Scientific Papers. Series A. Agronomy, Vol. LXI, No. 1, 2018
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

CHISEL PLOW TILLAGE DEPTH EFFECT ON SOIL CARBON DIOXIDE EMISSION

Ghassan AL-AZZAWI, Davut AKBOLAT

Suleyman Demirel University, Faculty of Agriculture, Agricultural Machinery and Technologies Engineering Department, 32260, Isparta, TURKEY

Corresponding author mail: davutakbolat@sdu.edu.tr

Abstract

The aim of this study is to determine the effect of different soil tillage depth using chisel plow on soil CO_2 emission and some soil physical properties. The experiment was carried out using chisel plow at three depths of 15 (A), 25 (B), 35 (C) cm and control (D) treatment and three replications.
According to the obtained results, carbon dioxide emissions are determined for A, B, C and D treatment as: 0.148, 0.172, 0221 and 0.165 g m^{-2} h^{-1} respectively. The highest carbon dioxide emissions were obtained for C treatment and it is statistically significant ($p \leq 0.01$). Soil bulk density for A, B, C and D treatment are 1.33, 1.32, 1.24, and 1.39 g cm^{-3} respectively. The differences between soil bulk density, also porosity between treatments were not significant in statistical considerations ($p \leq 0.01$). Soil penetration resistance for A, B, C and D treatment found as 1.13, 1.12, 1.1, and 1.19 MPa respectively. The soil particle size also increased as the soil tillage depth increased. Soil evaporation for A, B, C, and D treatment found to be 4.51, 5.27, 5.76 and 5.26 g m^{-2} h^{-1} respectively.

***Key words**: chisel plow, soil carbon dioxide emission, tillage depth.*

INTRODUCTION

Soil contributes in global warming by producing main greenhouse gases like (CO_2, CH_4 and N_2O) and emitting these gases to the atmosphere (Batjes, 1996). In term of CO_2 emissions related to land use, soil management such as tillage and fertilization affect carbon build up in soil or the amount of atmospheric CO_2 (Nyakatawa et al., 2012). Soil mixing intensity has an effect on the amount of carbon (C) that disappears from the soil in the form of CO_2. Also, increasing aeration in the soil usually increases soil CO_2 emissions due to decomposition (Dao, 1998). In another hand, zero-tillage system (which considered alternative to conventional or reduced tillage) may enhance soil carbon in shallow soil surface but not in deeper layers (Luo et al., 2010). Furthermore, deep tillage improves soil physical properties and increases crops productivity (Qin et al., 2008; Sornpoon and Jayasuriya, 2013; Cai et al., 2014; Guan et al., 2014), as well, conventional tillage is reducing soil compaction more than no-tillage (Ferreras et al., 2000). Using tillage implements in minimal can reduce soil CO_2 emission by reducing the volume of disturbed soil. Also, reducing tillage depth will reduce influenced vertical soil section. This will reduce microbial potential to generate CO_2 when consuming soil organic matter (Beare et al., 1994), and will not increase exposing of soil surface to exchange more gases with atmosphere.

Soil also emits water vapor, which considered important greenhouse gas. Similar to CO_2, tillage had the ability to mitigate soil H_2O evaporation, by reducing soil compaction, which means more root expansion and utilization of soil water instead of transformation to vapor, by improving soil aggregates to holding water, and by increasing water to penetrate deeper in soil.

Most of researches that were conducted to investigate the effects of soil tillage on CO_2 emissions referred to the fact that the differing in tillage methods, systems or intensively will raise up CO_2 emissions. Researches supports this theory; La Scala et al. (2001) by comparing different tillage systems with non-tilled and Akbolat et al. (2009) by studying the effect of intensive tillage on soil CO_2, all found that the no tillage emit less than any used tillage systems in their experiments. But some other studies like Tóth et al. (2009) reported that ploughing will decrease CO_2 effluxes comparing to non-tilled soil. Also, Akbolat and Kucukalbay, (2014) stated that the direct seeding lead to more CO_2 emission than chiseling.

