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The effects of cover crops in no-till systems on microbial activity

Michelle L. Schulz

ABSTRACT

Cover crops are being used in no-till systems to provide both chemical and physical benefits to the soil. This study was performed to investigate the effects of those cover crops on CO_2 production in the soil, which is used as a direct measure of microbial activity. Microbes in the soil respire, giving off CO_2. The rate of respiration was measured by determining the CO_2 production of the microbes per grams per minute in a controlled environment. The study examined the effect of six different cover crops on microbial activity. The cover crops included cowpeas (*Vigna unguiculata*), hairy vetch (*Vicia villosa*), sunn hemp (*Crotalaria juncea*), soybeans (*Glycine max*), pearl millet (*Pennisetum glaucum*) and canola (*Brassica spp*.). The results indicated that the variables temperature and percent moisture were the most significant with P-values of 0.0006 and 0.1501 respectively. By comparison of the crops with graphical representations, the study revealed that sunn hemp and the soybeans had the most amount of microbial activity.

Keywords: *cover crops, no-till systems, microbial activity, CO_2 production, Vigna unguiculata, Vicia villosa, Crotalaria juncea, Glycine max, Pennisetum glaucum, Brassica spp.*

INTRODUCTION

Tillage involves the partial or complete incorporation of surface matter such as crop residues. There are a growing number of concerns about the effects of various tillage methods that are leading researchers and farmers to focus on no-till farming. No-till farming is a system that focuses on not disrupting the natural equilibrium of the soil. When soil is cultivated, its equilibrium is disturbed, and significant changes occur in its physical, chemical, and biological (microbial) properties (Noll et al., 1995). Land in no-till systems can result in many benefits for the ground and the farmer, which include saving soil, oil, and toil.

In addition to not tilling the ground, placing a cover crop on the land can also provide many benefits for a no-till field. In a Kentucky study (Frye and Blevins, 1989), corn grown following a hairy vetch crop produced higher yields than any rate of manufactured nitrogen fertilizer; however the addition of 100 kg N/ha to the corn following a vetch crop produced the highest corn yields in the experiment, as well as generated the highest net return to the producer. Cover crops can provide protection for the field, flexibility in a rotation, and nitrogen for the soil (legumes). At the Red River Research Station in Bossier City, LA, it was found that a number of soil properties were improved with the use of cover crops, including increased soil organic matter, saturated hydraulic conductivity, and water infiltration rates (Scott et al., 1990). Cover crop impacts also include their contributions to soil organic matter (SOM) and benefits to the biological processes the take place beneath the surface of the soil, with respect to the residues they leave behind. The amount of carbon (C) input into the soil from a crop residue increases SOM (Peterson et al., 1998). SOM stabilizes soil pH, which plays a central role in nutrient supply and availability for plant uptake (Campbell et al., 1996).

No-till systems and cover crops have been shown to have a great impact on soil microbial activity. A study performed comparing the CO_2 production of cultivated soil and adjacent native soils revealed that at four different locations there was significantly lower microbial activity in the cultivated soils (Chan et al., 1988). Microbes in the soil respire. A measure of microbial activity can be viewed by looking at soil respiration. One method of measuring soil respiration is by measuring the rate of increase in the CO_2, concentration within a chamber placed on the soil surface, with an opening to the soil. In this method the errors associated with the technique have been minimized by careful design of the chamber and the sampling system, and by the use of a sensitive infra-red gas analyzer (IRGA) for the analysis of the CO_2 concentration (Parkinson, 1981). Parkinson's measurements were performed with the PP Systems CIRAS-1 Portable Photosynthesis System. An IRGA can also be used to measure CO_2 concentrations by injecting a known amount of CO_2 into a chamber on a portable photosynthesis system. The system, which can be calibrated by diverting air flow through a scrubber that absorbs CO_2, then produces measurements by which soil respiration can be gauged. The objectives of this study were as follows; first to examine the impact of certain cover crops in no-till systems on soil quality as it relates to microbial activity and second to determine the effects of legumes vs. non-legumes on no-till systems. The main focus was on microbial activity, but chemical and physical properties of the soil were also considered.

