ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

A COMPARATIVE ANALYSIS OF RESPIRATORY ACTIVITY AND MINERALIZATION INDEX IN SOILS OF DIFFERENT LOCATIONS OF THE DRY TROPICAL WOODLANDS IN HUILA-STATE, COLOMBIA

Jennifer Katiusca Castro, Nestor Enrique Cerquera and Freddy Humberto Escobar
Universidad Surcolombiana/CENIGAA, Avenida Pastrana, Neiva, Huila, Colombia
E-Mail: fescobar@usco.edu.co

ABSTRACT

A comparative analysis was performed on carbon dioxide emission and the organic matter mineralization index among the soils of three different locations of the dry tropical woodlands (bsT) in the Huila-State (Colombia) by means of the adaptation of a static method for estimating the biologic activity, measured by the breathing of microorganisms contained in soils. According to the soil precedence three treatments were implemented and soil characterization before and after the tests for respiratory follow-up was performed as well. Each test included measurements of pH, organic carbon, cationic exchange capacity and temperature with the purpose of evaluating the behavior of these properties during the process. Following this, the mineralization index for each soil type was calculated from the contain of organic carbon and CO2 released from respiration. Results show that breathing behavior with respect to treatment times is different including significant breathing changes and releasing the highest amount of CO_2 during the first 48 hr. Furthermore, low values for the mineralization index proving the degradation potential of soil microorganisms were obtained for medium and low organic matter content.

Keywords: respirometry, mineralization rate, organic matter.

INTRODUCTION

According to Murcia and Ochoa (2008), soil respiration is defined as total carbon dioxide production per both unit area and time, caused by the respiration of edaphic organisms, roots, mycorrhizas and for chemical oxidation of organic compounds. Breathing is regulated by such biotic and abiotic factors as temperature, soil humidity, nutrient contents, vegetation: structure, photosynthetic activity o phonologic development, Subke *et al*. (2006), and also biomass of fine roots and microbial (Adachi *et al*. 2006).

Different static-type techniques have been used for soil respirometry. These techniques are based upon measuring CO_2 or Oxygen consumption or production in a given soil -Sánchez *et al*. (2012)-. Among the developed researches on respiration rate in soils the work reported by Alzate and Campiño (2014) is found. They performed an approximation of the soil microbial activity, complementing this procedure with counting bacteria and fungus, finding a higher amount of microbial activity in the conventional-type soil, due to its handling conditions; Ramírez and Moreno (2008) estimated the soils' respiration rates and its components (respiration of roots and microorganisms) during a year in 10 small holdings using a soil respiratory chamber connected to an infrared gas analyzer. Gasca (2010) evaluated the changes in the exchange sodium percentage (PSI), the sodium absorption ratio (RAS) and its influence in the activity and microbial biomass of soils which permitted establishing that the biological activity (CO_2) and in the C-biomass microbial resulted significant increments in the ideal range for setting up a sugarcane crop.

Several chemical and biologic processes take place in organic matter. It is stood up, among them, the mineralization through respiration during a given time. Considering that highest weight content of organic matter is due to carbon, the proportion of produced C-CO_2 by microbial respiration as a function of C-Total of organic matter corresponds to the soil mineralization index, Rosales *et al*. (2008).

Chiriboga (2008) valuated the soil respiration in laboratory (basal respiration) and the respiration in the field by means of an infrared gas analyzer. He evaluated such factors as humidity and soil temperature in response to respiration; Ochoa and Urroz (2011) determined the microbial activity using the measurement of soil basal respiration (CO_2 released per unit time) and the soil organic mineralization index in Nicaragua. Mendiara (2012) utilized gas chromatography for estimating the soil basal temperatures and studied the mineralization index as an influential parameter in the microbial activity.

The goal of this research is to perform a comparative analysis of the carbon dioxide emission and the organic matter mineralization index among soils located in several places of the soils in the tropical dry woodlands.

