Journal of Soil Science and Plant Nutrition, 2015, 15 (3), 737-750

RESEARCH ARTICLE

Effects of different no-tillage modes on soil CO_2 fluxes from paddy fields in central China

L.J. Guo[1], R.D. Zhang[1], Z.S. Zhang[1], C.G. Cao[1], C.F. Li[1, 2,*]

[1]MOA Key Laboratory of Crop Ecophysiology and Farming System in the Middle Reaches of the Yangtze River/ College of Plant Science and Technology, Huazhong Agricultural University, Wuhan, 430070, P.R. China [2]Hubei Collaborative Innovation Center for Grain Industry, Jingzhou 434023, Hubei, P.R. China

[*]Corresponding author: lichengfang@126.com

Abstract

Differences in soil CO_2 emissions between no-tillage (NT) and conventional intensive tillage have been well assessed in paddy fields, but few studies evaluate the effects of different NT modes on soil CO_2 emissions. Therefore, a field experiment was conducted to assess paddy soil CO_2 flux as affected by different NT modes [ridge cultivation with NT (RNT) and conventional flat cultivation with NT (FNT)] and its influencing factors during the 2012-2014 rice growing seasons in central China. Soil CO_2 fluxes were determined by a LI-8100A soil CO_2 flux system. The mean soil CO_2 fluxes on the ridges in the RNT treatment increased by 49%, 52% and 35% compared with those on the flat land in the FNT treatment in 2012, 2013 and 2014, respectively. Cumulative CO_2 emissions ranged from 1042 g m^{-2} to 1489 g m^{-2} from the RNT treatment, and from 724 g m^{-2} to 1016 g m^{-2} for the FNT treatment. Moreover, soil CO_2 its emissions were significantly correlated with dissolved organic C, aboveground biomass and root biomass. Therefore, our results suggesting that annual rice-fallow-oilseed rape rotation should be considered to assess the effects of tillage systems on soil CO_2 emission.

Keywords: Biomass, CO_2 flux, dissolved organic C, no-tillage, ridge tillage

1. Introduction

Carbon dioxide (CO_2) is the most greenhouse gas (GHG), contributing 76% to the global greenhouse effect (IPCC, 2014). Soil CO_2 flux, one of the primary fluxes of carbon (C) between soils and the atmosphere, is an important component of the C cycle in terrestrial ecosystems (Schlesinger and Andrews, 2000). Controlling soil CO_2 fluxes is critical because relatively small changes in soil CO_2 fluxes may significantly alter atmospheric CO_2 concentration and soil C sequestration (Iqbal *et al.*, 2009). Accordingly, characterization of soil CO_2 emissions is important in investigating the feedback mechanism between soil C cycle and climate change (Zhu and Cheng, 2013). Field investigation on soil

CO_2 emissions have been intensively performed over the recent decades, with considerable effort devoted to upland ecosystems (Hanson *et al*., 2000). Although paddy ecosystems are C sink of atmospheric CO_2, changes in their C pool can directly affect CO_2 concentration in the atmosphere (Kuzyakov and Cheng, 2004). Accordingly, soil CO_2 emissions from paddy soils have been increasingly investigated.

No-tillage (NT) practices have been adapted by farmers in China over the past decades (Derpsch and Friedrich, 2009). NT practices aim to conserve soils and reduce production cost by saving fuel, equipment, and labor relative to conventional flat intensive tillage (Huang *et al.*, 2013). Ridge cultivation with NT (RNT) developed from ridge tillage cultivation is a newly established technique for rice production in southern China (Jiang and Xie, 2009; Zheng *et al.*, 2014). This technique primarily aims to improve efficient water use, air aeration, and supply of soil nutrition compared with conventional flat NT (FNT) and conventional flat intensive tillage (Zheng *et al.*, 2014). RNT is characterized by a permanent ridge–furrow configuration (Figure 1), where the furrows are used for irrigation ditches and the ridges are undisturbed perennially for rice growth with moist irrigation (Zheng *et al.*, 2014). The type of configuration can result in water saving and highly efficient rice production (Jiang and Xie, 2009; Zheng *et al.*, 2014).

Many studies have investigated the effects of RNT on rice production (Gao *et al.*, 2004; Tang *et al.*, 2005; Jiang and Xie, 2009; Zheng *et al.*, 2014), and reported that RNT can increase the rice yield compared with FNT and conventional flat intensive tillage because it improves soil aeration and nutrient supply. However, to our knowledge, few studies have been conducted to investigate the effects of RNT on soil CO_2 emissions in upland systems (Govaerts *et al.*, 2006; Patiño-Zúñiga *et al.*, 2009), particularly in paddy fields. Elucidating these effects can contribute to our knowledge on zone-specific management. Thus, this study assessed the effects of RNT and FNT on paddy soil CO_2 flux during the 2012-2014 rice growing seasons in central China, and also evaluated the relationships between soil CO_2 flux and aboveground biomass, root biomass and soil organic C.

