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The Response of CO_2 Flux to Soil Warming, Manure Application and Soil Salinity

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ABSTRACT: In this research effect of different soil types (normal and saline), farmyard manure norms (2 ton/ha - 4 ton/ha), manure application techniques (surface and subsurface) and soil temperature levels (20-25°C, 25-30°C, 30-35°C, 35-40°C, 40-45°C and 45-50°C) were examined of the soil CO_2 flux on the pots at the laboratory conditions. According to obtained results, soil type (ST), manure norm (MN), manure application technique (MAT) and soil temperature (T) values changed CO_2 flux. CO_2 flux value of saline soil condition smaller than the normal soil condition. As an expected result, increased the manure amount increased the CO_2 flux from soil to atmosphere. However, CO_2 flux on the condition that subsurface manure application was less than surface manure application. CO_2 flux values at the high soil temperatures were more than low soil temperature conditions. According to the interaction (T*ST, T*MN and T*MAT) results were not statistically significant. Soil CO_2 flux were affected by gradually increasing of temperature.

Keywords: CO_2 flux, farmyard manure, saline soil, soil respiration, temperature

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INTRODUCTION

There are a few main factors effecting soil CO_2 flux such as soil organic matter content, soil type, soil tillage and management systems, root respiration etc. Soil compaction, soil moisture, temperature, and fertilization also effect CO_2 flux from soil to the atmosphere. In addition, global warming close interaction with amount of CO_2 into the atmosphere (Van Groenigen et al., 2014). Decomposition of soil organic matter cause CO_2 flux (Kuzyakov 2002; Fender et al., 2013). CO_2 flux can also be named as soil respiration or basal respiration (Jassal et al., 2004). Fertilization especially N fertilization accelerate CO_2 flux due to effect root development (Shao et al., 2013) and microbial activity (Yan et al., 2010). This situation cannot be acceptable all the soil conditions. Some of the researchers stated that N fertilization either increase or decrease of soil carbon amount (Yan et al., 2010; Ni et al., 2012; Ding et al., 2010).

The application of farmyard manure into the soil increase level of CO_2 flux (Fangueiro et al., 2008). Farmyard manure can be applied in two different methods. The first of this method is surface manure application that manure lay on the soil surface. The second method is subsurface application that manure mixed with soil approximately 15 cm soil depth with a farm machinery such as rotary tiller. In this way manure both decomposed and lay on subsurface of the soil homogeneously (Fangueiro et al., 2008). Liquid manure application within the soil is another application method. According to some of the researchers, liquid farmyard application within the soil decreased N transport (Daverede et al., 2004). In addition, liquid farmyard manure application caused less NH_3 flux from soil to atmosphere compare to the others application methods (Misselbrook et al., 1996).

Soil temperature and soil moisture affect to soil CO_2 flux due to affect microbial activity directly (Risk et al., 2002). There are a lot of experimental research about effects of soil temperature and moisture content on the CO_2 flux (Lloyd and Taylor 1994). There is a positive relation between soil temperature and CO flux. Soil respiration amount increased with increase the soil temperature approximately 20% (Kirschbaum 1995; Rustad et al., 2001). William et al. (1994) stated that there is a positive linear correlation between soil temperature and CO_2 flux, but this relation was not observed with soil moisture content. They observed a decrease level of CO_2 flux on the condition that high soil moisture content. Similarly, Lou et al. (2003) observed soil CO_2 flux more affected by soil temperature, than soil moisture content and amount of organic matter. Lu et al. (2008) reported that the increase of soil temperature by -2 to +2 °C increased the amount of soil respiration and as a result of this situation decomposition of the soil organic matter increased. Another factor that affected soil CO_2 flux is salinity. Xie et al. (2009) reported that in the saline soil condition soil CO_2 flux less (0.3-3 mmol/m^2/s) than normal soil condition. The reason of this result is inorganic and non-biological process into the saline soil condition.

The aim of this research examines effects of soil type, manure amount and application methods and levels of soil temperature on the soil CO_2 flux from soil to the atmosphere in the laboratory condition.

MATERIAL AND METHODS

In this study two different types soil (normal and saline), two different farmyard manure norms (2 ton/ha and 4 ton/ha), two different manure application methods (surface and subsurface) and five different soil temperature ranges (20-25°C, 25-30°C, 30-35°C, 35-40°C, 40-55°C, 45-50°C) were examined at the laboratory conditions.

