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Soil CO_2 Emission in Tomato Trial Field Under Different Irrigation Regimes and Compost Doses at Agronomic Experimentation Station in University of Lome

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ABSTRACT

Compostuse in cropping systems may lead to soil CO_2 emission into atmosphere although the processes involved are not fully understood. To explore municipal wastes compost use and soil CO_2 emission could result, this study was conducted to assess effects of irrigation regimes and urban solid wastes compost doses on soil CO_2 emission in tomato field in research station of Agronomic School in University of Lome in West Africa. Experiments were conducted in dry season in a Randomized Complete Block Design with three repetitions. The treatments included control, plots treated with compost and chemical fertilizers at different doses. Water was supplied according to three irrigation regimesof 1, 2 and 4 interval days. Soil samples were collected from experimental plots and incubated. Soil CO_2 emission was measured every day during 28 incubation days using 0.1 N HCl after precipitating the carbonate with a $BaCl_2$ solution by alkali back-titrating. The results shown that highest tomato yieldswere obtained from plots treated with compost and submitted to irrigation at two days interval and lowest values from control plots and treated plots submitted to irrigation at daily and four days interval. Highest soil CO_2 emission were recorded from treated plots irrigated at two days interval, while lowest values were obtained both from control plots and treated plots submitted to irrigation at daily and four days interval

Keywords: Household waste compost, Irrigation interval day,Soil CO_2 emission, Tomato yield.

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INTRODUCTION

The red soils commonly called “Terre de Barre” in coastal region of Southern Togo constitute the main part of agricultural soils and are frequently cultivated without fallow and no organic restitution (use of crop residues as household fuel). These soils are overused and do not have the necessary time to replenish their organic matter stock. This can be explained by the excessive need of cultivable land due to the concern to multiply crop areas to ensure a minimum harvest faced to the rains irregularity due to climate change.

In fact, demographic pressure and excess land use have led to a total depletion of agricultural soil, resulting in a decrease in the stock of organic carbon and a destructuring of the surface horizons, reducing mainly food crop production (maize, cassava, cow pea, tomato). The smallholder farmers are facing famine and malnutrition. One possibility to restore these soils is the use of compost to increase organic matter that could reduce the process of degradation, raise the potential crop production and allow a conservative agriculture.Researchers have shown that application of waste composts at reasonable rates improves soil physical properties, increases available soil nutrient levels and plant growth (Hossain et al. 2017,Coulibaly et al. 2019).

Tomato (*Lycopersiconesculentum* Mill.) is one of the most important vegetables in Togo and is cultivated in almost all parts of the country.Water stress constitutes one of the most important factor limiting plant growth and yield in dry season when the incidence of pests and diseases is minimal. Field water management practices is the most influential factors affecting crop yield particularly in irrigated agriculture. Irrigation regime improves water use efficiency and has significant effect on the growth and yield of crops (Gudugi et al. 2012).

Compost use in cropping systems may lead to soil CO_2 emission into atmosphere although the processes involved are not fully understood. Barton et al. (2016) reported that incorporating organic matter alters soil greenhouse gas emissions and increases grain yield in a semi-arid climate.

To explore municipal wastes compost use in cropping systemsand soil CO_2 emission could result, this study was conducted to assess effects of irrigation regimes and urban solid wastes compost doses on soil CO_2 emission in the tomato trial field in research station of Agronomic School in University of Lome in West Africa.

