Nitrogen oxides and CO_2 from an Oxisol cultivated with corn in succession to cover crops

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Abstract – The objective of this work was to evaluate the effect of two legumes (*Crotalaria juncea* and *Mucuna pruriens*), as cover crops, and of natural fallow, as a control treatment, on the emissions of NO_x, N_2O, and CO_2 from an Oxisol cultivated with corn, under conventional and no-tillage systems, in the Cerrado region, in Central Brazil. Variations of CO_2 fluxes in the soil were explained mainly by soil humidity and, in the legumes, under conventional system, by soil NH_4^+-N concentration. Plots with legumes under no-tillage system had higher annual emissions of CO_2, NO_x, and N_2O than natural fallow. Results show that the use of legumes as cover crops favors the emissions of NO_x-N + N_2O-N and CO_2-C. However, when considering the potential for mitigation of CO_2 and nitrogen oxide emissions from the soil, it is important to evaluate changes in soil carbon and nitrogen stocks.

Index terms: *Crotalaria juncea*, *Mucuna pruriens*, carbon and nitrogen stocks, Cerrado, mitigating greenhouse gases.

Óxidos de nitrogênio e CO_2 de Latossolo cultivado com milho em sucessão a plantas de cobertura

Resumo – O objetivo deste trabalho foi avaliar o efeito de duas leguminosas (*Crotalaria juncea* e *Mucuna pruriens*), usadas como plantas de cobertura, e de vegetação espontânea, como tratamento-controle, sobre as emissões de NO_x, N_2O e CO_2 de um Latossolo Vermelho cultivado com milho, em sistemas convencional e de plantio direto, na região do Cerrado, no Brasil Central. As variações dos fluxos de CO_2 no solo foram explicadas principalmente pela umidade do solo e, nas leguminosas, sob sistema convencional, pela concentração de N-NH_4^+. Parcelas com leguminosas em sistema plantio direto mostraram maiores emissões anuais de CO_2, NO_x e N_2O do que a vegetação espontânea. Os resultados mostram que o uso de leguminosas como plantas de cobertura favorece as emissões de N-NO_x + N-N_2O e C-CO_2. Entretanto, ao se considerar o potencial de mitigação de emissões de CO_2 e de óxidos de nitrogênio oriundas do solo, é importante avaliar as variações nos estoques de carbono e nitrogênio no solo.

Termos para indexação: *Crotalaria juncea*, *Mucuna pruriens*, estoques de carbono e nitrogênio, Cerrado, mitigação de gases de efeito estufa.

Introduction

The Cerrado (Brazilian savanna) biome originally occupied approximately 200 million hectares, but since the 1970s has been changed by an intense agricultural expansion. It is estimated that more than 50% of the area has lost its original vegetation, mainly through conversion to pastures and croplands (Beuchle et al., 2015). Currently, the Cerrado is the most important region for beef and grain production in Brazil and a potential area for the expansion of integrated crop-livestock systems (IBGE, 2015). The dominant soils are Oxisols, and no-tillage systems were introduced in the mid-1980s, but with a rare use of cover crops to prevent soil erosion (Bayer et al., 2009). In addition, there is a demand for the selection of suitable cover crops to improve soil organic carbon and to mitigate the emissions of greenhouse gases (GHGs) from the soil to the atmosphere.

The conversion of the native vegetation of the Brazilian Cerrado to soybean (*Glycine max* L.) monoculture using conventional tillage is estimated to reduce soil C stocks between 0.50–0.67 Mg ha^{-1} C per year, at the 0–0.40-m layer, after 50 years of adoption (Corbeels et al., 2006). However, in the same study, these authors also predicted that the conversion of traditional soybean monoculture to cropping systems with no-tillage and direct seeding into a mulch of crop residues could result in the storage of 0.70–1.15 Mg ha^{-1} C per year, at the same layer, during the first 12 years after the conversion. Therefore, the intensification of crop production with no-tillage practices can enhance C accumulation rates by increasing biomass production, through which greater amounts of crop residues are returned to the soil (Battle-Bayer et al., 2010; Carvalho et al., 2014b).

In Brazil, the Agriculture, Forestry and Other Land Uses (Afolu) sector contributes with approximately 46 and 95% of the total anthropogenic CO_2 and N_2O emissions, respectively (Estimativas..., 2014). Some of the factors and management practices that might affect the emission of greenhouse gases from the soil to the atmosphere, include: soil tillage (conventional and no-tillage), deposition of crop residues, organic and inorganic N fertilization amendments, irrigation, low N use efficiency by annual crops, and cultivation of N-fixing species (Edenhofer et al., 2014). However, with the increasing establishment of no-tillage cropping practices based on direct seeding into a mulch of crop residues, an improved understanding of the relationship between cover crops and CO_2, N_2O, and NO_x fluxes is important for the development of sustainable agricultural practices for the Cerrado region. Cover crops combined with the use of no-tillage or reduced tillage have been identified as potentially beneficial for mitigating greenhouse gas emissions (Abdalla et al., 2014; Edenhofer et al., 2014).

