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Response of CO_2 efflux from forest and annual crop as a function of water retention capacity and the addition of nitrogen

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Abstract

The carbon dioxide (CO_2) efflux from various terrestrial ecosystems under various moisture contents provides a good understanding of the carbon cycle. The aim of this study was to evaluate the impact of extreme moisture content in the presence and absence of nitrogen (N) fertilizer application on CO_2 efflux (ECO_2) from forest and annual crop soils. The clay (forest (F) soil) and sandy loam (annual crop (AC) soil) with or without *Rhodic Ferrasol* (*FR-ro*) N fertilizer application were incubated under increasing concentrations of water corresponding to 40–700% of the water retention capacity (WRC). Even with the same classification, the two soils presented particular chemical and physical characteristics, probably due to the conversion of the forest area to agriculture in the AC soil. In all assays, the most ECO_2 was found at 24 h soil incubation period. After 24 h of incubation, ECO_2 diminished, and the decreased ECO_2 was found in annual crop $AC_{700}{}^{1}$ (incubated for 1728 h in 60, 80, 100, 150, 200, 300, 500 and 700 % WRC) soil. The effect of WRC varied between soils during all incubation periods. The highest ECO_2 was found in annual crop AC_{200} (incubated for 144 h in 50, 75, 100, 150 and 200 % WRC) and AC_{700} (incubated for 144 h in 60, 100, 150, 200, 300 and 700 % WRC) soils with 100% and 60% WRC, respectively. No effect on microbial respiratory activity by the N addition in the soil was found. In waterlogged soils or soils subject to the increased amount of water contents, incubation time and moisture concentration are two important factors that influence ECO_2.

Key words: carbon cycle, nitrogen fertilization, regression equations, respiratory activity, waterlogged soil, water retention capacity.

Introduction

Studies on the dynamics of soil carbon (C) in different ecosystems are often used to measure the evolution of carbon dioxide (CO_2) into the atmosphere; due to respiration by the roots of plants, microorganisms, and macroorganisms (Dorodnikov et al., 2009; Silva et al., 2013). The source of C comes from soil organic matter (SOM), or more specifically from the soil organic carbon (SOC), as a result of the disposal of animal waste and plant residues of sustainable ecosystems or after harvesting the plants (Monforti et al., 2015). The CO_2 production mechanism involves the oxidation of organic compounds under aerobic conditions, and oxygen (O_2) is used as the final electron acceptor (Muñoz et al., 2010; Keiluweit et al., 2016).

The C content depends on the soil type and management practices, such as tillage, cultivation system, crop rotation and nitrogen (N) fertilization (Sainju et al., 2010; Silva-Olaya et al., 2013). The use of nitrogen fertilizer promotes plant growth, which enhances the crop productivity (Xia, Wan, 2008). Organic N is used by the microorganisms for growth in a biochemical mechanism of nitrification, producing nitrite (NO_2^-) and nitrate (NO_3^-) by the oxidation of ammonia (Prommer et al., 2014). Microorganisms or plants can absorb the NO_3^-. In anaerobic conditions, NO_3^- can be reduced by microbial denitrification process, which produces nitric oxide (NO) and nitrous oxide (N_2O) gases that are released into the atmosphere (Signor, Cerri, 2013).

In addition, climatic factors and the physical and chemical properties of the soil influence the biochemical transformation of SOM (Hernández-Jiménez et al., 2016; Karmakar et al., 2016). The temperature and soil water

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content are considered important factors that regulate the emission of CO_2 (Ryu et al., 2009; Gritsch et al., 2015). Thus, the CO_2 flux is higher in an irrigated system than in non- irrigated system (Sainju et al., 2010). Increasing concentrations of moisture significantly stimulated the mineralization of C with significant increase in CO_2 emissions (Qi et al., 2011). However, low moisture contents decrease the microbial activity and high contents reduce the O_2 availability, thereby decreasing the SOM decomposition. High moisture contents occur in permanently waterlogged soils, as in mangroves, that are subject to constant tidal flows (Pupin, Nahas, 2014), or temporarily due to prolonged rains, as in Pantanal tropical wetland ecosystem (Johnson et al., 2013), with moisture contents beyond their water retention capacity (WRC).

When a soil is subject to flooding, as in irrigated rice crop, the chemical transformations in this soil occur in a different way. The replacement of air by water in the porous spaces and the establishment of a surface of water on the ground restrict the gas exchange with the atmosphere, and the remaining oxygen is rapidly consumed and the CO_2 evolved, where the diffusion of gases through the water is very difficult (Hossain, Puteh, 2013). The influence of high moisture levels and nitrogen fertilization in soils with different clay contents on the microbial metabolism is still poorly studied. No study, to our knowledge, has been conducted using high WRC values up to 700%. Moreover, Peng et al. (2010) stated that long-term studies are needed to evaluate the effect of fertilization with N and respiratory activity.