MATERIALS AND METHODS

Field experiments

Field experiments were carried out at the University of Lome in the Teaching Research and Demonstration Farm of Agronomic School during two dry seasons January to April in years 2018 and 2019. The land had been cropped previously for many years. The soil type was a ferralsol locally called “Terre de Barre” that developed from a continental deposit. This soil is red, deep and suitable for almost all crops. The particle size distribution analyses revealed that soil surface layer (0 - 15 cm) of experimental site was loamy sand. For this study, the land was manually ploughed and divided into plots with plot area of 3.84 m^2 (2.4 m × 1.6 m). Each plot was separated from the adjacent by 1 m interval while the replicates were separated by 1.5 m interval. Tomato (*Lycopersiconesculentum* Mill.) mongal F_1, a high-yielding hybrid cultivar, was used. The tomato seedlings were raised in the nursery for three weeks before transported on plots and planted at a spacing of 0.5 m. The treatments were arranged in a Randomized Complete Block Design. Each treatment was replicated three times. There were five treatments per block where T_0 refers to control plots without any compost use while T_{20}, T_{30} and T_{40} refer to plots treated with compost at 20 t ha^{-1}, 30 t ha^{-1} and 40 t ha^{-1} doses respectively and TFM refers to 0.2 t ha^{-1} of NPK 15-15-15 and 0.1 t ha^{-1} of Urea (46% N) which are the national application doses of chemical fertilizers NPK 15-15-15 and Urea (46% N). These treatments were in combination with three irrigation regimes (interval of 1, 2 and 4 days). The compost used was produced with 70% of household wastes collected from Agbalepedogan district in Lome mixed with 30% poultry manure. It was applied at the beginning of tomato cultivation. On each plot, the compost was incorporatedinto the surface layerof 0—5 cm. Preventivephytosanitary treatments were performed against potential pests and diseases of tomato.

Irrigation regimes

Irrigation schedule, including 1, 2 and 4 days interval, was applied during all experimental period. At each irrigation event, an amount of water corresponding to field capacity water content in 15 cm soil depth was applied. Irrigation was applied manually using a watering can with capacity known in order to make sure that all the experimental plots received the same amount of water.

Soil sampling, incubation and CO_2 emission measurement

The soil was collected at 0 -15 cm depth in each experimental plot, dried, sieved at 2 mm and homogenized before the beginning of incubation. The study was conducted in four months (120 days) during field experiments January to April in year 2019. The protocol was adapted to those of Rahman (2013). Twenty five grams of each dry soil sample was incubated at 30°C in hermetically sealed glass vial of 1000 ml volume. The soil water content has been adjusted to 25% (i.e. 12.5 g of demineralized water for the 50 g of soil). The sodium hydroxide (NaOH, 1N) solution (20 ml 1.0 N NaOH + 25 ml distilled water) was prepared for trapping CO_2. The trap solution in plasticpillbox was placed in the vial of 1000 ml volume containing soil sample. The CO_2 released during the incubation is trapped in 15 ml of sodium hydroxide (NaOH, 1N) contained in plastic pill boxes put with the soil in the glass vials. For each treatment, threerepetitions are performed.The measurements were carried out every day during 28 days of incubation. At each measurement, the pillboxes are sacrificed for evaluation of the amount of CO_2 released inside the glass vials and soda solution (NaOH, 1N) is renewed.After each measurement, the NaOH vials are changed and the jars aerated. The humidity of the soil samples is checked and adjusted on the eighth, sixteenth and twenty-fourth day. The CO_2 emission was measured from the soil using 0.1 N HCl after precipitating the carbonate with a $BaCl_2$ solution by back-titrating the alkali. The alkali solution pillboxes were removed and titrated with 0.1 N HCl solution using phenolphthalein indicator and $BaCl_2$ solutions. Controls for this experiment consist of glass vial without soil sample but with the alkali of same strength was used. The alkali solutions from the control were titrated to determine the quantity of alkali that has not reacted with CO_2 excess $BaCl_2$. The determination of the CO_2 emitted is done on 10 ml of trap solution (NaOH) taken after his homogenization in the pillbox. A few drops of phenolphthalein were added as indicator and titrated with 0.1 N HCl directly in the beaker. The volume of acid needed to titrate the alkali was noted. The amount of CO_2emittedwas calculated using the following formula:

Milligram of CO_2 = [(B – V).N.E] /M

Where,*B* is the volume of HCl used to titrate the control (mL), *V* the volume of HCl used to titrate the sample (mL), *N* the normality of HCl, *E* (= 22) the molar mass of CO_2 divided by 2 (because 2 mol of OH- is consumed by 1 mol of CO_2), *M* = Soil weight.

Tomato fruit harvest

When the fruits turned yellowish red, they were harvested at a regular interval from each plot. Fruits were picked by hand at 3 days interval during three weeks. The tomato fruits were sorted into categories marketable and unmarketable (cracked fruits, unripe fruits, tiny fruits, fruits having blossom - end rot, diseased, malformed and damaged by insect pests). The first harvest in all treatments was considered as early ripening. Yield from all pickings were added up and total yield was expressed in ton per hectare

Statistical analysis

Tomato total yield data were grabbed into the Excel spreadsheet and analysis of variance (ANOVA) was carried out with the CropStat software. Means comparisons between treatments were performed with Newman and Keuls test at the threshold of 5%.