The application of N fertilizers is a common practice for intensive agriculture in the Brazilian Cerrado, especially in crops with high demands of this nutrient, as, for example, corn (*Zea mays* L.). The use of N-fixing legumes, such as *Crotalaria juncea* L. and *Mucuna pruriens* (L.) DC., as cover crops in agricultural systems can incorporate more than 230 kg ha^{-1} N (Calegari et al., 2008). This practice could contribute to the reduction of the quantities of mineral N fertilizers applied, but its impacts on GHG emissions from the soil are still not widely evaluated in tropical agricultural systems (Carvalho, 2005; Carvalho et al., 2006; Metay et al., 2007; Cruvinel et al., 2011; Abdalla et al., 2014).

The objective of this work was to evaluate the effect of two legumes, as cover crops, and of natural fallow, as a control treatment, on the emissions of NO_x-N, N_2O-N, and CO_2-C from a Oxisol cultivated with corn under conventional and no-tillage systems, in the Cerrado region, in Central Brazil.

Materials and Methods

The experiment was carried out in Planaltina, Brasília, DF, Brazil (15º39'S, 47º44'W, at an altitude of 1,100 m), on a plateau in the center of the Cerrado region. During the study period, from June 2002 to June 2003, monthly rainfall ranged from null, in June 2002, to 252 mm in January 2003. The monthly mean temperature oscillated between 19ºC, in June 2003, and 27ºC in March 2003 (Figure 1). The original vegetation, classified as Cerrado stricto sensu, was removed in 1975 and, after corrective fertilization with lime and phosphate, was subjected to different land uses, including crops, pasture, and fallow. The soil is classified as a Latossolo Vermelho distroférrico, i.e., a Typic Acrustox, with clay texture (Santos et al., 2013). The experiment was set up in November 1996 when corn was cultivated, and cover crops were planted at the end of the rainy season, in April 1996, after harvesting the previous corn crop.

In 1996, before the experiment installation, the results of soil chemical and particle size analyses, at the 0.0–0.20-m layer, were: 6.2 pH in water; 3.4 mg kg^{-1} available P; 3.4 cmol$_c$ kg^{-1} exchangeable K^++Ca^{2+}+Mg^{2+}; 3.3 cmol$_c$ kg^{-1} H+Al; 0.01 cmol$_c$ kg^{-1} exchangeable Al^{3+}; 23.6 g kg^{-1} organic matter; 513 g kg^{-1} clay; 186 g kg^{-1} silt; and 301 g kg^{-1} sand.

At the beginning of the experiment in January 1996, the area was fertilized with 180 kg ha^{-1} P_2O_5 (as single superphosphate), 60 kg ha^{-1} K_2O (as potassium chloride), 50 kg ha^{-1} micronutrients (7% Zn, 2.5% Bo, 1% Cu, 4% Fe, 4% Mn, 0.1% Mo, and 0.1% Co), and 500 kg ha^{-1} $CaSO_4$.

The experimental design was a randomized complete block in a split-plot arrangement with experimental units replicated three times. Cover crops were sown into 12x30-m whole plots in March, at the end of each rainy season, following corn cultivation under conventional and no-tillage systems, both in 12x15-m subplots. Plots and subplots were separated by a 1-m border. Fertilizers were incorporated with the

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plant residues before corn sowing: under conventional system, using a disk plough and harrow in subplots; and, under no-tillage system, applied on soil surface.

Two legumes were used as cover crops before the next corn cultivation: *Crotalaria juncea* and *Mucuna pruriens* (both Leguminosae), with seeds sown 3 cm deep in 0.5-m wide rows, using a no-tillage seeder. The control treatment consisted of natural fallow. Additional information on management practices in the experimental area is described by Carvalho et al. (2014a).

