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The effect of soil tillage intensity on carbon dioxide emissions released from soil into the atmosphere

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Abstract. Soil tillage is among the factors which affect the amount of carbon dioxide (CO_2) emissions released from soil into the atmosphere. The objective of the study was to compare three tillage systems which overall represents the most commonly used systems. No-tillage, reduced tillage (shallow disc cultivation) performed by LEMKEN Rubin 9/600 KU disc cultivator and ploughing performed by LEMKEN EuroDiamant 8 mouldboard plough. Experimental area was divided into three replications of each tillage treatment as a randomized block design and the effect of soil tillage intensity on CO_2 emissions were observed in field conditions by using ACE device (Automated Soil CO_2 Exchange Station, ADC Bio-Scientific Ltd., UK). There were found an effect of soil tillage intensity on CO_2 emissions released from soil into the atmosphere. Increasing tillage intensity resulted in increasing rate of CO_2 emissions released from soil into the atmosphere where reduced tillage was reflected as 43% and ploughing as114% of this escalation. The results of our study supporting the more ecological effects of reduced tillage and no-tillage systems in comparison with widespread conventional systems by using mouldboard ploughs.

Key words: carbon dioxide, soil emissions, soil tillage.

INTRODUCTION

Chirinda et al. (2011) concluded that gas exchange between soil and atmosphere is an important factor which affects release of greenhouse gases into the atmosphere. There are three most important gases: carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Global climate change is a phenomenon which negatively affects the entire mankind. In this regard, among the most mentioned gases overall is a carbon dioxide (Goh, 2004). Agriculture is considered as one of the significant producer of carbon dioxide (IPCC 2007). The amount of emissions released from soil into the atmosphere is relatively low though in regards on total area of cultivated soils it represents a huge amount of carbon dioxide emissions (Krištof et al., 2011).

The research on CO_2 emissions released from soil into the atmosphere is realised by many, mostly terrain, methods: absorbing, gasometrical, gradient and micrometeorogical (Pumpanen et al., 2006; Šima et al., 2012). The extensive research on global climatic change leads to an extensive discussion about releasing of CO_2 emissions from soil into the atmosphere inducted by soil tillage. As Reicosky a Saxton (2007) indicated, conventional soil tillage based on using plough contributes on higher soil carbon losses through CO_2 emissions. But they also point, soil conservation tillage has a great potential to reduce the release of greenhouse gases from soil into the atmosphere. This phenomenon can be explained by the way how each tillage technology affects the soil environment (Carter et al., 2003a and 2003b). Since soil conservation tillage technologies are characterised by lowered tillage intensity and soil surface which reduce the extent of soil organic matter by oxidation processes (Batey, 2009) and therefore the release of CO_2 emissions from soil into the atmosphere. However, as Robertson et al. (2000) had stated, issue of the soil tillage technologies effect is only one of the whole complex system how agriculture affect the environment through production of greenhouse gases such as CO_2.

The primary process which is responsible for CO_2 emissions releasing from soil into the atmosphere is diffusion (Buchmann, 2000). It is affected by roots of plants and organisms of soil respiration, and soil organic matter decomposition (Normanet al., 1992). Future more, among other factors which directly affect the amount of produced emissions are counted: temperature, atmospheric pressure (Garcia et al., 2004), soil type (Welles et al., 2001), organic matter (Reicosky & Saxton, 2007), fertilisers (Li et al., 2004; Chirinda et al., 2011; Ludwig et al., 2011), soil compaction (Buc et al., 2011; Šima & Dubeňová, 2013; Šima et al., 2013a), soil tillage (Krištof et al., 2011; Šima et al., 2013b) and moisture (Norman, et al., 1992).

The objective of the study was to compare three tillage systems which overall represents the most commonly used systems (no-tillage, reduced tillage and ploughing) and its effect on carbon dioxide emission released from soil into the atmosphere.

MATERIALS AND METHODS

The experiment was placed in lands of AGRO Divízia ltd. Selice, cca 40 km from Nitra city during spring 2012 (Temperature range: 2–15°C; Average temperature: 7.9°C; Air humidity range: 31–81%; Air pressure range: 980–1,010 hPa; Rainfall: 0.6 mm). As a study area was selected flat land with balanced microrelief, high uniformity of soil conditions after year of dormancy. After soil sampling and following analysis where soil identified as a sandy loam (particles < 0.01 mm below 20–30%) with high soil organic matter and humus (3.00–4.99%) and neutral soil reaction (pH in H_2O: 6.9–7.3; pH in KCl: 6.5–7.2)

The area were divided and marked by wooden stakes in three replication of each tillage treatment as a randomized block experiment. Reduced tillage (shallow disccultivation) was performed by LEMKEN Rubin 9/600 KU disc cultivator, ploughing was performed by LEMKEN EuroDiamant 8 mouldboard plough and no-tillage areas with no cultivation.