We considered the hypothesis that varying amounts of moisture, from normal up to high WRC, combined with the effect of N fertilization and soil incubation time, have an uneven effect on respiratory activity. Our objectives were to (i) evaluate the effect of increasing water concentrations (calculated as WRC) added to the soil at increasing incubation times on respiratory activity and (ii) determine the effect of adding or not adding nitrogen (N) to soil on carbon dioxide (CO_2) efflux.

Materials and methods

Description of study site. The soil used in this study was collected at Faculdade de Ciências Agrárias e Veterinárias in Jaboticabal (21°15′29″ N and 48°16′47″ W, alt. of 614 m), San Paolo, Brazil. The climate, according to Köppen (1918) classification, is Cwa – mesothermal with hot summers and dry winters; average temperature of 21°C and average rainfall of 1.428 mm per year. The soil of both forest (F) and annual crop (AC) is classified as *Rhodic Ferrasol* (*FR-ro*), according to the FAO (WRB, 2014) with clay and sandy loam texture, respectively (Table 1). The forest area is reminiscent of native forest, and the annual crop of 20 ha has been planted with corn for the last three years. The soil was collected in randomly selected areas during the summer (February) 2012 at a depth of 0–10 cm in five locations of each area with a hoe to obtain uniform distribution of sub-samples. Each sample consisted of three subsamples that were pooled to form a composite sample. The samples were transported to the laboratory in plastic bags, sieved through a 4-mm sieve to remove the plant material.

Table 1. Chemical composition and particle size of forest and annual crop soils

Chemical composition	Unit	Forest (F)	Annual crop (AC)
Phosphorus (P) resin	mg kg^{-1}	43	15
Soil organic matter (SOM)	g kg^{-1}	38	15
Potassium cation (K^+)	$mmol_c$ dm^{-3}	2.6	1.4
Calcium cation (Ca^{2+})	$mmol_c$ dm^{-3}	73	19
Magnesium cation (Mg^{2+})	$mmol_c$ dm^{-3}	21	8
Exchangeable acidity (H^++Al^{3+})	$mmol_c$ dm^{-3}	24.3	34.6
Base some (BS)	$mmol_c$ dm^{-3}	115.2	48.6
Cation exchange capacity (CEC)	$mmol_c$ dm^{-3}	139.5	83.2
Base degree saturation %, g 100 g^{-1} (V)	%	79	56
pH		5.4	5.7
Clay	g kg^{-1}	490	320
Silt	g kg^{-1}	290	70
Sand coarse	g kg^{-1}	110	280
Sand fine	g kg^{-1}	110	330
Texture		clay	sandy loam

Soil sampling. The samples were air dried at room temperature for several days and then gently sieved through a 2 mm sieve. The water retention capacity (WRC) of soil is basically explained by soil capillary and adsorption responses. To determine WRC, polyvinyl chloride (PVC) tubes with a perforated bottom for water penetration were weighed with and without dry soil from samples. The PVC tubes were placed in flasks containing distilled water for moisture absorption and kept for 24 h. Next, the tubes were weighed again. To calculate the WRC, the weights of the obtained samples were used, the result being expressed in ml water absorbed by 100 g^{-1} dry soil. Therefore, 100% of the WRC from forest and annual crop soils were 45.5 and 39.0 ml 100 g^{-1} dry soil, respectively.

The soils were fertilized in physical weight: (1) soil with nitrogen (N): with 100-40-30 kg ha^{-1} as urea-triple superphosphate-potassium chloride and (2) soil without N, with no added urea, but with triple superphosphate-potassium. After fertilization, water was added to the soils in an amount equivalent of WRC to: 1) F_{120}: 40-60-80-100-120% WRC and incubation time of up to 384 h, 2) AC_{120}: 40-60-80-100-120% WRC and incubation time of up to 384 h, 3) AC_{200}: 50-75-100-150-200% WRC and incubation time of up to 144 h, 4) AC_{700}: 60-100-150-200-300-700% WRC and incubation time of up to 144 h, and 5) $AC_{700}{}^{1}$: 60-80-100-150-200-300-500-700% and incubation time of up to 1728 h. All results reported are averages of duplicate determinations.

Microbial respiratory activity. The carbon dioxide (CO_2) production was determined according to Rezende et al. (2004). Samples of 100 g dry soil were placed in 2.5 L vials and water was added in amounts corresponding to the respective WRC. Then a beaker with 20 ml of distilled water and another beaker with 20 m of 0.5 M sodium hydroxide (NaOH) were added. In the blank test, the soil was not added. The vials were sealed with polythene sheets and kept at a temperature of 30°C in the dark for predetermined times. The CO_2 emitted was determined by titration of the excess of 0.5 M NaOH with 0.5 M HCl using phenolphthalein as indicator. The calculation of released CO_2 was the difference between the volumes of hydrochloric acid (0.5 M HCl) spent to titrate 0.5 M NaOH from the sample in the vials with soil and in the blank test. The results were transformed to carbon dioxide mass (CO_2-C) for soil mass, mg of CO_2-C 100 g^{-1} dry soil. All results reported are averages of duplicate determinations.