Gas measurements were performed as follows. NO_x-N and CO_2-C were measured using the dynamic chamber technique. For this, polyvinyl chloride (PVC) cylindrical chambers with 24 cm in diameter and 8.7 L were used. Chamber bases were inserted 2 cm into the soil 30 min before each measurement, according to Cruvinel et al. (2011) and Lessa et al. (2015). Air was circulated in a closed loop between the chamber and the analyzers. NO_x was analyzed using a NO_x Box LMA-3D (Drummond Technology Inc., Unisearch Associates, Inc., Bowmanville, Ontario, Canada), after first converting NO to NO_2 by passing the gas sample through CrO_3. NO_2 reacts with Luminol solution to produce a luminescent reaction that is functionally related to the mixing ratio of NO_2. NO concentration was recorded over a 5-min period. Fluxes were calculated from the increase rate of NO concentration, using the linear portion of the accumulation curve. Calibration was conducted in the field before and after chamber measurements using mixtures of a NO standard (0.4 ppm) with NO^- and NO_2^- free air. CO_2-C was analyzed over a 3-min period using a photosynthesis system with integrated infrared gas analyzer and data system, model LI-COR 6200 (LI-COR Biosciences, Lincoln, NE, USA). CO_2-C concentrations were logged every 2 s, yielding a continuous monitoring of increasing CO_2 concentrations that were used to fit the most appropriate regression function.

N_2O-N fluxes were measured using a static chamber technique. To determine N_2O-N fluxes, four gas samples were collected from the headspace of a static chamber using 60 mL polypropylene syringes with siliconized polypropylene plungers. The first sample was taken immediately after chamber closure, at time point zero, whereas the other samples were removed 10, 20, and 30 min after chamber closure. At the laboratory, the samples were analyzed within 24 hours after sample collection with a gas chromatograph Shimadzu GC-14A (Shimadzu do Brasil, São Paulo, SP, Brazil) fitted with a ^{63}Ni electron capture detector. N_2O-N fluxes were calculated from the increase rate of the concentration, determined by linear regression based on the four samples taken. The detection limit of 0.6 ng N_2O-N cm^{-2} h^{-1} was adopted in the present study, since similar system and methods were used (Carvalho et al., 2006).

Measurements of CO_2-C and NO_x emissions were performed from June 2002 to June 2003, during a period of 367 days, while fluxes of N_2O-N were measured during nine months, from September 2002 to June 2003. Gas samples were taken monthly and

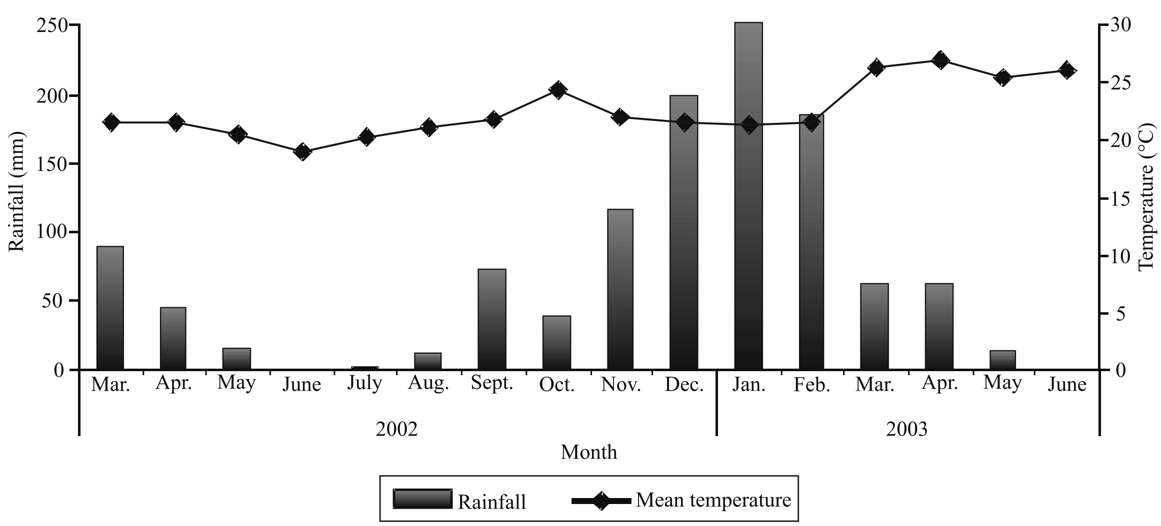

Figure 1. Monthly rainfall distribution and air temperature from March 2002 to June 2003, measured at the meteorological station of Embrapa Cerrados in Planaltina, Brasília, DF, Brazil.

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for three consecutive days after corn and cover crop management events and rainfall. Table 1 shows the sampling events and the main agricultural practices. In the case of fertilization events, gas fluxes were measured on the third day after fertilizer application and subsequently for three days, which is in alignment with previous studies under similar conditions, in which the highest emissions were detected three days after fertilizer application (Carvalho et al., 2006; Paredes et al., 2014). Annual CO_2-C, NO-N, and N_2O-N fluxes were estimated from the average of fluxes obtained during the 12 total measurement campaigns.