MATERIALS AND METHODS

The study was conducted in Rice County at S ½ NE ¼ sec. 13, T 20S, R 6W, 6th P.M. The field has been in no-till for the past seven years. Six different cover

crops were planted into the field on July 10, 2001. Of those six cover crops there were four legumes and two non-legumes. The cover crops were as follows: the legumes include cowpeas, hairy vetch, sunn hemp, and soybeans; and the non-legumes include pearl millet and canola. The crops were arranged as shown in Figure 1 and were marked with marking flag.

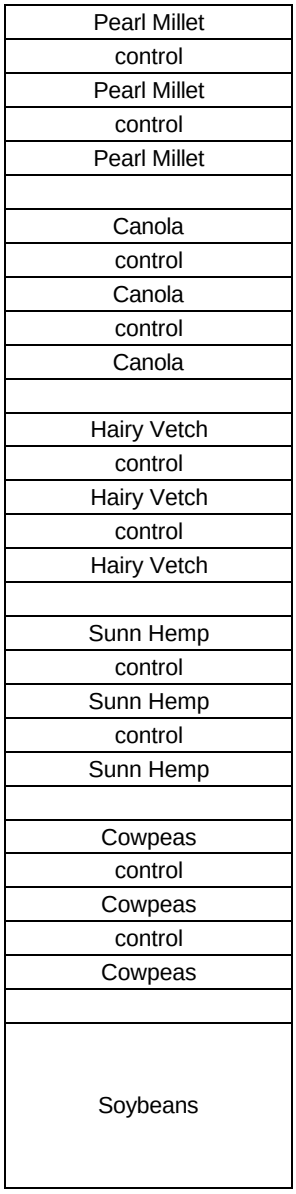

Figure 1. Diagram of field plot where sampling was performed and divisions that were created for this study. Total acreage of the plot was approximately 7 acres. Each strip was approximately 4.3 m by 50 m.

Sampling began in May 2002 and ended in September 2002. All samples were 8" soil samples. For each cover crop, there were a total of three separate strips. Three subsamples were taken from each (total of nine subsamples) and combined within strips to form a total of three samples for each crop. Each cover crop also had two control strips located between the three strips of each individual crop. Two subsamples were taken from each control strip (total of four subsamples) and mixed to make one control sample for each of the six cover crops. Thus, a total of 78 subsamples were taken each time to make 24 samples total for each sampling period. Soil subsamples were mixed immediately upon withdrawal from the field and stored in 18 oz Whirl-Pack bags. Soil samples were then placed on ice and taken to McPherson College. A soil thermometer was placed in the soil at the study site for 1 hour and soil temperature was recorded. At each of the 78 locations from which subsamples were obtained, soil compaction was also measured with a penetrometer and recorded. In addition, a sample of the ambient air was taken in a 3 mL autosampler vial, approximately 3 ½ ft above the soil surface. The autosampler vial was then crimped and capped. This was used for a controlled comparison of CO_2 concentration in the air to CO_2 concentrations of each soil sample.

Soil samples were taken to a lab at McPherson College where testing and analysis could be performed. Once in the lab, soil moisture and microbial activity were immediately analyzed before the soil dried. Soil microbial activity was examined by measure of CO_2 production. This was done using a Licor Model 6200 Portable Photosynthesis System. From each soil sample, 3 g of soil were placed in 3 mL autosampler vials. The vials were then capped and crimped. The time of crimping was then recorded. Following this, a Hamilton SampleLock Syringe (1 mL) was used to draw off the CO_2 from the vial headspace, which was measured by the Licor system. The time was recorded again at this point. Soil moisture was measured by the following formula: soil moisture equals the weight before oven drying minus the weight after oven drying divided by the weight before oven drying and then multiplied by 100. This is determined by finding the weight of the soil before and after oven drying. Samples were placed in aluminum containers that weighed an average of 5.8 g. Each container was then weighed on a Denver Instrument Company model TR-603D scale. The containers were then place in an oven at 140º C for two days. The samples were then removed and weighed again.