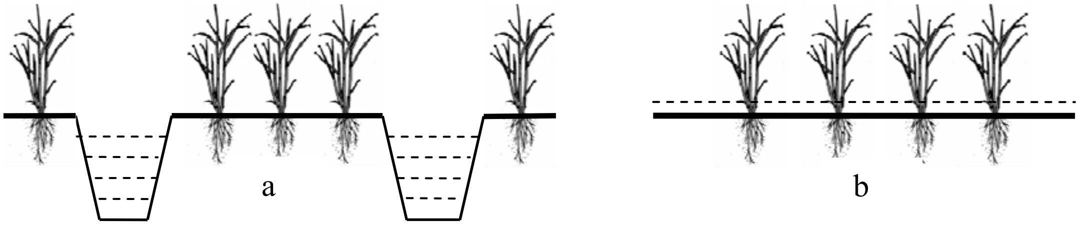

Figure 1. Sectional view of RNT (a) and FNT (b) paddy field

2. Materials and Methods

2.1. Study site and experimental design

Field experiment was started on May 2011 at the Huazhong Agricultural University Research Farm, which is located at Lanjie Village, Wuxue City, Hubei Province, China (29º51´N, 115º33´E). This region experiences a humid mid-subtropical monsoon climate with an average annual temperature of 17.8 °C and a mean annual precipitation of 1,361 mm. The local soil is classified as Gleysol (FAO classification). The soil exhibits a texture of sandy clay loam with a bulk density of 1.20 g cm^{-3}, clay (<0.002 mm) fraction of 12%, silt (0.002 mm - 0.02 mm) fraction of 10%, sand (0.02 mm - 2 mm) fraction of 78%, pH of 5.90, organic C content of 16.4 g kg^{-1}, and total nitrogen (N) content of 2.36 g kg^{-1}. The experimental site was cultivated with rotation of an oilseed rape (*Brassica napus*) and rice (*Oryza sativa* L.) for more than 10 years. Soil CO_2 flux was measured during the 2012-2014 rice growing seasons. To evaluate the effects of different NT modes on soil CO_2 emissions, we included FNT and RNT treatments in the field experiment. The treatments were arranged in a completely randomized design. Each treatment was replicated three times, and each plot presented an area of 73.5 m^2. For the RNT system, the ridges and furrows were manually performed in the field on May 2010. The ridges were 0.6-m wide on the top, and the furrows were 30-cm wide and 35-cm deep (Figure 1). After rice was harvested, mud from the furrows was artificially stacked on the top of the ridges. The ridges without soil disturbances were arranged at north and south directions. The water level in the furrows was consistently maintained at 5 cm – 30 cm depth, and the top soil of the ridges was maintained moist throughout the 2012-2014 rice growing seasons. For the FNT system, the ridges and furrows were not formed and no soil disturbance occurred throughout the rice growing seasons. Based on the conventional irrigation–drainage practices, we regularly irrigated the plots to a depth of 10 cm above soil surface when their water level decreased to 1 cm–2 cm in the plots. The plots were drained at approximately half a month before rice harvesting.

Weeds were controlled by spraying 20% paraquat at 3 L ha^{-1} before rice was directly seeded. After 3 d, the field was submerged. Subsequently, the rice seeds were manually directly seeded at a rate of 22.5 kg ha^{-1} on May 26 (2012), June 16 (2013) and June 18 (2014). The rice was harvested on September 28 (2012), October 19 (2013) and October 14 (2014). For the RNT rice field, the rice seeds were broadcast on the top of the ridges. A total of 180 kg N ha^{-1}, 90 kg P_2O_5 ha^{-1}, and 180 kg K_2O ha^{-1} were supplied using a fertilizer consisting of inorganic N (15% N), phosphorus (P, 15% P_2O_5), and potassium (K, 15% K_2O), urea (46% N), single superphosphate (12% P_2O_5), and potassium chloride (60% K_2O) for both treatments during the rice growing seasons. P and K fertilizers were only used as basal fertilizers after seeding. N fertilizers were immediately supplied at a rate of 90 kg N ha^{-1} in the form of basal fertilizers. The remaining N fertilizers were split into three doses: 36 kg N ha^{-1} at the tillering stage, 21.6 kg N ha^{-1} at the boosting stage, and 32.4 kg N ha^{-1} at the heading stage. For the RNT rice field, the fertilizers were broadcast on the soil surface of the ridges.

2.2. CO_2 measurement

In this study, CO_2 fluxes from paddy soil were measured at about 10-d intervals during the rice growing seasons by an 8100-103 short-term chamber connected to a LI-8100A soil CO_2 flux system (Li-Cor Inc., Lincoln, NE). Based on pre-experiment data (data not shown), we found that the mean flux from 9:00 AM to 12:00 AM is representative of the daily average. Thus, in this study, the fluxes were measured in this interval. Similarly, Lou *et al.* (2003) reported that the interval from 9:00 AM to 11:00 AM was representative of daily means in this region. At the beginning of the experiment, three base collars (20-cm inner diameter) of the short-term chambers were randomly inserted at a 5-cm depth on the soil surface, and were maintained in the fields throughout the rice growing seasons. For the RNT treatment, these base collars were placed on the ridges. The detailed measurement of CO_2 fluxes was described in our previous study (Li *et al.*, 2013). Each soil CO_2 fluxes was determined every 20 s for 180 s. Three measurements were obtained at each position on each sampling day, and measurement of soil respiration rate at a position was the average of three individual measurements. In the present study, soil CO_2 fluxes were determined at approximately 10-day intervals during the rice growing seasons. Seasonal CO_2 emissions in the plots were calculated by linearly interpolating the CO_2 emissions between the sampling dates.

2.3. Sampling and analytical methods

Root and aboveground biomasses were measured at harvesting in 2013 and 2014. Plants within the 1-m^2 area from the ridges in the RNT treatment and from the flat land in the FNT treatment were removed from two sites in each plot. These plants were separated into the roots and aboveground plants, which were then dried at 80 ºC and weighed.

Concurrent with soil CO_2 flux measurement, soil samples with 20 cm depth were immediately obtained using a soil core sampler with 5-cm inner diameter to analyze soil properties. Dissolved organic C (DOC) was extracted from 10 g of fresh soil with 1:3 ratio of soil to water (Jiang *et al.*, 2006). After the soil was shaken at 250 r min^{-1} for 1 h and centrifuged at 4,500×g for 10 min, the supernatant was filtered using a 0.45-μm membrane filter. The DOC content of the filtrate was measured through oxidation with potassium dichromate and titration with ferrous ammonium sulfate (Jones 2001). SOC content was determined using a C/N elemental analyzer (Elementar Marcro, Germany).

2.4. Data analysis

All statistical analyses were conducted using SPSS 16.0 analytical software package (SPSS Inc. USA). A one-way ANOVA of SPSS 16.0 was performed to determine the effects of different NT modes on soil CO_2 flux, SOC, DOC, aboveground biomass, and root biomass. Individual means were compared according to the least significant difference test. Difference at $P \leq 0.05$ was considered significant. Linear regression was used to evaluate the relationships between soil CO_2 flux and DOC content, root biomass, and aboveground biomass.

