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Short-term soil carbon dioxide (CO_2) emission after application of conventional and reduced tillage for red clover in Western Slovakia

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Abstract

Tillage systems have impact on soil properties, crop growth and through this directly and indirectly influence the cropland CO_2 emission and therefore the global warming. In Slovakia, the wider adoption of conservation practices has barriers such as large acreage of compacted soils, the absence of detailed regionalization of suitable soils for such practices and the scientific evaluation of its application on sustainable soil productivity and environment protection. This study evaluated the short-termeffect of conventional tillage (CT) and reduced tillage (RT) with (N1) and without (N0) N fertilizer application on soil CO_2 emission from cropland planted with a red clover (*Trifoliumpratense*) during 40 days in 2013 on a tillage field experiment initiated in 1994. CO_2 flux, soil temperature, and soil water contentwere monitored during the studied period in western Slovakia.Results of this study showed that there wasn't significant difference (p< 0.05) in soil CO_2 between conventional tillage and reduced tillage for both, not fertilized and fertilized plots. Averaged 40 days CO_2 emissions were greater in reduced tillage as compared to conventional tillage for both fertilization levels. A linear regression between CO_2 emission and soil temperature in conventionally and reduced tilled plots showed that soil temperature (r = 0.88-0.94; P <0.05) and not the soil moisture was a controlling factor. The highest CO_2 emission were recorded on the CT and RT plots during the first two weeks after tillage, showing that the tillage resulted in a rapid physical release of CO_2.

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Introduction

The greenhouse gas exchange between croplands and atmosphere plays an important role in the global carbon cycle and carbon dioxide concentration in the atmosphere (CO_2). Increased atmospheric CO_2 has been considered a major contributor to global warming. Measurements of soil gas fluxes for different tillage treatments and cropping systems are important for identifying management practices that can influence positively the global carbon balance (Post et al., 1990, Reicosky et al., 1997). Carbon loss from soil to the atmosphere as CO_2 has been enhanced due to inappropriate tillage practices (Reicosky et al. 1997).

Reduced tillage is regarded as one of the most effective agricultural practices to reduce CO_2 emission and sequester atmospheric C in the soil (Kern and Johnson, 1993; Curtin et al. 2000; Al-Kaisi and Yin, 2005). Studies showed that decreased tillage intensity reduces soil disturbance and microbial activities, thus reducing CO_2 emission (Lal and Kimble, 1997; Curtin et al. 2000). On the other hand, increased tillage intensity showed increased CO_2 emission through increasing aeration due to increased soil disturbance (Roberts and Chan, 1990) and to physical degassing of dissolved CO_2 from the soil solution (Reicosky and Lindstrom, 1993).

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The reduced tillage practices so far received great attention in America, Australia and South Africa, often in semi-arid areas. In Europe, no-tillage is less often practices than reduced tillage, which involves one or more stubble cultivations. The adoption of conservation tillage practices in Europe has been much slower, possibly due to the previously high production subsidies and smaller scale production in European agriculture, which has increased the financial risks associated with these practices. Implementation of conservation systems including reduced tillage and no-till systems is also an indirect measure resulting from ecological standards of the European Union for securing good agricultural and environmental conditions (GAEC) (ecological conditionality for direct payment obtaining also in condition of Slovak Republic). Measures of Slovak Republic for implementation of minimalization techniques came in force on 1. January 2009 (Cross-compliance, 2007). Spreading of these techniques in condition of Slovak Republic is limited by large acreage of not suitable compacted soils or partly compacted soils. But there is also an absence of detailed regionalization of suitable soils for this conservation systems as well as absence of long term field research in different ecological conditions (Kovac et al., 2003). Implementation of conservation systems on agricultural land involves quantification of these effects on biogeochemical cycles of nitrogen (N) and carbon (C) in different soil-climatic conditions and farming managements which differs in time and space.

In this study we evaluated the short-term effect of conventional tillage (CT) and reduced tillage (RT) with (N1) and without (N0) N fertilizer application on soil CO_2 emission from cropland planted with a red clover (*Trifoliumpratense*) during 40 days in 2013 on a tillage field experiment initiated in 1994. Other factors such as soil water content and temperature were also measured to take a closer look on their role (magnitude of influence) in soil CO_2 emission.

