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EFFECT OF DIFFERENT MANURE APPLICATIONS AND WETTING-DRYING CYCLES ON CO_2 EMISSIONS FROM SOIL

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Abstract

Organic carbon is transformed into CO_2 by various interventions applied to the soil and diffuse to the atmosphere. The manures which used unconscious under available soil moisture and temperature condition makes the soil microorganism activity increased. This causes CO_2 emission increase as well by oxidation of organic matter. In this study, it was aimed to evaluate different amounts of sheep (20, 40 and 60 t ha^{-1}) and poultry (15, 30 and 45 t ha^{-1}) manure under different wetting-drying cycles (irrigation intervals of 3, 6 and 9-days) in terms of CO_2 emission and to understand the relationship of soil temperature and soil moisture with CO_2 emission. The study was conducted according to arranged in a complete randomized block design with three replications as a pot study in greenhouse conditions. The frequent irrigation and using high amount of manure increased CO_2 emissions. Although the same amount of organic matter was provided to the soil in different amounts of sheep and poultry manures, CO_2 emission was higher in sheep manure. Soil temperature increased by irrigation at infrequent intervals and high amount of manure. Moisture retention in the soil increased by using high amount of manure. The linear relationship of soil temperature (R^2=0.922) and soil moisture (R^2=0.895) with CO_2 emission was found to be quite significant ($P<0.01$). As a result of the study, using low amount of poultry manure (15 or 30 t ha^{-1}) instead of sheep manure and irrigation at infrequent intervals (9-days) can be suggested as precautions to decrease CO_2 emissions.

Key words: CO_2, irrigation interval, manure, soil organic matter, wetting-drying cycles

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1. Introduction

The amounts of CO_2 emissions readily generated by anthropogenic effects increases continuously in the atmosphere. The agricultural sector contributes significantly to this increase (Dias Feiber et al., 2020; Tubiello et al., 2015). CO_2 emission in the agricultural sector is caused by livestock activities and mismanagement of the land used in crop production. CO_2 emission from soil occurs as a result of organic carbon mineralization, which is an indicator of soil fertility, loss of carbon causes global warming and as well as poor soil. Although CH_4 and N_2O cause global warming 21 times and 310 times more than CO_2, respectively (Forster et al., 2007), 82% of CO_2 share among greenhouse gases considers CO_2 as the most important greenhouse gas (Thangarajan et al., 2012).

CO_2 emission from the soil is affected by many variables such as soil moisture, temperature and tillage (Evans and Burke, 2013), and physical, chemical and biological properties of soil (Haddaway et al., 2016). Soil moisture provides more carbon gain to the soil from plant roots and residues (Entry et al., 2008). Increased microbial activity with increased soil moisture causes decomposition of organic matter and thus increasing CO_2 emissions (Jabro et al., 2008; Liu et al., 2008). When soil pores are completely saturated with water, CO_2 emission reaches the peak level (Hou et al., 2016). The amount and interval of irrigation affect soil biology and change the organic matter dynamics in the soil (Li et al., 2010), thereby

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triggering the emission. Soil wetting-drying cycles and processes greatly affect carbon and nitrogen mineralization (Morugán-Coronado et al., 2011; Shi and Marschner, 2014). Especially in arid or semi-arid regions, remoistening of dried soil can increase the microbial activity rate (Lamparter et al., 2009). Soil temperature affecting the biological activity of soil is an important factor for CO_2 emissions. There is a positive linear relationship between soil temperature and CO_2 emissions (Rey et al., 2011; Sainju et al., 2008). However, CO_2 emission may tend to increase or decrease depend on the change of soil temperature with water intake into the soil. Intensive soil tillage provides a favourable environment for microbial activities, both by increasing the O_2 level of the soil and by ensuring closer contact of the surface residues with the soil particles and thus lead to increased emission.

Organic manures increase both sustainable management and fertility of the soil by improving soil properties. Organic manures contribute positively to nutrient availability, water holding capacity, biological activity, cation exchange capacity and many properties of the soil (Bhatt et al., 2019; Zhang et al., 2020). These contributions are significant advantages in increasing crop production but increased microbial activity together with organic material enriched in the soil may cause an increase in CO_2 emissions. Especially by using of various manures, increasing organic carbon in the soil becomes the main source of CO_2 emissions in conditions where the soil is mismanaged (Johansen et al., 2013). Organic carbon loss from the soil can be affected by the quantity and quality of the manure. The components of manures consisting of different amounts of organic matter depend on the diet regime of the animal, the method and environmental conditions under which the fermentation processes are applied and also the C:N ratio of manure can affect the CO_2 emission (Al-Kaisi and Yin, 2005) by changing the decomposition duration and rate of organic matter (Zheng et al., 2021). Low C:N ratio promotes faster microbial activity (Awasthi et al., 2018) and causing more CO_2 emission.