Saline and normal type soil samples provided East of Iğdır pasture and West of Iğdır pasture, Turkey respectively. East of Iğdır, pasture has saline soil properties. In this region soils have salinity properties as a result of wrong field application such as excess irrigation, conventional agriculture etc. The properties of the soil that used laboratory experiments were given in Table 1. Before the experiments soil samples were sieved by sieving machinery at the 50Hz. At the end of the sieved, <1mm, and >8 mm aggregate size eliminated out of the soil samples because this particle size groups not appropriate for seed–bed condition (Eghball et al., 1993). Aggregate size between 1 mm and 8 mm were added into the pot and used in the experiments. Fermented cattle farmyard manure was used in the experiments at the amount of 2-4 t/ha. Some of the farmyard manure properties were given in Table 2.

Table 1. Properties of soil samples

Soil properties	Normal soil	Saline soil
Soil texture	Clay-loam	Clay-loam
$CaCO_3$	6.53%	10.2%
EC	0.0054 dS/m	1.228 dS/m
pH	8	9.3

EC: Electrical conductivity

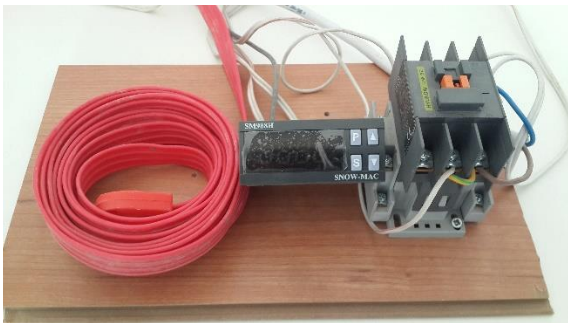
Table 2. Chemical content of the farmyard manure

Properties	Values
Organic matter	352 g/kg
pH	7.2
EC	3.4 dS/m
N	16 g/kg
P	8.2 g/kg
K	6.9 g/kg
Ca	65 g/kg
Mg	5.8 g/kg

The manure used in the experiments was applied two different application methods as surface and sub-surface. Manure had been homogenously layed on the soil surface as surface application method. In the subsurface application manure layed on the 10 cm soil depth and then mixture with a paddle.

A flex type temperature resistance used in the laboratory experiments. The resistance layed on the soil surface approximately 15 cm soil depth. The electronic control unit was used for blocked temperature fluctuation thus experiments conducted on the stabile temperature value. In the study, automated ACE and Soil CO_2 Exchange System (ADC BioScientific Ltd. Global House Geddings Road Hoddesdon Herts EN11 0NT England) was used for determining the CO_2 flux meter. The resistance equipped with electronic control unit and soil CO_2 flux meter are given in Figure 1. Technical information of CO_2 flux meter is given in Table 3. Also, volumetric soil moisture percentage (%) and temperature (°C) were simultaneously measured via device sensors.

CO_2 flux device



Temperature resistance and ECU

Figure 1. CO_2 flux meter, temperature resistance and electronic control unit

Table 3. Technical information of CO_2 fluxmeter

Technical Specifications	Unit
Measurement of CO_2	Standard range: (Molar) approximately 40.0 µmols/m^3.
Measurement of PAR	0-3000 µmols/m^2/s Silicon photocell
Measurement of soil temperature	6 selectable inputs for thermistors
Measurement of soil moisture	4 selectable inputs for industry standard sensors
Flow control to chamber	200 -5000 ml/min^1 (137-3425 µmols.s^{-1})
Chamber volume	Closed type 2.6 l/ Open type 1.0 l
Chamber diameter	230 mm

Statistical Analysis

Analysis of variance (ANOVA) was used to assess the significance of each treatment on soil properties and CO_2 fluxes and O_2 content. Means were compared when the F-test for treatment was significant at 5% level by using Duncan's Multiple Range Tests.

RESULTS AND DISCUSSION

Soil CO_2 flux was affected by soil type, farmyard manure norm, manure application techniques and soil temperature statistically highly significant ($p<0.001$), but this trend was not observed interaction values (Table 4).

Effects of soil temperature on the CO_2 flux was observed statistically significant. Through experimental periods determined a linear interaction between CO_2 flux and soil temperature. While in the initial temperature conditions (20-25 °C) CO_2 flux assigned as 1.173 µmol/m^2/s, CO_2 flux gradually raised up according to higher soil temperature conditions. When the soil temperature had been reached the maximum level (45-50 °C) CO_2 flux from soil to atmosphere determined as 6.62 µmol/m^2/s (Figure 2). Ratio of percentage change of soil CO_2 flux with temperature was 82.28%. There are a lot of scientific research about effects of soil temperature on the CO_2 flux. In these researches has been found increase of soil temperature increased CO_2 flux. For example; Wei et al. (2014) researched effects of land slope, soil temperature and moisture content on the CO_2 fluxes. According to obtained results, soil temperature accelerated CO_2 flux from soil to atmosphere. Trumbore (2000) stated that there is a linear correlation between the soil temperature and CO_2 flux. In addition, Fang and Moncrieff (2001) concluded that CO_2 flux at the high soil temperature condition was more than normal temperature at the rate of 144%. Soil moisture more effective than soil temperature on the CO_2 flux (Xu and Qi 2001). Stubble on the soil surface is another important factor for CO_2 flux. Stubble of the soil surface blocks sun rays and thus soil surface is not warm and leads to less CO_2 flux (Parkin and Kaspar 2003).