Material and Methods

Experimental site

This study was conducted at the Experimental site of the Department of Plant Production of SAU-Nitra, in Nitra region of Slovakia (lat. 48°19´00´´; lon. 18°09´00´´) during 40 days in 2013 on a long-term tillage field experiment initiated in 1994.The soil type was classified as OrthicLuvisol (FAO, 1998) containing 360.4 g kg^{-1} of sand, 488.3 g kg^{-1} of silt and 151.3 g kg^{-1} of clay (Šimanský et al. 2008). The average annual air temperature was 10.3°C and annual precipitation was 614mm during the studied year (Table 1). Tillage treatments were conducted during the fall 2 months after the cut of red clover.The N-fertilizers application rate and other information on farming practices for the crop including the timing for tillage, planting day, harvesting day, etc. were set according to the individual needs of crops recommended in terms of good agricultural practices.

The experiment compared two tillage methods (conventional tillage-CT and reduced tillage-RT) combined with unamended control (N0) and addition of nitrogen fertilizers (N1). Experiment was arranged in a split plot design with tillage as the main plots and the treatments N0 and N1 as the sub-plots with three replicates. In the spring before planting, both treatments received onecultivation by harrow cultivator to 10 cm depth.CT consisted of tillage to 22 – 25 cm and RT consisted of disking to 10-12 cm depth both appliedtwo months after the cut of red clover on 3 September, 2013.

Table 1. 30-year mean and actual (2013) monthly climate data for the nearby automatic weather station (300 m from the field site)

Month	30 - yearmean (1961-1990)		2013	
	Precip. (mm)	Mean temp. (°C)	Precip. (mm)	Mean temp. (°C)
January	31.0	-1.7	58.0	-1.2
February	32.0	0.7	82.4	1.2
March	30.0	5.0	93.2	2.7
April	39.0	10.4	23.0	11.7
May	58.0	15.1	65.6	15.1
June	66.0	18.0	54.8	18.5
July	52.0	19.8	2.2	22.2
August	61.0	19.3	70.0	20.9
September	40.0	15.6	60.8	13.6
October	36.0	10.4	25.0	11.1
November	55.0	4.5	66.2	5.8
December	40.0	0.1	12.6	1.5
Annual (total/average)	539.0	9.8	613.8	10.3

Measurement of soil CO_2 emissions, water content and temperature

The soil surface CO_2 flux was measured weekly from all plots starting on 4. September (1 day after tillage operations and lasted for 40 days using closed chamber technique. All gas samples were taken between 9 A.M and 12 A.M. of the day to reduce variability in CO_2 flux due to diurnal changes in temperature (Parkin and Kaspar, 2003). The metal collar frame was inserted 10 cm deep into the soil in every plot and left undisturbed until the end of experiment. On every gas sampling, the chamber (30 cm in diameter and 25 cm in height) were water sealed onto bottom collars and gas samples (20 mL) were collected through tube fittings (sealed with septum) at 0, 30 and 60 min after chamber deployment using an air-tight syringe (Hamilton) and transferred to pre-evacuated 12 mL glass vials (LabcoExetainer). Gas samples were analyzed for CO_2 using a gas chromatograph (GC-2010 Plus Shimadzu) equipped with a thermal conductivity detector. The GC was calibrated using 3 certified standard gas mixtures (CO_2, N_2O, and N_2) in the expected concentration ranges. CO_2 fluxes between soil/crop and atmosphere were calculated from the change of concentration during the chamber closure using a linear approach. Soil water content at 0-10 cm depth (gravimetric method) and soil temperature at 5 cm depth (Volcraft DET3R thermometer) was measured at each gas sampling event.

Statistical Analyses

The statistical processing of the data included the determination of means, standard deviations, errors, Pearson coefficients of correlation at the confidence level of $p<0.05$. The significance of the differences between the means was evaluated using one-way ANOVA at $p<0.05$.