METHODOLOGY

Soil samples were collected from three rural properties located in Huila-State (Colombia) and they were analyzed in two laboratories of Universidad Surcolombiana (Neiva-Huila, Colombia). The treatments were defined considering the soil precedence in the following manner: soil from rural property in “El Caguán”

ARPN Journal of Engineering and Applied Sciences

village (T1), soil from rural property eco-region "Tatacoa dessert" (T2) and soil from town property in the city of Neiva (T3). Two kilograms were collected by sample as suggested by the sampling protocol of IGAC (2014).

INITIAL AND FINAL CHARACTERIZATION OF THE SOILS UNDER STUDY

Soil properties before and after respiratory testing were determined to evaluate their behavior during the procedure. Each treatment included measurements of pH (according procedure from NTC 5264), organic carbon (%CO), (modified NTC 5403), cationic exchange capacity (CIC), (modified NTC 5268), humidity (%) and temperature (°C), -IGAC, (2006)- and organoleptic texture, Torrente (2014).

SOIL RESPIROMETRY

Soil respiration estimative for each treatment was performed by adapting the static method utilized by Mora (2006) and validated by Ochoa and Urroz (2011). It consisted of settling 200 grams of soil at field capacity in a transparent recipient of a known volume and hermetically closed. It was then taken to incubation in a dark room at environmental conditions of 25˚C and 58% of relative humidity during a time of 24 hr. Once time passed, two glassful of precipitate were placed inside the recipient, one with 20 ml of NaOH0.2 N and other with 20 ml of drinking water. The last one was used to make the soil humidity keep steady. After 24 hr, the glass containing 20 ml of NaOH 0.2N was withdrawn and an aliquot part of 1ml of $BaCl_2$at 20%, three drops of phenolthalein and was taken to titration with HCl 0.1N, verifying with a potentiometer Schott Instruments that pH reaches 8.3. Same former procedure was performed with a control without soil simple in which the glassful with 20 ml de NaOH 0.2N was settled. Each time the glass containing NaOH had been with drawn was immediately replaced by a new one with the same amount of this solution inside the recipient which was hermetically sealed.

Each treatment was repeated three times. Measurements every 24 hr were conducted during a period of 96 hr. CO_2 concentration of the samples was calculated by comparing with the control, expressing the results in grams of CO_2, utilizing Equation (1), Mora (2006).

$$CO2 = \left(10 - \frac{n}{2}\right) * 0.00044 \quad (\text{gr } CO_2) \tag{1}$$

Being n the amount of HCl 0.1 N consumed in the titration.

CALCULATION OF ORGANIC MATTER MINERALIZATION INDEX

This parameter was determined with the organic carbon contain and the CO_2 concentration expressed in grams, for each time interval using Equation (2), Rosales *et al*. (2008).

$$\%\, mineralizationIndex = (grCO2/grCO) * 100 \tag{2}$$

Variance analysis was made to establish both if CO2 concentration is different for each type of soil and if the mineralization index changes with respect to organic carbon contain in each treatment.

RESULTS

Initial characterization of the studied soils

When determining the texture by the organoleptic method, it could be observed that the soil with treatment T1 stained the hand, it did not feel rough, and allowed easily molding according to the description given by FAO (2014). This soil was classified as Franco clayey. Soils with treatments T2 and T3, the samples stained the hand but did not allow molding. They had particles with rough sensation. These soils were classified as loose-texture to Sandy. Soils' texture and agro climate conditions of the rural properties are given in Table-1.

Table-1. Agro climatic conditions of the rural properties and "in-situ" texture.