Statistical analysis. The experimental design was completely randomized. Regression equations and coefficients of determination (R^2) for relationship between CO_2 flux as a function of the WRC and incubation time of soil samples were determined using Microsoft Office *Excel 2010*®. The completely randomized factorial design 2 × 2 × 12 (soil × N × WRC) was used, with four replications. Statistical analysis was performed using statistical software *SISVAR*® (Ferreira, 2011). Means were compared using a Tukey test ($P < 0.05$).

Results

The same trend was observed in the evolution of CO_2 from forest F_{120} and annual crop AC_{120} soil samples, with N added or not, in the period of 0 to 384 h of incubation and with increasing moisture concentrations ranging from 40% to 120% WRC (Figs 1 and 2). The highest respiratory activity was found with 24 h of incubation of both soils, and it then decreased until the end of the studied period. The decrease in the F_{120} soil ranged from 43% to 86% without N and 41% to 82% in the soil with N, and in the AC_{120} soil from 36% to 89% and 31% to 87%, respectively. In both soils, the greatest decrease was observed after incubation periods of 48 h.

Comparing the soil without N and the soil with N, the CO_2 evolution increased on average 8% and 4% in the forest and annual crops, respectively. While the total quantity of CO_2 released in F_{120} soil ranged from 184.80 to 218.90 (without N) and 198.28 to 221.93 mg of CO_2-C 100 g^{-1} dry soil (with N), and the AC_{120} soil ranged from 185.91 to 220.01 (without N) and 192.79 to 216.43 mg of CO_2 100 g^{-1} dry soil (with N) (Table 2). The highest total amounts of CO_2 released were found in the soils with the highest WRC – 100% and 120%.

With increased WRC of AC_{200} soil ranging from 50% to 200% in the zero to 144 h period, most CO_2 evolution was also found in the samples with or without N with incubation of 24 h (Fig. 3). Then CO_2 evolution decreased from 53% to 64% in soil without N and from 33% to 63% in soil with N. In general, increased respiration rate was found in both the soils with or without N and with 100% WRC. The respiratory activity increased 22% for the soil with N in relation to the soil without N. The total amounts of CO_2 emitted ranged from 79.76 to 95.98 in the soil without N and 104.78 to 124.30 mg of CO_2 100 g^{-1} dry soil in the soil with N, and the lowest values were found in the soil with 200% WRC (Table 2).

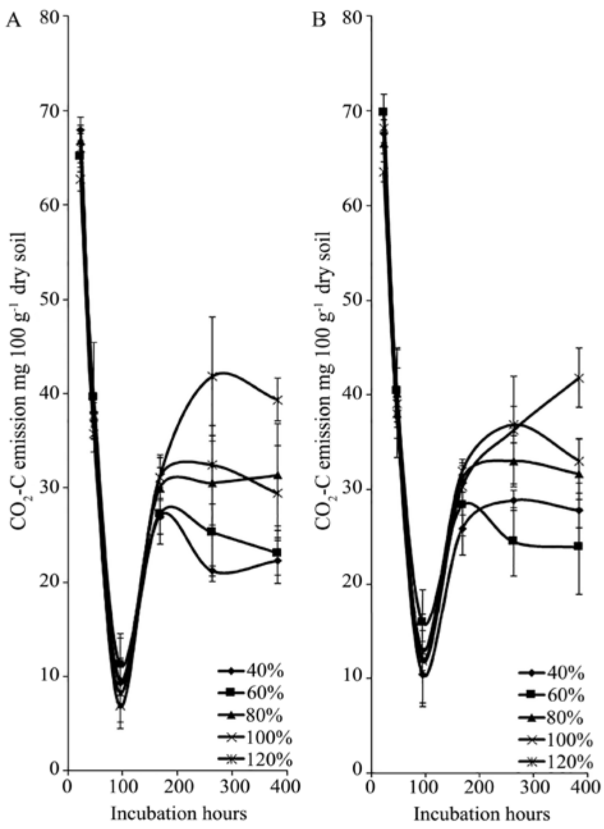

Figure 1. Carbon dioxide (CO_2) flux from forest (F) soil without (A) and with (B) nitrogen (N) added, and incubated for 384 h in 40, 60, 80, 100 and 120 % (F_{120}) water retention capacity (WRC)