Results and Discussion

Soil water content and temperature

There wasn't found significant difference ($p< 0.05$) in soil temperature between CT and RT for both fertilization levels (N0, N1) (Figure 1). The average temperature was slightly lower in the conventional tillage as compared to reduced tillage for both fertilization levels. In the CTN0 and RTN0 system, the average temperatures were 16.4 and 16.6°C respectively, ranging between 13.6 and 20.6°C in CTN0 and 13.6 and 20.4 °C in RTN0. In the fertilized treatment CTN1 and RTN1, the average temperatures were 16.3 and 16.4°C respectively, ranging between 13.5 and 20.4°C in CTN1 and 13.6 and 19.5 °C in RTN1. Soil tillage and soil disturbance as a consequence may modify the relationship between the volume of air and the volume of soil particles inducing changes in the soil thermal conductivity and affecting the soil temperature. Soil tillage exhibits lower conductivity compared to soil non-tillage (Hillel, 1998). Since we had almost the same temperatures for both tillage treatments and nitrogen levels, this wasn't our case.

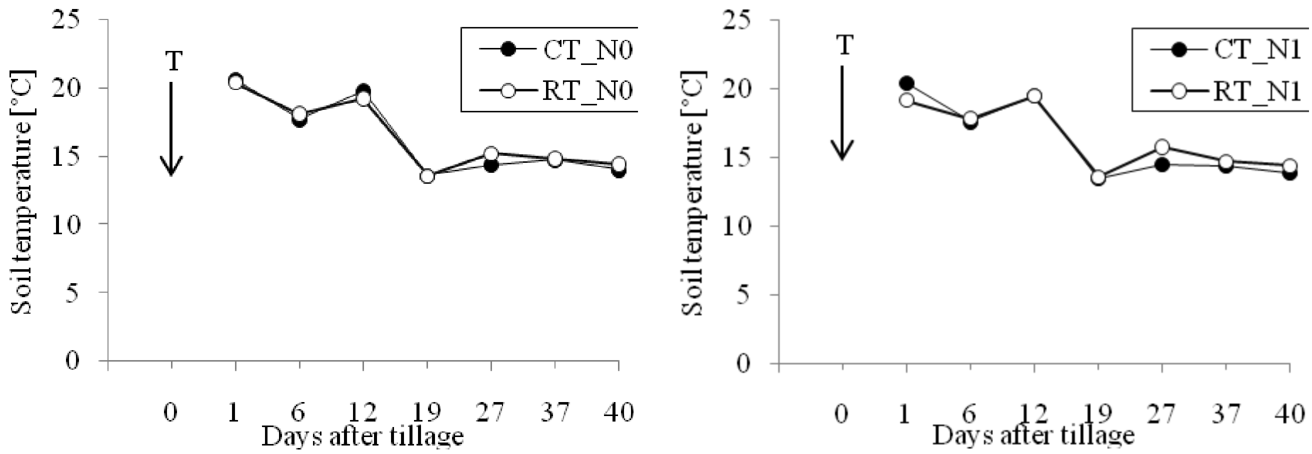

Figure 1. Soil temperature during 40 days after conventional (CT) and reduced tillage (RT) operations combined with and without N fertilizer application (N0, N1)and arrow indicate the day of tillage operations (3 September, 2013).

The Figure 2 shows SWC for conventional tillage (CT) and reduced tillage (RT) combined with unamended control (N0) and addition of nitrogen fertilizers (N1) over the studied period. There wasn't found significant difference ($p < 0.05$) between both tillage treatments combined with fertilization levels also in the case of SWC. The average SWC was slightly lower in conventional tillage as compared to reduced tillage for both fertilization levels. In the CTN0 and RTN0 system, the average SWC were 16.2 and 16.8 (% by mass), ranging from 12.5 to 19.7 and from 13.5 to 21.5 for CTNO and RTN0, respectively. In case of fertilized plots, the average SWC for CTN1 and RTN1were 16.6 and 16.8 (% by mass), respectively and ranging from 12.7 to 20.1 and from 13.9 to 21.2 (% by mass) for CTN1 and RTN1, respectively. Slightly higher SWC in RT may indicate that tillage systems that involve less physical disturbance help to maintain soil water. The tillage activity influences the evaporative area and consequently a greater water loss. This effect depends on the depth, degree and frequency of soil tillage activities, the subsequent climatic conditions and the restructuring of the prepared layer (Salton and Mielniczuk, 1995).

