Effect of crop residues on CO_2 flux in the CTF system during soil tillage by a disc harrow Lemken Rubin 9

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Abstract

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Carbon dioxide is one of the most important greenhouse gases. Agriculture, especially soil tillage, contributes to CO_2 emissions significantly. The aim of the paper was the comparison of the amounts of carbon dioxide emissions released from the soil into the atmosphere depending on the controlled traffic farming (CTF) and crop residues. Three variants of the experiment were realised: before the soil tillage, immediately after the soil tillage, and seven days after the soil tillage. The soil tillage was carried out after the harvest of winter wheat by disc harrow Lemken Rubin 9 with a tractor John Deere 8230 on the loamy soil. The monitoring points were selected in parts of the field with and without the crop residues and in trafficked and non-trafficked areas. The CTF system affects CO_2 flux, the amounts of emissions from the non-trafficked areas being higher than those from the trafficked areas. The crop residues left on the field cause a decrease of CO_2 flux. The incorporation of crop residues causes an increase of CO_2 flux.

Keywords: carbon dioxide; emissions from the soil; controlled traffic farming; soil compaction

Agriculture causes some environmental problems, mainly the greenhouse effect, contamination of water resources, and soil erosion. Carbon dioxide (CO_2) is one of the three most important greenhouse gases (Reicosky, Lindstrom 1993; Inselsbacher et al. 2011). Atmospheric concentrations of CO_2 are increasing at a rate of approximately 0.6% per year (IPCC 2007). Since this increase contributes to the changes in the Earth's climate, the interest in quantifying significant sources and sinks of CO_2 is growing and the international community has taken steps to reduce these emissions (Flessa et al. 2002; Reicosky e t al. 2005). The emissions released from the arable soil into the atmosphere are relatively small when compared with other sources, but the total area of the agricultural land is a source of a huge amount of emissions. The intensification of agriculture and continued upward pressure on the food production in sufficient quantity and adequate quality result in environmental aspects being side-lined (Šima et al. 2012). The controlled traffic farming is facilitated by the integration of information and communication technologies in farming (Auernhammer 2001; Chamen 2007) and that is a technology which minimises the compacted area of the field. It has the potential to increase the

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economic (Kingwell, Fuchsbichler 2011) and environmental benefits (Zhang et al. 2002). The controlled traffic farming (CTF) confines all field traffic and compaction to permanent traffic lanes and reduces field trafficking (Majdan et al. 2011), improves the soil porosity and infiltration (Krištof et al. 2012; Smith et al. 2012). The soil compaction is one of the most important factors which influences the aeration of the soil, nutrient uptake efficiency, emissions of greenhouse gases like CO_2 and NO_x, and affects the quality of the soil tillage (Frančák et al. 2004; Páltik et al. 2007; Poničan, Korenko 2008; Findura et al. 2009). Precision agriculture increases the crop production efficiency (Krištof, Hašana 2007; Líška et al. 2008). The incorporation of the crop residues into the soil has been widely accepted to maintain soil fertility and enhance crop productivity. The incorporation of residues supplies additional C and N into the soil (Zou et al. 2004) and affects CO_2 flux (Reicosky et al. 2002). The soil tillage causes an accelerated flux of carbon dioxide emissions released from the soil into the atmosphere (Reicosky 1997, 2001; Buc et al. 2010; Krištof et al. 2011; Macák et al. 2011).

The aim of this paper was the comparison of the amounts of carbon dioxide emissions released from the soil into the atmosphere depending on the controlled traffic farming and crop residues.

MATERIAL AND METHODS

The experiment was carried out at the SUA University Farm Kolíňany Ltd., Kolíňany, Slovak Republic. The controlled traffic farming was implemented in a 16 ha field "Pri Jeleneckej ceste". The measurements of carbon dioxide emissions released from the soil into the atmosphere were realised after the harvest of wheat. The soil tillage was carried out by disc harrow Lemken Rubin 9 (Lemken GmbH & Co., Alpen, Germany) with the tractor John Deere 8230 (John Deere, Moline, USA).

There were three variants of the experiment:
- before the soil tillage,
- immediately after the soil tillage,
- seven days after the soil tillage.

Four monitoring points were selected:
- trafficked area with the crop residues (T-CR),
- trafficked area tracks without the crop residues (T-noCR),
- non-trafficked area tracks with the crop residues (nT-CR),
- non-trafficked area tracks without the crop residues (nT-noCR).