RESULTS AND DISCUSSION

Tomato total yield under different irrigation regimes and compost doses

Total yield of tomato includes early ripening yield, marketable yield and unmarketable yield. The highest values of tomato total yield (14.20 t ha^{-1} - 30.59 t ha^{-1}) were recorded on plots treated with compost and mineral fertilizers and submitted to irrigation regime of two days interval, while the lowest values (3.58 t ha^{-1} - 11.63 t ha^{-1}) were recorded on control plots and plots treated with compost and mineral fertilizers but submitted to daily irrigation regime and to irrigation regime at four days interval (Table 1). In addition, tomato yields obtained were proportional to compost doses applied. This explains that tomato yield was influenced by compost doses applied and irrigation regimes.The tendency of results of this study may be attributed to the fact that adequate watering conditions led to the development of an abundant ovules per

Table 1. Tomato total yield. T_0 refers to control plot without any compost use while T_{10}, T_{20}, T_{30} and T_{40} refer to compost applied at 20 t ha^{-1}, 30 t ha^{-1} and 40 t ha^{-1} doses respectively. T_{FM} refers to 0.2 t ha^{-1} of NPK 15-15-15 and 0.1 t ha^{-1} of Urea. Tomato total yield includes early ripening yield marketable yield and unmarketable yield. In a columa, treatment mean values followed by same letter are not significantly different at the threshold of 5%.

Compost dose (t ha^{-1})	Irrigation interval days	Total yield (t ha^{-1}) Year 2018	Total yield (t ha^{-1}) Year 2019
	daily	4.05±0.02g	3.62±0.01g
T_0	2 days	4.19±0.02g	3.65±0.01g
	4 days	3.92±0.03g	3.58±0.02g
	daily	7.45±0.02f	8.49±0.01f
T_{20}	2 days	14.20±0.04d	17.79±0.02c
	4 days	7.42±0.03f	8.53±0.01f
	daily	10.37±0.04e	11.57±0.01d
T_{30}	2 days	20.12±0.04b	25.56±0.03b
	4 days	7.40±0.03f	10.25±0.02e
	daily	10.39±0.03e	11.63±0.01d
T_{40}	2 days	24.84±0.02a	30.59±0.03a
	4 days	7.48±0.03f	10.26±0.02e
	daily	10.35±0.03e	11.70±0.03d
T_{PM}	2 days	18.54±0.02c	25.41±0.02b
	4 days	7.41±0.03f	10.24±0.03e

floret consequently higher yield fruit under irrigation regime of two days interval. Our results are in line with the findings of Gudugi et al. (2012) who suggested that number of tomato fruits had been related with irrigation intervals.Decreasing yield recorded on plots irrigated every day (Table 1) may be explained by the excess irrigation witch would lead to explained by the excess irrigation witch would lead to water draining past the root zone, leaching nutrients and reducing nutrient use efficiency. Too much water in the root zone would reduce also the amount of oxygen available and leading to plant stress.

In conditions of too frequent irrigation, the roots are without air after each irrigation until the free water has drained from the soil profile. During this time, plant growth and development nearly would stop. On the other hand, the reduction in yield of plants irrigated at four days interval indicates that these plants were subjected to high water deficit stress. Decreasing yield recorded from these plants may be explained by the high percent abortion observed on these severe stressed plants due to the fact that as the water deficit stress increases, the number of ovules per floret decreases. Lower soil moisture may lead to the flower abortion and fewer fruits. The results of this study corroborate with those of Birhanu and Tilahun (2010) who reported a decreased number and sizes of tomato fruits from plants subjected to moisture stress and the effects of water deficit stress on tomato yield parameters.

Soil CO_2 emission under different irrigation regimes and compost doses

Although soil CO_2 emissions were measured every

Table 2. Results of soil CO_2 emission (mg) in twenty-four hours of incubation. T_0 refers to control plot without any compost use while T_{20}, T_{30} and T_{40} refer to compost applied at 20 t ha^{-1}, 30 t ha^{-1} and 40 t ha^{-1} doses respectively. T_{FM} refers to 0.2 t ha^{-1} of NPK 15-15-15 and 0.1 t ha^{-1} of Urea.

