Effect of Tillage Technology on Carbon Dioxide Emissions Released from Soil into the Atmosphere

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Abstract: *The tillage technology significantly affects the release of carbon dioxide (CO_2) emissions from the soil to the atmosphere as well as the actual time course of this release. With the device, ACE (Automated Soil CO_2 Exchange Station), allowing measurement of the amount of CO_2 emissions released from the soil to the atmosphere, it was confirmed that tillage disturbs the equilibrium of surface soil layers. From the results achieved in our field measurements which showed that the average amount of CO_2 emissions after the soil conservation tillage technology in 2009 was lower (3,698 $\mu mol.m^{-2}.s^{-1}$) than the conventional tillage technology (4,429 $\mu mol.m^{-2}.s^{-1}$). It follows that the soil conservation tillage technology leads to smaller values of soil respiration, which specifically means less CO_2 emissions released from soil into the atmosphere. In 2009 the average value of CO_2 emissions after conventional tillage technology with plough was above 19,7 % higher, compared with using soil conservation tillage technology based on mulch cultivator. The similar results were observed in 2010. For this year of observation it was found that the average CO_2 emissions after conventional tillage technology using plough was higher by 17,3 % in comparison with soil conservation tillage technology mulch cultivator. Both technologies varied also in the minimum and maximum values of CO_2 emission from soil into the atmosphere. Soil conservation tillage technology based on mulch cultivator enables to achieve significantly lower values in comparison with conventional tillage technology using plough. In addition, soil conservation tillage technology has also less dispersion in the values of CO_2 emissions for both reference years what can be explained by more uniform effects of this tillage technology on the soil environment.*

Keywords: *CO_2 emissions, tillage, tillage technology, soil conservation tillage, conventional tillage*

INTRODUCTION

The results from research in the world, as the Reicosky and Saxton [7] clearly speak in favour of new and improved tools for the soil conservation tillage technologies, which are characterized by a high potential for maintaining and increasing the level of carbon in the soil [2]. Support of this trend in the future will be beneficial not only for agriculture but also for the human population, which will have better opportunities to manage the global carbon balance [3, 4, 6].

The issue of effect of crop production systems, especially the tillage technology on CO_2 emissions released from soil into the atmosphere is intensively studied in research center North Central Soil Conservation Research Laboratory, Morris, Minnesota, USA more than two decades. The research centre conducted a broad and comprehensive research in this area which describe Reicosky and Lindstrom [5, 6] and Reicosky [3, 4], in terms of the effects of tillage technology on CO_2 emissions from soil into the atmosphere. Reicosky and Lindstrom [5, 6] in their research compared tillage technologies effect on the amount of CO_2 emissions released from the soil into the atmosphere.

Attention was devoted also in the effects of crop residues on the soil surface. It was found that the highest CO_2 flux from soil into the atmosphere was recorded immediately after conventional tillage using plough. In the next 19 days of observation the largest intensity of CO_2 emissions released from soil was recorded [7]. High initial levels of CO_2 flux from soil were directly related with increasing ploughing depth. The main reason the authors have identified was enlarged surface area characterized by larger inequalities and many cavities [2, 7].

The aim of this study was to compare the effect of conventional and soil conservation tillage technologies on CO_2 emissions released from soil into the atmosphere. The study was conducted in two years (2009 and 2010).

MATERIAL AND METODS

As experimental site was selected farm AGRO Division Ltd., Selice, which is located in corn production area and the area is characterized by very hot, very dry conditions, with

a relatively long growing season. Field measurements were carried out on the plot no. 261 with a total area of 14.27 hectares. For measurement of the amount of CO_2 released from soil into the atmosphere was used appliance ACE - Automated Soil CO2 Exchange Station [1]. ACE station is designed for long-term unattended field measurements of soil respiration. The base measurement unit of ACE system for observation of the CO_2 emissions is an infrared gas analyzer, which is located directly in the assembly of soil chamber (Figure 1). This allows a short transition between the soil chamber and separate analyzer. In the construction of the device use of hose or pipe is not needed, which could be characterized by the possibility of leakage of aspirated air samples [1]. Small distance between the soil chamber and analyzer provides an immediate opportunity to respond to changes in the exchange of CO_2 between the soil and the atmosphere. The design of the device is thus simple and at the same time expresses the necessary robustness for the field measurements [1,2].