Each soil sample was dried and ground before organic matter and pH were measured. Organic matter was determined by placing 5.0 grams of oven-dried soil from each sample in pre-weighed, porcelain crucibles. The crucibles were placed in a muffle furnace at 350-400º C for several hours (usually need at least one to two hours). The samples were then cooled and reweighed. Organic matter was calculated by the following formula: Percent organic matter = (weight difference/weight before heating) (100). With the use of a pH meter, soil pH was determined by using the wet oxidation method (Nyakatawa et al., 2000; Walkley and Black, 1934). For each soil sample a 1:1 soil to

distilled water mixture, using 5 grams of soil and 5 ml of distilled water, was prepared. Each sample was allowed to stand for 15 to 20 minutes. During this time period samples were stirred several times. Each sample was stirred immediately before recording data from the pH meter.

A two way analysis of variance (ANOVA) and a best subject regression, both done in SigmaSTAT were used to perform an analysis of the data that included all of the variables within the study and to determine levels of significance for each variable. Graphical representations were used to examine variation between months, variation over time, and variation between legumes and non-legumes.

RESULTS

The two way analysis of variance resulted in normality tests and equal variance tests that each failed. So, the results of a best subject regression were then used to determine which factors were significant. The P-values revealed that a significance in the data lie in the variables of percent moisture and temperature. Temperature had a P-value of 0.0006 and percent moisture had a P-value of 0.1501. Therefore, temperature was determined to have the greatest impact on variation in microbial activity and percent moisture to have the next greatest impact. The remaining factors all had P-values that were considerably higher. Compaction had a P-value of 0.4264, pH had a P-value of 0.5101, and percent organic matter has a P-Value of 0.3187. Thus, these three factors were all ruled out as contributing factors to the results.

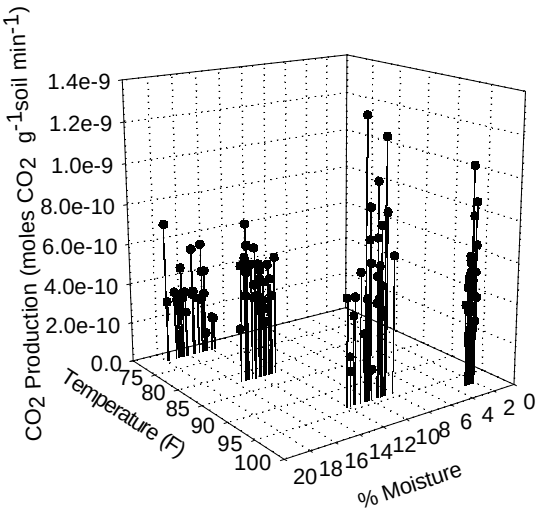

Figure 2. CO_2 production (moles CO_2 g^{-1} soil min^{-1}) versus temperature (°F) and percent moisture.

Percent moisture and temperature each have a different effect on microbial activity, which is measured by CO_2 production in moles CO_2 g^{-1} soil min^{-1}. Figure 2 shows a three-dimensional graph comparing both variables to CO_2 production. From Figure 2 it is concluded that temperature and microbial activity are directly proportional. An increase in temperature results in an increase in CO_2 production. A decrease in temperature results in a decrease in CO_2 production. It can also be concluded that percent moisture and microbial activity are inversely proportional. The higher the percent moisture is in the soil, the lower the rate of CO_2 production by microbes. The lower the percent moisture is in the soil, the higher the rate of CO_2 production by microbe.