The amount of the crop residues was 0.897 kg/m^2. Loamy soil was studied. The soil bulk density for the trafficked and non-trafficked areas was 1.69 and 1.38 g/cm^3, respectively. The soil moisture content was measured by a gravimetric method and ranged from 11.54 to 12.31%, and pH in the trafficked area was 7.32 and 6.06 for H_2O and KCl, respectively. The non-trafficked area pH reaction was 7.37 and 6.11 for H_2O and KCl, respectively. The soil properties were analysed at the Department of Soil Science and Geology at the Slovak University of Agriculture in Nitra, Nitra, Slovak Republic.

Methodical procedure. The used method of measuring CO_2 emissions released from the soil into the atmosphere was that described by Šima et al. (2012). The laboratory method consists of collecting soil samples from the field and their subsequent analysis in the laboratory. Big sampling probes were inserted into the soil at 150 mm depth, the surrounding soil was removed and the sampling probes were closed up from the bottom. INNOVA devices (LumaSense Technologies, Ballerup, Denmark) were used consisting of a photoacoustic field gas monitor INNOVA 1412 based on the photoacoustic infrared detection method, a multipoint sampler INNOVA 1309 used for the transport of the gas samples to the gas analyser INNOVA 1412, and a notebook with the operation software used for the control and setup of the analysis.

Statistical analysis. The data were analysed by using the ANOVA or Kruskal-Wallis test after normality test by using the Kolmogorov-Smirnov test and the homogeneity of variance by using the Levene's test. With ANOVA $P < 0.05$ we continued in the post-hoc LSD test. With Kruskal-Wallis test $P < 0.05$ we continued in the post-hoc Turkey's HSD test. We used the software Statgraphics Centurion XVI.I (Statpoint Technologies, Warrenton, USA). The graphic processing of the results was performed using the software Statistica 7 (Statsoft, Tulsa, USA).

RESULTS AND DISCUSSION

The soil tillage, crop residues, and soil compaction affect carbon dioxide emissions released from the soil to the atmosphere (Fig. 1). A multifactor analysis of variance for CO_2 emissions was used. *P*-values for the time interval, variants and their

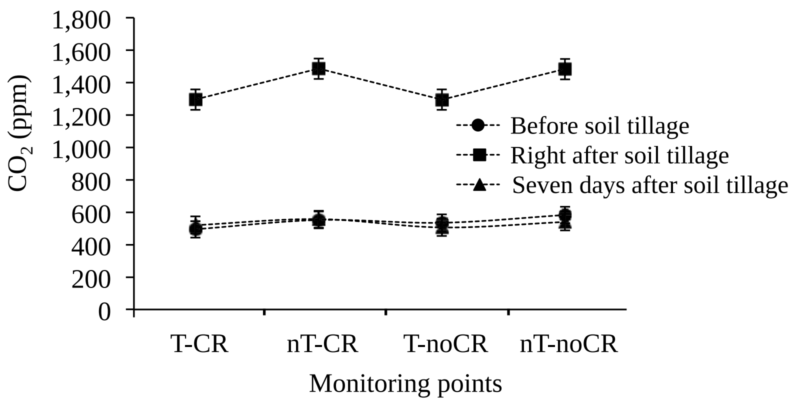

Fig. 1. Interactions and 95.0% confidence level for all variants of the experiment T-CR – trafficked area with crop residues; T-noCR – trafficked area without crop residues; nT-CR – non-trafficked area with crop residues; nT-noCR – non-trafficked area without crop residues

Table 1. Multiple Range tests 95.0% LSD for monitoring points

Monitoring point	Count	LS Mean	LS Sigma	Homogeneous groups	
T-CR	235	770.139	16.5052	×	
T-noCR	235	778.503	16.5052	×	
nT-CR	235	865.069	16.5052		×
nT-noCR	235	868.655	16.5052		×

LSD – least significant difference; LS – least squares; for abbreviations see Fig. 1

interaction were 0.0000, 0.0000 and 0.0083, respectively. Both factors had a statistically significant effect on CO_2 emissions at the 95.0% confidence level. Multiple Range tests for two factor affected CO_2 flux denote statistically significant differences between the trafficked and non-trafficked areas (Tables 1 and 2). The soil compaction significantly affects the flux of CO_2 released from the soil into the atmosphere at 95.0% confidence level. Tables 3 and 4 show that a statistically significant difference exists between the amounts of CO_2 emissions released from the soil into the atmosphere in the variant immediately after the soil tillage and those before the soil tillage and seven days after the soil tillage.