In many studies, it is emphasized that CO_2 emission is greatly influenced by seasonal temperature changes (Franzluebbers et al., 2002;

Raich and Tufekcioglu 2000; Rochette et al., 1991). Akinremi et al. (1999) stated that CO_2 flux values which determined afternoon more than in the morning.

Farmyard manure can be either layed on the soil that named as surface application with manure spreader machinery or mixtured into the soil named as sub-surface application with different farm machinery such as rotary tiller, cultivator etc. In the laboratory there are significant different on the CO_2 flux between surface and sub-surface manure applications. CO_2 fluxes were 4.303 μmol/m^2/s and 2.426 μmol/m^2/s surface and subsurface applications, respectively. These results showed similarities Smith et al. (2012)'s results according to application of manure. CO_2 flux on the surface manure application were bigger than subsurface manure application approximate 50% (Table 4).

As an expected result, CO_2 flux increased with increasing manure norm. CO_2 flux determined as 2.754 and 3.975 μmol/m^2/s for 2 ton/ha and 4 ton/ha manure norm, respectively. Ozlu and Kumar (2018) indicated that higher manure rates resulted in higher CO2 flux compared to lower rates of manure. When examined effects on soil type on the CO_2 flux, maximum CO_2 flux values were observed at the normal type soil with 3.758 μmol/m^2/s and minimum values determined at the saline soil conditions with 2.971 μmol/m^2/s (Table 4).

Table 4. Variance analysis according to the factors

	Factors	**F**	**P**
Main Factors	Soil temperature (T)	18.235	0.000**
	Soil type (ST)	3.782	0.05 *
	Manure norm (MN)	9.108	0.006**
	Manure Application Technic (MAT)	21.501	0.000**
Interactions	(T) * (ST)	0.269	0.926 ns
	(T) * (MN)	0.588	0.709 ns
	(T) * (MAT)	0.479	0.789 ns

	Temperature					
CO_2 flux	**20-25 °C**	**25-30 °C**	**30-35 °C**	**35-40 °C**	**40-45 °C**	**45-50 °C**
	1.173 c	1.401 c	2.350 c	3.935 b	4.705 b	6.620 a

Soil Type	**CO_2 flux**
Normal	3.758 a
Saline	2.971 b
Manure Norm	**CO_2 flux**
2 t/ha	2.754 b
4 t/ha	3.975 a
Manure Application Technic	**CO_2 flux**
Surface	4.303 a
Subsurface	2.426 b

ns: nonsignificant, *: statistically significant ($P < 0.05$), **: statistically highly significant ($P < 0.01$).

Soil CO_2 fluxes were affected by soil type in the study. Soil CO_2 flux were observed 3.758 μmol/m^2/s, and 2.971 μmol/m^2/s in normal soil and saline soil, respectively. Houska et al. (2017) and Maucieri et al. (2017) stated that radioactively active greenhouse gas like CO_2 and N_2O affected by saline soil and moisture conditions. Drying and excess salt limit microbial activity by osmotic stress (Smith et al., 2003; Yemadje et al., 2016). Heterotrophic soil microorganism's activity is restricted by ion toxicity (Rath et al., 2016) and osmotic stress (Setia et al., 2011) and thus reduce CO_2 flux.