Four field-moist samples were collected at 0–0.05-m depth in every plot, in all sampling dates, in order to determine water-filled pore space (WFPS, in percentage), NO_3^--N, and NH_4^+-N. Other co-variables, including water content and soil temperatures, at 0.025- and 0.050-m depth, were obtained during the gas flux measurements. Soil samples were dried to constant weight, at 105°C, for determination of soil moisture by the gravimetric method. Bulk density was determined at 0–0.05-m depth from undisturbed samples (Santos et al., 2013); the particle density value of 2.65 g cm^{-3} was considered. The values of gravimetric water contents θ_g (g g^{-1}) were converted into WFPS, using the following equation: WFPS (%) = $\{(\theta_g \times ds \times 100)/[1 - (ds/dp)\}100$, in which ds is soil density and dp is particle density, both expressed in g cm^{-3}.

To measure NO_3^--N and NH_4^+-N, soil samples were extracted at 0–0.05-m depth, with 2 mol L^{-1} KCl for 1 hour, and the inorganic-N concentrations were obtained colorimetrically. Specifically, NO_3^--N was determined by UV absorption according to Meier (1991), and NH_4^+-N, through reaction with Nessler reagent. The results were expressed on a 105°C oven-dry weight basis.

Multiple regression analysis was performed through the statistical method of variable selection (stepwise), at 5% probability, to determine the variable(s) that better explain the fluxes of NO_x-N and CO_2-C. The variables measured during sampling were subjected to analysis of correlation to avoid that those with high correlation coefficients (high collinearity) be tested together through the multiple regression model. Wilcoxon's nonparametric test was used to compare the averages of the fluxes of CO_2-C, NO-N, and N_2O-N obtained in the treatments, at 5% probability. Analyses were performed using SAS systems for Windows, version 9.3 (SAS Institute Inc., Cary, NC, USA).

Results and Discussion

The WFPS values, at 0–0.05-m depth, mainly related to rainfall events, increased between July (10–20%) and November (41%) before corn sowing (Figure 2). During N fertilization, the WFPS values were 32%, on November 28, and 42% on December 19 and January 31. Soil humidity decreased again to 20% from April

Table 1. Temporal distribution of gas measurements in plots with corn (*Zea mays*) planted in succession to cover crops.

Season	Management and fertilizer application	Rainfall (mm)	CO_2	NO_x	N_2O
Dry season					
June 2002 and July 2002	Cutting of cover crops and cutting of cover crops	0	x	x	
Transition dry/wet season					
September 2002	First rainfall events	61.0	x	x	x
October 2002		39.3	x	x	
Rainy season					
November 2002	Before corn planting	37.0	x	x	x
November 2002	At corn planting (20 kg ha^{-1} N as urea, 150 kg ha^{-1} P_2O_5, and 80 kg ha^{-1} K_2O) and after corn planting	17.2	x	x	x
November 2002	N fertilization side-dressed at the V-6 stage (50 kg ha^{-1} N as urea)	51.4	x	x	x
December 2002	N fertilization side-dressed with 50 kg ha^{-1} N as urea at the V-8 and at the silking stage	199.0	x	x	
Transition wet/dry season					
April 2003 and May 2003	After corn maturation and Post-harvest	63.8	x	x	x
Dry season					
June 2003	Fallow	0	x	x	x

to June, which represents the transition from the wet to the dry season.

The NO_x-N and CO_2-C fluxes started to increase at end of the dry season, i.e., from July-August to September, after the first rainfall events of the transition from the dry to the wet season (Figures 1 and 3). Pulses of NO_x-N emissions with first rainfall events, after a long dry period, have been reported and are related to the reactiveness of the water-stressed soil decomposers and to dormant nitrifying bacteria that start to mineralize and metabolize organic and inorganic N in the soil, releasing NO as a by-product (Cruvinel et al., 2011; Hudman et