Table 2. Statistically significant difference for monitoring points

Contrast	Significant	Difference	+/– Limits
T-CR – T-noCR		–8.36405	45.7493
T-CR – nT-CR	*	–94.9297	45.7493
T-CR – nT-noCR	*	–98.5161	45.7493
T-noCR – nT-CR	*	–86.5656	45.7493
T-noCR – nT-noCR	*	–90.1521	45.7493
nT-CR – nT-noCR		–3.58647	45.7493

*denotes a statistically significant difference; for abbreviations see Fig. 1

Before soil tillage

By using the Kolmogorov-Smirnov test, we did not find a normal distribution for any sets of values tested. The Kruskal-Wallis test was used. The *P*-value of the Kruskal-Wallis test ($P = 0$) was below 0.05 indicating that a statistically significant difference existed between the medians at 95.0% confidence level. To determine which means were significantly different, the Multiple Range test Turkey HSD was used (Table 5). The carbon dioxide emissions released from the soil into the atmosphere were affected by the crop residues on the soil surface and the trafficked and non-trafficked areas in the field. Table 5 shows that there were statistically significant differences between the monitoring points. Leaving the crop residues on the soil surface positively affected carbon dioxide flux from the soil into the atmosphere in the untilled soil with 8.24% and 5.60% in the trafficked and non-trafficked area, respectively. A positive environmental effect of the crop residues on the soil surface before the soil tillage was 2.42% higher in the trafficked area. The soil surface without the crop residues was a more

Table 3. Multiple Range tests 95.0% LSD for the variants of the experiment

Variant	Count	LS Mean	LS Sigma	Homogeneous groups	
Seven days after soil tillage	344	531.212	13.4008	×	
Before soil tillage	360	541.035	13.0997	×	
Right after soil tillage	236	1389.53	16.1791		×

for abbreviations see Table 1

Table 4. Statistically significant difference for the variants of the experiment

Contrast	Significant	Difference	+/– Limits
Before soil tillage – right after soil tillage	*	–848.492	40.8015
Before soil tillage – seven days after soil tillage		9.82281	36.7296
Right after soil tillage – seven days after soil tillage	*	858.315	41.1755

*denotes a statistically significant difference

Table 5. Multiple Range test Turkey's HSD of samples before soil tillage

Sample	Count	Mean	Homogeneous groups			
T-CR	90	494.214	×			
nT-CR	90	552.04			×	
T-noCR	90	534.952		×		
nT-noCR	90	582.934				×

for abbreviations see Table 1

significant source of CO_2 emissions than the monitoring points with the crop residues. Emission flux from the trafficked area was lower than that from the non-trafficked area with 11.70 and 8.89% for the variants with and without the crop residues on the soil surface, respectively. These results (Fig. 2) are in agreement with the results obtained by Nozdrovický et al. (2011).

Immediately after soil tillage

By using the Kolmogorov-Smirnov test, we found a normal distribution for all tested sets of values. The ANOVA test was used. The *P*-value of ANOVA was below 0.05 (P = 0.036). There was a statistically significant difference between the means of values at 95.0% confidence level. To determine which means were significantly different, the Multiple Range tests LSD test was used (Table 6). The soil tillage had an effect on carbon dioxide emissions flux. Table 6 shows no statistically significant difference between releasing CO_2 emissions from the monitoring points with and without the crop residues incorporated into the soil. A significant difference was found between the trafficked and non-trafficked areas in the field. The CTF system significantly affected carbon dioxide flux. The soil from the non-trafficked area released more emissions than the trafficked soil (Fig. 3), with 14.72 and 14.57% for the variants with and without the crop residues incorporated into the soil.

