SOIL CARBON SEQUESTRATION AS INFLUENCED BY TILLAGE AND RESIDUE MANAGEMENT BY GROWING OF COMMON PEA

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Abstract: *Long term field study (1996-2003) was conducted at the experimental site of Slovak University of Agriculture in Nitra in south-western Slovakia, to investigate the effects of different soil tillage practices and residue management on soil carbon sequestration under peas for grain growing after cereal forecrops. The average annual/growing season rainfall is 561/327 mm. The mean annual/growing season temperature is 9.7℃/16.2℃. The soil type is Orthic Luvisol. Plots were subjected to primary soil tillage treatments as follows: mouldboard ploughing to a depth of 0.22 m (conventional tillage), twice shallow loosening to a depth of 0.1 m (reduced tillage). Three fertilization treatments as follows: 0–without organic and inorganic fertilization, PH–mineral fertilizers calculated to the 3 t yield level, PZ–incorporation of all above-ground plant material supplemented with mineral fertilizer to the balance equilibrium level. Common pea (Pisum sativum L.) was growing after cereal forecrop (spring barley, since 2001–winter wheat). Temporal change was evaluated as absolute and net change. Absolute change in stored C from first year of field trial was strongly decline from 36.6 t ha^{-1} (1994) to average level 32 t ha^{-1} (1996-2003). Net change of soil organic matter between tillage treatments revealed significant differences. The reduced tillage creates better soil condition for soil carbon accumulation (32.5 t ha^{-1}) with comparison to mouldboard ploughing (31.4 t ha^{-1}) in 0.2 soil layer. The fertilization treatments sequestered more carboneum with comparison to control treatment. Differences between the samples with application of mineral fertilizers (PH) or organic and mineral fertilizers (PZ) are associated with the decomposition of common pea residues or great amount of biomass production.*

Key words: *carbon sequestration, peas, residue management, tillage*

INTRODUCTION

The carbon sequestration potential of soil depends on its capacity to store resistant plant components together with protecting, and accumulating, humic substances. The quantity of soil carbon present is controlled by a complex interaction of processes determined by carbon inputs and decomposition rates. Sequestration of carbon from plant biomass into organic matter is a key sequestration pathway in agriculture. The net change in SOC depends not only on the C loss as CO_2 emission but also on the C input by residue and manure (LACKO-BARTOŠOVÁ, 2006; CVIJANOVIĆ et al. 2007). Tillage accelerate organic C oxidation to CO_2 by improving soil aeration, increasing contact between soil and crop residues and exposing aggregate-protected organic mater to microbial attack (BEARE et al., 1994; BIRKÁS et al., 2008). To promote carbon sequestration research and human activity needs to maximise the inputs and minimise the outputs to increase sustainability and resilience of agroecosystem and particular crop rotation pattern (HABÁN and OTEPKA, 2007; LACKO-BARTOŠOVÁ and KORCZYK-SABO, 2008; TÝR et al., 2009). There is also a verified link between inputs of mineral fertilizers and soil organic carbon (SOC) sequestration via biomass production (KOVÁČIK et al., 2006; FOGARASSY et al., 2008). Organic matter stock and microbial respiration are recommended indicators for evaluation of soil in EÚ (MICHÉLI et al., 2008). Long-term field experiment have shown that there is direct linear relationship between the quantity of carbon added to soil as organic matter and amount of carbon accumulated in the soil, other factor remaining constant (DUIKER and LAL, 1999). However, the dynamics of soil organic matter are complex and the factor controlling the flux of carbon will interact uniquely at each site. Land use changes and soil and crop management practices with potential for SOC sequestration include conservation tillage methods, use of crop residues, diverse crop rotations, erosion control (SINGH and LAL, 2005; POSPIŠIL et al., 2009) and judicious use of fertilizers and manures (KOVÁČIK et al., 2009).

The objective of this study was to investigate the effects of different soil tillage practices and residue management on soil carbon sequestration under peas for grain growing after cereal forecrops.

MATERIAL AND METHODS

TField trials were conducted over a seven year period from 1996 through 2003 at the experimental station of the Slovak University of Agricultural in Nitra in south-western Slovakia. The experimental site is located in a warm and moderate arid climatic region. The average annual rainfall is 561 mm. The average annual rainfall during the growing season is 327 mm. The mean annual temperature is 9.7°C. The mean temperature during the growing season is 16.2°C. The soil type is Orthic Luvisol with a loamy texture, 2.3% of humus content, and a pH of 5.7.