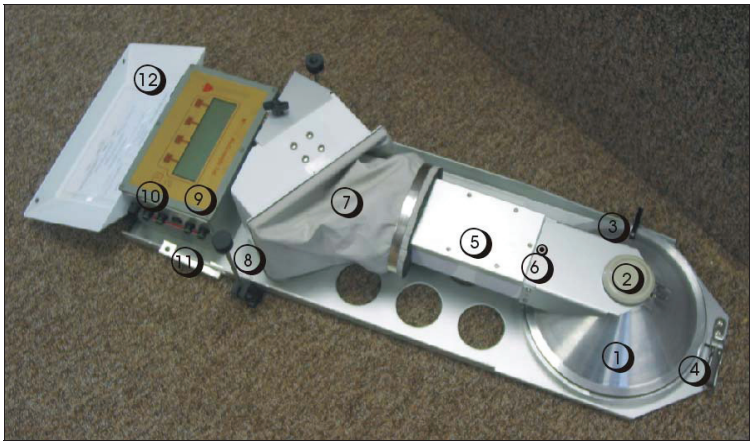

Figure 1 - Apparatus for measurement of CO_2 emissions released from soil - ACE Automated Soil CO_2 Exchange Station
(1 – soil chamber, 2 – pressure release valve, 3 – conduction chamber, 4 – fastening ring with buckle, 5 – swing arm, 6 – sensor PAR, 7 – deflection arm mechanism with a waterproof overlay, 8 – base, 9 - control panel, 10 – connectors for sensors, 11 – roller with lockable cover, 12 – sealable cover of control panel)

The ACE measurement unit allows to measure the CO_2 content in the standard range from 40,0 $mmol.m^{-3}$ (0 to 896 ppm at standard atmospheric pressure and temperature) to 0,05 $mmol.m^{-3}$ (1 ppm resolution). For the purpose of measuring CO_2 release from soil into the atmosphere ACE measurement unit can operate in two modes. In both modes of measurement, when the chamber is in a covered position, the amount of CO_2 emission is recorded as the difference between the reference gas entering the chamber and analyzed gas present in the chamber on the end of the experiment and each measurement cycle [1].

Statistical analysis of the results was performed using the statistical program Statgraphic Centurion XV.I. The results were evaluated by single-factor analysis of variance (ANOVA). By comparing the average values (LSD´s test, Seffe´s test) were found statistically significant differences at a significance level of $P < 0.05$ and finding correlations between observed variables. For comparison between the different levels of impact factor (eg. conventional tillage and soil conservation tillage technology) a Kruskal-Wallis test was used, which is used on values with a large variety. In this case, values of medians were compared instead of mean values.

RESULTS

The following table reflects the characteristics of descriptive statistics showing the data on CO_2 emissions released from soil into the atmosphere expressed in relation to the specific soil tillage technologies.

Table 1. Statistical characteristic of evaluated effect of soil tillage technology on CO_2 emissions released from soil into the atmosphere

Statistical parameter	CO_2 emissions from soil, $\mu mol.m^{-2}.s^{-1}$			
	Soil conservation tillage technology		Conventional tillage technology	
Year	2009	2010	2009	2010
Mean	3,698	3,712	4,429	4,357
Standard deviation	0,219	0,227	0,300	0,177
Skewness	-0,568	-0,583	-0,814	-1,143
Kurtosis	-0,815	-0,302	1,462	0,629
Minimum	3,23	3,26	4,07	4,12
Maximum	4,09	4,12	4,98	4,67
Range	0,86	0,86	0,51	0,55
c.v, %	5,922	6,122	6,779	4,079
N, count	24	24	24	24

Table 1 shows that the average amount of CO_2 emissions released from soil into the atmosphere after soil conservation tillage technology based on mulch cultivator in 2009 were significantly smaller (3,698 $\mu mol.m^{-2}.s^{-1}$), as after conventional tillage technology based on plough (4,429 $\mu mol.m^{-2}.s^{-1}$). It follows that the soil conservation tillage leads to smaller values of soil respiration, which specifically means less CO_2 emissions released from soil into the atmosphere. For example, in 2009 the average value of CO_2 emissions from soil into the atmosphere after conventional tillage by plough were increased by 19,7% in comparison with the use of soil conservation technology based on mulch cultivator. The same results were observed in 2010, when it was found that the average CO_2 emissions from soil after conventional tillage technology was higher by 17.3% in comparison with the use of soil conservation tillage technology. Both compared technologies varied also in the minimum and maximum values. Soil conservation tillage technology based on mulch cultivator was characterized by significantly lower values in comparison with conventional tillage technology by using plough. In addition, observations for soil conservation tillage technology had lower dispersion in value what can be explained by more uniform effect of soil conservation technology on the soil environment. Coefficient of variation was relatively balanced for soil conservation tillage (eg. 5,922 % in 2009 and 6,122 % in 2010), however, for conventional tillage by using plough it was 6,779 % in 2009 and in 2010 only 4,079 %.