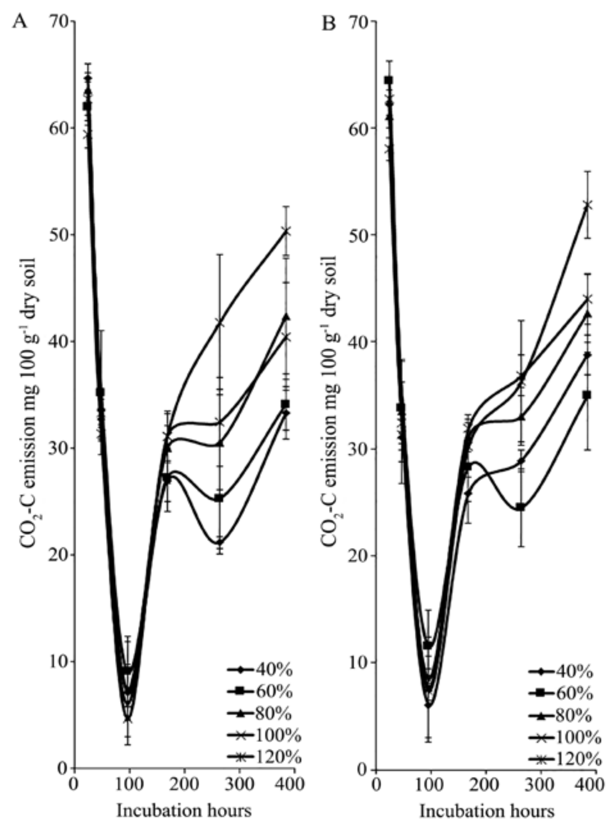

Figure 2. Carbon dioxide (CO_2) flux from annual crop (AC) soil without (A) and with (B) nitrogen (N) added and incubated for 384 h in 40, 60, 80, 100 and 120 % (AC_{120}) water retention capacity (WRC)

Table 2. Total carbon dioxide (CO_2) quantities released by forest (F) and annual crop (AC) soils fertilized or not with nitrogen (N), varying the water retention capacity (WRC)

N addition	F_{120}		AC_{120}		AC_{200}		AC_{700}		$AC_{700}{}^1$	
	WRC	CO_2	WRC	CO_2	WRC	CO_2	WRC	CO_2	WRC	CO_2
Without N	40	184.8 c	40	185.9 c	50	85.5 ab	60	91.9 a	60	416.5 a
	60	191.7 bc	60	192.8 bc	75	89.7 ab	100	95.2 a	80	405.5 ab
	80	206.5 b	80	207.6 b	100	96.0 a	150	81.7 b	100	394.9 ab
	100	203.5 b	100	204.6 b	150	87.2 ab	200	77.0 bc	150	385.0 b
	120	218.9 a	120	220.0 a	200	79.8 b	300	69.3 c	200	375.9 bc
							700	40.0 d	300	365.9 c
									500	352.7 cd
									700	345.4 d
With N	40	198.3 b	40	192.8 b	50	106.4 b	60	100.3 a	60	436.0 a
	60	203.0 ab	60	197.5 ab	75	121.3 a	100	104.0 a	80	420.9 ab
	80	214.5 ab	80	209.0 a	100	124.3 a	150	87.2 b	100	414.3 b
	100	221.9 a	100	216.4 a	150	110.3 b	200	78.7 bc	150	408.5 bc
	120	221.7 a	120	216.2 a	200	104.8 b	300	73.4 c	200	398.9 bc
							700	37.8 d	300	390.1 bc
									500	381.3 c
									700	368.5 d

Note. Means followed by the same letters in the same column do not differ by Tukey test at 5%.

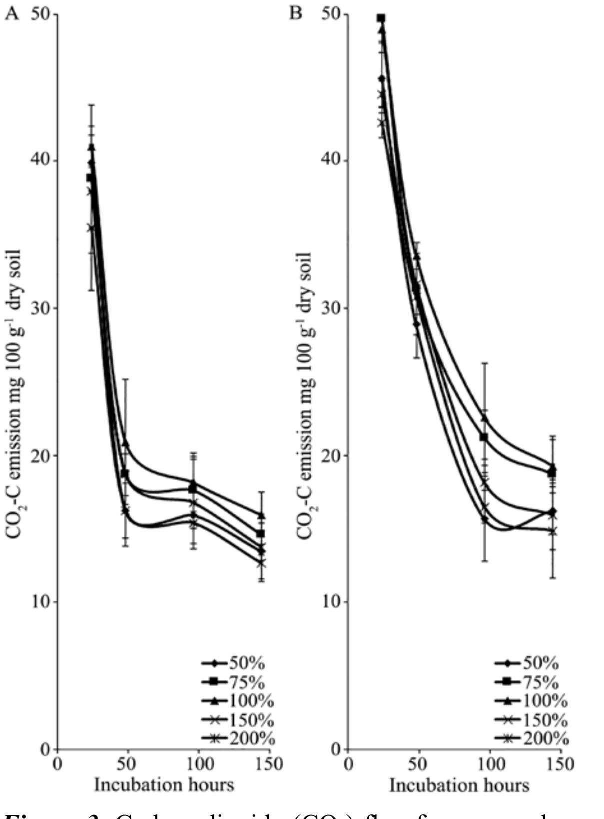

Figure 3. Carbon dioxide (CO_2) flux from annual crop (AC) soil without (A) and with (B) nitrogen (N) added and incubated for 144 h in 50, 75, 100, 150 and 200 % (AC_{200}) water retention capacity (WRC)