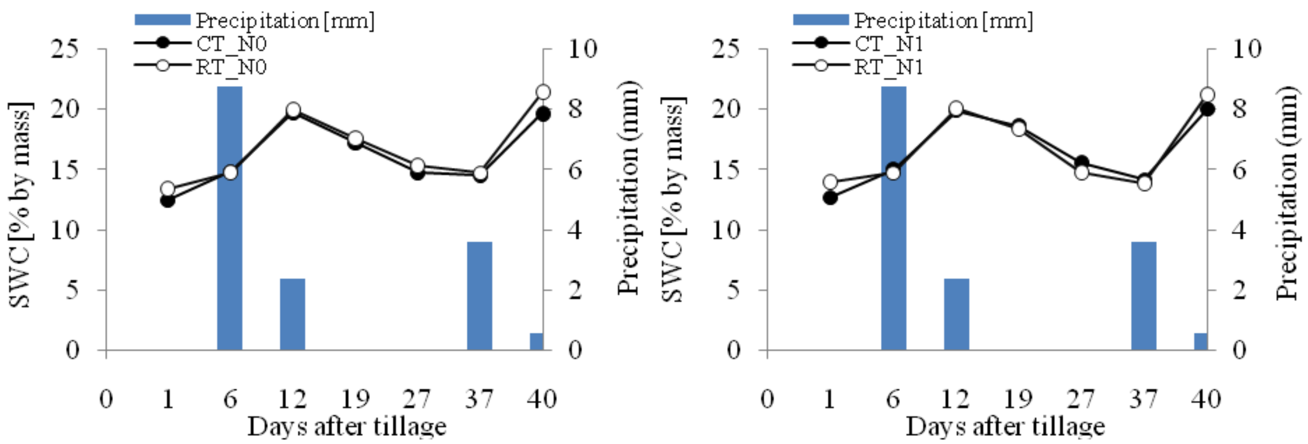

Figure 2. Soil water content (SWC) and precipitation during 40 days after conventional (CT) and reduced tillage (RT) operations combined with and without N fertilizer application (N0, N1)

Soil CO_2 emission

Figure 1 presents soil CO_2 emission means in the plot on each of the studied days. Shortly after tillage was applied emissions were as hight as. There wasn't found significant difference ($p < 0.05$) in soil CO_2 between conventional tillage and reduced tillage for both, not fertilized and fertilized plots. Soil CO_2 emissions were slightly greater in CT as compared to RT when the treatments were fertilized (5 out of 7 measurements) (Figure 3). Opposite results were found when no N fertilizers were applied, with CO_2 emission being greater from RT as compared to CT almost the whole period studied, except 1 out of all measurements. However, averaged 40 days CO_2 emissions were greater in reduced tillage as compared to conventional tillage for bothfertilization levels (Table 2).CTN0 and RTN0 reached values of 84.0 and 93.5 kg ha^{-1} day^{-1}, respectively. In case of fertilized plots, average CO_2 emissions reached values of 82.4 and 82.8 kg ha^{-1} day^{-1} for CTN1 and RTN1, respectively. The maximum CO_2emission from all treatments were found after tillage operations and lasted for two weeks. However, CO_2 sharply decreased after two weeks by 53 to 57% as compared to the CO_2 emissions measured on 12th day after tillage operations.

A higher CO_2 emissions right after tillage operations may be attributed to the increase in soil aeration that was induced by tillage disturbance (Jackson et al., 2003). The sharp decrease of CO_2 emissions after two weeks of measurements could be attributed to sharp decrease of soil temperature (Figure 1). A correlation between soil CO_2 emission and soil temperature support the fact that soil CO_2 emission is affected by soil temperature. The significant relationship between CO_2 emission and soil temperature is well known (Follet, 1997; Parkin and Kaspar, 2003).Cumulative total CO_2 emissions were calculated by interpolating the emissions between each sampling day. On quantifying the total emissions during the studied period (40 days) we found that the emissions were greater for reduced tillage as compared to conventional tillage for both fertilization levels. The emissions were 3.2 and 3.6 t ha^{-1} in CTN0 and RTN0 and 3.1 and 3.3 t ha^{-1} in CTN1 and RTN1, respectively (Table 2).

