Original Research

Influence of Seed Bed Preparation Methods in Chickpea Cultivation on Soil Carbon Dioxide (CO_2) Emissions

Davut Akbolat*, Murat Kucukalbay

Department of Farm Machinery, Agricultural Faculty, Süleyman Demirel University, 32260 Isparta,Turkey

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Abstract

This study determined carbon dioxide (CO_2) emissions from the cultivation of chickpeas cultivated in Usak using conventional wheat-chickpea crop rotation methods as a function of conventional tillage (CT), reduced tillage (RT), and direct seeding (DS). Measurements of carbon dioxide (CO_2) emissions from the soil were started after planting using a portable CO_2 measurement system (PP System) for a period of 55 days.

Our results indicated CO_2 emissions at rates of 4.1, 4.5, and 5.3 g·m^{-2}·h^{-1} in response to the CT, RT, and DS treatments, respectively. A significant difference was found between CT and RT, and CO_2 emissions under the DS treatment were higher than those of the other two treatments ($p<0.05$). Soil evaporation rates were estimated at 11.6, 10.9, and 13.1 g·m^{-2}·h^{-1} under the CT, RT, and DS treatments, respectively. Mean soil temperature was 17.5, 18.1, and 18.3ºC for the CT, RT, and DS treatments, respectively ($p<0.05$). Mean values of soil moisture content (wet base) after tillage were 19.7%, 19.1%, and 18.8% for CT, RT, and DS, respectively. Soil temperature and seedbed preparation methods appeared to influence soil CO_2 emissions.

Keywords: chickpea, direct seeding, soil CO_2 emission, tillage systems

Introduction

Carbon dioxide (CO_2) as one of the greenhouse gases contributes to global warming by about 60% [1]. Agricultural soils as a function of soil management such as tillage and fertilization practices play an important role as sources or sinks for atmospheric CO_2, thus affecting the global carbon (C) cycle [2]. Mixing intensity of the soil and the volume of the mixed soil are of great importance in that decomposition and mineralization of soil organic carbon (SOC) speed up as aeration in the soil increases, thus increasing soil respiration [3]. The amount and rate of CO_2 emissions from the soil also depend on soil moisture and temperature regimes, soil type, land usage, and cultivation methods, along with the amount of organic wastes mixed with the soil and irrigation methods [4-7]. Soil CO_2 emissions decrease with the adoption of reduced tillage and different soil tillage depths. For example, Akbolat et al. [8] found that the highest CO_2 emission was from conventional tillage including plough, whereas the lowest CO_2 emission was observed in the control treatment representing the no-till method. In another study out of three tillage widths and conventional width of plough tillage, the highest CO_2 emission was obtained with the conventional (full-width) method [9]. In comparing the conventional (CT), reduced (RT), and no-till (NT) systems in terms of CO_2 emission, the highest C sequestration was obtained with NT, followed by RT and CT [10]. In a short-term study examining CO_2

*e-mail: davutakbolat@sdu.edu.tr

Table 1. The description of treatments used in seed bed preparation.

Treatments	Description
CT (Conventional tillage)	Moldboard plow, one pass (tillage depth of 20 cm, tillage width of 90 cm, four bottoms) followed by cultivator, one pass (tillage depth of 15 cm, tillage width of 200 cm, 9 tines, share width 23 cm), Seeder is the same as used in direct seeding treatment.
RT (Reduced tillage)	Chisel plow, one pass (tillage depth of 30 cm, tillage width of 200 cm, 9 tines), followed by cultivator, one pass (tillage depth of 15 cm, tillage width of 200 cm, 9 shanks, share width of 23 cm), Seeder is the same as used in direct seeding treatment.
DS (Direct seeding)	Seeder mounted on the rigid tine cultivator, working width of 200 cm, inter-row spacing of 22 cm, share width of 5 cm.