The amount of CO_2 in the soil is 30-40 times more than the atmosphere (Karberg et al., 2005) and 3 times more than crops (Granier et al., 2000). In fact, the soil is not only a factor for CO_2 emission but also it is a reserve. As long as soil carbon, which is the main factor of CO_2 emission from the soil, is trapped in the soil, both CO_2 emissions can be decreased and soil fertility can be increased (Mancinelli et al., 2010). For this reason, the studies for terrestrial carbon sequestration have increased. However, little is known about the effects of different manures and wetting-drying cycles of the soil on CO_2 emission. This study was hypothesized that increasing the amount of manure under frequent irrigation intervals would increase CO_2 emissions due to intense mineralization of organic matter. The objectives of this study were: (i) compare different mixing amount of the sheep manure and poultry manure under different irrigation intervals (wetting-drying cycles) in terms of soil CO_2 emission (ii) establish if the soil treated with different irrigation intervals and amounts of manure, represents a source or a sink of organic carbon (iii) understand the relationship of soil temperature and soil moisture with CO_2 emission.

2. Material and methods

The study was carried out in a greenhouse of Van Yuzuncu Yil University (38°34'50.9"N, 43°16'50.6"E) in 2020. During the study, the mean temperature inside the greenhouse was determined as 24±2°C and humidity 50±5%. The study was organized considering the different amounts of sheep and poultry manures and different irrigation intervals as 3, 6 and 9-days (wetting-drying cycles). The sheep and poultry manures were applied in the amount of 20, 40 and 60 t ha^{-1} and 15, 30 and 45 t ha^{-1}, respectively. The recommended amount of sheep manure was taken into consideration and the amount of poultry manure was adjusted according to sheep manure to provide the same amount of organic matter to the soil. The study was conducted according to arranged in a complete randomized block design with three replications as a pot study and the locations of the pots were changed randomly every week.

The air-dried soils were sieved through 2 mm sieves. The determined amount of manures mixed with soil was placed in 5 kg plastic pots with a diameter of 26 cm preserving their natural volume. Soil texture and specific gravity were determined according to bouyoucos hydrometer (Gee and Bauder, 1986) and picnometer methods (Blake and Hartge, 1986), respectively. Bulk density was determined by cylinder method (Blake and Hartge, 1986) and porosity was calculated according to Danielson and Sutherland (1986). Aggregate stability was determined by the wet sieving method (Kemper and Rosenau, 1986) and soil reaction (pH) and electrical conductivity (EC) in the saturation extract were determined via using pH-meter and conductometer, respectively. Calcareousness ($CaCO_3$) was determined by Scheibler Calcimeter method (Nelson, 1982). Total nitrogen and organic matter were determined by Kjeldahl (Bremner and Mulvaney, 1982) and Walkley-Black methods (Nelson and Sommers, 1982), respectively. Organic Carbon was calculated according to Avramidis et al. (2015). The soil was classified as clay loam by USDA classification and some properties of the soil were given in Table 1. Also some properties manures were given in Table 2.

The irrigation water with pH of 7.27 electrical conductivity of 0.675 dS m^{-1} and sodium adsorption ratio of 0.27 was used for irrigations. The first irrigation was applied on the same day to bring all the applications to the field capacity and then irrigation interval applications were started and totally of seven irrigations were applied for each application. The irrigation quantities for each application were applied according to bringing the current moisture to the field capacity at the time of moisture measurement. TDR probe was used to measure the soil moisture (IMKO, 2018). The field capacity value of the soil (non-manure) was 0.175 m^3 m^{-3}. It was determined 0.184, 0.189, 0.198, 0.184, 0.188 and 0.193 m^3 m^{-3}, respectively for the amount of sheep manure (20, 40 and 60 t ha^{-1}) and poultry manure (15, 30 and 45 t ha^{-1}).