Table 2. Mean, maximum, minimum and total cumulative CO_2 emissions during 40 days after conventional (CT) and reduced tillage (RT) operations combined with and without N fertilizer application (N0, N1)

Soiltillage and N level		CO_2emissions			
		Mean	Maximum	Minimum	Total
		kg ha^{-1} day^{-1}			t ha^{-1}
CTN0	notfertilized	84.0	137.4	49.2	3.2
RTN0	notfertilized	93.5	158.8	27.3	3.6
CTN1	fertilized	82.4	141.3	27.4	3.1
RTN1	fertilized	82.8	122.1	45.5	3.3

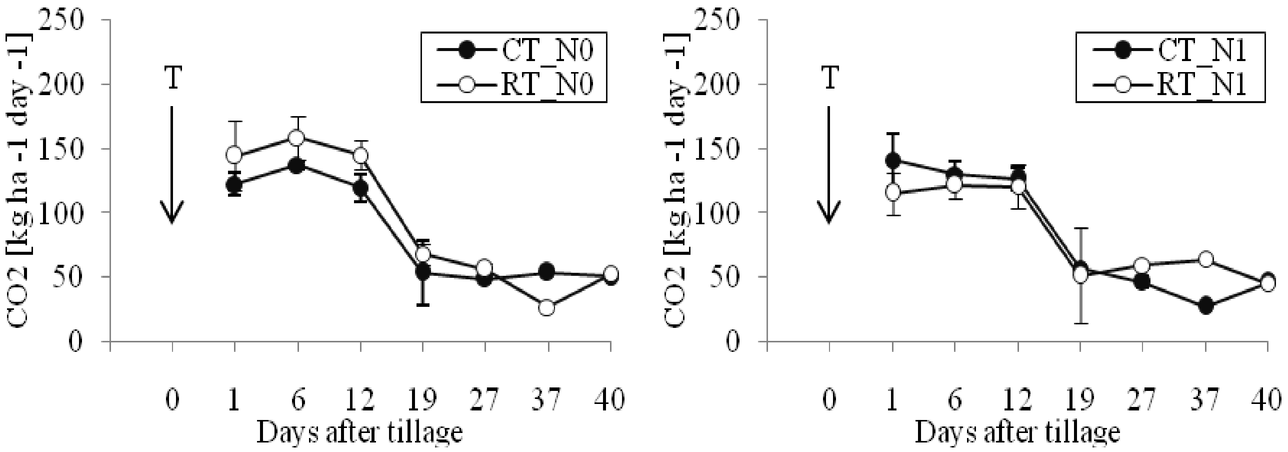

Figure 3. Soil CO_2 emission during 40 days after conventional (CT) and reduced tillage (RT) operations combined with and without N fertilizer application (N0, N1). Barsindicate S.E. (n=3) and arrow indicate the day of tillage operations (3 September, 2013).

Relationship between CO_2 and soil temperature and soil water content

The Pearson correlation coefficient between the CO_2 flux and soil temperature during the studied period was significant (p< 0.05) for both conventional (r = 0.90 for CTN0; r = 0.93 for CTN1) and reduced tillage (r = 0.88 for RTN0; r = 0.94 for RTN1) whether the plots were fertilized or not. On the other hand, the correlation between the CO_2 flux and soil water content was not significant (p< 0.05) and showed weak relationship for both conventional (r = 0.20 for CTN0; r = 0.19 for CTN1) and reduced tillage (r = 0.16 for RTN0; r = 0.25 for RTN1) systems combined with and without N.The significant relationship between CO_2 emission and soil temperature is well known (Follet, 1997; Parkin and Kaspar, 2003).