For measurement of CO_2 emissions released from soil into the atmosphere were used ACE device (Automated soil CO_2 Exchange station produced by ADC Bio-Scientific Ltd., UK). The device is designed for automatic long term terrain measurement of soil respiration. The basis of device is infrared gas analyser which is placed directly inside of the gas chamber supplement. It allows tubeless and shortened transfer of gases between the chamber and analyser and prevents any leakage from the system. In addition, short distance between soil chamber and analyser provides immediate responsiveness on change of CO_2 exchange between soil and the air.

The data of CO_2 exchange between soil and air was observed for 30 days until seeding was conducted.

Obtained data where analysed by ANOVA analysis, LSD test after normality test by Kolmogorov-Smirnov procedure and homogeneity of variance by using Levene's test ($P < 0.05$ at 95% confidence level).

RESULTS AND DISCUSSION

Table 1 shows the effect of soil tillage intensity on carbon dioxide emissions released from soil into the atmosphere. While mean value measured on non-tilled areas was 2.014 μmol m^{-2} s^{-1} it is in contrast with obtained value at areas which was cultivated by LEMKEN Rubin 9/600 KU and even greater difference was observed in contrast with areas cultivated by LEMKEN EuroDiamant 8 mouldboard plough, 2.889 and 4.318 μmol m^{-2} s^{-1}, respectively.

Table 1. The effect of soil tillage intensity on carbon dioxide emissions released from soil into the atmosphere, μmol m^{-2} s^{-1} (n = 60)

Parameter	CO_2 emissions, μmol m^{-2} s^{-1}		
	No-tillage	Reduced tillage	Ploughing
Mean	2.014^{a}	2.889^{b}	4.318^{c}
Standard deviation	0.444	0.346	0.421
Min.	1.150	2.310	3.180
Max	2.960	3.380	4.990
Range	1.810	1.070	1.810
Coefficient of variation, %	22.064	11.993	9.750

Different letters in superscript (^{a,b,c}) mean the effect of the soil tillage intensity on carbon dioxide emissions released from soil into the atmosphere. It indicates that means are significantly different at $P < 0.05$ according to the LSD multiple-range test at the 95.0% confidence level.

While selected variants used in our study also represents a different systems of soil tillage it is possible to conclude that direct drilling (no-tillage) system is characterised by lowest influence on soil and therefore causes lowest CO_2 emissions released from soil into the atmosphere. If direct drilling will be taken as a basis for comparison then using reduced tillage system will be reflected as escalation by 43.44% in regards to CO_2 emissions released from soil. In comparison with systems using conventional ploughs it was increase by 114.39% which is more than double amount of CO_2 emissions and carbon loss from the soil. While in case of difference between reduced tillage and conventional tillage by using mouldboard plough it was only 49.46% increase it still means almost a half more CO_2 emissions released from soil.

As it was stated (Goh, 2004; Reicosky, 2007), the agriculture can change its role from CO_2 producer into CO_2 absorber. There are still many problems in terms of establishment and development of some crops in reduced tillage and no-tillage systems (Jones et al., 2006); however the global pressure to reduce air pollution should be taken into account even more. The measurement methods may be divided into many incomparable methods (Pumpanen et al., 2004), but all of them are trying to send out the same message. Greater intensity of soil tillage have an effect on CO_2 emissions released from soil into the atmosphere and lower intensity can reduce greatly the way how agriculture pollute the environment, moreover how agriculture can contribute in reduction of air pollution by greenhouse gases widely supported by many researchers (Reicosky, 2001; Lloyd % Taylor, 2004; Reicosky et al., 2005; Lal et al., 2007; Reicosky and Saxton, 2007, Khaledian et al., 2012).

CONCLUSION

From the analysis of measured data it is possible to conclude that no-tillage, direct drilling technology caused the lowest carbon dioxide emissions released from soil into the atmosphere in comparison with other tested technologies. Reduced tillage technology caused higher amount of CO_2 emissions then no-tillage but lesser then it was observed in case of use of conventional technology with using mouldboard plough. There is a great effect of soil tillage intensity on CO_2 emissions released from soil into the atmosphere and therefore a great effect from environmental perspective.

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