3. Results

Seasonal changes in soil CO_2 fluxes in the RNT and FNT treatments during the 2012 and 2014 rice growing seasons are shown in Figure 2. The soil CO_2 fluxes peaked at the tillering stage (June 28 in 2012, July 29 in 2013 and June 19 in 2014, about 3–4 weeks after seeding) in three years. For the FNT treatment, the CO_2 fluxes ranged from 118.0 mg m^{-2} h^{-1} to 626.9 mg m^{-2} h^{-1} in 2012, from 179.1 mg m^{-2} h^{-1} to 1370.1 mg m^{-2} h^{-1} in 2013, and from 117.4 mg m^{-2} h^{-1} to 660.9 mg m^{-2} h^{-1} in 2014 (Figure 2). For the RNT treatment, the CO_2 fluxes varied from 118.4 mg m^{-2} h^{-1} to 900.0 mg m^{-2} h^{-1} in 2012, from 110.6 mg m^{-2} h^{-1} to 1970.5 mg m^{-2} h^{-1} in 2013, and 218.1 mg m^{-2} h^{-1} to 799.1 mg m^{-2} h^{-1} in 2014 (Figure 2). Mean soil CO_2 fluxes in the RNT treatment were significantly higher by 49%, 52% and 35% than those in the FNT treatment in 2012, 2013 and 2014, respectively (Table 1).

Cumulative CO_2 emissions from paddy soils were significantly different between the RNT and FNT treatments (Table 2). The RNT treatment significantly increased the emissions by 44%, 47% and 34% compared with the FNT treatment in 2012, 2013 and 2014, respectively (Table 2).

There was significant seasonal variation in DOC contents in the RNT and FNT treatments during the 2012-2014 rice growing seasons (Figure 3). The peaks of DOC contents were found at the tillering stage in three years. Mean DOC contents in the RNT treatment (0.97 g kg^{-1} in 2012, 0.90 g kg^{-1} in 2013, and 1.02 g kg^{-1} in 2014) were 1.11-1.18 times higher than those in the FNT treatment.

Significantly higher root and aboveground biomasses were found in the RNT treatment than those in the FNT treatment, whereas no significant difference was observed in the SOC content between the two treatments (Table 3). RNT treatment significantly increased root and aboveground biomasses by 16% and 38% in 2013, and 60% and 35% in 2014 than those in FNT treatment, respectively.

In general, significant relationship between CO_2 flux and DOC content was observed (Figure 4), and the *r* values ranged from 0.728 to 0.911 for the RNT treatment and from 0.646 to 0.894 for the FNT treatment. In addition, cumulative CO_2 emissions were significantly and positively correlated with root and aboveground biomasses (Figures 5 and 6).

Table 1. Changes in mean soil CO_2 fluxes from the ridges in the RNT treatment and the flat land in the FNT treatment in 2012-2014/(mg m^{-2} h^{-1})

Treatments	2012	2013	2014
RNT	356.2±22.1 a	589.3±33.1 a	412.8±36.7
FNT	238.6±18.9 b	387.2± 28.9 b	306.3±38.9

Different small letters in a column mean significant difference at the 5% level. Values are mean ± standard errors.

Table 2. Changes in cumulative CO_2 emissions under different NT treatments in 2012-2014/(g m^{-2})

Treatments	2012	2013	2014
RNT	1042±77 a	1489±127 a	1072±89 a
FNT	724±68 b	1016±186 b	798±80 b

Different small letters in a column mean significant difference at the 5% level. Values are mean ± standard errors.

Table 3. Differences in SOC content, root biomass and aboveground biomass between the ridges in the RNT treatment and the flat land in the FNT treatment at harvesting in 2013 and 2014

Treatments	2013			2014		
	SOC (g kg^{-1})	Root biomass (g m^{-2})	Aboveground biomass (g m^{-2})	SOC (g kg^{-1})	Root biomass (g m^{-2})	Aboveground biomass (g m^{-2})
RNT	1.98±0.02 a	241.1±11.3 a	2060±243 a	2.01±0.01 a	305.1±10.5 a	2840±311 a
FNT	2.04±0.03 a	207.7±15.3 b	1488±267 b	2.03±0.04 a	190.5±9.8 b	2100±320 b

Different small letters in a column mean significant difference at the 5% level. SOC, soil organic C; DOC, dissolved organic C. Values are mean ± standard errors.