Treatment	Texture	T (˚C)	Rainfall (mm/year)	Altitude*
T1	Franco clayey	24.93	1300	532
T2	Loose-texture to Sandy	25.00	1210	563
T3	Loose-texture to Sandy	27.70	1346	442

(*) Meters above see label

Soils' characteristics before initiating the measurement respiratory tests are shown in Figure-1. Figure-2 presents soils' characteristics after 96 hr of the respiratory test. It is observed in Figures-1 and 2 that the pH of soils goes from neutral value to slightly basic during the testing time. Armado *et al*. (2009) conducted a study in which they found that soil pH correlates significantly with some enzymatic activities but does not correlate with soils' basal respiration. This result is because of the existence of microorganisms which adapt themselves to soil pH; therefore, it cannot be confirmed that soils with a given pH have greater or lesser biological activity. Arteta (2006) cited by Ochoa and Urroz (2011) affirms many organisms, particularly nitrifying, are inhibited by acid pH, while others need a low pH to improve their population growing rate. Besides, alkalinity leads to abnormal behavior in the microbial colonies.

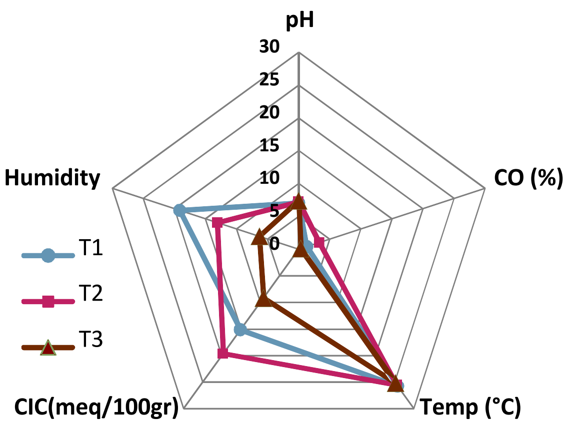

Figure-1. Characterization of soils at starting of measurement procedure.

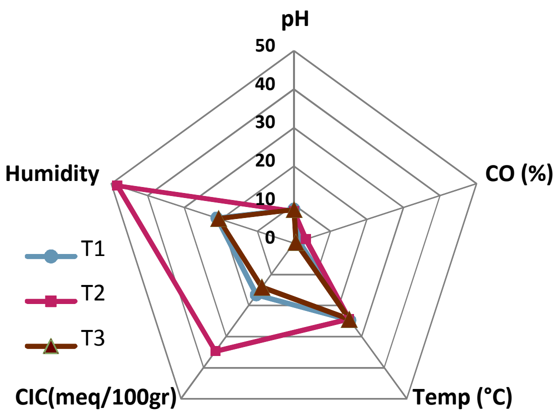

Figure-2. Characterization of studied soils after 96 hr of respirometry.

The organic matter content, (% CO), did not suffer significant changes in any treatment. It kept steady with low to medium content. According to the study by Gasca *et al*. (2011), the organic matter fluctuation is linked to microbial activity variations since the organisms perform rapid organic matter decomposition depending on the soil environmental conditions.

The cationic exchange capacity had an increasing tendency in the three treatments. It was observed in treatment 2 a considerable increase from 19.68 meq*100gr^{-1}at starting the measurements to 34.74 meq*100gr^{-1} at the end of the test. It was found in that treatment gave the highest organic carbon content (3.3%CO) which suggests that the greater the organic matter availability in the studied soils, the higher cationic exchange capacity. Soils' temperature was kept steady in the three treatments and presented a slight decrease during all tests.

Respirometry of soils

Figure-3 shows the evolution of CO_2 concentration from the treatments with respect to time. It is observed that T1 presents the least respiratory activity with average CO_2values of 0.0026 gr. T2 had the highest respiratory activity with 0.0066 gr of CO_2, which corroborates that soils with medium organic matter and high humidity conditions favor the proliferation of microorganisms and their mineralizing activity. Studies conducted by García *et al.* (2003) and Peña (2004) demonstrated the susceptibility of the response of microbial activity on handling variations of soils. This demonstrates that the organisms are sensitive to changes of temperature, humidity, humidity-dried effects and organic matter content with results that present same tendencies to those from this research.