Treatments	Irrigation interval days	Firstmonth	Second month	Third month	Fourth month
	daily	0.60±0.02	0.78±0.02	0.96±0.02	1.10±0.01
T_0	2 days	0.88±0.02	1.41±0.02	1.76±0.02	2.10±0.01
	4 days	0.40±0.03	0.44±0.03	0.52±0.03	0.60±0.02
	daily	0.77±0.02	0.99±0.02	1.20±0.02	1.38±0.01
T_{20}	2 days	1.06±0.04	1.70±0.04	2.13±0.04	2.56±0.02
	4 days	0.35±0.03	0.39±0.03	0.46±0.03	0.53±0.01
	daily	0.78±0.04	1.02±0.04	1.25±0.04	1.41±0.01
T_{30}	2 days	1.47±0.04	2.35±0.04	2.94±0.04	3.52±0.03
	4 days	0.72±0.03	0.79±0.03	0.94±0.03	1.08±0.02
	daily	0.88±0.03	1.14±0.03	1.41±0.03	1.58±0.01
T_{40}	2 days	1.73±0.02	2.77±0.02	3.47±0.02	4.16±0.03
	4 days	0.75±0.03	0.83±0.03	0.98±0.03	1.13±0.02
	days	0.69±0.03	0.89±0.03	1.10±0.03	1.20±0.03
T_{FM}	2 days	0.80±0.02	1.28±0.02	1.60±0.02	1.92±0.02
	4 days	0.37±0.03	0.41±0.03	0.48±0.03	0.55±0.03

Table 3. Results of soil CO_2 emission (mg) at four days incubation. T_0 refers to control plot without any compost use while T_{20}, T_{30} ,T_{40} refer to compost applied at 20 t ha^{-1}, 30 t ha^{-1} and 40 t ha^{-1} doses respectively. T_{FM} refers to 0.2 t ha^{-1} of NPK 15-15-15 and 0.1 t ha^{-1} of Urea.

Treatments	Irrigation interval days	First month	Second month	Thirf month	Forth month
	daily	0.56±0.02	0.73±0.02	0.90±0.02	1.01±0.01
T_0	2 days	0.75±0.02	1.20±0.02	1.50±0.02	1.80±0.01
	4 days	0.35±0.03	0.39±0.03	0.46±0.03	0.53±0.02
	daily	0.56±0.02	0.73±0.02	0.90±0.02	1.00±0.01
T_{20}	2 days	0.73±0.04	1.17±0.04	1.47±0.04	1.75±0.02
	4 days	0.29±0.03	0.32±0.03	0.38±0.03	0.44±0.01
	daily	0.75±0.04	0.97±0.04	1.20±0.04	1.35±0.01
T_{30}	2 days	1.17±0.04	1.87±0.04	2.34±0.04	2.81±0.03
	4 days	0.44±0.03	0.48±0.03	0.57±0.03	0.66±0.02
	daily	0.85±0.03	1.10±0.03	1.35±0.03	1.52±0.01
T_{40}	2 days	1.55±0.02	2.48±0.02	3.10±0.02	3.72±0.03
	4 days	0.54±0.03	0.59±0.03	0.70±0.03	0.81±0.02
	daily	0.69±0.03	0.89±0.03	1.10±0.03	1.24±0.03
T_{FM}	2 days	0.73±0.02	1.17±0.02	1.46±0.02	1.73±0.02
	4 days	0.33±0.03	0.37±0.03	0.43±0.03	0.50±0.03

day during 28 days of incubation, because of general tendency of results obtained, only the results of twenty four hours of incubation, those of fourth, eighth, sixteenth and twenty eighth incubation days have been recorded in Tables 2-6.