emissions in sugar beet cultivation via conventional, reduced, and no-till cultivation systems, the highest CO_2 emission was recorded in the conventional system followed by reduced and no-till systems [11]. Short-term studies generally reported that CO_2 emission rapidly increases following tillage and then decreases to low levels, probably due to the discharge of gases accumulated in the pores and cavities prior to the process, or an attack by rapidly developing microorganisms [12, 13]. A study about the effect of plough tillage depths (102, 153, 203, and 280 mm) on soil C sequestration and CO_2 emission determined that 3.8, 6.7, 8.2, and 10.3 times more CO_2 emissions occured relative to the no-till system as a function of the tillage depths, respectively [14]. These results indicate that soil tillage depths and soil mixing intensity affects soil CO_2 emissions.

The cultivation of chickpeas among edible legumes ranks Turkey first in terms of both the amount and cultivated area. The objective of this study was to determine the effect of (CT), (RT), and direct seeding (DS) methods used locally for chickpea cultivation on soil carbon dioxide (CO_2) emissions.

Materials and Methods

The study was carried out on the wheat-chickpea crop rotation for the period of April 12 and June 6, 2013, in Uşak (38º24'N latitude and 29º23'E longitude with an altitude of 890 m).

The prevailing climate of Uşak is transitional between the Aegean and Central Anatolia regions, characterized as a continental climate. Summers are hot and dry, whereas winters are long and cold. Mean annual precpitation varies between 430 mm and 700 mm, with air temperature ranging from -24ºC to +39.8ºC. Most of the precipitation occrus during winter [15]. Soil texture of the study area is of clay (C) class consisting of 42.28% clay, 28.06% silt, and 29.66% sand, with an organic matter content of 2.12%. Crop residues from the previous harvest at the experimental site are negligible.

Soil tillage and planting methods used in this study are defined in Table 1. Conventional tillage (CT) is descibed as deep tillage with moldboard plow in autumn followed by a secondary seedbed preparation with cultivators in the spring before planting. Reduced tillage is defined as chisel plowing in spring followed by secondary tillage with cultivator and seeding. The direct seeding method was applied with a seeder mounted on a rigid tine cultivator in this study.

A 48 kW tractor was used as the power source during trials. The forward speed of the tractor was 3 $km \cdot h^{-1}$ and the engine speed was held constant at 2,000 rpm. The seeder used in chickpea production in trial is mounted on a rigid tine cultivator and its planting unit is operated by a chain gear driven from the support wheel.

The seeder used for planting in CT method was also used for planting in the RT treatment. The seeder used in CT and RT was also used as a direct seeding machine without tillage.

A randomized complete block design with three replications was selected for the experiment. The parcel width used in the trial was 4 m and the parcel length was 40 m.

In-situ soil respiration was measured using a CFX-2 soil CO_2 flux system (PP Systems, Hitchin, UK) consisting of integral CO_2 analyzer and H_2O sensor, soil respiration chamber, and soil temperature probe [8, 16, 17]. First measurements of soil CO_2 emission were made five minutes after the seeding. Three records were randomly taken at different locations from every plot within 90 s. A soil CO_2 emission chamber was installed 1.5 cm deep at randomly selected locations for the plots. The measurements were made on days 0, 1, 2, 5, 11, 13, 19, 22, 29, 37, and 55 after seeding, at the end of which soil CO_2 emission in the plots was near equilibrium. In addition, evaporation and soil temperature were concomitantly measured.

Soil samples acquired from a soil depth of 0-30 cm were analyzed at 105ºC for 24 hours, based on a gravimetric method for moisture content [18]. Soil samples taken from depths of 0-10, 10-20, and 20-30 cm were analyzed for the physical soil properties of bulk density and porosity according to Blake and Hartge [18]. The organic matter content was determined according to the Walkley-Black method [19], whereas soil texture was determined according to the Bouyoucos hydrometer [20] method.