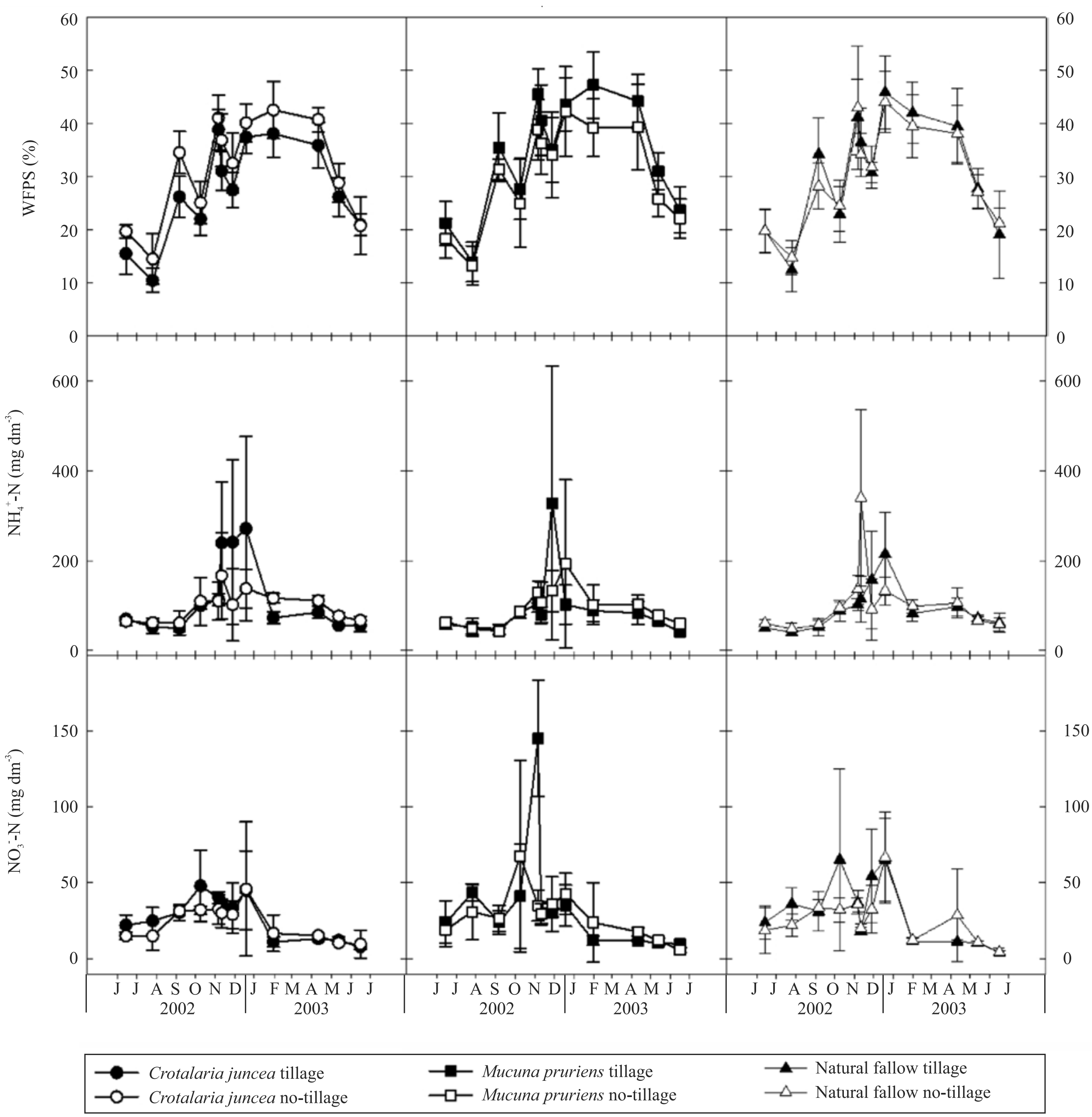

Figure 2. Water-filled pore space (WFPS), NH_4^+-N, and NO_3^--N concentrations in an Oxisol in the Cerrado region, in Central Brazil, at 0–0.05-m depth, as affected by cover crops planted before corn (*Zea mays*) under conventional and no-tillage systems.

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al., 2012; Marquina et al., 2015). In addition, CO_2-C fluxes are positively correlated with NO_x-N emissions and also to microbial activity that can explain higher fluxes of CO_2-C with the first rainfall events, after a long dry period (Marquina et al., 2015). Samples collected during the dry season show low emissions of GHGs due to soil humidity, as observed by Metay et al. (2007).

The highest value (8.2 ng NO_x-N cm^{-2} h^{-1}) of NO_x-N fluxes in September was measured in the plots with *M. pruriens* under conventional tillage and no-