CO_2 emissions were measured 24±2 hours after the irrigation of each application. Three CO_2 measurements were made for each application. CO_2 emission was measured between 8-12 am (Mancinelli et al., 2015) to decrease diurnal variation in the CO_2 emissions without exception (Adviento-Borbe et al., 2007). CO_2 emission was measured with a gas analyzer instrument (EGM-5, PP Systems, Stotfold, UK), which a portable dynamic closed chamber infrared gas analyzer system (Pumpanen, 2004). The non-steady-state through flow chamber (SRC-1, PP Systems, Stotfold, UK; volume 1334 cm^3, area 78.5 cm^2) had only one opening to the soil.

CO_2 emission was measured only as heterotrophic (microbial) since the study was conducted in pots without crops. Besides, soil temperature that was recorded simultaneously with CO_2 emission, was measured at depth of 5 cm (Buragiene et al., 2019) with an STP-1 soil temperature probe connected to the EGM-5. TDR probe was used to determine the soil moisture at every CO_2 emission at the time of measurement.

Statistical analyses were performed by using the SPSS software, v23.0 (Yuzuncu Yil University, BBAUM). ANOVA analysis was applied to CO_2 emissions, soil moisture and temperature data. Duncan's multiple range test was used to compare significant means. The correlations of CO_2 emissions with soil temperature and soil moisture were determined using the same statistical package.

3. Results and discussion

CO_2 emission increased by irrigation at frequent intervals (Fig. 1). In sheep manure applications, the increase in CO_2 emission was significant with the decrease of irrigation intervals in 3 and 6-day irrigation intervals, while the significant effect was observed in poultry manure especially in the 3-day irrigation interval and with increasing amount of manure (Table 3).

The results of variance analysis for the effects of amount of sheep manure, poultry manure and irrigation intervals on CO_2 emissions, soil temperature and soil moisture are given in Table 4. All manure applications, irrigation intervals and the interaction of manure-irrigation intervals resulted from important effects statistically on these parameters.

Table 1. Some properties of soil used in the study

Properties	***Soil***	***Properties***	***Soil***
Soil Texture	Clay loam	Aggregate Stability (%)	44.3
Sand (%)	33.3	$CaCO_3$ (%)	9.30
Silt (%)	34.6	pH	8.32
Clay (%)	32.1	Electrical Conductivity (dS m^{-1})	2.145
Bulk Density (g cm^{-3})	1.38	Total Nitrogen (%)	0.095
Specific Gravity	2.78	Organic Matter (%)	1.42
Porosity (%)	50.4	Organic Carbon (%)	0.82
C:N Ratio	8.63		

Table 2. Some properties of manure used in the study

Properties	***Sheep***	***Poultry***
pH	9.07	4.17
Electrical Conductivity (dS m^{-1})	4.131	6.592
Total Nitrogen (%)	1.61	1.73
Organic Matter (%)	27.87	37.71
Organic Carbon (%)	16.16	21.87
C:N Ratio	10.04	12.64

Table 3. Relationship equations for CO_2 emissions with irrigation period in different manure and irrigation interval applications

Applications	***3-days***		***6-days***		***9-days***	
	Equation	R^2	***Equation***	R^2	***Equation***	R^2
Non-Manure	y=-0.006x+0.277	0.120	y=-0.012x+0.289	0.421*	y=-0.025x+0.248	0.973**
Poultry 15 t ha^{-1}	y= 0.006x+0.466	0.050	y= 0.005x+0.434	0.185	y=-0.017x+0.469	0.738**
Poultry 30 t ha^{-1}	y= 0.082x+0.443	0.849**	y= 0.025x+0.551	0.202*	y=-0.004x+0.535	0.021
Poultry 45 t ha^{-1}	y= 0.053x+0.619	0.767**	y= 0.014x+0.711	0.096	y=-0.006x+0.683	0.039
Sheep 20 t ha^{-1}	y= 0.079x+0.381	0.954**	y= 0.055x+0.414	0.951**	y= 0.007x+0.422	0.085
Sheep 40 t ha^{-1}	y= 0.050x+0.565	0.587**	y= 0.065x+0.549	0.748**	y= 0.022x+0.560	0.263*
Sheep 60 t ha^{-1}	y= 0.029x+0.739	0.369*	y= 0.048x+0.628	0.802**	y= 0.045x+0.563	0.678**