The amount of soil CO_2 emissions depends on soil moisture and temperature regime, soil type, land usage and production method as well as the amount of soil organic carbon and even crop type (Johnson et al., 2007; Wright et al., 2007; Chianese et al., 2009; Shrestha et al., 2009; Feiziene et al., 2010). Thus, dispute in results for above mentioned studies can be attributed to previous circumstances.

Besides that, soil cover like crop residue affect soil CO_2 emissions. According to Reicosky and Lindstrom (1993) report, more CO_2 emissions occurred when the wastes were mixed with the soil than when left on the soil surface. In addition, Akbolat and Ekinci (2017) had found similar results. Another research done by Silva-Olaya et al. (2013) and reached to that among all used tillage systems the deepest tillage with subsoiler (45 cm in depth) led to more CO_2 emissions in their experiment.

In term of effect of soil tillage depths Reicosky and Archer (2007) reached to that there is a significant difference in CO_2 emission when tillage by moldboard plow at different tillage depths CO_2 emissions were increased with the increasing of tillage depth.

As it can be seen from previous researches, it was not possible to find a study of soil tillage at different tillage depths with chisel plow. Therefore, the aim of this study is to determine the effect of soil tillage depth with the chisel plow on soil carbon dioxide emission.

MATERIALS AND METHODS

This experiment was carried out in Süleyman Demirel University (37°47′N; 30°30′E), Isparta province of Turkey. The soil of study area composed of 33.9% sand, 43.8% silt, 22.3% clay, and organic matter content of C 1.7% at the depth of 0-30 cm with pH 7.87 (Karatepe 2000).

The area was planted with wheat crop and the preparations for experiment implementation began in the day after harvest which was done in 19 July 2017. The average weight of crop residue and length of stubble that covered soil surface was about 6720 kg ha^{-2} and 12 cm, respectively. After the wheat crop harvested, the trial area was irrigated by sprinklers at six hours a day for two consecutive days, then it was left to reach the suitable moisture content for tillage. Based on tillage depths, the experiment had three treatments with three replications for each treatment, thus the total of plots was 12, each plot with dimensions of 3 × 40 m distributed according to randomize block design method.

Tractor with 90 HP was used for power requirement for tilling and chisel plow consists of 5 shanks, distance between front shanks is 50 cm and 25 in rear. The tillage depth was adjusted on the chisel plow shank for each parcel before starting to tillage.

Taking of soil samples, measuring of CO_2 and penetration resistance started immediately after the soil tillage is finished. As for Mean Weight Diameter of soil (MWD), the samples were taken in the following day. Determination of CO_2 emission continued for two months started with five consecutive days. An auger was used soil sample for bulk density and soil moisture.

Soil sample cylinder “Eijkelkamp” with volume of 100 cm^3 were used to collecting the soil samples. From every plot three samples at three different soil depths of 0-10, 10-20 and 20-30 cm taken and weighed by sensitive balance. Samples placed in the oven on 105°C for 24 hrs. after that the samples were cooled off out the oven for 30 min, then, reweighted to determine soil bulk density, porosity and moisture according to (Sims et al., 1994).

Penetrologger “Eijkelkamp” was used to take records till 40 cm soil depth, used cone was 2 cm^2 (base area) with 60° top angle. Data were statistically analyzed to investigate the effect of tillage depth on soil penetration resistance.

Samples equivalent to 2.5 kg from depth 0-30 cm were taken by shovel from each plot and left for 4 weeks to dry in the laboratory then treated by sieves that had diameters of 63, 32, 16, 8, 4, 2, 1, 0.5 and 0.25 mm and weighted by balance. Following equation was used to determine the mean weight diameters (Verhulst et al., 2013):

$$MWD = \sum_{i=1}^{n} X_i W_i \quad (1)$$

Where: MWD = mean weight diameter (mm);

Xi = (previous sieve diameter + diameter of current sieve) / 2 (mm); Wi = weight of sample in current sieve/whole sample weight (%).