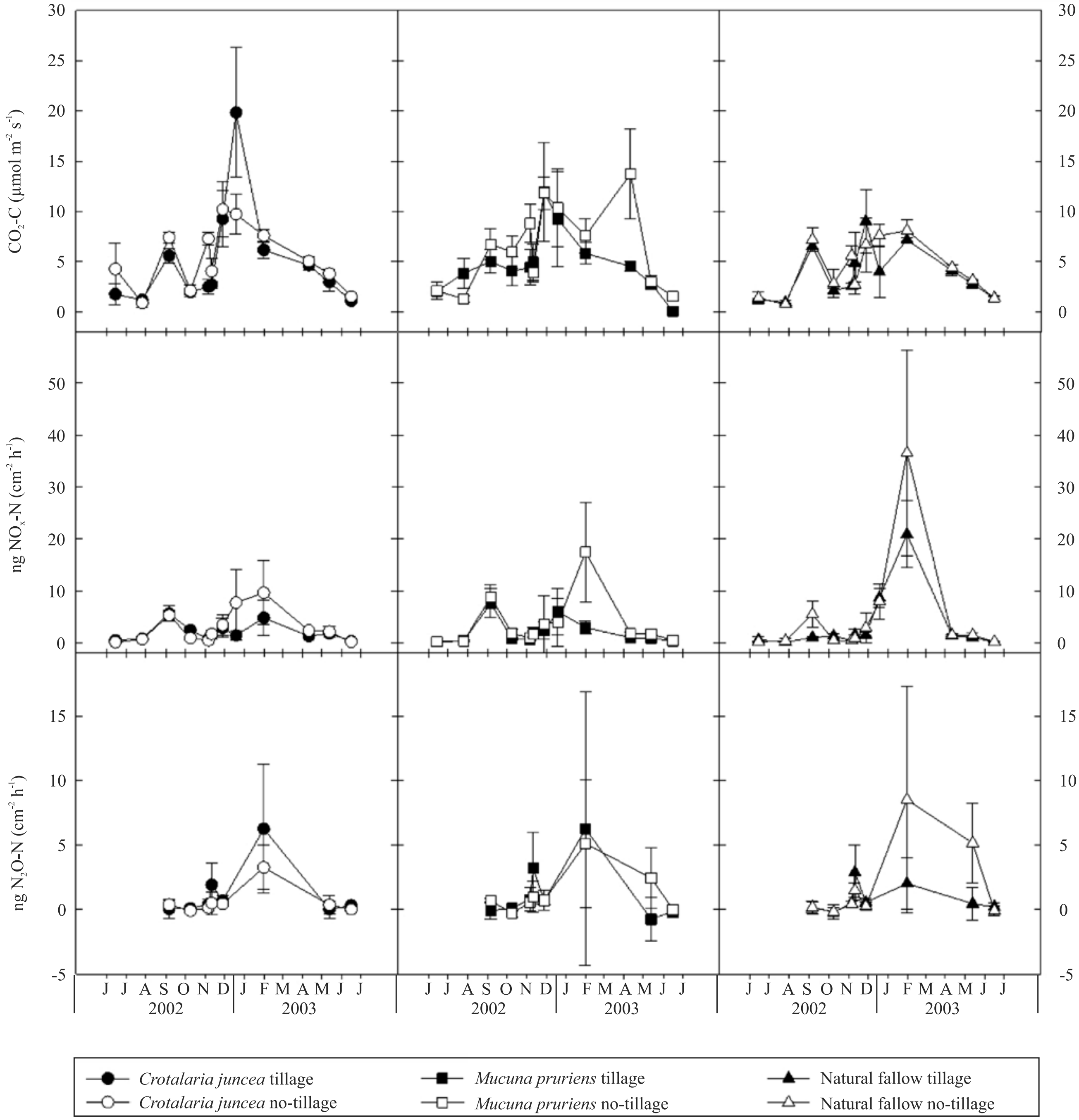

Figure 3. CO_2-C, NO_x-N, and N_2O-N fluxes from an Oxisol in the Cerrado region, in Central Brazil, as affected by cover crops planted before corn (*Zea mays*) under conventional and no-tillage systems.

tillage systems, whereas the lowest one (1.0 ng NO-N cm^{-2} h^{-1}) was determined in plots with natural fallow under both systems. However, CO_2-C fluxes did not differ significantly between cover crops. In the same month, considering the two legumes and natural fallow, soil CO_2-C fluxes showed slightly higher value (7.1 µmol CO_2-C m^{-2} s^{-1}) under no-tillage system than under conventional tillage (5.7 µmol CO_2-C m^{-2} s^{-1}).

The highest peaks of CO_2-C and NO_x-N generally occurred after the application of N fertilizer for corn grown from November to December. In April, at the end of the wet season, a CO_2 peak was measured in the area cultivated with *M. pruriens* under no-tillage (Figure 3), when WFPS was still 40%; it decreased to 28 and 21% in May and July, respectively (Figure 2).

The average concentrations of NH_4^+-N and NO_3^--N, considering the two management systems and cover crops, from June to September, were 52 and 30 mg kg^{-1}, respectively (Figure 2). In October, the concentrations of NH_4^+-N and NO_3^--N increased to 94 and 48 mg kg^{-1}, respectively. Before corn sowing in November, soil concentration of NH_4^+-N reached 116 mg kg^{-1}, which is the mean of all treatments. For NO_3^--N, there was a slight increase of 40 mg kg^{-1} from the previous months to November, with the exception of the plots with *M. pruriens*, which showed a greater average increase of 145 mg kg^{-1} under conventional tillage. After N fertilizer applications, mean concentrations of soil NH_4^+-N ranged from 93 to 175 mg kg^{-1}.