The results presented in Tables 2-6 revealed the variation of soil CO_2 emissions. It was observed that soil CO_2 emission values depended on the irrigation regime, the nature of fertilizer (compost or mineral fertilizers), the dose of compost, number of incubation days (date of measurement of soil CO_2 emission) and the period of soil sampling for incubation during the field experiment.The highest soil CO_2 emission values were recorded on the plots irrigated at two days interval regardless fertilizer nature and compost dose, while the lowest values were obtained both on the control plots and on the plots receiving compost or mineral fertilizer and submitted to daily irrigation regime and irrigation regime at four days interval. These results suggest that soil moisture and organic matter level affects microbial activities and soil respiration, which indirectly affect CO_2 emission. Irrigation regime at two days interval could enhance

Table 4. Results of soil CO_2 emission (mg) at eight days incubation. T_0 refers to control plot without any compost use while T_{20}, T_{30} and T_{40} refer to compost applied at 20 t ha^{-1}, 30 t ha^{-1} and 40 t ha^{-1} doses respectively. T_{FM} refers to 0.21 t ha^{-1} of NPK 15-15-15, 0.1 t ha^{-1} of Urea.

Treaatments	Irrigation interval days	First month	Second month	Third month	Fourth month
	daily	0.50±0.02	0.65±0.02	0.80±0.02	0.90±0.01
T_0	2 days	0.60±0.02	0.96±0.02	1.20±0.02	1.44±0.01
	4 days	0.32±0.03	0.35±0.03	0.42±0.03	0.48±0.02
	daily	0.37±0.02	0.48±0.02	0.79±0.02	0.67±0.01
T_{20}	2 days	0.52±0.04	0.83±0.04	1.04±0.04	1.25±0.02
	4 days	0.20±0.03	0.22±0.03	0.26±0.03	0.30±0.01
	daily	0.40±0.04	0.51±0.4	0.63±0.04	0.71±0.01
T_{30}	2 days	0.90±0.04	1.45±0.04	1.81±0.04	2.17±0.03
	4 days	0.41±0.03	0.45±0.03	0.54±0.03	0.62±0.02
	daily	0.49±0.03	0.64±0.03	0.79±0.03	0.91±0.01
T_{40}	2 days	1.31±0.02	2.10±0.02	2.62±0.02	3.15±0.03
	4 days	0.36±0.03	0.40±0.03	0.47 ±0.03	0.54±0.02
	daily	0.49±0.03	0.64±0.03	0.79±0.03	0.89±0.03
TFM	2 days	0.70±0.02	1.12±0.02	1.40±0.02	1.68±0.02
	4 days	0.31±0.03	0.34±0.03	0.40±0.03	0.46±0.03

soil wetting-drying cycles and thus increase the CO_2 fluxes by promoting microbial activities and respiration (Guo et al. 2017). The higher soil CO_2 emissions were potentially resulted from the effect of increased oxygen and soil microbial (Guadieet al. 2014).

Irrigating too frequently could have negative impact on microbial population. In this case of daily irrigation regime, the microorganisms could have insufficient air. This explains the low values of soil CO_2 emission noted on plots submitted to daily irrigation regime.The low CO_2emission from plots irrigated at four days interval indicates that these plots were subjected to high water deficit stress. Decreasing CO_2 emission recorded from these plots may be explained by the low microbial activities and respiration due to the water deficit stress increases. Our results are in line with the findings of Hou et al. (2019) who concluded that deficit irrigation effectively reduced CO_2 emissions from winter wheat field soils in Northwest China.

On the other hand, the soil CO_2 emission increases throughout the field experiment.This was observed that CO_2 emission from soil samplestaken in third and fourth months of field experiment were more than those form soil samples collected in first and second months (Tables 2-6). These observations are in accordance with the study of Russell (1973) which stated that the presence of crops on the field affect (increase) CO_2 emissions from the soil. Soil CO_2 emission increasing in the two last months of field experiment is also in line with the finding of Han et al.(2012) who reported that the presence of vegetation or crop affected CO_2 fluxes primarily by photosynthesizing and by increasing the total ecosystem respiration.

However, CO_2 emission decrease gradually during incubation days. Results of soil CO_2 emission in twenty-four hours of incubation are more than those recorded at four, eight, sixteen and twenty eight incubation days(Tables 2-6).All these variations in soil CO_2 emissions may be explained by the abundance or rarity of microorganisms in the soils sampled and incubated. From this view point, monitoring the soil CO_2 emission during incubation mean to measure the respiration of microbial populations in the soil. Our results suggest that the application of household solid urban waste compost increase soil microbial populations and soil CO_2 emissions. The levels of soil CO_2emission observed in this study are in line with the findings of several authors.Previous studies had found that crop root and soil microbial respiration were the main sources of soil CO_2 emissions. Researchers performed a long-term fertilization study on wheat and maize growing season and observed that the highest soil CO_2 flux was found from organic fertilizer treatment (Galic et al. 2019). Compost application may be associated with increased amount of carbon available that increases the microbial activity and thus stimulate respiration of autotrophic and heterotrophicmicroorganisms in the soil (De Urzedo et al. 2013,Carmo et al. 2014).