** represent P<0.05 and ** represent P<0.01.*

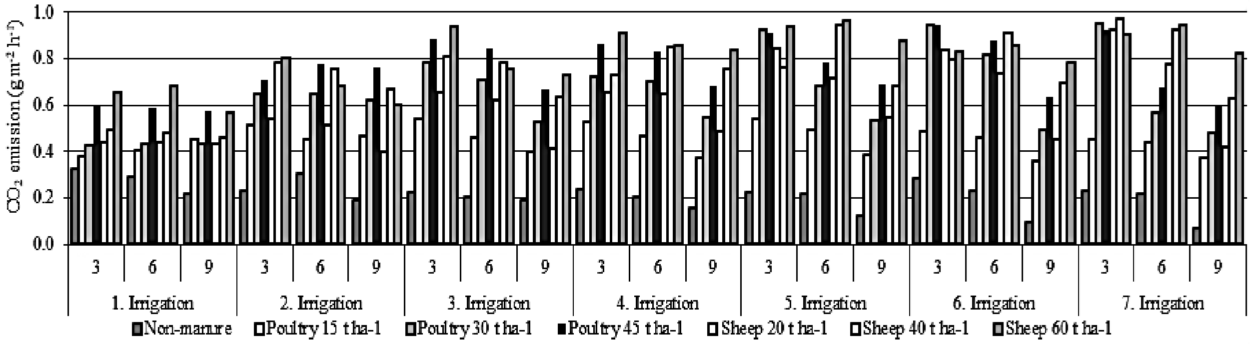

Fig. 1. The effect of manure applications and irrigation intervals on CO_2 emission (g m^{-2} h^{-1}) during irrigation period

Table 4. The means of CO_2 emission, soil temperature and soil moisture values under different applications and the statistical analysis results

Applications	*CO_2 emission (g m^{-2} h^{-1})*				*Soil temperature (°C)*				*Soil moisture (m^3 m^{-3})*			
	3-days	*6-days*	*9-days*	*Mean*	*3-days*	*6-days*	*9-days*	*Mean*	*3-days*	*6-days*	*9-days*	*Mean*
Non manure	0.2522 l**	0.2389 l	0.1483 m	0.2131 G**	22.5 n**	23.2 m	25.5 efg	23.7 E**	0.168 i **	0.167 i	0.166 j	0.167 F**
Poultry 15 t ha^{-1}	0.4910 i	0.4547 j	0.4012 k	0.4490 F	23.9 l	23.6 l	25.0 ij	24.2 D	0.174 fe	0.173 eg	0.172 gh	0.173 E
Poultry 30 t ha^{-1}	0.7729 d	0.6520 g	0.5197 h	0.6482 D	24.9 j	25.3 fghi	24.6 k	24.9 C	0.180 d	0.179 d	0.178 d	0.179 C
Poultry 45 t ha^{-1}	0.8330 b	0.7691 d	0.6604 g	0.7542 B	25.0 ij	25.6 ef	26.0 cd	25.5 B	0.185 b	0.185 b	0.184 c	0.185 B
Sheep 20 t ha^{-1}	0.7004 f	0.6370 g	0.4497 j	0.5957 E	25.2 ghij	25.1 hij	26.2 b	25.5 B	0.174 f	0.173 feg	0.171 h	0.173 E
Sheep 40 t ha^{-1}	0.7663 de	0.8081 c	0.6473 g	0.7406 C	25.3 fghi	25.4 fgh	25.5 efg	25.4 B	0.179 d	0.176 e	0.176 e	0.177 D
Sheep 60 t ha^{-1}	0.8557 a	0.8213 bc	0.7454 e	0.8075 A	26.1 bc	25.9 de	27.0 a	26.3 A	0.188 a	0.187 a	0.188 a	0.188 A
Mean	0.6674 A**	0.6259 B	0.5103 C	-	24.7 C**	24.9 B	25.7 A	-	0.178 A**	0.177 B	0.176 C	-

** represent P<0.05 and ** represent P<0.01.*

The results of variance analysis for the effects of amount of sheep manure, poultry manure and irrigation intervals on CO_2 emissions, soil temperature and soil moisture are given in Table 4. All manure applications, irrigation intervals and the interaction of manure-irrigation intervals resulted from important effects statistically on these parameters.