Losses of N in the form of NO_x-N are higher than in the form of N_2O-N during the evaluated period, as also found in other studies, under different cropping systems (Cruvinel et al., 2011; Marquina et al., 2015). The incorporation of the residues before corn cultivation promoted higher soil aeration and may have stimulated NO_x emissions over N_2O emissions (Carvalho et al., 2006; Metay et al., 2007). Most of soil N_2O fluxes were below the detection limit, i.e., <0.6 ng N_2O-N cm^{-2} h^{-1}. However, an increase in N_2O-N fluxes was observed after corn was planted, with a mean of 1.8 ng N_2O-N cm^{-2} h^{-1}, besides higher values under conventional tillage. Higher N_2O emissions after this post-management period, specially under this system, could be related with higher N mineralization, with increases in NH_4^+-N and NO_3^--N, due to the faster decomposition of the cover crop residues with the application of N fertilizer and soil plowing (Jantalia et al., 2008; Bayer et al., 2015). The highest mean flux of N_2O-N, which was 5.3 ng N_2O-N cm^{-2} h^{-1}, was measured in January, as also observed for NO fluxes. In May, peaks of 2.5 and 5.2 ng N_2O-N cm^{-2} h^{-1} were measured in the plots with *M. pruriens* and natural fallow under no-tillage, respectively. The N_2O-N peaks measured in April, even under lower rainfall, can be explained by the slow decomposition of the material from *M. pruriens*. This legume, compared to *C. juncea* and natural fallow, has the highest proportion of aromatic carbon groups highly resistant to decomposition (Carvalho et al., 2009), explaining the peaks even eight months after the deposition of its biomass.

The stepwise multiple regression model indicated that the variations of CO_2-C fluxes, between 33 and 64%, were explained mostly by WFPS at 0–0.05-m depth (Table 2). However, under conventional tillage with *C. juncea* and *M. pruriens*, CO_2-C fluxes were mainly explained by soil NH_4^+-N concentrations. The multiple regression model also explained approximately 71% of the variations of CO_2-C fluxes

Table 2. Multiple regressions used to explain the variation of CO_2-C and NO_x-N fluxes from an Oxisol in the Cerrado region, in Central Brazil, as affected by cover crops planted before corn (*Zea mays*), under conventional (CT) and no-tillage systems (NT).

Cover crop	CO_2-C fluxes[(1)]			NO_x-N fluxes
	WFPS	NH_4^+-N	Soil temperature (ºC)[(2)]	WFPS
Crotalaria juncea NT	R_T^2 = 0.528 (p<0.001)	-	-	R_T^2 = 0.38 (p<0.032)
Crotalaria juncea CT	-	R_T^2 = 0.467 (p<0.001)	-	-
Mucuna pruriens NT	R_T^2 = 0.795 (p<0.001); Rp^2 = 0.639	-	Rp^2 = 0.156	-
Mucuna pruriens CT	R_T^2 = 0.808 (p<0.001); Rp^2 = 0.081	Rp^2 = 0.665	Rp^2 = 0.062	-
Natural fallow NT	R_T^2 = 0.71 (p<0.005); Rp^2 = 0.60	Rp^2 = 0.11	-	-
Natural fallow CT	R_T^2 = 0.329 (p<0.005)	-	-	R_T^2 = 0.23 (p<0.09)

[(1)]R_T^2 and Rp^2, coefficient of total determination and coefficient of partial determination, respectively. [(2)]At 0.0–0.05-m depth. WFPS, water-filled pore space.

measured in natural fallow plots under no-tillage, for which the explanatory variables were: WFPS, 60%; and soil NH_4^+-N concentration, 11%. In the case of *M. pruriens*, under no-tillage, 80% of the variations of CO_2-C fluxes were explained by the variables WFPS and soil temperature. Available NH_4^+-N in the soil did not significantly explain the variations of NO_x-N fluxes, contrarily to what was observed for the emissions of CO_2-C (Table 2). Alterations in WFPS values at 0–0.05-m depth explained 38% of the variations of NO_x-N fluxes in *C. juncea* plots under no-tillage and 23% in natural fallow under conventional tillage. Variations of GHG emissions due to available N (NH_4^+-N and NO_3^--N) and WFPS were also reported in other studies (Cruvinel et al., 2011; Marquina et al., 2015); however, in the present study, NO_3^--N concentrations were not significant as an explanatory variable for soil emissions.