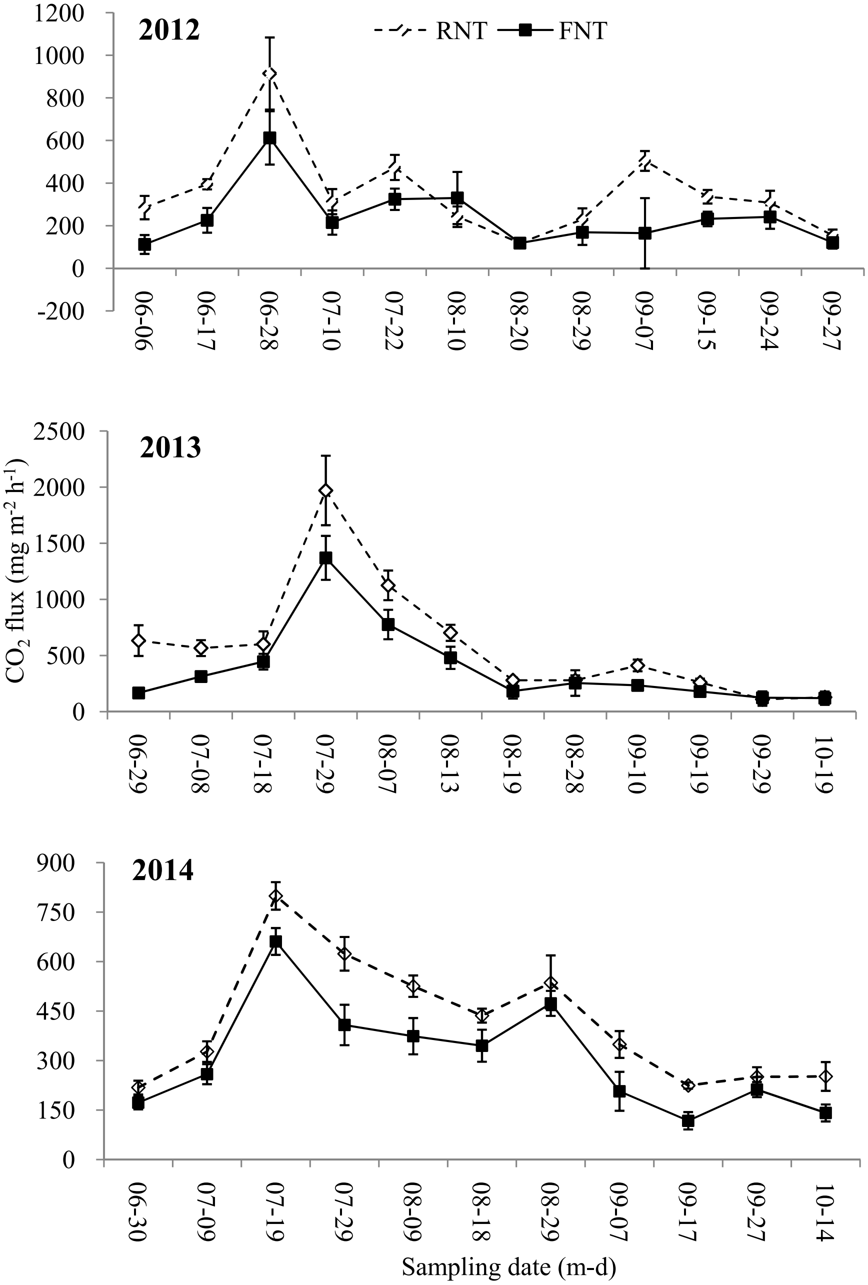

Figure 2. Seasonal changes in paddy soil CO_2 fluxes from the ridges in the RNT treatment and from the flat land in the FNT treatment during the 2012-2014 rice growing seasons

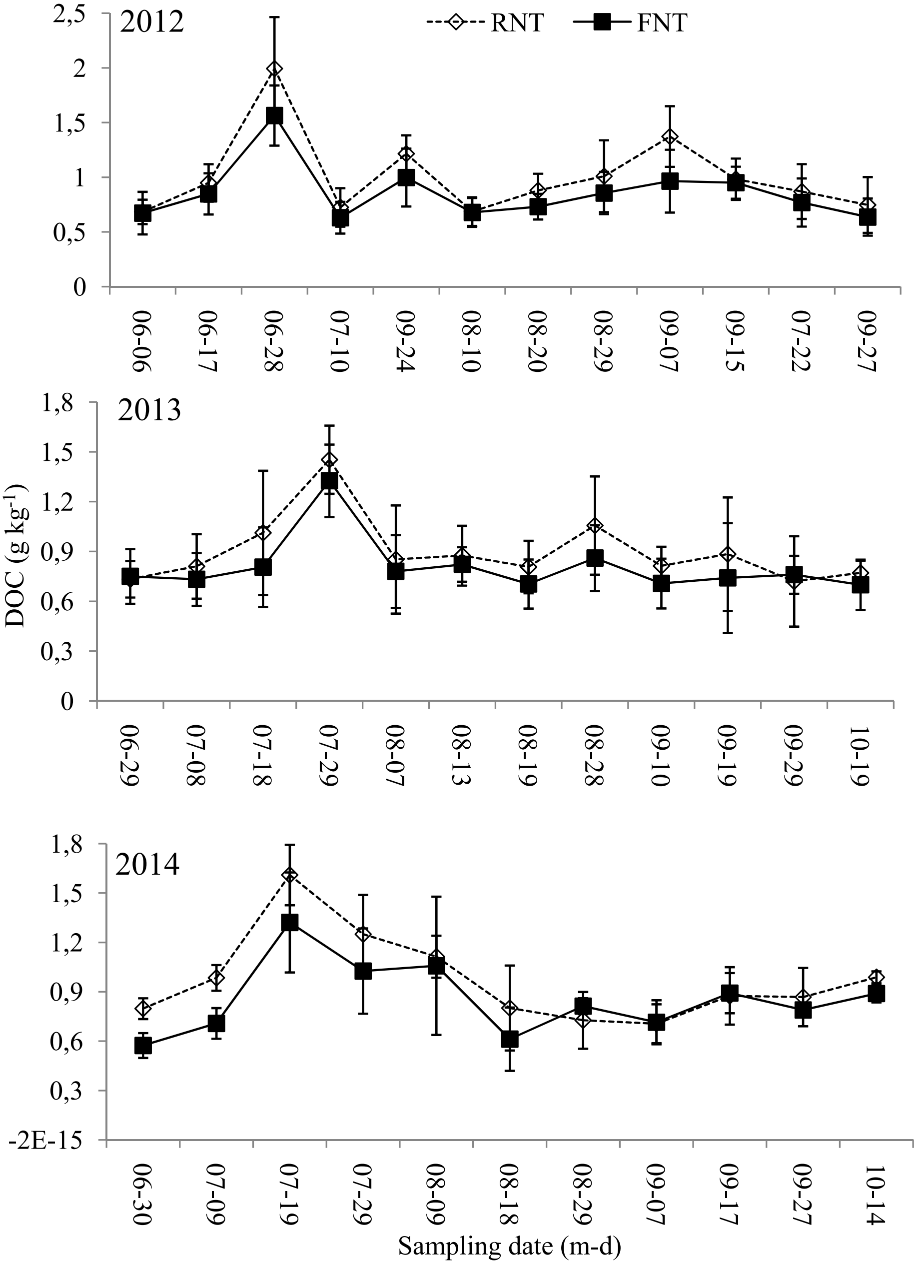

Figure 3. Seasonal changes in paddy soil DOC from the ridges in the RNT treatment and from the flat land in the FNT treatment during the 2012-2014 rice growing seasons. DOC, dissolved organic C.