Conclusion

Results of this study showed that there wasn't significant difference in soil CO_2 between conventional tillage and reduced tillage for both, not fertilized and fertilized plots. Soil CO_2 emissions were slightly greater in CT as compared to RT when the treatments were fertilized (5 out of 7 measurements). Opposite results were found when no N fertilizers were applied, with CO_2 emission being greater from RT as compared to CT almost the whole period studied, except 1 out of all measurements. However, averaged 40 days CO_2 emissions were greater in reduced tillage as compared to conventional tillage for both fertilization levels.

A linear regression between CO_2 emission and soil temperature in conventionally and reduced tilled plots showed that soil temperature (r = 0.88-0.94; P <0.05) and not the soil moisture was a controlling factor. The highest CO_2 emission were recorded on the CT and RT plots during the first two weeks after tillage, showing that the tillage resulted in a rapid physical release of CO_2.

The results of this study showed that, from the short-term perspective, adopting less intensive tillage practices such as reduced tillage are not effective in reducing soil CO_2 emission. However, it also has to be mentioned that this was a short-term study, and that there should be taken into account the effect of less intensive tillage practices on CO_2 emission for a longer period, such as period of crop growing season.

affect on soil structure. The structural state of irrigated soils reflects the balance between these processes.

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References

Al-Kaisi, M.M., Yin, X., 2005. Tillage and cropresidueeffects on soilcarbon and carbon dioxide emision in cron-soybeanrotation. *Journal of Environmental Quality* 34: 437-445.

Cross-compliance, 2007. Ministry of Agriculture of the Slovak Republic, viewed 17 February 2014, <http://www.land.gov.sk/sk/?navID=1&id=559>.

Curtin, D, Wang, H, Selles, F, McConkey, B.G., Campbell, C.A., 2000. Tillage effects on carbon fluxes in continuous wheat and fallow-wheat rotations. *Soil Science Society America Journal* 64: 2080-2086.

Follett, R.F., 1997. CRP and microbial biomass Dynamics in temperate climates. In: R Lal (Eds.), Management of carbon sequestration in soil.CRC Press. Boca Raton. pp.305-322.

Hillel, D., 1998. Environmental Soil Physics. Academic Press, San Diego.

Jackson, L.E., Calderon, F.J., Steenwerth, K.L., Scow, K.M., Rolston., D.E., 2003. Responses of soil microbial processes and community structure to tillage events and implications for soil quality. *Geoderma* 114: 305-317.

Kern, J.S., Johnson, M.G., 1993. Conservation tillage impacts on national soil and atmospheric carbon levels. *Soil Science Society America Journal* 57: 200-210.

Kovac, K., 2003.General plant production.S UA, Nitra (in Slovak).

Lal, R., Kimble, J.M., 1997.Conservation tillage for carbon sequestration. *Nutrient Cycling in Agroecos*ystems 49: 243-253.

Parkin, T.B., Kaspar, T.C., 2003. Temperature controls on diurnal carbon dioxide flux: Implications for estimating soil carbon loss. *Soil Science Society America Journal* 67: 1763-1772.

Post, W.M, Peng, T.H., Emmanuel, W.R., King, A.W., Dale, V.H., De Angelis., D.L., 1990. The global carbon cycle. *American Science* 78: 310-326.

Reicosky, D.C., Dugas, W.A., Torbert, H.A., 1997. Tillage-induced soil carbon dioxide loss from different cropping systems. *Soil Tillage Research* 41: 105-108.

Reicosky, D.C., Lindstrom, M.J., 1993. Fall tillage method: Effect on short-term carbon dioxide flux from soil. *Agronomy Journal* 85: 1237-1243.

Reicosky, D.C., Reeves, D.W., Prior, S.A., Runion, G.B., Rogers, H.H., Raper, R.L., 1999. Effects of residue management and controlled traffic on carbon dioxide and water loss. *Soil Tillage Research* 52: 153-165.

Roberts, W.P., Chan, K.Y., 1990. Tillage-induced increases in carbon dioxide loss from soil. *Soil Tillage Research* 17: 143-151.

Šimanský, V., Tobiašová, E., Chlpík, J., 2008. Soil tillage and fertilization of Orthic Luvisol and their influence on chemical properties, soilstructure stability and carbon distribution in water-stable macro-aggregates. *Soil Tillage Research* 100: 125-132.