Soil temperature was measured at the same time range of each day of testing with the soil temperature probe inserted into a soil depth of 20 cm into the soil at the randomly selected locations. Differences in soil resistance to

Table 2. Soil carbon dioxide emissions, evaporation, and soil temperatures.

Tratments	Time after seeding (day)												
	0	1	2	5	11	13	15	19	22	29	37	55	Mean
	Soil carbon dioxide emission (g $CO_2 \cdot m^{-2} \cdot h^{-1}$)												
CT (n=117)	8.4^{a}	3.9	3.2	4.2	3.1	3.4	5.5	2.0	0.4^{a}	2.3	4.0^{a}	8.1^{a}	4.1^{a}
RT (n=117)	4.8^{b}	4.8	2.3	5.6	3.3	4.5	4.7	1.4	3.8^{b}	1.6	3.6^{a}	13.4^{b}	4.5^{a}
DS (n=126)	19.8^{c}	2.7	2.6	6.1	4.4	4.8	4.4	2.8	0.4^{a}	1.2	6.6^{b}	7.2^{a}	5.3^{b}
	Soil evaporation (g $H_2O \cdot m^{-2} \cdot h^{-1}$)												
CT (n=117)	66.9^{a}	1.7^{a}	8.4^{a}	13.9^{a}	-3.3^{a}	2.5	-4.2	1.5	18.7^{a}	4.5^{a}	2.2^{a}	26.1^{a}	11.6^{ab}
RT (n=117)	51.2^{b}	3.5^{b}	1.8^{b}	33.1^{b}	3.7^{b}	2.8	-6.2	1.6	7.5^{b}	-1.5^{ab}	-0.5^{a}	33.7^{bc}	10.9^{a}
DS (n=126)	61.6^{a}	9.1^{c}	3.1^{ab}	20.0^{a}	1.2^{a}	3.9	-7.7	3.2	17.4^{a}	6.1^{ac}	10.8^{b}	28.7^{ac}	13.1^{b}
	Soil temperature (ºC)												
CT (n=117)	14.2^{a}	15.4^{a}	14.5^{a}	14.6^{a}	15.1^{a}	16.1^{a}	18.1^{a}	20.3^{a}	20.4	19.6	22.2^{a}	20.0	17.5^{a}
RT (n=117)	14.1^{a}	15.3^{a}	14.2^{a}	17.4^{b}	15.6^{b}	16.9^{b}	19.6^{b}	20.8^{b}	20.6	19.8	22.6^{ab}	20.3	18.1^{b}
DS (n=126)	15.6^{b}	16.7^{b}	15.6^{b}	15.9^{c}	16.4^{c}	16.6^{b}	19.3^{b}	20.8^{b}	20.6	19.6	23.1^{b}	19.6	18.3^{c}

Values in each column followed by different letters are statistically different at $P < 0.05$ level.

penetration among the treatments were measured after the tillage treatments using a digital penetrologger (Eijkelkamp Equipment, Model 06.15 Eijkelkamp, Giesbeck, The Netherlands).

Data were analyzed using the general linear model (GLM) procedures of SAS (SAS Inst. Inc., Cary, NC) by including treatments in the model, and PDIFF statements were used to compare treatment means for dependent variables at significance level of $P<0.05$ [21].

Table 3. Soil moisture content (%).

Treatments	0	13	15	19	22	29	Mean
CT (n=20)	24.3	20.1	19.3	18.1^{a}	17.8	18.7^{a}	19.7^{a}
RT (n=20)	24.6	19.6	18.3	17.1^{a}	17.3	17.3^{b}	19,1^{b}
DS (n=20)	23.8	19.9	18.8	16.5^{b}	16.6	16.9^{b}	18.8^{b}

Values in each column followed by different letters are statistically different at $P < 0.05$ level.