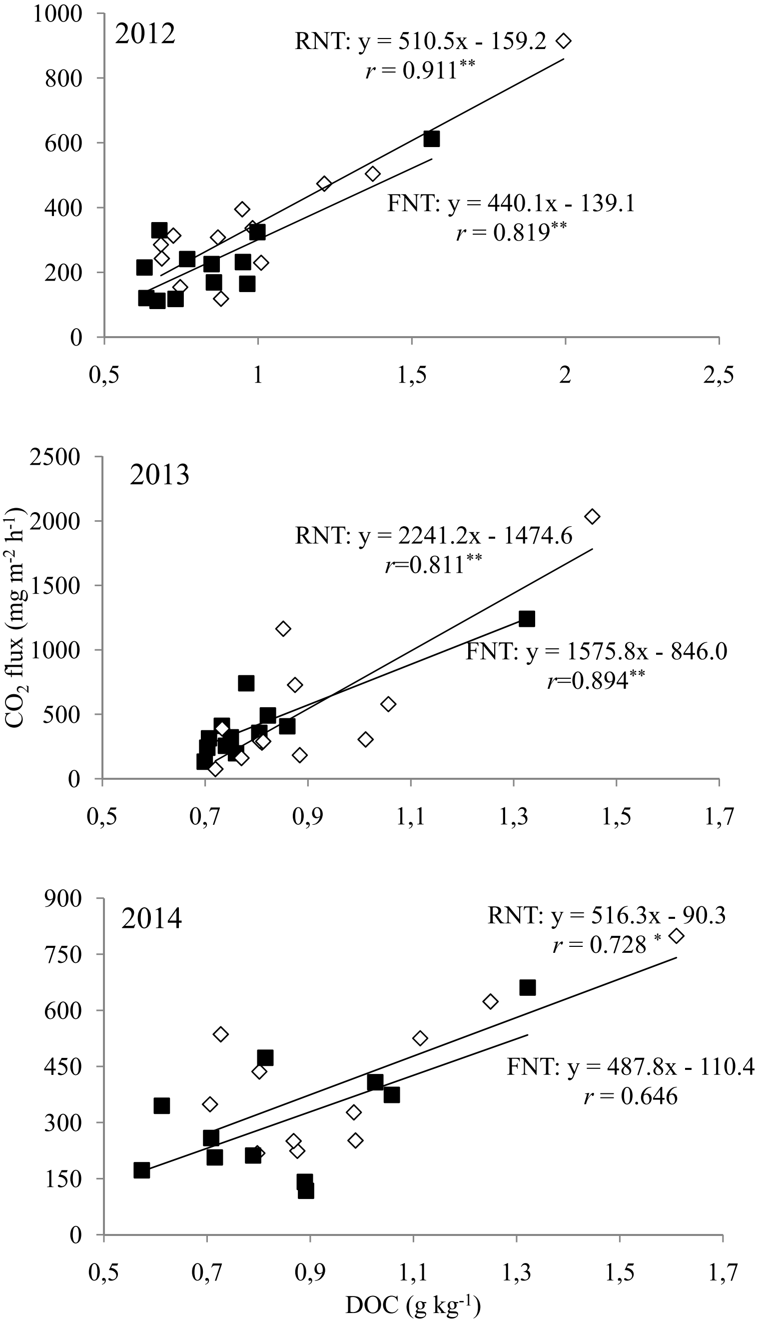

Figure 4. Linear correlations between CO_2 flux and DOC content under different treatments. DOC, dissolved organic C

4. Discussion

The differences in soil CO_2 emissions between NT and conventional flat intensive tillage have been well assessed in dry lands and paddy fields (Patiño-Zúñiga *et al.*, 2009; Li *et al.*, 2013). However, relatively few studies investigated the differences in soil CO_2 emissions between RNT and FNT (Patiño-Zúñiga *et al.*, 2009). In the present study, we investigated the effects of RNT and FNT on paddy soil CO_2 emissions in central China.

In this study, soil CO_2 fluxes peaked at the tillering stage (Figure 2), because of the increased substrates derived from root exudation and microbial decomposition of the remaining residues from previous crops (Li *et al.*, 2013). The microenvironment of the rice field drastically changes when conventional flat intensive tillage is converted into RNT (Figure 1), resulting in high solar energy and good ventilation; subsequently, a vigorous photosynthesis and plant growth under RNT occur (Gao *et al.*, 2004; Jiang and Xie, 2009). Moreover, the improved water use efficiency, air permeability, and supply of soil nutrition under RNT relative to FNT stimulate rice growth (Zheng *et al.*, 2014). In the present study, the root and aboveground biomasses in the RNT treatment were higher than those in the FNT treatment (Table 3). Moreover, the higher sowing density in the RNT treatment than that in the FNT treatment may partially explain this phenomenon. Similar results were reported by Gao *et al.* (2004) and Jiang and Xie (2009). Ren *et al.* (2007) also indicated that the ridge tillage cultivation can promote rice root growth compared with the flat land; in this study, biomass, volume, length, and superficial area of roots increased by 14–20%, 14–34%, 9–11% and 14–15%, respectively.

As a labile organic C, DOC consists of labile compounds, including organic acids, sugars, and amino acids (Haynes, 2005). DOC is readily degradable and is the major energy source for microorganisms (Haynes, 2005; Hu *et al.*, 1997). Bi *et al.* (2013) reported that soil CO_2 emissions may be aggravated by the electroactive moieties in soil DOC; these moieties function as electron shuttles and facilitate electron transfer reactions in soil respiration and SOC mineralization. Thus, some researchers reported that DOC is significantly related to soil respiration (Bi *et al.*, 2013; Wang *et al.*, 2013), which is also reported by our study (Figure 4). In the present study, the higher root and aboveground biomasses in the RNT treatment than those in the FNT treatment (Table 3) may demonstrate a higher DOC content, which was derived from the root exudates and photosynthates translocated from the aboveground biomass; this phenomenon partially explains the higher soil CO_2 flux in the RNT treatment than those in the FNT treatment (Figure 2; Tables 1 and 2).