The biological activity of the treatments measured by emitted CO_2 concentration in the soils had an increase during the first 48 hr, then; its decrement was presented in all the treatments. As observed in Table-2, the breathing behavior with respect to time is different among the treatments with a significance level of 5 %. This respiratory change is significant indicating that the existing microorganisms in the soils released CO_2. There was a decrement of organic matter content in treatment T2 at the end of the process. This indicates that the existing microorganisms contributed to soil's organic matter decomposition.

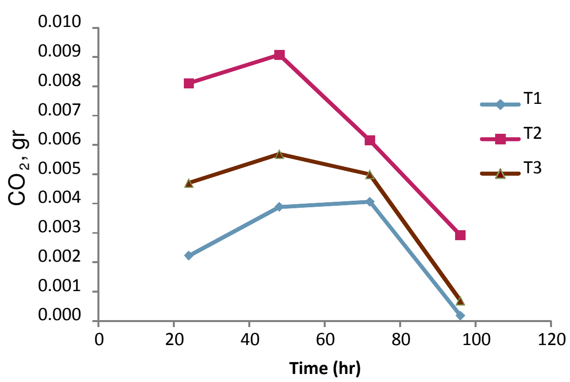

Figure-3. CO_2 Concentration emitted by soils throughout the time.

Mineralization index of organic matter

ARPN Journal of Engineering and Applied Sciences

The mineralization index calculation was carried out after the respiratory behavior analysis in the treatments. These experiments permitted evaluating the biotic and abiotic factor variations on the organic matter decomposition. Susceptibility and decomposition velocity of both synthetic and natural organic compounds can be evaluated through the mineralization studies, Ochoa and Urroz (2011).

Figure-4 shows the behavior of the mineralization index in in the treatments at both starting and ending of the respirometry process. It is shown there that the highest mineralization indexes are given for T3 with values over 100 %. This index presents similar results to researches conducted by Acuña (2006) who found in soils that the higher organic matter contents the lower mineralization index due to organic substrate accumulation. Gómez (2000) affirms that a soil rich in both organic matter and microbial activity is an indicator of high fertility and availability of nutrients. The variety of microorganisms utilizes carbon energy for their metabolism; thereby, it exists a direct relationship between microorganisms, soil's fertility and soil's organic matter.

According to Zibilske (1994) cited by Ochoa and Urroz (2011), the determination of a given soil mineralization index allows finding information on the physiological state or metabolic activity of the existing microbial population, the biomass and the contribution of microorganisms to the total soil carbon flow. Taken into account this premise, the obtained values of mineralization index indicate the degradation potential of the soils' microorganisms for medium to low organic matter content, food sources in these processes, non metabolisable; then, its activity is low. In conformity with Ceccanti and García (1994), it is the labile fraction of the organic matter inducing an increase in the microbial activity. The labile fraction contributes to maintain a high microbiological activity which favors the release of nutrients and degradation of contaminant compounds.

Table-2. Analysis of variance of CO_2 emission with respect to time in the conducted treatments.

Variations origin	Square summation	Freedom degree	Square average	F	Probability	F critical value
Treatments	3.2345E-05	2	1.6172E-05	26.1034637	0.03689565	19
Time	7.6358E-06	1	7.6358E-06	12.3247822	0.07243231	18.5128205
Error	1.2391E-06	2	6.1955E-07	-	-	-
Total	4.122E-05	5				

Table-3. Analysis of variance of the mineralization index with respect to time.