Figure 3 illustrates the average percent moisture and average temperature for each sampling date. Average temperatures were higher on the sampling dates of June 29 and August 5 and were lower on May 21 and September 23. Average percent moisture was higher on the sampling dates of May 21 and September 23 and lower on June 29 and August 5. Thus May and September can be referred to as the cool, wet months, while June and August are referred to as the warm, dry months. Figure 3 indicates that as temperature increased, percent moisture decreases.

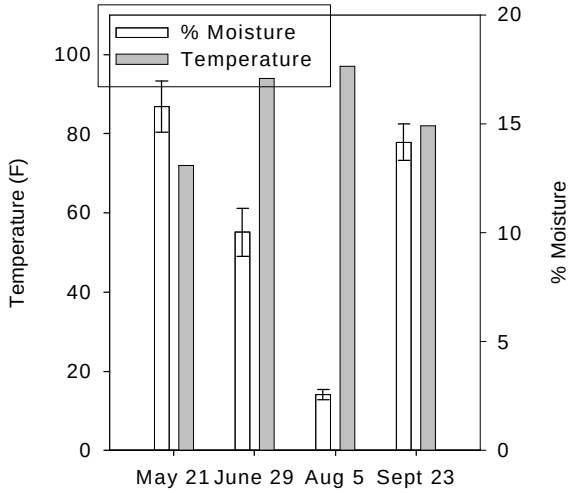

Figure 3. Average percent moisture and average temperature for each sampling date. Error bars represent +/- one standard deviation.

Variations between legumes and non-legumes, between individual cover crops, and between sampling dates are all represented in Figure 4. A slight difference between non-legumes and legumes is seen in the months of August and September. Otherwise, there is no apparent differentiation among legumes and non-legumes. Of the individual cover crops, it is evident that sunn hemp had a superior performance, especially in the month of August. Soybeans and pearl millet also exhibit larger amount of CO_2 production than the other cover crops. The least amount of CO_2

production is in canola.

The differences in microbial activity between sampling dates is also shown in Figure 4. This figure expresses a significant difference in microbial activity between sampling dates. The May 21 samples have the least amount of microbial activity. The August 5 samples have the most amount of microbial activity. The June 29 and September 23 samples are in the middle for microbial activity with June 29 having less activity than September 23.

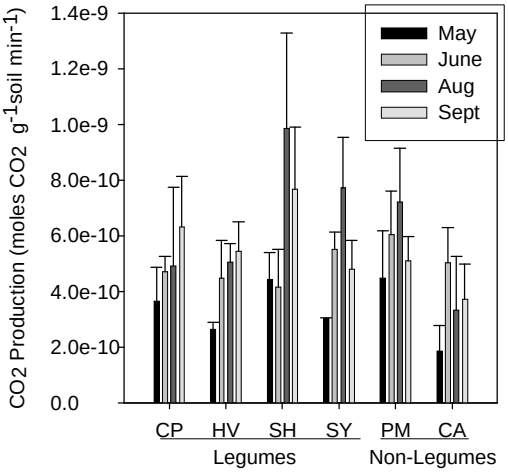

Figure 4. CO_2 production (moles CO_2 g^{-1} soil min^{-1}) by legumes and non-legumes, by individual cover crop, and by each date for individual cover crops. Cover crops are abbreviated as follows: CP-Cowpeas, HV-Hairy Vetch, SH-Sunn Hemp, SY-Soybeans, PM-Pearl Millet, and CA-Canola.

DISCUSSION

The results suggest that variations in microbial activity for this study are primarily a result of variance in percent moisture and temperature readings between sampling dates. The period for which the sampling was done was characterized by an unusually wet period followed by a drought period that was more severe than most years and then followed by another unusually wet period as shown in Figure 3. Because of this weather pattern, the crops in the area were significantly affected. The microbial populations were also affected.

An extremity in weather patterns is a possible explanation for lack of significant in percent organic matter, pH, and compaction. In a similar study, it was concluded that "organic matter content, nutrient levels, and pH were undoubtedly the major factors governing the marked population difference" (Priester and Harms, 1971).