Evidence has shown that the aboveground biomass of crops is linked to soil CO_2 emission (Raich and Tufekcioglu, 2000). We observed significant linear correlations between soil CO emissions and aboveground biomass (Figure 5). Similar results were reported by Ding *et al.* (2007) and Xu *et al.* (2008). Root respiration is sensitive to seasonal changes in crop aboveground biomass, because it largely depends on the amount of photosynthates translocated from the aboveground biomass (Curiel-Yuste *et al.*, 2004; Kuzyakov and Cheng, 2004; Xu *et al.*, 2008; Chaudhary *et al.* 2014). Moreover, the aboveground biomass can provide aboveground litter and belowground organic detritus to the soil (Raich and Potter, 1995; Kara *et al.* 2014). In the present study, high aboveground biomass in the RNT treatment (Table 3) indicates high soil DOC content in the RNT treatment, resulting in increased soil CO_2 emissions (Figure 2; Tables 1 and 2).

Roots significantly affect soil CO_2 emissions. On one hand, respiring roots below the measurement collars significantly affect soil CO_2 flux because root respiration is an important part of soil respiration

(Hanson *et al.*, 2000); on the other hand, during the rice growing season, the root exudates from photosynthetic production and root litter that are allocated into the soil can increase soil CO_2 emission by stimulating microbial growth and activity (Lohila *et al.*, 2003). Moreover, the increased root exudates can stimulate the decomposition of SOC by priming soil microbial activity (de Graaff *et al.*, 2014). Thus, a significant correlation between soil CO_2 emissions and root biomass is generally reported (Raich and Schlesinger, 1992; Zhu and Cheng, 2013). In the present study, we observed that soil CO_2 emissions were positively correlated with root biomass (Fig. 6). Root biomass in the RNT treatment was higher than that in the FNT treatment (Table 3). The high root biomass in the RNT treatment is associated with high root growth, resulting in high CO_2 emissions directly derived from roots (Hanson *et al.*, 2000; Zhu & Cheng, 2013). The high ROOT biomass in the RNT treatment might contribute high availability of C in the rhizosphere as a result of increased root exudation. This possibility is supported by high soil DOC in the RNT treatment (Figure 3), thereby leading to high soil respiration. In addition, RNT improves soil aeration on the ridges compared with FNT (Gao *et al.*, 2004), resulting in high decomposition of SOC.

As mentioned above, soil DOC, root biomass and aboveground biomass are important factors influencing soil CO_2 emissions. Moreover, the differences in DOC, root biomass and aboveground biomass between FNT and RNT coincide with the differences in soil CO_2 emissions, suggesting that abiotic and biotic factors should been simultaneously taken into account to explain the differences in soil CO_2 emissions in agroecosystems under tillage practices. In addition, infrequent sampling (about 10-d interval) due to labor intensive process may mischaracterize variability of soil CO_2 emissions or episodic flux events. However, the results obtained from three seasons in this study may be reliable because they demonstrated similar results. Furthermore, Mosier *et al.* (2005) suggested that entire crop growing and fallow seasons shall be considered when assessing effects of tillage systems on soil CO_2 emissions. Hence, in our study, a further study integrated rice-fallow-oilseed rape seasons should be taken into account to evaluate the effects of tillage systems on soil CO_2 emission from paddy fields.

5. Conclusion

The present study investigated the effects of ridge cultivation with no-tillage and conventional flat cultivation with no-tillage on soil CO_2 fluxes in rice fields of central China. The microenvironment of the rice fields changes dramatically when conventional flat cultivation with no-tillage is converted to ridge cultivation with no-tillage, which results in significant differences in soil dissolved organic C, root biomass and aboveground biomass between the treatments of ridge cultivation with no-tillage and conventional flat cultivation with no-tillage, thus affecting soil CO_2 emissions. The cumulative CO_2 emissions in the ridge cultivation with no-tillage treatment were increased by 44%, 47% and 34% than those in the conventional flat cultivation with no-tillage treatment in 2012, 2013 and 2014, respectively. Regression analyses showed significant correlations between soil CO_2 emissions and dissolved organic C, aboveground biomass and root biomass. Therefore, our results suggested that the soil CO_2 emissions from integrated rice-based system should be taken into account to assess tillage system effects.

