The Response of CO$_2$ Flux to Soil Warming, Manure Application and Soil Salinity

Sefa ALTIKAT$^1$ Hasan Kaan KÜÇÜKERDEM$^1$* Aysun ALTIKAT$^2$

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 (Missetbrook 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$_2$ 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

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Normal soil</th>
<th>Saline soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil texture</td>
<td>Clay-loam</td>
<td>Clay-loam</td>
</tr>
<tr>
<td>CaCO₃</td>
<td>6.53%</td>
<td>10.2%</td>
</tr>
<tr>
<td>EC</td>
<td>0.0054 dS/m</td>
<td>1.228 dS/m</td>
</tr>
<tr>
<td>pH</td>
<td>8</td>
<td>9.3</td>
</tr>
</tbody>
</table>

EC: Electrical conductivity

Table 2. Chemical content of the farmyard manure

<table>
<thead>
<tr>
<th>Properties</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic matter</td>
<td>352 g/kg</td>
</tr>
<tr>
<td>pH</td>
<td>7.2</td>
</tr>
<tr>
<td>EC</td>
<td>3.4 dS/m</td>
</tr>
<tr>
<td>N</td>
<td>16 g/kg</td>
</tr>
<tr>
<td>P</td>
<td>8.2 g/kg</td>
</tr>
<tr>
<td>K</td>
<td>6.9 g/kg</td>
</tr>
<tr>
<td>Ca</td>
<td>65 g/kg</td>
</tr>
<tr>
<td>Mg</td>
<td>5.8 g/kg</td>
</tr>
</tbody>
</table>

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 CO₂ Exchange System (ADC BioScientific Ltd. Global House Geddings Road Hoddesdon Herts EN11 0NT England) was used for determining the CO₂ flux meter. The resistance equipped with electronic control unit and soil CO₂ flux meter are given in Figure 1. Technical information of CO₂ flux meter is given in Table 3. Also, volumetric soil moisture percentage (%) and temperature (°C) were simultaneously measured via device sensors.
CO₂ flux device

Figure 1. CO₂ flux meter, temperature resistance and electronic control unit

<table>
<thead>
<tr>
<th>Technical Specifications</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement of CO₂</td>
<td>Standard range: (Molar) approximately 40.0 µmols/m².</td>
</tr>
<tr>
<td>Measurement of PAR</td>
<td>0-3000 µmols/m²/s Silicon photocell</td>
</tr>
<tr>
<td>Measurement of soil temperature</td>
<td>6 selectable inputs for thermistors</td>
</tr>
<tr>
<td>Measurement of soil moisture</td>
<td>4 selectable inputs for industry standard sensors</td>
</tr>
<tr>
<td>Flow control to chamber</td>
<td>200 -5000 ml/min¹ (137-3425 µmols.s⁻¹)</td>
</tr>
<tr>
<td>Chamber volume</td>
<td>Closed type 2.6 l/ Open type 1.0 l</td>
</tr>
<tr>
<td>Chamber diameter</td>
<td>230 mm</td>
</tr>
</tbody>
</table>

Table 3. Technical information of CO₂ fluxmeter

Statistical Analysis

Analysis of variance (ANOVA) was used to assess the significance of each treatment on soil properties and CO₂ fluxes and O₂ 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 CO₂ 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 CO₂ flux was observed statistically significant. Through experimental periods determined a linear interaction between CO₂ flux and soil temperature. While in the initial temperature conditions (20-25 °C) CO₂ flux assigned as 1.173 µmol/m²/s, CO₂ flux gradually raised up according to higher soil temperature conditions.

When the soil temperature had been reached the maximum level (45-50 °C) CO₂ flux from soil to atmosphere determined as 6.62 µmol/m²/s (Figure 2). Ratio of percentage change of soil CO₂ flux with temperature was 82.28%. There are a lot of scientific research about effects of soil temperature on the CO₂ flux. In these researches has been found increase of soil temperature increased CO₂ flux. For example; Wei et al. (2014) researched effects of land slope, soil temperature and moisture content on the CO₂ fluxes. According to obtained results, soil temperature accelerated CO₂ flux from soil to atmosphere. Trumbore (2000) stated that there is a linear correlation between the soil temperature and CO₂ flux. In addition, Fang and Moncrieff (2001) concluded that CO₂ 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 CO₂ fluxes (Xu and Qi 2001). Stubble on the soil surface is another important factor for CO₂ flux. Stubble of the soil surface blocks sun rays and thus soil surface is not warm and leads to less CO₂ flux (Parkin and Kaspar 2003).

In many studies, it is emphasized that CO₂ emission is greatly influenced by seasonal temperature changes (Franzluebbers et al., 2002;
Raich and Tufek cioglu 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 mixed 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 CO$_2$ 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>
<thead>
<tr>
<th>Factors</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Factors</td>
<td>-----</td>
<td>-------</td>
</tr>
<tr>
<td>Soil temperature (T)</td>
<td>18.235</td>
<td>0.000**</td>
</tr>
<tr>
<td>Soil type (ST)</td>
<td>3.782</td>
<td>0.05*</td>
</tr>
<tr>
<td>Manure norm (MN)</td>
<td>9.108</td>
<td>0.006**</td>
</tr>
<tr>
<td>Manure Application Technic (MAT)</td>
<td>21.501</td>
<td>0.000**</td>
</tr>
<tr>
<td>Interactions</td>
<td>-----</td>
<td>-------</td>
</tr>
<tr>
<td>(T) * (ST)</td>
<td>0.269</td>
<td>0.926 ns</td>
</tr>
<tr>
<td>(T) * (MN)</td>
<td>0.588</td>
<td>0.709 ns</td>
</tr>
<tr>
<td>(T) * (MAT)</td>
<td>0.479</td>
<td>0.789 ns</td>
</tr>
</tbody>
</table>

**Table 4. Variance analysis according to the factors**

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$_2$O 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.
Changes in CO$_2$ flux according to the soil temperature, soil type, manure norm and manure application technics are given in Figure 3.

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.
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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 CO₂ flux, surface manure application causes more CO₂ flux all the soil conditions.

REFERENCES