Variations origin	Square summation	Freedom degree	Square average	F	Probability	F critical value
Treatments	13261.5483	6	2210.25806	1.53541246	0.30783162	4.28386571
IM	19188.7907	1	19188.7907	13.3299858	0.01069324	5.98737761
Error	8637.12434	6	1439.52072	-	-	-
Total	41087.4634	13				

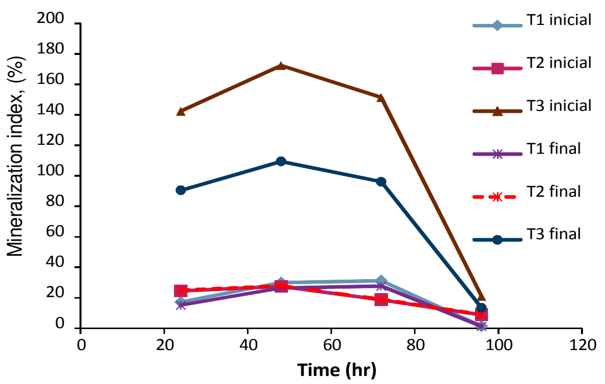

Figure-4. Mineralization index behavior with respect to time.

The behavior of the mineralization index curves of the different treatments keep the same tendency and do not present significant differences (Table-3). The mineralization index (IM) of the soils present significant differences. This indicates that in spite of metabolism activity of the organic matter is low; there was a low activity of the labile fraction which permitted the microorganisms of the soil generate CO_2 measured in respiration. Treatment 2 shows a steady behavior with a low mineralization index and medium %CO with a higher respiration rate than the other two treatments because the existence of microorganisms in the treatment utilize a great amount of energy for decomposing the organic matter of the samples under study.

ARPN Journal of Engineering and Applied Sciences

CONCLUSIONS

a) Emitted CO_2 concentration by existing microorganisms in the studied treatments had a growing behavior during the first 48 hours. The respiration behavior among the treatments with respect to time was individually different. There was a reduction of organic matter content in treatment T2 at the end of the process. This indicates that existing microorganisms contributed to organic matter decomposition of the soil.

b) The highest mineralization indexes were obtained with treatment T3 with values above 100%. Mineralization indexes obtained for both medium and low organic matter content indicate a low degradation potential of the microorganisms in these types of soils.

c) Treatment 2 provided a low mineralization index and medium %CO with the highest respiration rate compared to the other two studied treatments. This suggests the existence of a higher microorganism's activity on the organic matter substrate that is contained in the samples of this treatment.

REFERENCES

Acuña O., Peña W., Serrano E., Pocasangre L., Rosales F., Delgado E., Trejos J. and Segura A. 2006. La importancia de los microorganismos en la calidad y salud de suelos. Memorias de Acorbat, Santa Catarina, Brasil. Fecha del evento 20 al 26 de Octubre.

Adachi M., Bekku Y. S., Rashidah W., Okuda T. and Koizumi H. 2006. Differences in soil respiration between tropical ecosystems. Applied Soil Ecology. 34, 258-265.

Alzate J.D. and Campiño D. 2014. Actividad microbiana de suelos con manejo orgánico y convencional. Universidad Tecnológica de Pereira. pp. 69. Pereira, Colombia.

Armado A., Contreras F., García P. and Paolini J. 2009. Correlación de actividades enzimáticas con la respiración basal en suelos cacaoteros del occidente venezolano. Avances en Química, 4(2): 73-77. Universidad de Los Andes de Mérida. Mérida, Venezuela.

Ceccanti B. and García C. 1994. Coupled chemical and biochemical methodologies to characterize a composting process and the humic substances. EnSenesi N, Miano TM (Eds). Humic substances in the Global Environment and Implications on Human Health. Elsevier. Amsterdam, Holanda. pp. 1279-1284.

FAO. 2014. El Suelo, Diferencias Según Su Aspecto Físico Y Químico. Consultado el 28 de noviembre de 2014.http://www.fao.org/docrep/009/ah645s/AH645S04.htm.

García C., Gil-Sotres F., Hernández T. and Trasar-Cepeda C. 2003. Técnicas de análisis de parámetros bioquímicos en suelos: medida de actividades enzimáticas y biomasa microbiana. Mundi-Prensa, Madrid. p. 371.

Gasca C.A. 2010. Cambio en el PSI y la RAS de un suelo y su influencia en la actividad biológica y la biomasa microbiana. Trabajo de grado para optar al título de Magíster en ciencias agropecuarias línea de investigación en suelos. Universidad Nacional de Colombia. pp. 66, Palmira, Colombia.