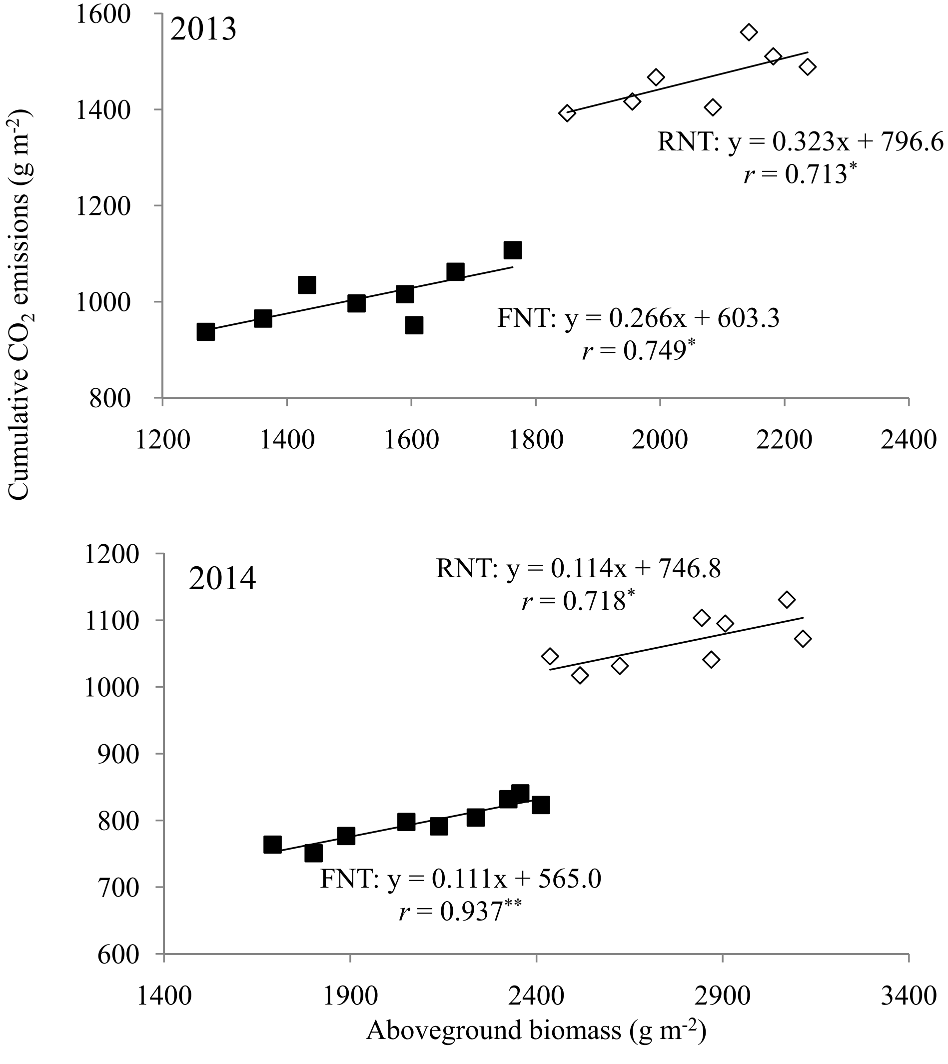

Figure 5. Linear correlations between cumulative CO_2 emissions and aboveground biomass under different treatments.

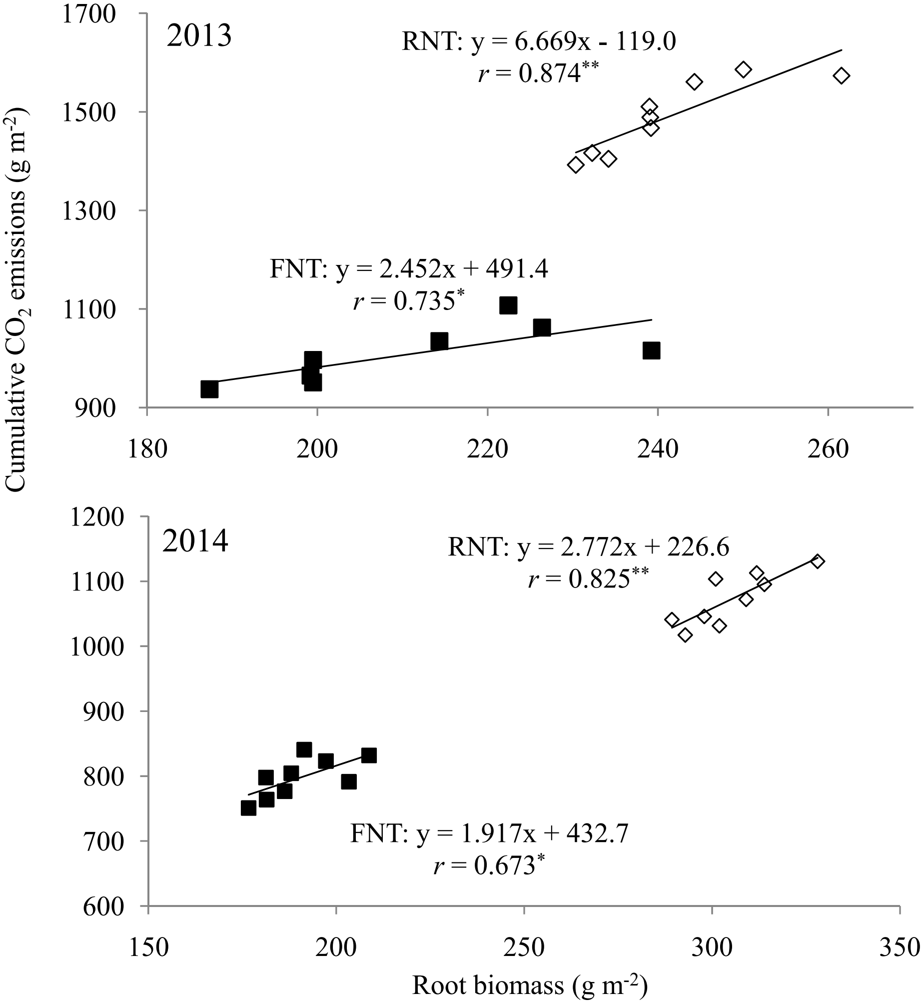

Figure 6. Linear correlations between cumulative CO_2 emissions and root biomass under different treatments

Acknowledgements

This work was funded by the National Natural Science Foundation of China (31100319), (31471454) Fundamental Research Funds for the Central Universities (2013PY106), and National Technology Project for High Food Yield of China (2011BAD16B02). We are grateful to Dr. María de la Luz Mora, Editor-in-chief of Journal of Soil Science and Plant Nutrition, Dr. Alex Seguel, Managing Editor of the Journal, and anonymous referees for their critical comments on the original manuscript.

References

Bi, R., Lu, Q., Yu, W., Yuan, Y., Zhou. S. 2013. Electron transfer capacity of soil dissolved organic matter and its potential impact on soil respiration. J. Soils Sediments 13, 1553–1560.

Chaudhary, D.R., Chikara, J., Ghosh, A. 2014. Carbon and nitrogen mineralization potential of biofuel crop (*Jatropha curcas* L.) residues in soil. J. Soil Sci. Plant Nutr. 14, 15–30.

Curiel-Yuste, J., Janssens, I.A., Carrara, A., Ceulemans, R. 2004. Annual Q_{10} of soil respiration reflects plant phonological patterns as well as temperature sensitivity. Global Change Biol. 10, 161–169.

de Graaff, M.A., Jastrow, J.D., Gillette, S., Johns, A., Wullschleger, S.D. 2014. Differential priming of soil carbon driven by soil depth and root impacts on carbon availability. Soil Biol. Biochem. 69, 147–156.

Derpsch, R., Friedrich, T. 2009. Development and current status of no-till adoption in the world. In Proceedings on CD, 18th Triennial Conference of the International. Soil Tillage Research Organisation, (ISTRO).

Ding, W.X., Meng, L., Yin, Y.F., Cai, Z.C., Zheng, X.H. 2007. CO_2 emission in an intensively cultivated loam as affected by long-term application of organic manure and nitrogen fertilizer. Soil Biol. Biochem. 39, 669–679.

