Field evaluation of N_2O, CO_2 and CH_4 emissions and enzyme activities under corn-soybean intercropping system

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Abstract
The effect of cover crops (ryegrass, hairy vetch, and oilseed radish) in terms of microbial biomass carbon (MBC), C and N mineralization, and enzymatic activities in a corn-wheat-soybean cropping systems under a Mollisol was evaluated. The distributions of total organic C (TOC), total Kjeldahl N (TKN), microbial biomass C (MBC), readily mineralizable C and N, and five enzyme activities (*β-glucosidase, β-glucosamidase, acid phosphatase, arylamidase, and fluorescein diacetate hydrolysis*) involved in the cycling of C, N, P and S were studied in three soil depths (0-5. 5-10, 10-20 cm) while soil surface fluxes of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) were estimated.

Rye grass showed higher activity in acid phosphatase, β-glucosidase and β-glucosaminidase. Rye grass and hairy vetch significantly increased organic C and N, and MBC. Level of mineralized C and N were the same in rye grass and hairy vetch. There was no clear variation in CO_2, N_2O and CH_4 fluxes from the cover crop treatments. N_2O fluxes increased with increase in soil moisture. The negative CH_4 fluxes manifest the soil as CH_4 sink. No significant differences among cover crop treatments in terms of CO_2-C, N_2O-N and CH_4-C emissions.

Empirical data on carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) fluxes are important in management systems to evaluate mitigation strategies, while microbial biomass and enzyme activities can be used as sensitive indicators of ecological stability.

Key Words
Carbon sequestration, Soil Quality, Microbial Activity, Greenhouse Gas Emission, Nitrous oxide

Introduction

Climate change is one of the pressing issues today and is considered the biggest environmental, social and economic threats the world is experiencing at the moment. The causes and challenging issues of climate change, particularly its negative impacts on crop production have become the interest of research and development-oriented groups and organizations. The emission of greenhouse gases such as CO_2, CH_4 and N_2O are believed to contribute much to the rapid increase in earth's temperature and presumed to induce global warming. Beside fossil fuel combustion, the agriculture industry particularly land use change and soil cultivation have been identified as contributory to the global emission of these gases in the atmosphere (USEPA, 2009). Agriculture productivity depends upon the soil which serves as the reservoir of nutrients and water necessary for plant growth; however, it also produces CO_2 as a result of aerobic respiration from soil microbes and plant roots. The conversion of soil N thru the processes of nitrification and denitrification release the N_2O in the atmosphere (Sahrawat and Keeney, 1986), while intensive rice farming releases CH_4 in the environment (Sommer et al 2004).

The potential of soil to sequester carbon is now being looked upon to offset global climate change. Soil carbon sequestration implies removal of atmospheric CO_2 by plants, and storage of fixed carbon as soil organic matter, where one strategy for carbon stock build up is to addition of crop residue and decrease the rate of soil organic matter decomposition (Lal, 2004). With improvement of soil organic matter, it lessens the potential to release the carbon in the atmosphere. Other than acting as reservoir for atmospheric CO_2, soil organic matter (SOM) is an important attribute of soil quality as it controls the many key functions of the soil (Doran and Parkin, 1994). Soil organic matter affects soil structure, water retention, nutrient availability, and soil microorganisms (Aparicio and Costa 2007; Leite et al. 2007). The increase of organic matter both in terms of quality and quantity can have beneficial effects on soil quality because it is related to aggregation, water infiltration and availability for crop production (Doran and Parkin 1994; Franzluebbers2002)).

The adoption of good agricultural practices (GAP) that improves soil organic matter content can reduce the emission rate of atmospheric CO_2 while leaving positive impacts on soil quality. One of these recommended GAP is cover cropping that has been widely recognized and promoted as a practical way to enhance soil productivity and environmental quality (Walsh et al.1996; Baumann et al.2001). The practice involves the use of cover crops, which adds organic matter to soil and release available nutrients as the organic matter breaks down for uptake of crop (Sanchez et al. 2007). Microbial communities play a role in the decomposition of these organic materials and plant residues incorporated into the soil, leading to energy flow, nutrient cycling and organic matter build up or soil carbon sequestration (Lynch and Bragg 1985; Kandeler et al. 1996). Soil microorganisms mediate the mineralization of soil organic matter and nutrients. The microbial biomass is a small but important reservoir of nutrients, and many transformations of nutrient occur in the biomass (Dick, 1992). Soil microbes respond quickly to any stress affecting the ecosystem; hence are used as a biological indicator in the evaluation of agricultural management practices with respect to soil quality.

The study was undertaken to evaluate the effect of cover crops currently used in the area (ryegrass, hairy vetch, and oilseed radish) in terms of microbial biomass carbon (MBC), C and N mineralization, and enzymatic activities and greenhouse gas emission in a corn-wheat-soybean cropping systems grown under a Mollisol.

Methodology

A field experiment was established at the Purdue Agricultural Center, Lafayette, Indiana on plots grown to corn--soybean rotation for 10 years. A total of eight blocks; each having four plots measured 10 by 20 meters assigned for the three cover crop treatment (hairy vetch, oilseed radish and rye grass), and a control (no cover crop). The experiment was arranged in a completely randomized block design with four replicates per treatment.