Table 2 Effect of tillage technology on CO_2 emissions released from soil into the atmosphere using Multiple Range Test (95 % LSD method).

Year / Tillage technology	N	Mean CO_2 emissions, $\mu mol.m^{-2}.s^{-1}$	Homogenous groups	
			Group 1	Group 2
2009 / Soil conservation tillage	24	3,6987	X	
2010 / Soil conservation tillage	24	3,7129	X	
2009 / Conventional tillage	24	4,4296		X
2010 / Conventional tillage	24	4,3575		X

It was used a LSD Method (least squares method) as the most sensitive method of surface levels of evidence supporting factor. The test compared the two different tillage technologies: conventional tillage technology using a plough LEMKEN Eurodiamant 8 and

soil conservation tillage technology using a mulch cultivator SXH KOMONDOR K-600 in two years of study (2009-2010). Table 3 shows the significance of individual soil tillage technology which are marked with an asterisk. It means that the technologies marked with an asterisk are statistically comparable.

Table 3. Significant differences between compared tillage technologies

Contrast	Sig.	Difference	+/- Limits
2009,Soil conservation tillage – 2009,Conventional tillage	*	-0,73083	0,1349
2009,Soil conservation tillage – 2010,Soil conservation tillage		-0,01417	0,1349
2009,Soil conservation tillage – 2010,Conventional tillage	*	-0,65875	0,1349
2009,Conventional tillage – 2010,Soil conservation tillage	*	0,716667	0,1349
2009,Conventional tillage – 2010,Conventional tillage		0,072083	0,1349
2010,Soil conservation tillage – 2010,Conventional tillage	*	-0,64458	0,1349

*statistical significant difference (α = 0,05)

As follows from the results of analysis of variance it can be concluded that each tillage technology whether soil conservation tillage using mulch cultivator SXH KOMONDOR K-600 or conventional tillage using plough LEMKEN Eurodiamant 8 are statistically comparable and it was expressed in Table 3 and Figure 2.

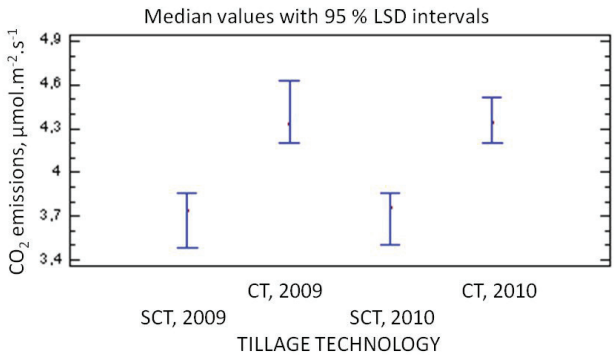

Figure 2. Box plot charts of CO_2 emissions released from soil into the atmosphere sorted for tillage technology and year of observation (CT – Conventional tillage; SCT – Soil conservation technology).

CONCLUSIONS

The results of our experiments show that the soil tillage technology significantly affects the amount of CO_2 emissions released from soil into the atmosphere. Using ACE device (Automated Soil CO_2 Exchange Station) allowing measuring the amount of CO_2 emissions released from soil into the atmosphere confirmed that soil tillage technology disrupts the equilibrium of soil surface layer. This is evidenced by our results concerning the comparison of the effects of conventional tillage technology using plough and soil conservation tillage technology using mulch cultivator. From the results obtained can be seen that the use of the plough caused a 1,2-times more releasing CO_2 emissions than using mulch cultivator. On the basis of our own knowledge and the knowledge gained from the study of literature can be said that research in this field needs to conduct complex experiments to gain insight into the long-term effects of wider range of tillage machinery on

the production of CO_2 emissions released from soil into the atmosphere, also taking into account other factors.

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