We report the overall seven year results, as well as the results from the 28 peas plots and the 84 tillage subplots. The experimental design was a split-plot with four replicates. The tillage was the main plot factor; the fertilization was the subplot factor. The subplots were 3 m wide by 10 m long and plots were subjected to primary soil tillage treatments as follows: mouldboard ploughing (CT) to a depth of 0.22 m (conventional tillage), and combined cultivator, twice shallow loosening (RT) to a depth of 0.1 m (reduced cultivation). Three fertilization treatments as follows: 0-without organic and inorganic fertilization, PH –mineral fertilizers calculated to the 3 t yield level, PR- incorporation of all above-ground plant material supplemented with mineral fertilizer to the balance equilibrium level. Common pea (*Pisum sativum* L.) was growing after cereal forecrop (spring barley from 2001–winter wheat). The soil samples were collected from the 0.20 topsoil layer three times (spring, summer and autumn samples). The soil samples were incubated at 28 ºC and soil respiration was measured 17-18 days according Bernát and Seifert method. SOC content was determined by the Tjurin method. For organic matter stock (kg ha^{-1}) calculation the soil bulk density was determined by soil core sampling kit.

RESULTS AND DISCUSSIONS

The influence of tillage systems on soil basal respiration is illustrated in Fig. 1. From the starting point in 1996 the tillage and different level of soil disturbance has significant impact on potential flux of CO_2 and input output balance. The quantity of carbon within any soil has been described by REICOSKY (1997) as a simple mass balance relationship: carbon input-carbon output=net carbon accumulation. On the side of output the basal respiration significantly indicated the better condition for carbon sequestration in reduced tillage treatments. No significant differences between fertilization treatments have been found. Basal respiration range from 2.52 mg CO_2-C 100g day^{-1} in control treatments to 2.64-2.61 mg CO_2-C 100g day^{-1} in fertilization treatments.

The seasonal dynamics of basal respiration is documented in Figure 2. In concordance with (FRANCHINI et al., 2007) the autumn samples, both conventional and reduced soil tillage treatments reflect the influence of crop residues and soil preconditions for mineralization processes The differences in CO_2 were identified after the addition of crop residues to the soil, stimulating microbial activity and resulting in stronger decomposition in both soil management systems. The seasonal dynamics of particular fertilization treatments was described by linear and polynomic equation. The most efficient method of accumulating carbon in soils must be by direct decomposition of plant material. If carbon passes through the heterotrophe chain some will be lost directly to the atmosphere as CO_2 as a consequence of the respiratory activity. According Rothamsted soil carbon model evaluated system is in steady when 5 t C ha^{-1} in the form of plant residue or manure, was added for 5 consecutive years. Assuming a 50% carbon content of the plant material 10 t of plant residue would actually be required to provide each 5 t application of plant carbon (SCHLESINGER, 2000).

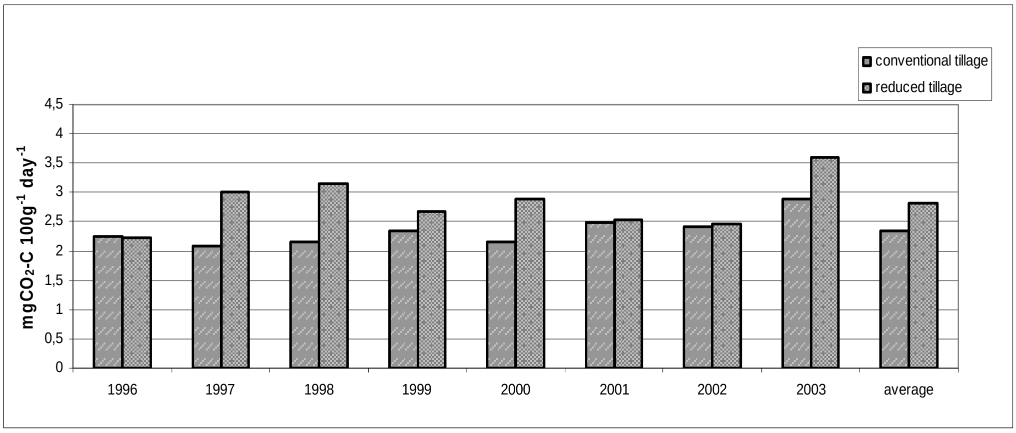

Figure 1: Soil basal respiration in conventional and reduced tillage treatment from 1996-2003, Dolná Malanta Experimental Station