Plots with legumes under conventional tillage showed significantly higher annual N oxide emissions (0.9 kg ha^{-1} N per year) than those with natural fallow (0.5 kg ha^{-1} N per year) (Table 3). Annual emissions of CO_2-C were also higher with the use of legumes than with natural fallow under both management systems, as shown by the averages obtained for conventional tillage and no-tillage, respectively: 19 and 21 Mg CO_2-C ha^{-1} per year for plots with legumes versus 15 and 16 Mg CO_2-C ha^{-1} per year for plots with natural fallow. The N contents of *C. juncea* (91 kg ha^{-1} N) and *M. pruriens* (94 kg ha^{-1} N), when cut at the flowering stage, are significantly higher than those of natural fallow (59 kg ha^{-1} N), which may explain the higher annual emissions of NO_x-N + N_2O-N and CO_2-C from plots with legumes as cover crops (Carvalho et al., 2015). Mitchell et al. (2013), while studying the effects of cover crops on N_2O emissions, found that available mineralizable C can also control N_2O emissions from the soil and, consequently, that C from cover crop residues can increase these emissions.

Table 3. Annual emissions of gases from an Oxisol in the Cerrado region, in Central Brazil, as affected by cover crops planted before corn (*Zea mays*) under conventional (CT) and no-tillage (NT) systems[(1)].

Cover crop	CO_2-C (Mg ha^{-1})		$(NO_x + N_2O)$-N (kg ha^{-1})	
	CT	NT	CT	NT
Crotalaria juncea	18.8a	20.1a	0.9a	0.7a
Mucuna pruriens	18.5a	24.2a	0.9a	1.0a
Natural fallow	14.7b	16.3b	0.5b	0.9a
Mean	17.3A	20.2A	0.8A	0.9A

[(1)]Means followed by equal letters, lower case in the columns and upper case in the rows, do not differ, at 5% probability.

However, annual emissions of CO_2-C did not differ significantly between management systems, as also reported in other studies (Abdalla et al., 2014; Carvalho, 2005). These results were attributed to the peaks of microbial respiration that do not occur simultaneously because of soil moisture, organic carbon, porosity, tortuosity, macro and mesofauna, among others. Soil CO_2-C emissions were correlated with soil water content, temperature, and available NH_4^+-N. Although the concentration of NH_4^+-N was not correlated with NO_x-N and N_2O-N emissions, higher fluxes were observed after fertilizer application, when accompanied by rainfall. The source of N (urea) and the form of application (surface coverage) of this element should have favored emissions after fertilization and greater rainfall (Carvalho et al., 2006).

Even though the obtained results show that the use of legumes as cover crops favors the emissions of NO_x-N + N_2O-N and CO_2-C, mitigating the emission of greenhouse gases also depends on the input and quality of plant residues, as well as on the magnitude of the increases in CO_2 uptake by the cover crop and of the C stored in the soil (Abdalla et al., 2013). The increase in C stocks in the soil depends on C and N inputs, residue decomposition, microbial biomass growth and activity, management practices, and soil and climatic factors (Cruvinel et al., 2011); soil organic matter is higher in the surface layer due to the accumulation of plant residues there (Carvalho et al., 2014b; Boddey et al., 2010). Significant differences in soil C and N stocks were found between different cover crops grown in succession to corn in the same experimental plots evaluated in the present study (Carvalho et al., 2014b). The use of *M. pruriens* under no-tillage may enhance soil organic matter and, therefore, increase soil C and N stocks (Carvalho et al., 2014b). Moreover, the increase of the soil C/N ratio at 0–0.05-m depth, in the dry season, in plots with the addition of *M. pruriens* residues (C/N = 18), when compared to those with natural fallow (C/N = 9.4), may be another indicator of the increase in soil C, which is possibly attributed to the high concentration of aromatic compounds in the species (Carvalho et al., 2009; Talbot et al., 2012; Carvalho et al., 2014a). However, it should be noted that higher microbial biomass and activity in the soil surface layer under no-tillage system may favor higher CO_2 emissions (Carvalho, 2005).

Conclusions

1. Emissions of NO_x-N, N_2O-N, and CO_2-C are higher in plots with legumes, used as cover crops, than in those with natural fallow.

2. Changes in soil humidity and inorganic-N concentration are related to soil emissions during the corn (*Zea mays*) crop cycle.

3. Although legume cover crops result in higher nitrogen oxide and CO_2-C emissions, it is important to evaluate changes in soil C and N stocks when considering the effectiveness in mitigating the emission of greenhouse gases.

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