Results and Discussion

Experimental results for the predefined intervals right after planting based on the tillage and planting methods are presented in Table 2. Concurrently, evaporation (H_2O emission) and soil temperature records were recorded with the same system used for soil carbon dioxide measurement. As far as CO_2 emissions on different days of the experiment were concerned, no significant difference was found among the treatments for most days (days 1, 2, 5, 11, 13, 15, 19, and 29). Higher CO_2 emissions occurred with the DS treatment than with the others on day 0 after planting. CO_2 emission reached its lowest value on 22 days after planting, with more emissions from the RT treatment. There was no significant difference between CT and RT treatments in terms of average CO_2 emissions; however, CO_2 emission was higher with DS than with the others. This was contrary to the results by [11]; however, the DS by [11]; corresponded to data acquired from bare soil.

The differences among the treatments may mostly disappear if the first CO_2 emission measurements (0 days of experiment) 5 minutes after the planting are neglected. One of the reasons for high CO_2 emission values of the DT and DS treatments is the high evaporation value in these treatments. In addition, temperature also was effective on CO_2 emissions during the first day of DS treatment. CO_2 emissions measured in all the treatments after planting were high and had a tendency to decrease, which is in accordance with results obtained by [11]. Moreover, a two-year study in paddy cultivation [22] that is similar to our study revealed that the DS method released more CO_2 emissions than the traditional system, especially in the second year of the study. The reason for this was stated to be related to soil temperature, amount of standing biomass on the soil surface, and SOC content. Whereas no difference was detected in mean values of soil moisture content, lower soil moisture content was determined for the DS treatment on days 19 and 29. The average soil moistures of the RT and DS treatments were determined to be lower than that of CT (Table 3). The reason why the average soil moisture was high in CT treatment can be explained by the high moisture retention capacity of this treatment. The higher average soil moisture content of CT could be attributed to its high moisture-holding capacity.

The cumulative CO_2 emissions calculated for the 55 days after seeding are presented in Fig. 1. The CO_2 emissions reached the lowest level on the day 22 of the trial and

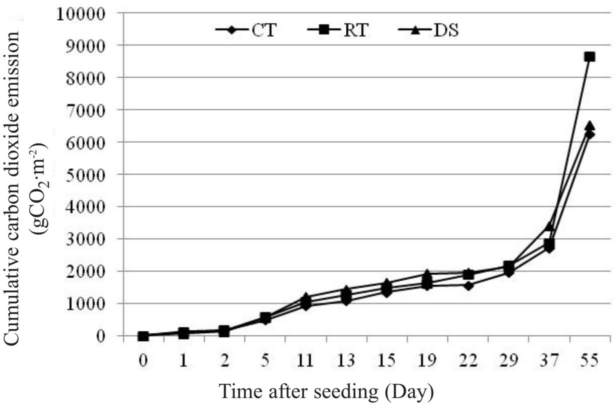

Fig. 1. Cumulative soil carbon dioxide (CO_2) emissions of the tillage methods as a function of time after seeding.

started to increase afterward. The reason for this may be rainfall before day 29, which appears to be effective on CO_2 emissions, given the soil moisture values on that day (Table 3). The cumulative CO_2 emissions were estimated at the end of the trial for the CT, RT, and DS treatments as 6,243.1, 8,661.8, and 6,527.3 g $CO_2 \cdot m^{-2}$, respectively. The cumulative CO_2 emissions of the RT treatment was higher than that of the other treatments. The average CO_2 emissions obtained in this study (4.1, 4.5, and 5.3 $g \cdot m^{-2} \cdot h^{-1}$) are quite a bit higher than those obtained by [8] in Isparta for CT, RT and NT (0.18, 0.09, and 0.03 $g \cdot m^{-2} \cdot h^{-1}$), respectively. These differences could be due to differences in climate, soil type, organic matter content, and soil moisture between the experimental sites. CO_2 emissions determined on the first day of this study under CT and RT (8.4 and 4.8 $g \cdot m^{-2} \cdot h^{-1}$) were lower than short-term CO_2 emissions for CT and RT after tillage (about 12 and 7 $g \cdot m^{-2} \cdot h^{-1}$) carried out by [23].