PP SYSTEMS (PP Systems, Hitchin, UK) „Soil CO_2 flux system" were used in this experiment to investigate the effect of elected tillage depths on the emitted CO_2 from soil. This device consists of CO_2 CFX-2 flux chamber to measure CO_2 and temperature probe with switch in the device body to change between the soil or air measuring (Akbolat and Ark., 2009). Also, this integrated device measures water (H_2O) evaporation. The measurements were made on days of 0, 1, 2, 3, 4, 6, 9, 14, 20, 27, 32, 37, 42, 47, 56 and 63 after the tillage at the end of which soil CO_2 emission in the plots was near equilibrium. In addition, evaporation and soil temperature were concomitantly measured.

In same CO_2 measuring days, soil samples to the depth of 15 cm from every plot were taken by auger to determining the soil moisture. These samples were weighed then dried by oven on 105°C for 24 hrs. Tukey test with significance level $p \leq 0.01$ was adopted as statistical analyze method for the collected data.

RESULTS AND DISCUSSIONS

The average results obtained at the end of the study to determine the effect of soil tillage depth with chisel plow on soil carbon dioxide emissions are given in table 1.

Results taken directly after tillage referred to that there was significant effect of tillage depths on CO_2 effluxes ($p \leq 0.01$). As shown in the **Error! Reference source not found.**a, the treatment of C emitted more CO_2 than other treatments. This condition completely inverted in the second day. Carbon dioxide emission in all treatments were less than the previous day observations, furthermore, CO_2 emission in the D treatment was higher than the other treatments but the difference was not statistically significant.

Broadly, results for whole days show that the deep tillage (C) emit more CO_2 most of days after tillage followed by the control treatment (D) and even some days non-tilled emit the large quantity of CO_2 (**Error! Reference source not found.**).

These results were compared with weather conditions for the same period of experiment and found that the CO_2 was relatively affected by precipitation. When the soil humidity was decreased the emissions from all tilled soil was decreased too, nevertheless, the non-tilled soil seemed not affected too much comparing to the other treatments (Bowden et al., 1998) say CO_2 can affected by soil moisture and temperature, according to their laboratory study forest soil CO_2 efflux was less in the drier soil. Soil moisture may have affected by atmospheric relative humidity, the researches refer to a complex relationship between humidity, temperature, respiration and even clouds (Reicosky and Archer, 2007). The effect of rainfall was greater than the soil temperature on the CO_2 emissions for all treatments.

Rainfall prompted the soil to emit more CO_2 in all treatment, this effect is especially apparent on the 27th and 37th days after tillage.

Soil CO_2 efflux in D treatment seemed to be almost constant before the day 27th after tillage because of the undisturbed soil or the presence of straw on the soil surface, but it was greatly increased after this date due to the precipitation after the day 20th after the tillage. This condition is similar to (Akbolal and Ekinci, 2017) study that indicates no-till soil surface with straw emit less CO_2 than no-till with bare soil.

Soil carbon dioxide emissions in all treatments reached a minimum level on the 63th day after the tillage. For this reason, data recording has been finished this date.

First day measurement (zero day after tillage) showed that the soil water evaporation behaved like CO_2 emissions when the deep tilth led to more evaporation and non-tilled soil released less H_2O, the different here just the B treatment released more H_2O than the C treatment (Figure 1b).

By illustrating the soil moisture as a chart (considering that the soil moisture is the accountable factor for the water evaporation) and comparing it with this result will be clearly that there is a contradiction between soil moisture and H_2O evaporation regarding to the treatment of C and D. Maybe if the rest of soil properties like available water and field capacity took in account this confusion could be answered since soil moisture was taken up to the depth of 30 cm.

Table 1. The average results obtained at the end of the study

Treatment	Soil CO_2 Emission ($g\ m^{-2}\ h^{-1}$)	Soil H_2O Emission ($g\ m^{-2}\ h^{-1}$)	Soil Temperature (^{o}C)	Soil Moisture (%)
A	0.148^{b}	4.51^{b}	31.8^{b}	16.5^{ab}
B	0.172^{b}	5.27^{ab}	32.3^{ab}	17.3^{ab}
C	0.221^{a}	5.76^{a}	32.0^{ab}	18.3^{a}
D	0.165^{b}	5.26^{ab}	33.1^{a}	15.5^{b}

Means have the same letter at the same column are not significantly different from each other ($P \leq 0.01$).