Seven days after soil tillage

Using the Kolmogorov-Smirnov test, we found a normal distribution for all tested sets of values. The ANOVA test was used. The *P*-value of ANOVA was below 0.05 (P = 0.0000). A statistically significant difference existed between the means of values at the 95.0% confidence level. To determine which means were significantly different, the Multiple Range tests LSD test was used (Table 7). The measurement conducted seven days after the soil tillage showed a statistically significant difference in all variants of the experiment. The negative effect of the crop residues incorporated into the soil on carbon dioxide flux was 2.96 and 3.22% in the trafficked and non-trafficked areas, respectively. It may be have been caused by organic matter decomposition. The soil compaction affected CO_2 flux. There was a higher amount of CO_2 in the non-trafficked area, with 6.69 and 6.68% in the variants with and

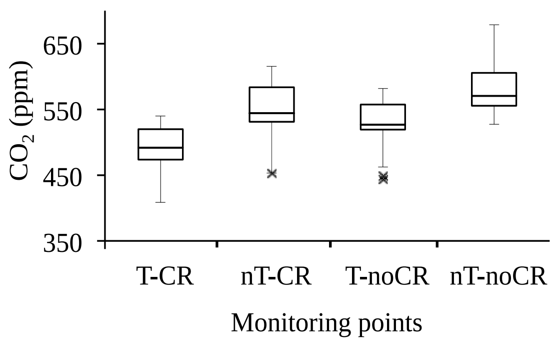

Fig. 2. Box-and-Whisker diagram of CO_2 concentration in monitoring points before soil tillage

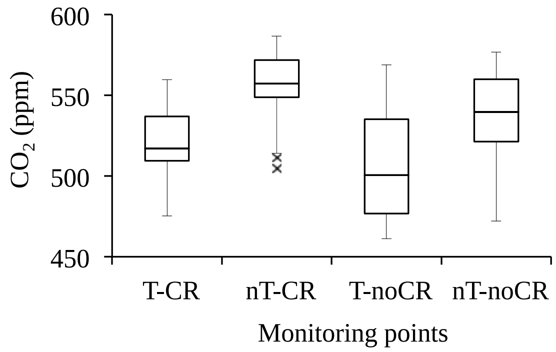

Fig. 4. Box-and-Whisker diagram of CO_2 concentration in monitoring points seven days after soil tillage

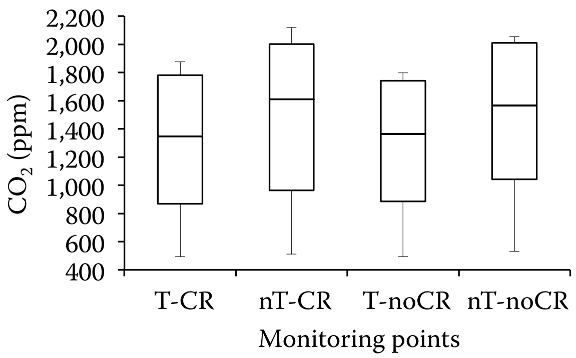

Fig. 3. Box-and-Whisker diagram of CO_2 concentration in monitoring points immediately after soil tillage

Table 6. Multiple Range test LSD of samples immediately after soil tillage

Sample	Count	Mean	Homogeneous groups	
T-CR	59	1,295.03	×	
nT-CR	59	1,485.72		×
T-noCR	59	1,294.36	×	
nT-noCR	59	1,483.0		×

for abbreviations see Fig. 1 and Table 1

Table 7. Multiple Range test LSD of samples seven days after soil tillage

Sample	Count	Mean	Homogeneous groups		
T-CR	86	521.176		×	
nT-CR	86	557.443			×
T-noCR	86	506.199	×		
nT-noCR	86	540.029		×	

for abbreviations see Fig. 1 and Table 1

without the crop residues in the soil, respectively. The CTF system and crop residues in the soil affected carbon dioxide flux. These results (Fig. 4) are in agreement with the results obtained by Buc et al. (2011).

CONCLUSION

Carbon dioxide emissions released from the soil into the atmosphere are one of the most important factors affecting the environment. The management of the crop production respecting environmental conditions may reduce carbon dioxide emissions in the global perspective. This study focused on analysing the effects of the crop residues left on the field and those incorporated into the soil in controlled traffic farming on releasing carbon dioxide emissions. The CTF system affects CO_2 flux, the amounts of emissions from the non-trafficked areas are higher than those from the trafficked areas. The crop residues left on the field decrease CO_2 flux. The effect of the crop residues on CO_2 emissions immediately after the soil tillage has not been shown. The incorporation of the crop residues causes an increasing CO_2 flux, which may be caused by organic matter decomposition.

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