Gao, M., Zhang, L., Wei, C.F., Xie, D.T. 2004. Study of the changes of the rice yield and soil fertility on the paddy field under long-term no-tillage and ridge culture conditions. Plant Nutr. Fertil. Sci. 10, 343–348. (in Chinese)

Govaerts, B., Sayre, K.D., Ceballos-Ramirez, J.M., Luna-Guido, M.L., Limon-Ortega, A., Deckers, J., Dendooven, L. 2006. Conventionally tilled and permanent raised beds with different crop residue management: effects on soil C and N dynamics. Plant Soil 280, 143–155.

Hanson, P.J., Edwards, N.T., Garten, C.T., Andrews, J.A., 2000. Separating root and soil microbial contributions to soil respiration: a review of methods and observations. Biogeochemistry 48, 115–146

Haynes, R.J. 2005. Labile organic matter fractions as central components of the quality of agricultural soils: an overview. Adv. Agron. 85, 221–268.

Hu, S., Coleman, D.C., Carroll, C.R., Hendrix, P.F., Beare, M.H. 1997. Labile soil carbon pools in subtropical forest and agricultural ecosystems as influenced by management practices and vegetation types. Agric. Ecosyst. Environ. 65, 69–78.

Huang, M., Jiang, L., Zou, Y., Xu, S., Deng, G. 2013. Changes in soil microbial properties with no-tillage in Chinese cropping systems. Biol. Fertil. Soils 49, 373-377.

IPCC. 2014. Climate Change 2014 - Mitigation of Climate Change: Working Group III Contribution to the Fourth Assessment Report of the IPCC. Cambridge University Press.

Iqbal, J., Hu, R., Lin, S., Hatano, R., Feng, M., Lu, L., Ahamadou, B., Du, L. 2009. CO_2 emission in a subtropical red paddy soil (Ultisol) as affected by straw and N-fertilizer applications: a case study in Southern China. Agric. Ecosyst. Environ. 131, 292–302.

Jiang, P.K., Xu, Q.F., Xu, Z.H., Cao, Z.H. 2006. Seasonal changes in soil labile organic pools within a Phyllostachys praecox stand under high rate fertilization and winter mulch in subtropical China. Forest Ecol. Manage. 236, 30–36.

Jiang, X.J., Xie, D.T. 2009. Combining ridge with no-tillage in lowland rice-based cropping system: long-term effect on soil and rice yield. Pedosphere 19, 515–522.

Jones, J.J.B. 2001. Laboratory Guide for Conducting Soil Tests and Plant Analysis. CTC Press, Boca Raton London, New York, Washington, DC, pp, 140–142.

Kara, O., Bolat, I., CaKıroglu, K., Senturk, M. 2014. Litter decomposition and microbial biomass in temperate forests in northwestern Turkey. J. Soil Sci. Plant Nutr. 14, 31–41.

Kuzyakov, Y., Cheng, W. 2004. Photosynthesis controls of CO_2 efflux from maize rhizosphere. Plant Soil 263, 85–99.

Li, C.F., Zhang, Z.S., Guo, L.J., Cao, C.G. 2013. Emissions of CH_4 and CO_2 from double rice cropping systems under varying tillage and seeding methods. Atmos. Environ. 80, 438–444.

Lohila, A., Aurela, M., Regina, K., Laurila, T. 2003. Soil and total ecosystem respiration in agricultural fields: effect of soil and crop type. Plant Soil 251, 303–317.

Lou, Y.S., Li, Z.P., Zhang, T.L. 2003. Carbon dioxide flux in a subtropical agricultural soil of China. Water Air Soil Pollut. 149, 281–293.

Mosier, A.R., Halvorson, A.D., Peterson, G.A., Robertson, G.P., Sherrod, L. 2005 Measurement of net global warming potential in three agroecosystems. Nutr. Cy. Agroecosyst. 72, 67–76.

Patiño-Zúñiga, L., Ceja-Navarro, J.A., Govaerts, B., Luna-Guido, M., Sayre, K.D., Dendooven, L. 2009. The effect of different tillage and residue management practices on soil characteristics, inorganic N dynamics and emissions of N_2O, CO_2 and CH_4 in the central highlands of Mexico: a laboratory study. Plant Soil 314, 231–241.

Raich, J.W., Tufekcioglu, A. 2000. Vegetation and soil respiration: correlations and controls. Biogeochemistry 48, 71-90.

Raich, J.W., Potter, C.S. 1995. Global patterns of carbon-dioxide emissions from soils. Global Biogeochem. Cy. 9, 23–36.

Raich, J.W., Schlesinger, W.H. 1992. The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. Tellus B 44, 81–99.

Ren, X.L., Jia, Z.K., Chen, X.L., Han, J., Han, Q.F. 2007. Effect of ridge and furrow planting of rainfall harvesting on soil available nutrient distribution and root growth of summer corn under simulated rainfall conditions. Transact. CSAE 23, 94–99. (in Chinese)

Schlesinger, W.H., Andrews, J.W. 2000. Soil respiration and the global carbon cycle. Biogeochemistry 48, 7–20.

Tang, Y.L., Zheng, J.G., Huang, G. 2005. Studies on permanent-bed-planting with double zero tillage for rice and wheat in Sichuan basin. Southwest China J. Agric. Sci. 18, 25–28. (in Chinese)

Wang, Q., Xiao, F., Zhang, F., Wang, S. 2013. Labile soil organic carbon and microbial activity in three subtropical plantations. Forestry 0, 1–6.

Xu, X., Kuzyakov, Y., Wanek, W., Richter, A. 2008. Root-derived respiration and non-structural carbon of rice seedlings. Euro. J. Soil Biol. 44, 22–29.

Zheng, H.B., Huang, H., Liu, J.X., Yao, L., He, H. 2014. Recent progress and prospects in the development of ridge tillage cultivation technology in China. Soil Tillage Res. 142, 1–7.

Zhu, B., Cheng, W. 2013. Impacts of drying–wetting cycles on rhizosphere respiration and soil organic matter decomposition. Soil Biol. Biochem. 63, 89–96.