In the second day (first day after tillage) the H_2O evaporation for all tilled treatments was decreased comparing with the zero day. The reason of this decreasing can be attributed to the same factors that effected the CO_2 emissions. As shown in Figure 1b, the emitted H_2O from non-tilled soil was orderly increased as a regular raised line till the 5th day of the experiment then sharply went down by 49% this may due to the slight decrease in soil and atmospheric temperatures and moisture as shown in Figures 1c and 1d. The rainfall had affective role on increasing of water evaporation (H_2O emission) for all treatments as shown in Figure 1b. Some rainy days (for example 27th and 37th day after tillage) raised the water evaporation more than the day when the tillage was performed. According to the analyzing of collected data after two months of the experiment regarding to soil water evaporation there was a significant difference between all the treatments at $p \leq 0.01$ (Table 1). The deep tillage which presented by C treatment led to more water evaporation than non-tilled (D) and shallow tillage (A, B).

The relationship between soil H_2O evaporation, temperature and CO_2 shown in Table 2. According to this table there is a positive but weak correlation between H_2O evaporation and soil temperature, also there is a positive correlation between H_2O and CO_2 $p \leq 0.01$.

The result in this experiment regarding to correlation between CO_2 and temperature is not conflict with result from (Qi and Ming Xu, 2001).

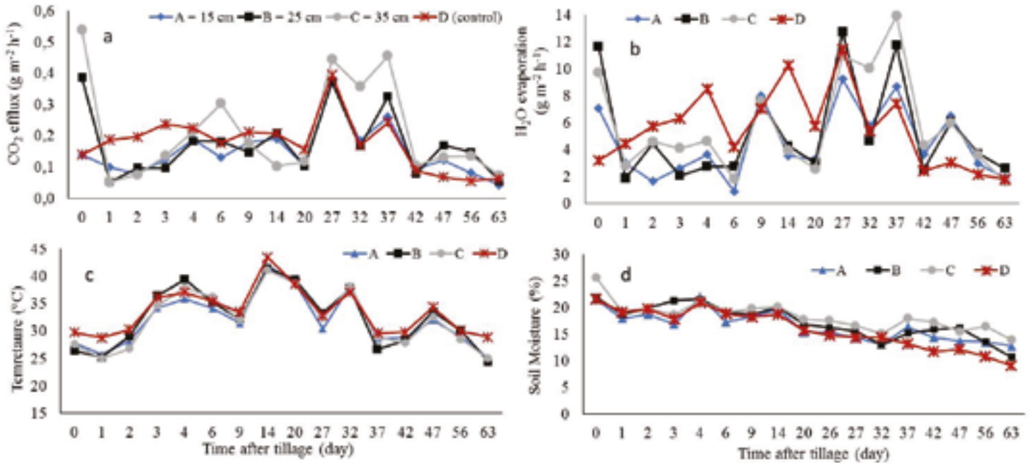

Figure 1. Results of CO_2 (a), H_2O (b), soil temperature (c), and soil moisture (d) depending on time after the tillage

Table 1. Correlation between soil CO_2, temperature and water evaporation

	CO_2	T	H_2O
CO2		0.022	0.481**
H2O	0.481**	0.066**	

** Correlation is significant at the 0.01 level.

The non-tilled soil (table1 and figure1c) was significantly warmer than the tilled soils $p \leq 0.01$.
The results of first day show that the treatment C had more soil moisture than other treatments (Table 1). All tilled soils kept the moisture more than non-tilled plots. the soil nematode values in all subjects declined gradually until the end of the experiment but were not affected by rainfall (Figure 1d.). Treatment of C in terms of soil moisture differed only from D treatment (Table 1).
As average in depth from 0-30 cm, bulk density and porosity had no significant differences between all of the treatments $p \leq 0.01$ (Table 3) Also, there were no differences between the treatments found in the same soil layer. Treatment of C in all soil layers had the lowest bulk density and highest porosity, even so, not considered statistically different $p \leq 0.01$. In the third soil layer (20-30 cm) each the A treatment and the D treatment had higher bulk density than the other treatments. Results in first 10 cm are with agreement with (Logsdon et al., 1999) when tilled soil had less bulk density than (D), but in opposed with it regarding to other depths.
Bulk density had entirely negative correlation with porosity (r= -684), and positive correlation with the depth of soil layer (r=0.684).As the soil depth increases, the bulk density was increased.
The depth of tillage made changes to the MWD (Table 4.) comparing to the non-tilled soil.