Previous results have suggested an increase in WRC of the annual crop. In the AC_{700} soil with WRC ranging from 60% to 700% and incubation time up to 144 h, the highest respiratory activity was also found after 24 h of incubation period (Fig. 4), and then it declined from 21% to 34% in the soil without N and from 26% to 31% in the soil with N. The highest CO_2 production was found in the soil with 100% WRC with or without N. The addition of N to the soil increased the CO_2 evolution on average 5% in relation to soil without N. The total amount of CO_2 released ranged from 39.98 to 95.16 in the soil without N, and 37.77 to 103.96 mg of CO_2 100 g^{-1} dry soil in the soil with N, where the lowest respiratory activity was found in the soil with 700% WRC (Table 2).

For the long incubation periods of the $AC_{700}{}^1$ soil ranging from 24 to 1728 h and 60% to 700% WRC, the highest CO_2 emission also occurred with 24 h of incubation (Fig. 5). Then it decreased from 3% to 59% in the soil without N and 44% to 58% in the soil with N, in which the largest decrease was found on the last day of incubation. Most respiratory activity was observed during all the soil incubation periods with 60% WRC, except in the soil without N and WRC of 120 and 168 h, which occurred with 80% WRC. CO_2 emission increased on

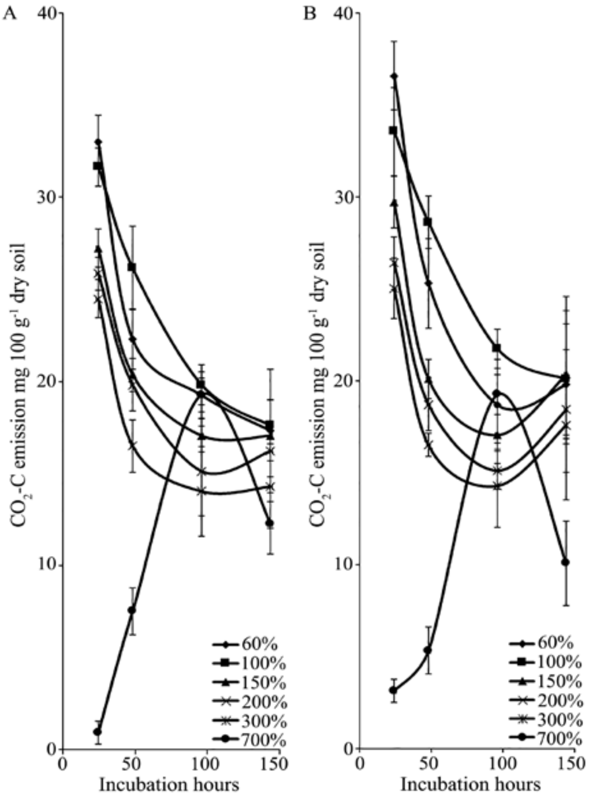

Figure 4. Carbon dioxide (CO_2) flux from annual crop (AC) soil without (A) and with (B) nitrogen (N) added and incubated for 144 h in 60, 100, 150, 200, 300 and 700 % (AC_{700}) water retention capacity (WRC)