In all applications, CO_2 emission decreased by increasing irrigation intervals and decreasing amount of manure. The highest CO_2 emission was obtained from the sheep manure 60 t ha^{-1} application with irrigated at 3-day interval (0.8557 g m^{-2} h^{-1}) and it increased by approximately 240% compared to non-manure applications. The lowest CO_2 emission was obtained from the non-manure applications by irrigated at 9, 6 and 3-day intervals, respectively (Table 4). Indirect effects of the manures on soil organic matter, soil reaction and salinity of the soil cause changes in CO_2 emission (Lal and Singh, 2000). We found that manures used in this study increased the CO_2 emission by promoting microbial activity probably. The bulk density of the soil decreases with the high amount of organic matter and decreased bulk density has been shown to affect negatively soil ecology by decreasing the numbers of soil bacteria, fungi and actinomycetes by almost 40% (Chaudhari et al., 2013) and thus decreases the CO_2 emission. In this case, in our study, it can be said that there is an inverse relationship between bulk density and CO_2 emission. For these reasons, the physical, chemical and biological properties of the soil and the manure are significant in terms of CO_2 emission. Especially manures that do not apply any thermal procedure in the decomposition and disintegrate processes, can cause higher amounts of CO_2 emission since they have easily biodegradable carbon. Yanardağ et al. (2015) were determined that the CO_2 emission from soil treated by manure was higher than in soils treated by pig slurry and biochar.

CO_2 emission varied in all applications depends on the wetting-drying cycle of the soil (Fig. 1, Table 4). CO_2 emission was higher in applications irrigated at frequent intervals (0.6674 g m^{-2} h^{-1}). We found that continuous water supply to the soil promotes microbial activity, increasing CO_2 emission by degradation of organic matter. Mineralization of carbon and nitrogen has been significantly affected by the soil's wetting-drying cycle (Yu et al., 2014). This effect is only related to the intensity and duration of the wetting-drying periods, as well as the amount of available organic substrates. In our study, the highest emission values were obtained from applications that were irrigated at 3-day intervals and had the highest manure amount.

We found that soil temperatures increased by increasing manure amounts and irrigation at infrequent intervals. The highest soil temperature was obtained from the sheep manure 60 t ha^{-1} application with irrigated at 9-day interval (27.0ºC). The lowest soil temperatures were obtained from the non-manure applications (Table 4).

According to the results obtained from this study, although the organic carbon and nitrogen content of poultry manure was higher than sheep manure which is shown by Table 2, CO_2 emission was lower in poultry manure. We can be explained by the fact that the high C:N ratio decreases the mineralization of organic matter (Awasthi et al., 2018) and also poultry manure that has low pH and high salinity, may be related to the decrease of soil pH and increased salinity and thus preventing microorganism activity in the soil and decreasing CO_2 emission as Zhai et al. (2011) stated. similar to the results we obtained, Sitaula et al. (1995) and Sakin and Yanardag (2019) stated that CO_2 emission from soil with pH 4 may be 2-12 times higher than soil with pH 3, CO_2 emission decreases with the increase in soil electrical conductivity, respectively.

Soil temperature increased as the amount of manure applied to the soil increased (Fig. 2, Table 4). We thought that the soil temperature increased as a result of a chemical reaction of the mineralization of organic matter. Cassman and Munns (1980) stated that soil temperature changes due to nitrogen mineralization, and Simeckova et al. (2016) stated that different manure applications have a significant effect on soil temperature and this effect varies according to different depths of the soil. The reason why poultry manure had lower soil temperature than sheep manure may be explained to slower mineralization due to lower pH, higher electrical conductivity and C:N ratio. Soil temperature was lower in applications that were irrigated at frequent intervals. This situation was related to the cooling of the soil and the decrease of the soil temperature by the water intake into the soil.

Soil moisture increased by frequent irrigation intervals and increase in manure amounts. The highest soil moisture was obtained from sheep manure 60 t ha^{-1} application (0.188 m^3 m^{-3}) and the effect of irrigation intervals in this application was statistically similar (Table 4). The lowest soil moisture was obtained from the non-manure application irrigated at 9-day interval (0.166 m^3 m^{-3}).

Higher moisture content and lower moisture loss were obtained from applications of enriched manure. In the study conducted by Devi et al. (2013) manure increases the moisture retention in the soil by increasing the number of pores and pore size distribution of soil and the specific surface area of soil. The manure increased soil biopores, soil aeration, better soil aggregation, soil organic carbon and total nitrogen can increase water holding capacity (Gangwar et al., 2006). However, this increase may vary depending on some chemical and physical properties of manures (Katkar et al., 2012). Although the total nitrogen and organic carbon amount of poultry manure were higher than sheep manure, soil moisture was lower than sheep manure (Fig. 3). This situation is thought to be related to the chemical properties of poultry manure and the effect of these chemical properties on the soil. The soil moisture was higher in frequent irrigated applications. This situation is explained to the continuous supply of irrigation water to the soil keeps the activity of microorganisms constantly alive, and therefore faster mineralization and consequently increase in water holding capacity of the soil.