Twelve core samples were taken using a one inch-diameter soil probe to a depth of 20 centimetres at one meter interval along two transects within each plot. The cores were divided into three layers, 0–5, 5–10, and 10–20 cm. A representative 200-g subsample was set aside, placed in a plastic bag, properly labelled and stored at 4°C for soil microbial biomass C determination, while another representative 200-g subsample portion was hand sieved to pass a 2-mm sieve, air dried, and stored at 4°C until use for measurement of enzymatic activities, potentially mineralizable C and N, soil organic C and total organic N.

The *β-glucosidase, β-glucosaminidase* and *Acid phosphatase* activities were determined by the method of Eivazi and Tabatabai (1988), Parham and Deng (2000), and Tabatabai (1994), respectively. *Arylamidase* activity was measured using the method of Acosta-Martinez and Tabatabai (2000) while the *Fluorescein diacetate* (FDA) hydrolysis was measured using the Green et al. (2006) procedure, modified by using tris(hydroxymethyl) aminomethane rather than a phosphate buffer (Prosser et al., 2011).

A modification of the chloroform-fumigation procedure of Jenkinson and Powlson (1976) was used to determine the soil microbial biomass C. Mineralization of C was determined from an incubated 10 gram 2-mm air-dried soil for 28 days in a dark chamber. CO_2 concentration was measured using a gas chromatograph (Varian Model 3800) equipped with a CombiPal auto sampler (CTC Analytics) and a thermal conductivity detector. Nitrogen mineralization was determined from the 28-day incubation of 10 g 2-mm air-dried soil. The concentrations of NO_3^- and NH_4^+ in the extracts were, determined with QuikChem methods 10–107–04–1–A and 10–107–06–2–A, respectively, on a Lachat flow injection analyzer (Lachat Instruments, Milwaukee, WI, USA). The net mineralized N in soil was the difference between the extractable inorganic N contents before and after incubation. Total organic C and Total organic N were determined by dry combustion with a Dohrman DC-80 total C analyzer (Santa Clara, CA). Gas sampling was done using a vented chamber technique. Gas samples were analysed for CO_2, N_2O, and CH_4 using a Varian Model 3900 gas chromatograph (Agilent Technologies, Santa Clara, CA), equipped with a thermal conductivity detector, electron capture detector, and flame ionization detector (Hernandez-Ramirez et al., 2009).

Results

Rye grass showed higher activity in acid phosphatase, β-glucosidase and β-glucosaminidase; while the three cover crops were similar in terms of arylamidase and FDA. In general, the activity of the five enzymes decreased with increasing soil depth due to the effect of the litter fall that stays in the surface soil, a characteristic of a non-tilled soil. Rye grass and hairy vetch cover crops have significantly higher organic C and N compared to oil seed radish. The concentrations of organic C and N are good indicators of soil quality and productivity due to their favorable effects on physical, chemical, and biological properties. The rye grass and hairy vetch cover crops in the no-tillage system can conserve and/or maintain organic C and N concentrations in the soil, thereby improving soil quality and productivity. The mean soil C:N ratio between the three cover crops was relatively constant and very narrow which implies that the crop residues and resulting soil organic matter fractions from these cover crops are low in C and high in nitrogen. Incorporating cover crops (rye grass and hairy vetch) significantly increase soil microbial biomass C in the top (0-10 cm) soil layer. The greater soil microbial biomass from cover crop treatments were probably related to the increased level of plant organic matter inputs. The net effects of cover cropping on soil microbial biomass were much less clear at deeper soil layer (10-20 cm). The accumulation of crop residues at the surface provides substrates for soil microorganisms, which accounts for the higher MBC at the soil surface layer. The levels of mineralized C and N were the same in rye grass and hairy vetch cover crops. This is likely due to greater C input from rye grass derived from its roots and residues which have been in the area for long time, while hairy vetch, being a legume have increased N level through its N-rich litter. In general, C and N mineralization decreases with depth because of the lower total carbon and nitrogen in deeper soil layers, which are generally observed in most agricultural soils.

There was no clear variation in soil CO_2, N_2O and CH_4 fluxes from the cover crop treatments. Mean CO_2-C flux ranged from 78.97 to 85.65 mg C m^{-2} h^{-1} higher than the bare plot with mean CO_2 flux of 46.30 mg C m^{-2} h^{-1}. The oil seed radish obtained the lowest average N_2O flux, relative to other cover crop treatments and the bare plot. N_2O fluxes have increased with soil moisture. The negative CH_4 fluxes manifest that the soil in the study area were sometimes a sink of CH_4. There were no significant differences among cover crop treatments in terms of CO_2-C, N_2O-N and CH_4-C emissions. The non-significant variation in the cumulative emission of these greenhouse gases in the three cover crops is a reflection that gas emissions are highly variable. It could be sometimes high and sometimes low. Besides, the gas flux measurement was only done for a short period of 4 months.

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