Table 3. Mean soil bulk density and porosity

Treatment	Bulk density (g cm^{-3})	Porosity %
A	1.33	49.7
B	1.32	49.8
C	1.24	52.9
D	1.39	47.5

Means have the same letter are not significantly different ($P \leq 0.01$).

As the mentioned table show the deep tillage impact the water stable aggregates by increasing the MWD. Non-tilled and shallow tillage soils were similar in the statistical analyzing estimations $p \leq 0.01$ with respect to the MWD. (Guedes Filho et al., 2013) claimed that the negative impact of chisel will last to 18 months when tilling to the depth of 25 cm, and the enhancement in other soil physical properties will extend to three seasons after tillage (Nunes et al., 2015). The positive effects of increasing in aggregate with large size caused by deep tillage can be come across reducing soil erosion and salting (Tatarko, 2001).
Mean weight diameter in tilled soil profile was increased significantly due to the deep tillage in treatments C and B comparing with D ($P \leq 0.01$), and reduced a bit in shallow tillage (difference is not significant at $p \leq 0.01$).The soil mean weight diameters of treatments is given in table 4.

Table 4. Mean weight diameter of treatments

Treatment	MWD (mm)
C	23.68 [a]
B	23.66 [a]
D	13.85 [b]
A	12.96 [b]

Means with same letters are not different ($p \leq 0.01$).

Decreasing soil penetration resistance means increasing of water penetration to deeper soil profile also allows plants roots to expand better in soil. Cone index was decreased with the increasing of tillage depth (Table 5), but these decreasing is not statistically significant at $p \leqslant 0.01$. As said by Zou et al. (2001) relationship between bulk density and soil hardness may vary according to soil roughness. But regardless of soil coarseness, at least in this study, soil bulk density gave more perception than penetration resistance in term of soil compaction. Also, bulk density described the inverse relationship between CO_2 emissions and soil compaction better than con index and this based on studies like (Torbert and Wood, 1992; Novara et al., 2012; Chappell and Johnson, 2015) that touched upon bulk density and soil CO_2 emissions. Procedures to determine bulk density may take more time comparing with cone index process(which was done by Penetrologger "Eijkelkamp" in this study) but it is seems that bulk density or porosity is more accurate than penetration resistance by describing the effects of tillage on soil compaction and CO_2 emissions. Hence, this study is conflict with Tavares et al. (2017) opinion.

Table 5. Mean penetration resistance of treatments

Treatment	Penetration resistance (MPa)
A	1.13
B	1.12
C	1.10
D	1.19

Means with same letters are not different($p \leq 0.01$).

In each treatment, penetration resistance was increased markedly with increasing in soil profile depth (0-40 cm). However, there was no difference between penetration resistance averages between treatments.

CONCLUSIONS

According to this experiment tillage with chiseling more than 35 cm led to more CO_2 emission and causing in more soil water evaporation. Precipitation have positive effect in term of increasing CO_2 emission and H_2O evaporation when tilling at any depth. The increase in tillage depth did not change the soil bulk density and porosity. C and B increased MWD significantly, while A decreased it with no meaningful change comparing with D. The soil penetration resistance did not change with the increase in soil tillage depth. According to the research results, the depth increases in the soil tillage with chisel plow increased soil CO_2 emissions. For this reason, deep tillage should be avoided in seed bed preparation for less greenhouse gas emissions in terms of environmental impact.

ACKNOWLEDGEMET

The data of this study were taken from the master's thesis titled „Effect of Different Depth of Tillage by Chisel for Seedbed Preparation on Soil Carbon Dioxide Emissions and Some Physical Soil Properties" We thank the SDU Scientific Research Projects Management unit for supporting the project numbered "5063-YL1-17".

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