The difference in earthworm biomass represented 109% in favour of reduced tillage plots. Reduced tillage improved the number and activity of earthworms. This is especially important in arable systems where generally earthworm activity is much reduced compared, for example, with grassland. The earthworm biomass correlated positively with soil reaction and negatively with N_t (Table 2).

Table 1. Soil chemical and biological characteristics in conventional and reduced tillage systems.

Tillage/ Indicator	pH/KCl	Corg (%)	Nt (%)	Microbial biomass (Cmic.g^{-1} dry matter)	Celulolytic bacteria (n.103 CFU /dry matter)	Number of earthworms (ks.m^{-2})	Earthworms biomass (g.m^{-2})
Conventional system	5.913	1.314	0.124	765.6	9.0	54	42.3
Reduced tillage system	5.985	1.432	0.131	862.0	11.4	134	88.4
ANOVA	ns	ns	ns	($^{+}$)	ns	($^{++}$)	($^{++}$)

($^{+}$) $P < 0.05$; ($^{++}$) $P < 0.01$; ns - non significant

Table 2. Correlation matrix (r) of chemical and microbiological soil parameters.

	pH	C_{org}	N_t	Microbial biomass	Celulolytic bacteria	Number of earthworms
C_{org}	0.12					
N_t	0.07	0.76^{+}				
Microbial biomass	0.2	0.11	0.06			
Celulolytic bacteria	0.24	0.27	0.26	0.36		
Number of earthworms	0.26	-0.26	-0.17	0.17	0.22	
Earthworms biomass	0.42^{+}	-0.38	-0.44^{+}	-0.04	0.06	0.73^{+}

$^{+}$ $P < 0.05$

CONCLUSIONS

Our study on a loam degraded Chernozem on loess in Slovakia showed that using reduced tillage in organic farming in the conversion period improves several chemical and biological soil properties. These improvements may contribute to long term sustainability of agricultural systems by maintaining soil quality.

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