Gasca C., Menjivar J. and Torrente A. 2011. Cambios en el porcentaje de sodio intercambiable (PSI) y la relación de absorción de sodio (RAS) de un suelo y su influencia en la actividad y biomasa microbiana. Acta agronómica. 60(1): 27-38. Universidad Nacional de Colombia, Colombia.

Gómez A. 2000. Elaboración de abonos orgánicos con bajos insumos en las condiciones del productor rural. Memoria del primer seminario de investigación científica y tecnológica sobre el istmo de los Estados de Veracruz, Chiapas, Tabasco y Oaxaca. ECOSUR, Unidad Tabasco.

Instituto Colombiano de Normas y Técnicas y Certificación. 2008. Calidad de suelo. Determinación del pH. NTC 5264. Bogotá, Colombia.

Instituto Colombiano de Normas y Técnicas y Certificación. 2013. Calidad de suelo. Determinación del carbono orgánico. NTC 5403. Bogotá, Colombia.

Instituto Colombiano de Normas y Técnicas y Certificación. 2014. Calidad de suelo. Determinación de la capacidad de Intercambio catiónico. NTC 5268. Bogotá, Colombia.

Instituto Geográfico Agustín Codazzi IGAC. Laboratorio de suelos, 2014. ¿Cómo realizar la toma de muestras para suelos? Consultado el 1 de diciembre de 2014, http: //www.igac.gov.co, Bogotá, Colombia.

Instituto Geográfico Agustín Codazzi IGAC. 2006. Métodos analíticos de laboratorio de suelos. pp. 375-372. Bogotá, Colombia.

Mendiara S. 2012. Efecto de los usos del suelo en la emisión de dióxido de carbono del suelo a la atmósfera en un agroecosistema semiárido del Valle del Ebro. Universidad Escuela Politécnica Superior. Sevilla, España.

ARPN Journal of Engineering and Applied Sciences

Murcia M. and Ochoa M. 2008. Respiración del suelo en una comunidad sucesional de pastizal del bosque Altoandino en la Cuenca del Río Pamplonita, Colombia. Revista Caldasia. 30(2): 337-353. Universidad Nacional de Colombia, Colombia.

Mora J. R. 2006. La Actividad Microbiana: Un Indicador Integral de la Calidad del Suelo. Revista Luna azul. pp. 6. Universidad de Caldas. Manizales, Colombia.

Ochoa C. and Urroz F. 2011. Determinación de los indicadores biológicos de suelos agrícolas. Universidad Nacional Autónoma de Nicaragua. León, Nicaragua.

Peña W. 2004. Los suelos desarrollados sobre serpentinitas y su relación con la flora endémica. Índice bioquímico y metales. Tesis doctoral, Universidad de Santiago de Compostela y CSIC, España. p. 404.

Ramírez A and Moreno F. 2008. Respiración microbial y de raíces en suelos de bosques tropicales primarios y secundarios (Porce, Colombia). Revista Facultad Nacional de Agronomía. 61(1): 4381-4393. Medellín, Colombia.

Rosales F., Pocasangre L., Trejos J., Serrano E. and Peña W. 2008. Guía de diagnóstico de la calidad y salud de suelos bananeros. Edit. Bioversityinternational. Costa Rica.

Sánchez V., Fernández F.J., Rodríguez L. and Villaseñor J. 2012. Respiration indices and stability measurements of compost through electrolytic respirometry.Journal of Environmental Management. 95 S134-S138.

Subke J.A., Inglima I. and Cotrufo M.F. 2006. Trends and methodological impacts in soil Co2 efflux partitioning: a metanalytical review. Global Change Biol. 12: 921-943.

Torrente A. 2014. Manual de laboratorio Análisis físico del suelo. Laboratorio de suelos de la Universidad Surcolombiana de Neiva. pp. 10-15. Neiva, Colombia.