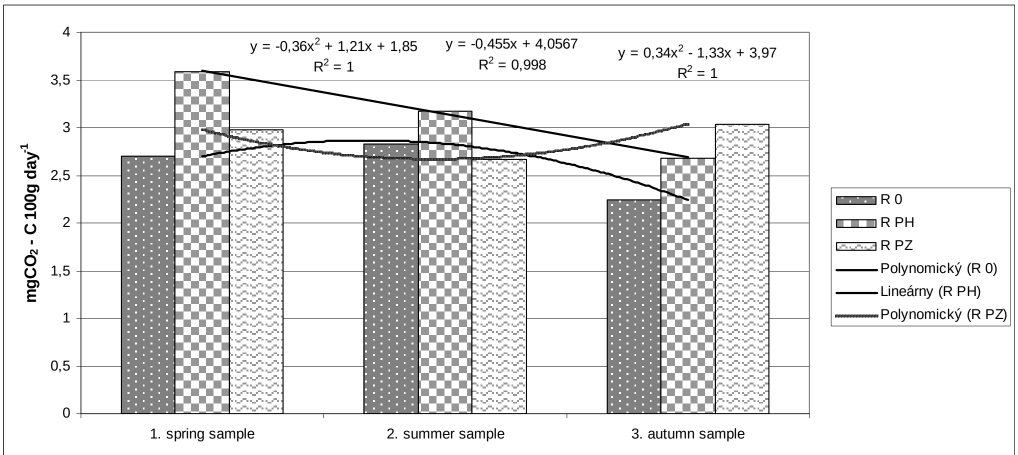

Figure 2: Seasonal dynamics of soil basal respiration in conventional tillage under different fertilization treatments from 2001-2003

In our evaluated treatments with incorporation of al plant residues (R-PZ) 5.15 t ha^{-1} dry matter of plant residues in an average of maize, winter wheat, spring barley and peas was added each year. Temporal change in SOC can be defined in two ways as an absolute change in stored carboneum or as a net change in storage among treatments. The former provides an estimate of the actual C exchange between soil and atmosphere; the later provides an estimate of the actual C exchange between soil and atmosphere, attributable to evaluated treatments (ELLERT et al., 2002). Changes between years and tillage treatments and between fertilization are documented in table 1.

Table 1

Soil carbon stocked in equivalent soil mass (t ha-1) in each tillage and fertilization treatments. The means between years (small letters) and tillage (capital letters) followed by the same letter are not significant at $P<0.05$ probability level.

Tillage/fertilization	1996	1999	2000	2001	2002	2003	Tillage
CT-0	33.0	33.7	31.0	31.0	27.7	28.9	31.4A
CT-PH	30.3	34.2	31.3	31.9	30.7	28.9	
CT-PZ	33.6	32.0	32.7	30.8	31.2	32.4	
R-0	30.3	34.2	33.0	29.4	31.8	34.2	32.5B
R-PH	31.8	33.5	33.8	32.1	32.3	34.2	
R-PZ	31.8	33.2	35.3	30.0	29.5	35.7	
Average	31.8b	33.5d	32.9c	30.9a	30.5a	32.4c	

The reduced tillage has positive influence on soil carbon sequestration with comparison to conventional mouldboard ploughing. Both fertilization treatments significantly influenced the soil carbon stock with comparison to treatments without any form of fertilization. In control treatment without fertilization 31.5 t ha^{-1} of carboneum in 0.20 m soil layer was stored. The mineral or organic fertilization increase the soil carboneum stock by 6 t ha^{-1} (PH treatment) and 0.9 t ha^{-1} (PZ treatment). Differences between the samples with application of mineral fertilizers (PH) or organic and mineral fertilizers (PZ) are associated with the decomposition of incorporated plant residues or great amount of biomass production (roots, exudates and post harvest residues).

CONCLUSIONS

The fertilization treatments do not revealed the significant differences in soil basal respiration in an average, but strong seasonal dynamics was recognised. Higher soil basal respiration and more CO_2 was realised from reduced-till compared to conventional tillage despite there being increased levels of soil carbon. The reduced tillage has positive influence on soil carbon sequestration with comparison to conventional mouldboard ploughing. Both fertilization treatments significantly influenced the soil carbon stock with comparison to treatments without any form of fertilization.

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