In our study, linear regression analysis results showed that the relationship of soil temperature and soil moisture with CO_2 emission was quite significant (Fig. 4). CO_2 emission increased by increasing of soil temperature and soil moisture values. Similar to the results we obtained Sainju et al. (2008) stated that there is a positive linear relationship between CO_2 emission and soil temperature, and Jabro et al. (2008) reported that soil temperature increases CO_2 emission by 59%. However, we found that the soil temperature may decrease with irrigation and precipitation water intake into the soil and thus CO_2 emission may tend to increase or decrease depend on the increase of soil moisture. In infrequent interval irrigations, rewetting of dried soil or deficit irrigation techniques can decrease CO_2 emission (Yerli et al., 2019) due to the conservation of organic matter (Denef et al., 2001).

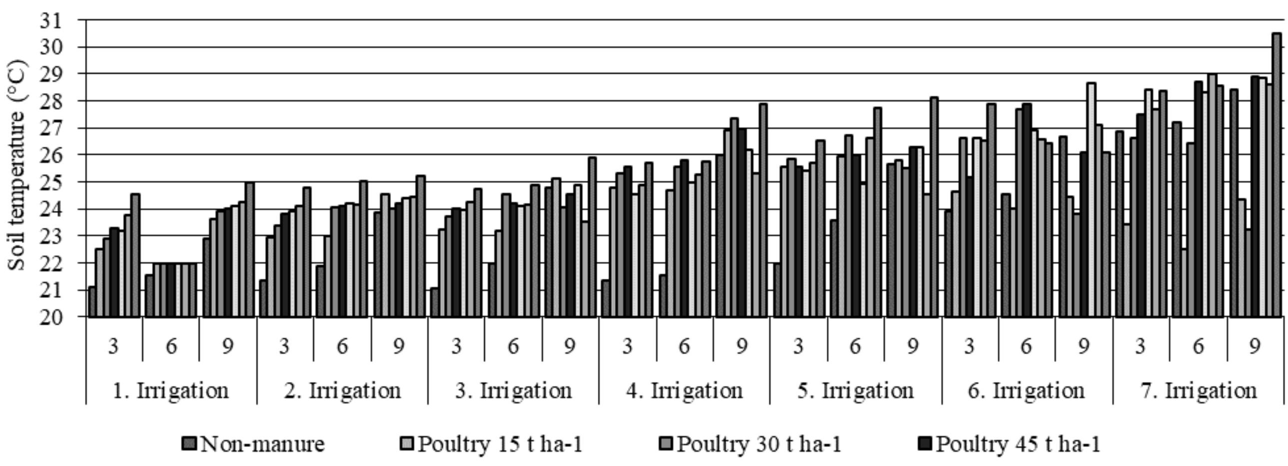

Fig. 2. The effects of manure applications and irrigation intervals on soil temperature (°C) during irrigation period

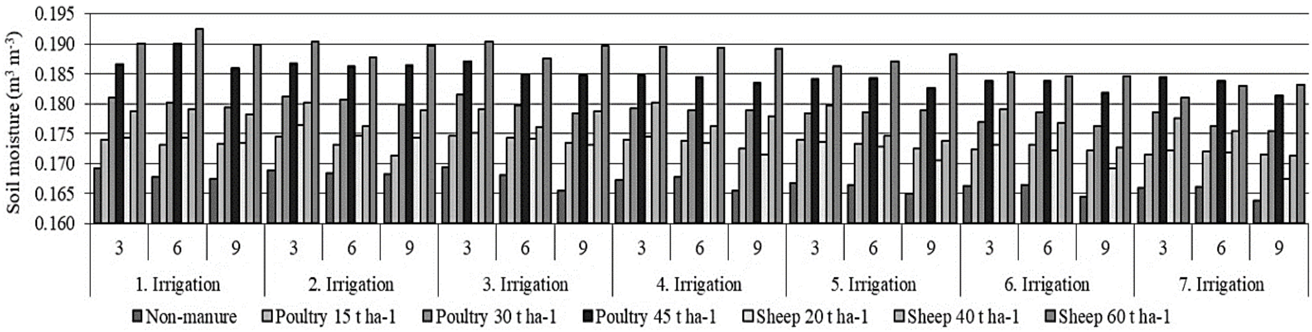

Fig. 3. The effect of manure applications and irrigation intervals on soil moisture (m^3 m^{-3}) during irrigation period