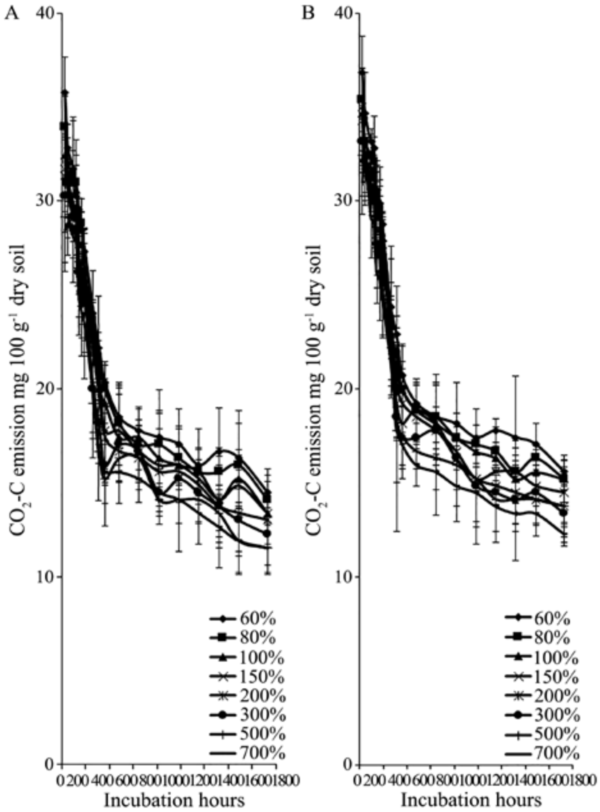

Figure 5. Carbon dioxide (CO_2) flux from annual crop (AC) soil without (A) and with (B) nitrogen (N) added and incubated for 1728 h in 60, 100, 150, 200, 300 and 700 % (AC_{700}[1]) water retention capacity (WRC)

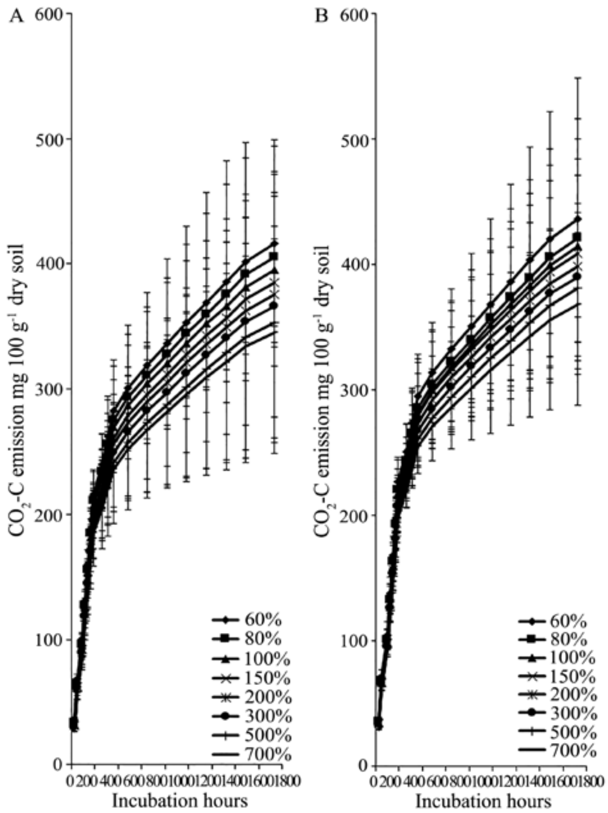

Figure 6. Cumulative carbon dioxide (CO_2) flux from AC_{700}[1] soil with water retention capacity (WRC) ranging from 60% to 700% for 1728 h incubation without (A) and adding (B) nitrogen (N)

average 5% as a result of adding N to the soil in relation to soil without N. The cumulative amount of CO_2 ranged from 345.40 to 416.63 in the soil without N, and 368.50 to 435.97 mg of CO_2 100 g^{-1} dry soil on the soil with N; the smallest value also corresponded to the greater WRC, which was 700% (Table 2).

The tendency lines of CO_2 emission of AC_{700}[1] soil, that follow logarithmic function, $y = a \times \ln(x) + b$ (Fig. 6, Table 3).

In general, the CO_2 emission was higher ($P < 0.05$) in the forest when compared to the annual crop soil, presenting a reduction of 37% (Table 4). It was also verified a significant increase of 10% in the soil that received nitrogen fertilization when compared to the soil that did not receive fertilization. However, changes in WRCs were observed ($P < 0.05$) 12.7 to 31.1 mg of CO_2 100 g^{-1} dry soil. The values in treatment WRC (700%) showed the lowest amount of CO_2 efflux and 120% WRC exhibited the highest amount of CO_2 efflux (Table 4).

Table 3. Regression equations and coefficients of determination (R^2) for relationship between carbon dioxide (CO_2) flux as function of the water retention capacity (WRC) and incubation time from AC_{700}[1] soil

WRC %	Without N		With N	
	equation	R^2	equation	R^2
60	y = 95.381ln(x) − 298.49	0.98	y = 99.628ln(x) − 311.46	0.98
80	y = 93.224ln(x) − 292.52	0.98	y = 96.356ln(x) − 300.97	0.98
100	y = 90.682ln(x) − 283.00	0.98	y = 95.111ln(x) − 297.94	0.98
150	y = 88.471ln(x) − 277.25	0.98	y = 93.647ln(x) − 291.18	0.98
200	y = 86.220ln(x) − 268.47	0.98	y = 91.354ln(x) − 282.81	0.98
300	y = 83.769ln(x) − 259.83	0.98	y = 89.232ln(x) − 276.03	0.98
500	y = 80.856ln(x) − 250.36	0.98	y = 86.822ln(x) − 267.74	0.98
700	y = 79.106ln(x) − 244.71	0.98	y = 83.993ln(x) − 257.82	0.98

y – amount of CO_2 released (mg CO_2 100 g^{-1} dry soil), x – incubation time (h)