CONCLUSION

Based on the results of this study, the application of compost to soil increased CO_2 emissions compared with the control and chemical fertilizer treatments. The highest soil CO_2 emission values were recorded on the plots irrigated at two days interval regardless fertilizer nature and compost dose.Our experiments are relatively short, to better assess the CO_2 emissions fromorganic matter added to soil, long-term experiments are needed for a more reliable conclusion on the effect of applying household urban solid waste compost on soil carbon dynamics. We therefore suggest that the carbon balance before and after addition to soil has to be taken into account when evaluating their CO_2 emission potential

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REFERENCES

Barton L., Hoyle F.C., Stefanova K.T. and Murphy D.V. (2016) Incorporating organic matter alters soil greenhouse gasemissions and increases grain yield in a semi-arid climate. Agric.Ecosyst. Environ.231: 320—330.

Birhanu K. and Tilahun K. (2010) Fruit yield and quality of drip-Irrigated tomato under deficit irrigation. Afr. J. Food Agric. Nutr. Develop.10(2): 2139—2152.

Carmo J.B., De Urzedo D.I., Filho P.J.F., Pereira E.A. and Pitombo L.M. (2014) CO2 emission from soil after reforestation and application of sewage sludge. Bragantia73(3): 312—318.

Coulibaly S.S., Kouassi K.I., Koffi K.K. and Zoro B.I.A. (2019) Effect of compost from different animal manures on maize (*Zea mays*) growth. J. Experim. Biol. Agric.Sci.JEBAS7(2): 178—185.

De Urzedo D.I., Franco M.P., Pitombo L.M. and Carmo J.B. (2013) Effects of organic and inorganic fertilizers on greenhouse gas (GHG) emissions in tropical forestry. For. Ecol.Manage. 310: 37—44.

Galic M., Bilandzija D., Percin A., Sestak I., Mesic M., Blazinkov M. and Zgorelec Y. (2019) Effects of agricultural practices on carbon emission and soil health. J. Sustain. Develop. Energy Water and Environ. Syst.JSDEWES7(3): 539—552.

Guadie A., Xia S., Zhang Z., Zeleke J., Guo W., Ngo H.H. and Hermanowicz S.W. (2014) Effect of intermittent aeration cycle on nutrient removal and microbial community in a flu idized bed reactor-membrane bioreactor combo system Bioresour.Technol.156: 195—205.

GudugiI.A.S., Odofin A.J., Adeboye M.K.A. and Oladiran J.A. (2012)Agronomic characteristics of tomato as influenced by irrigation and mulching. Adv. Appl. Sci. Res.3(5): 2539—2543.

Guo S., Qi Y., Peng Q., Dong Y., He Y., Yan Z. and Wang L. (2017) Influences of drip and flood irrigation on soil carbon dioxide emission and soil carbon sequestration of maize cropland in the North China Plain. J. Arid Land9(2): 222—233.

Han G.X., Yang L.Q., Yu J.B., Wang G.M., Mao P.L. and Gao Y.J. (2012) Environmental controls on net ecosystem CO_2 exchange over a reed (Phragmites Australis) Wetland in the yellow River Delta, China. EstuarCoast 36 (2): 1—3.

Hossain M.Z., von Fragstein und Niemsdorff P. and Heß J.(2017) Effect of different organic wastes on soil properties and plant growth and yield: A review.Sci. Agric. Bohem.48(4): 224—237.

Hou H., Yang Y., Han Z., Cai H. and Li Z. (2019) Deficit irrigation effectively reduces soil carbon dioxide emissions from wheat fields in Northwest China. J. Sci. Food Agric.99 (12): 5401—5408.

Rahman M.M.(2013) Carbon dioxide emission from soil. Agric. Res. 2(2): 132—139.

Russell E.W. (1973)Soil conditions and plant growth (10^{th} ed). Longmans, London, UK, pp. 403—405