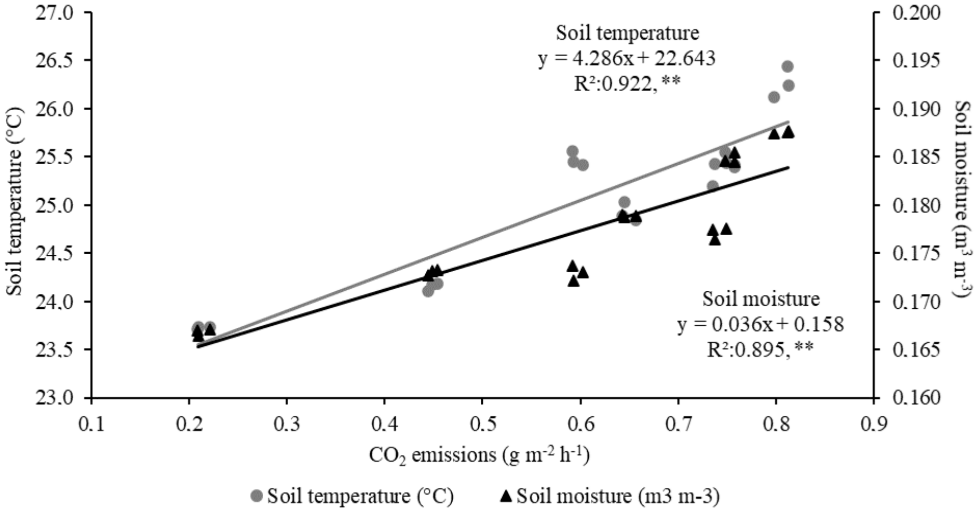

Fig. 4. The linear relatioships of the soil temperature and soil moisture with CO_2 emission

Zornoza et al. (2016) found that deficit irrigation decreased CO_2 emissions, similarly, Mancinelli et al. (2015) stated that at the levels that 100%, 75% and 50% of evapotranspiration is applied, CO_2 emission from the soil increases with the increase in the amount of irrigation. The findings and views made about the relationship of soil temperature and soil moisture with CO_2 emission support the findings of this study.

4. Conclusions

This study examining the effects of different manure applications and wetting-drying cycles on CO_2 emission were resulted in higher CO_2 emission by increasing manure amount and irrigation at frequent intervals due to the increase in organic matter mineralization.

The lowest emission amounts were from non-manure applications (0.2131 g m^{-2} h^{-1}*)* since they had lower organic matter than the manure applications. The highest emission amounts were from 60 t ha^{-1} poultry manure applications (0.8075g m^{-2} h^{-1}*)*. From the applications irrigated at intervals of 3, 6 and 9 days, the emission values were 0.6674, 0.6259 and 0.5103 g m^{-2} h^{-1}, respectively. Continuous water supply to the soil, that is irrigation at frequent intervals were caused higher CO_2 emission as it increased the soil microorganism activity. Since the increase soil microorganism activity due to the increase in soil temperature and moisture, CO_2 emission has increased accordingly.

When the poultry manure and sheep manure applications that provide the same amount of organic matter to the soil are examined, poultry manure has occurred a lower emission amount. This situation is related to the change of soil chemical properties such as soil reaction, electrical conductivity, total nitrogen, organic matter and carbon with the application of manure to the soil.

Although the manures have a significant role for increasing the emission of greenhouse gases, the emission amounts can be decreased by the manures to be used depend on the chemical content of the manure and the soil properties.

As a result of this study, we found that irrigation at infrequent intervals (9-days) and using low amounts of poultry manure (15 or 30 t ha^{-1}) instead of sheep manure is effective for decreasing CO_2 emission. However, there is a need for more long-term and large-scale studies for CO_2 emissions from soil and manures with different characteristics and relationships between physical, chemical and biological properties of soils with CO_2 emissions.

As a result of all these studies, by using suitable manures for every soil characteristic, plant-soil fertility would be increased and CO_2 emission would be decreased.

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