Table 4. Effect of forest and annual crop soil on carbon dioxide (CO_2) flux

Water retention capacity (WRC)	Forest (F) × annual crop (AC)											
	40	50	60	75	80	100	120	150	200	300	500	700
Means (WRC)	28.6 b	24.0 e	25.2 de	26.4 cd	27.1 c	26.8 c	31.1 a	21.9 f	20.9 f	18.4 g	17.2 h	12.7 i
Means (soil)			34.4 a						21.7 b			
Means (N)	without		25.2 B									
	with		22.6 A									

Note. Means followed by the same letter, uppercase (N) and lower (soil and WRC), do not differ by Tukey test at 5%.

Discussion

The highest CO_2 emissions were found in all soils with 24 h of incubation. Then, CO_2 emissions decreased after 48 h of incubation from 3% to 57% in the soils without N and 4% to 58% with N (data not shown). In the absence of plant roots as in this study, the variation of CO_2 emission has been attributed to heterotrophic respiration due to microbial biological activity (Oyonarte et al., 2012; Zhao et al., 2016), which decreases with reduced concentration of C source from organic matter in the soil (Zeng, 2017). According to Ramesh et al. (2012), the greater the CO_2 emission is, the greater the biological activity and the SOM loss are. Therefore, with 24 h of soil incubation, the greatest SOM loss should occur.

After 24 h incubation, smaller quantities of CO_2 were emitted in AC_{700}^1 soil. In addition, the total activity significantly decreased in the respiratory activity of AC_{200} and AC_{700} soils compared to the AC_{120} (Table 2). The F_{120} soil was considered clayey and more fertile than AC_{120}, but the same response was found in both, possibly because they received the same fertilizer. The effect of temperature and soil moisture has been reported by Guntiñas et al. (2013) and Zhou et al. (2014). The effect of rainfall can vary depending on its intensity – the respiratory activity decreased with increased rainfall in three soils of subtropical forest of China (Jiang et al., 2013). However, it has been reported that the CO_2 flow increased during the rainy season in soil from Mato Grosso, Brazil (Valentini et al., 2008). According to Hou et al. (2016), excess moisture due to rain, irrigation, or flood, decreases the availability of O_2. Therefore, the results found may suggest that, depending on the time of incubation, anaerobic conditions can prevail with increased WRC, which reduces aerobic microbial activity (Tokarz, Urban, 2015). Accordingly, the respiratory activity decreased considerably with the incubation time of AC_{700}^1 soil (Fig. 5).

With relationship as to the effect of WRC, in order to simulate very flooded soils, amounts of moisture were added in the soil that can be considered very high of up to 700%. In contrast, limits to 100% WRC have been reported in the literature. In the AC_{120} and F_{120} soils, the higher respiratory activity was found in the 60% to 80% WRC up to the incubation period of 168 h and in the 100–120% WRC in the remaining period. In general, in both the soils with or without N, throughout all the incubation periods, the highest respiration was found in the AC_{200} and AC_{700} soils with 100% WRC and in the AC_{700}^1 with 60% WRC. The cumulative flow of CO_2 in the AC_{700}^1 soil generally corresponds to the logarithmic function, which tended to decrease with increasing WRC and elapsed time. It can be assumed that with the irrigation of a crop, the water infiltration time in the soil depends on their physical characteristics, and tends to increase the WRC, decrease the biological activity, and in turn, the CO_2 flux due to anaerobiosis. The increase of the soil moisture content because of prolonged rains provides decreased respiratory activity due to the prevalence of anaerobic conditions (Deng et al., 2017). Our results contrast with the findings of Uhlirova et al. (2005), who obtained increased respiratory activity with WRC ranging from 13% to 100%, and Abro et al. (2011) in soil, with WRC varying from 55% to 100%. However, similar results as obtained in this study were reported by Tavares et al. (2016), where the CO_2 flux decreased in a low or high moisture concentration, as a result of the variation of the microbial activity (Oyonarte et al., 2012).

The effect of adding N on the total respiratory activity in relation to soils without N (Table 2) varied on average from 2% to 6%, suggesting no significant effect was observed. Al-Kaisi et al. (2008) reported that the CO_2 emission decreased with increased concentrations of N, which shows negative effect when the soil was fertilized with N. Likewise, Peng et al. (2010) reported that no change was found in the respiratory activity when increasing concentrations of N were added in the soil compared to unfertilized. Soil fertilized with 270 kg ha^{-1} N had reduced CO_2 emissions compared to the unfertilized soil (Wilson, Al-Kaisi, 2008). In our study, the soil was fertilized with urea which requires its hydrolysis by microorganisms to produce ammonia and carbon dioxide (Souza et al., 2017). This reaction was correlated with the carbon and nitrogen microbial biomass (Grunert et al., 2016; Souza et al., 2017) and can be measured by the amount of CO_2 released. Probably due to the effect of high soil moisture content, the microbial respiratory activity and the hydrolysis of urea decreased.