Priester and Harms also concluded that "the influence of soil moisture on population numbers is an effect of soil aeration rather that water stress and as soil moisture content increases, the amount of air in the soil decreases" (Priester and Harms, 1971). It can be concluded that as percent soil moisture increases that the percent of oxygen decreases, resulting in a decrease in CO_2 production and microbial activity.

The lack of a large variation between legume cover crops and non-legume cover crops can partly be explained by the drought conditions. Symbiotic nitrogen fixation in some legumes is very sensitive to drying soil with fixation declining very early in a drought cycle. (Serraj, et al., 1998)

The results have indicated that there is an impact of certain cover crops on microbial activity. The increased performance of certain cover crops compared to other cover crops could be the result of several things. The root systems of certain crops such as sunn hemp or soybeans may be favorable for soil properties to which microbes are sensitive. Also, the cover crops may leave an increased amount of residue, which provides cover and affects soil temperature. Since soil temperature was only taken at one location in the field on each sampling date, it is possible that there was a variation of temperature from one cover crop to another that caused a variation in microbial activity between cover crops.

Cover crops provide several benefits to a no-till system. One of those benefits relates to carbon sequestration. The United States, in addition to other industrialized countries pledged under the Kyoto Protocol that we would reduce their 1990 carbon emission for 2008-2012. In order to fulfill their pledge, some countries, including the United States have proposed the implementation of land management practices that sequester carbon from the atmosphere by storing it in the soil or biomass. (Feng, et al., 2000) If the United States were to implement this plan, there would be significant increase in the importance of cover crops that increase CO_2 production in the soil.

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LITERATURE CITED

Chan, KY., WD Bellotti, and WP Roberts. 1988. Changes in soil surface properties of Vertisols under dryland cropping in a semi-arid environment. Australia Journal of Soil Research. 26(3): 509-518.

Campbell, CA, BG McConkey, RP Zentner, F Selles, and D Curtin. 1996. Tillage and crop rotation effects on soil organic C and N in a course-textures Typic Haploboroll in southwestern Saskatchewan. Soil Tillage Research. 37: 3-14.

Feng, H, J Zhao, and CL Kling. 2000. Carbon

sequestration in agriculture: value and implementation. Iowa State University. 00-WP 256.
Frye, WW and RL Bevins., 1989. Economically sustainable crop production with legume cover and conservation tillage. Journal of Soil and Water Conservation. Jan-Feb: 57-60.
Nyakatawa, EZ, KC Reddy, and D Mays. 2000. Tillage, cover cropping, and poultry litter effects on selected soil chemical problems. Soil Tillage Research. 58: 69-79.
Noll, MG, CW Rice, CJ Sorenson. 1995. Biological Conditions of an Agriculture Soil Six Years after Conservation Reserve. Transactions of the Kansas Academy of Science. 98(3-4): 102-112.
Parkinson, KJ. 1981. An improved method for measuring soil respiration in the field. Journal of Applied Ecology. 18: 221-228.
Peterson, GA, AD Halvorson, JL Halvin, OR Jones, DJ Lyon, and DL Tanaka. 1998. Reduced tillage and increasing cropping intensity in the Great Plains conserve soil C. Soil Tillage Research. 47: 207-218.
Priester, DS and WR Harms. 1971. Microbial populations in two swamp soils in South Carolina. USDA Forest Service Research. SE-150.
Scott, HD, TC Keisling, BA Waddle, RW Williams, and RE Frans. 1990. Effects of winter cover cropson yield of cotton and soil properties. Arkansas Agriculture Experimental Station Bulletin. 924.
Serraj, R, TR Sinclair, and LH Allen Jr, 1998. Global climate change benefits symbiotic N2 fixation sensitivity to drought. Tektran USDA Agriculture Research Service.
Walkley, A and IA Black, 1934. An examination of the Defjaroff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science Journal. 37: 29-38.