Even though the highest soil CO_2 emission was stated for the conventional tillage and seedbed preparations [10, 12], other studies have stated that there is no difference between the conventional and DS treatments in terms of CO_2 emission and that DS leads to more CO_2 emissions [24-26].

Unlike this study, some studies about DS treatment in the related literature have reported CO_2 emissions from fields that have not been planted or bare (control) soils. Deep ploughing was performed in the spring for the (CT) seedbed preparation for chickpeas. Planting was carried out at the same time for all the treatments, whereas seedbed preparation was carried out one day prior to planting for the CT and RT treatments. On the other hand, soil mixing in the DS treatment during the planting increased due to the low row spacing (22 cm), even though planting was carried out on NT soil. This resulted, on average, in higher soil CO_2 emissions from the DS treatment than from the others. In a study by [27], the highest CO_2 emissions were obtained in the CT treatment. However, CO_2 emission values for the DS treatment during the first two days after planting were higher than those of the other treatments.

Soil evaporation that was generally in parallel with CO_2 emissions was determined to be quite high for all three treatments during the first record after planting, but decreased gradually in the following days. Negative evaporation values recorded on the 15th day after planting showed that soil evaporation in the soil was lower than the atmosphere, because the soil acted as a sink. The high evaporation rate for the last record (on day 55) appears to be related to rainfall before day 55.

Soil temperature is another significant factor that affects soil CO_2 emissions. Soil temperature was low during the planting and increased gradually at the beginning of June. The increase in soil temperature was attributed to the air getting warmer. Soil temperature was on average estimated at 17.5ºC, 18.1ºC, and 18.3ºC for the CT, RT, and DS treatments, respectively. CO_2 emissions for the CT, RT, and DS treatments were in a linear correlation with temperature. These results are in agreement with the linear relationship stated by Jabro et al. [17] between soil temperature and soil CO_2 emissions.

Changes occur in the soil pores of the soil, especially due to the repetitive use of tillage equipment causing changes in bulk density and penetration resistance.

It may be possible to establish a correlation of soil CO_2 emissions with soil pores, bulk density, and penetration resistance. In this study, soil penetration resistance, soil porosity, and bulk density were determined in order to evaluate the physical properties of the soil. The penetration resistances determined at tillage depths of about 0-40 cm are presented in Fig. 3. There is a distinct difference between the penetration resistances of the treatments at 0-25 cm (plough tillage depth). Average penetration resistances of 0.76, 0,95, and 1.04 mPa were determined at a tillage depth of 0-25 cm for the CT, RT, and DS treatments. Penetration resistances were on average 1.13, 1.27, and 1.28 mPa at soil depth of 0-40 cm, respectively. Similarly, [28] determined penetration resistances of 0.76 mPa and 1.03 mPa for the CT and DS treatments at a soil depth of 45 cm. Due to deep tillage of the CT treatment with plough, soil resistance and bulk density are expected to be low, whereas porosity is expected to be high. On the other hand, high penetration resistance is also expected in the DS treatment on which no tillage was carried out. Penetration resis-

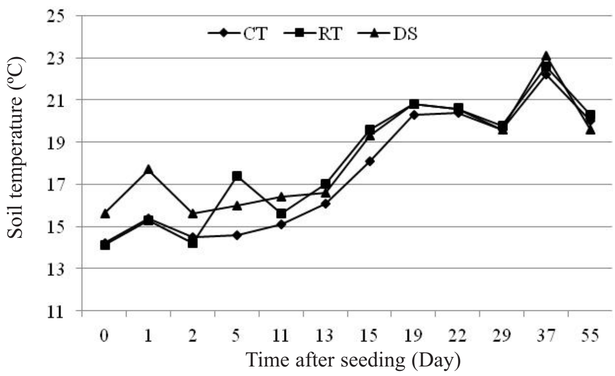

Fig. 2. Soil temperature of the tillage methods as a function of time after seeding.