Soil texture is the main abiotic factor for the regulation of soil microbial activity. Also it plays an important role in physical, chemical and biological processes able to alter the functioning of ecosystems (Bittar et al., 2013). The relative proportion of sand, silt and clay defines the soil textural class and modifies the potential of nutrient stock, carbon and WRC in the soils (Schoonover, Crim, 2015). However, soil texture is related to porosity and aeration into the soil, the texture also affects the air dynamics in this medium, interfering significantly in the microbial community and activities. In relation to the WRC, fine textured soils exhibited greater water availability in their superficial layers, consequently a higher WRC. On the other hand, in larger textured soils, high infiltration rates occur, shifting the available water to the deeper layers (Feiziene et al., 2010; Costa et al., 2013).

Conclusions

1. With the increased water retention capacity (WRC), as seen in annual crop AC_{200}, AC_{700} and AC_{700}^1 soils, respiratory activity of the soil tends to decrease. Therefore, soils with high WRC are more subject to that response. In permanently waterlogged soils, the soil CO_2 flux should correspond to the conditions after 24 h of incubation. In temporarily waterlogged soils due to heavy rains, the CO_2 emission would alter corresponding to the period before and after 24 h of soil incubation. A measure of the total CO_2 flow supports this idea.

2. Throughout the period of incubation, the respiratory activity was always the same for determining WRC of the soils; in the annual crop AC_{200} and AC_{700} soils, WRC soil was 100%, and in the AC_{700}^1, it was 60%. In this soil, the release of CO_2 was the result of a logarithmic function that varied with the WRC and the incubation time.

3. Compared to the soil without addition of nitrogen (N), the addition of N had no effect on the CO_2 flux.

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CO_2 emisijos iš miško dirvožemio ir dirvožemio, kuriame augo vienamečiai augalai, pilnas vandens imlumas, priklausomai nuo tręšimo azotu

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Santrauka

Anglies dioksido (CO_2) emisija iš įvairių ekosistemų, turinčių nevienodą kiekį drėgmės, leidžia išsiaiškinti anglies apykaitos ciklą. Tyrimo tikslas – įvertinti ekstremalaus drėgmės kiekio įtaką tręšiant ir netręšiant azoto (N) trąšomis CO_2 emisijai iš miško dirvožemio ir dirvožemio, kuriame augo vienamečiai augalai. Molio (miško) ir smėlingo priemolio (auginti vienamečiai augalai, VA) dirvožemis *Rhodic Ferrasol* (*FR-ro*) su ar be tręšimo N trąšomis buvo inkubuotas didinant vandens koncentraciją, atitinkančią 40–700 % pilno vandens imlumo. Tos pačios klasifikacijos du tirti dirvožemiai pasižymėjo specifinėmis cheminėmis ir fizikinėmis savybėmis galimai dėl miško dirvožemio panaudojimo žemės ūkio reikmėms (vienamečių augalų auginimo). Tyrimo metu didžiausia CO_2 emisija buvo nustatyta dirvožemį inkubuojant 24 valandas. Po 24 valandų inkubacijos CO_2 emisija sumažėjo. Mažesnė CO_2 emisija buvo nustatyta 1728 val. inkubuotame 60-80-100-150-200-300-500-700 % pilno vandens imlumo (VA_{700}[1]) dirvožemyje, kuriame augo vienamečiai augalai. Pilnas vandens imlumas varijavo tarp dirvožemių taikant visus inkubavimo periodus. Didžiausia CO_2 emisija buvo nustatyta 144 val. inkubuotuose 50-75-100-150-200% (VA_{200}) ir 60-100-150-200-300-700% (VA_{700}) pilno vandens imlumo dirvožemiuose, kuriuose augo vienamečiai augalai – atitinkamai 100 ir 60 % pilno vandens imlumo. Tręšimo azotu įtaka mikrobų respiraciniam aktyvumui dirvožemyje nebuvo nustatyta. Užmirkusiose dirvose arba dirvose, veikiamose didesnio kiekio vandens, inkubacijos laikas ir drėgmės koncentracija yra du svarbūs veiksniai, turintys įtakos CO_2 emisijai.

Reikšminiai žodžiai: anglies ciklas, pilnas vandens imlumas, regresijos lygtys, respiracijos aktyvumas, tręšimas azotu, užmirkusi dirva.