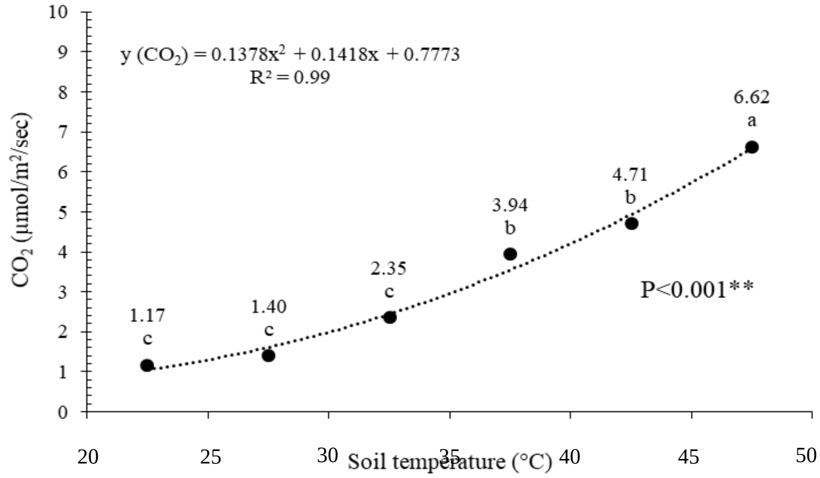


Figure 2. Changes in CO_2 flux depending on soil temperature

Changes in CO_2 flux according to the soil temperature, soil type, manure norm and manure application technics are given in Figure 3.

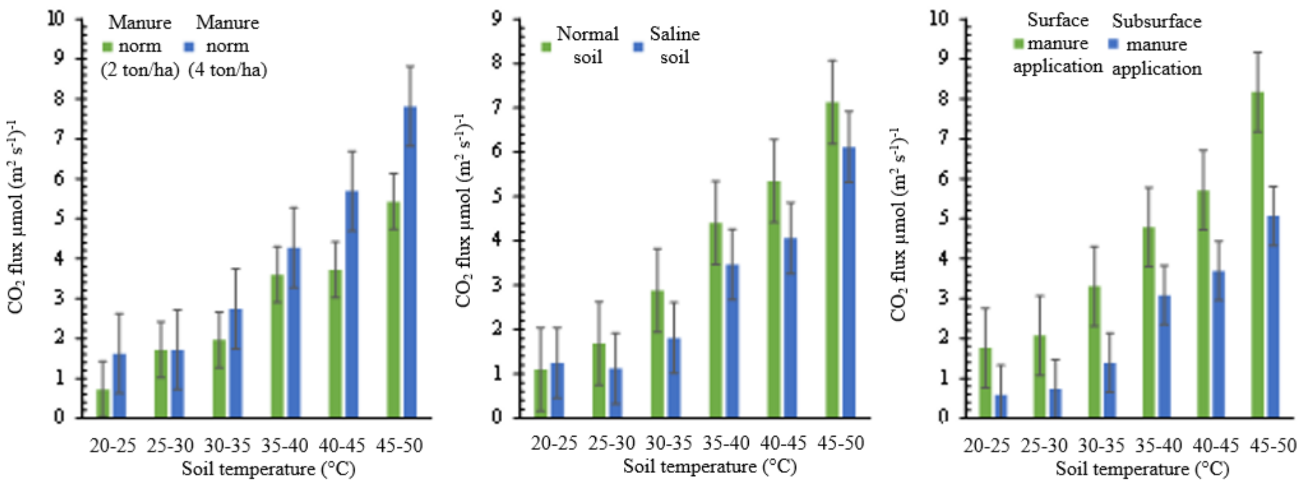


Figure 3. Effects of manure norm, soil type and manure application technic on soil CO_2 flux

Soil CO_2 flux from soil to atmosphere is a significant subject not only soil carbon due to caused decrease carbon into the soil but also global warming (Parkin and Kaspar 2003). It is highly important subject find out more information about loss of carbon for determination amount of carbon into the soil (Parkin et al., 1996; Paustian et al., 1997).

Soil organic carbon content generally changes with soil moisture content and soil temperature with directly proportional and inversely proportional, respectively (Trumbore 2000). In addition soil type, manure application, soil texture, soil moisture and temperature affect soil organic matter content (Davidson et al., 2000).

Farm-yard manure is an important source of greenhouse gases such as CH_4, NO_2 and CO_2. A large proportion of the CH_4 and CO_2 gases in the atmosphere has been emitted from animal manure. This rate was determined as 34% (IPCC, 2001). However, type of farm–yard manure can also cause differences in CO_2 emissions rate. Sebastian et al. (2013) determined a significant difference between sheep and cattle manure on the CO_2 flux rate. In the study CO_2 flux values determined as 61.3 and 4.7 ton/year for sheep and cattle manure, respectively.

CONCLUSION

A laboratory study was conducted to monitor the impacts of soil temperature, manure norm, soil type and manure application technic on soil CO2 fluxes. Results of this study showed that increase in soil temperature increase in soil CO2 flux. Soil CO2 flux affected by soil type and the flux at saline soil less than normal soil conditions. Increased the manure norm increase CO_2 flux, surface manure application causes more CO_2 flux all the soil conditions.

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