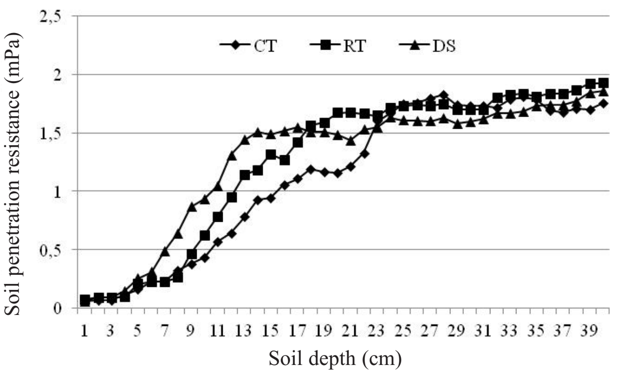

Fig. 3. Soil penetration resistance as a function of tillage depth and tillage methods.

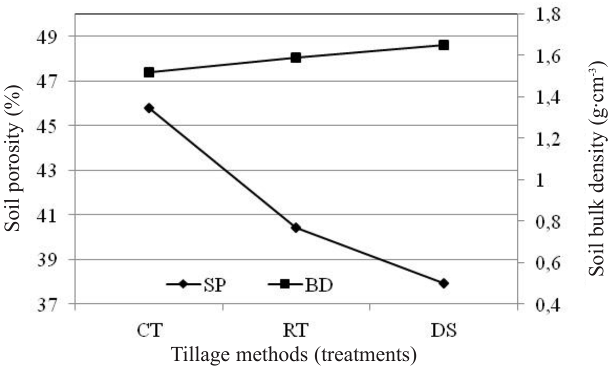

Fig. 4. Soil porosity (SP) and bulk density (BD) of tillage methods.

tance of the treatments was very close to each other for the part after tillage depth (25-40 cm).

Results of penetration resistance obtained in this study for the treatments are supported by [27]. Based on the assumption that porosity is high at low penetration resistances, CO_2 emission is most likely to increase soil aeration. Undisturbed soil samples taken after the planting for soil porosity and bulk density at a soil depth of 0-30 cm are presented in Fig. 4.

Mean soil porosity and bulk density of the treatments are presented for soil depths of 0-10, 10-20, and 20-30 cm in Fig. 4. Soil porosities for the CT, RT, and DS treatments were 45.7%, 40.4%, and 37.7%, respectively. According to treatments, bulk density values in the same order were determined to be 1.52, 1.59, and 1.65 g cm^3. Lower porosity and higher bulk density values were determined for the DS treatment not tilled at the soil depth of 30 cm than for the other treatments. However, a relationship between the CO_2 emissions for the treatments could not be established based on these results.

Conclusions

The highest CO_2 emissions were obtained with the DS in this study. The differences between soil temperatures support the differences between CO_2 emissions.

There is a linear relationship between soil CO_2 emission and soil temperature based on the treatments. In many soil tillage studies, the highest CO_2 emission was obtained with the CT treatment, and the lowest CO_2 emission was determined in the NT system. In this study, CO_2 emissions were determined in increasing order of CT, RT, and DS treatments. Similar results have been obtained from very few studies. This may be atributed to the difference in soil temperature and seedbed preparation for the CT and RT treatments prior to planting. Average CO_2 emissions under the DS treatment during the first record after the seeding was 2.35 times more than that of the CT treatment and 4.12 times more than that of the RT treatment. The high CO_2 emission under the DS treatment might be due to the narrow row spacing (22 cm) special to chickpea seeding, causing high soil mixing. As a result, the soil temperature differences among the treatments and the regional seedbed preparation methods characterized by the trial might have led to these results. However, lower inputs required and higher additions of organic matter to the soil involved in the DS method than in the other methods still enhance the ecological value of the DS method.

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