Soil Science: Chemistry, Physics, Biology, Biochemistry and Hydrology/ Ciencias del Suelo: Química, Física, Biología, Bioquímica e Hidrología

doi: http:// dx.doi.org/10.15446/acag.v64n4.47115 e-ISSN 2323-0118

Effect of application of vermicompost on the chemical properties of saline-sodic soil of Venezuelan semiarid

Efecto de la aplicación de un vermicompost en las propiedades químicas de un suelo salino-sódico del semiárido venezolano

José Pastor Mogollón Sandoval [1*], Alicia Elena Martínez [2] and Duilio Gilberto Torres[3]

[1]Universidad Nacional Experimental Francisco de Miranda, Coro, Falcón state. Department of Environment, Agricultural Technology, Venezuela. [2]Universidad Politécnica Territorial Alonso Gamero, Venezuela. [3]Universidad Centro Occidental Lisandro Alvarado, Venezuela. *Corresponding author: jmogollon15@gmail.com

Rec.: 06.11.2014 Acep.: 29.04.2015

Abstract

The objective was to evaluate the effect of vermicompost made with California red worm (*Eisenia foetida*), and substrate from remains of food, coffee waste, banana pseudostems and horse manure, on the properties of a sodium-saline soil of Cebollal plain. Incubation experiment was carried out to compare three doses of vermicompost. Four treatments were implemented: treatment without vermicompost (T1); T2: 1% vermicompost; T3: 5% vermicompost and T4: 10% vermicompost, for an incubation period of 28 days, with measurements at 7, 14, 21, and 28 days. In each dates were evaluated the soil pH, electrical conductivity (EC) and exchangeable sodium percentage (ESP). All variables decreased during the experiment. The EC T4 showed a reduction of 62% compared to baseline (3.48 dS/m). The application of different treatments reduced the initial values of soil pH (8.30); the most effective treatment was T4, since soils changed from the condition of alkali to neutral soils (pH ≤ 7.5). With the application of 10% vermicompost ESP was reduced to 50%. The addition of vermicompost proved to be a good strategy for the full recovery of saline-sodic soils.

Key words: Organic amendments, salinity, soil recovery, sodicity.

Resumen

En el trabajo se evaluó el efecto de un vermicompost, elaborado con lombriz roja californiana (*Eisenia foetida*), y sustrato de restos de alimento, broza de café, pseudotallos de plátano y estiércol equino en las propiedades de un suelo salino-sódico del Cebollal de Coro, municipio Miranda, estado Falcón, Venezuela. Para el efecto en un experimento de incubación se compararon tres dosis del producto (tratamientos, T1 = testigo, T2 = 1%, T3 = 5%, T4 = 10%) durante 28 días de incubación, con mediciones los días 7, 14, 21 y 28. Se midió el pH, la conductividad eléctrica (CE), los cationes intercambiables (Ca, Mg, Na y K), y el porcentaje de sodio intercambiable (PSI). Todas las variables disminuyeron durante el ensayo; la CE en T4 se redujo 62% con respecto al valor promedio inicial (3.48 dS/m), el pH inicial en el suelo (8.30) se redujo a 7.5 en el mismo tratamiento, igualmente el PSI se redujo 50%. La adición de este producto orgánico demostró ser una buena estrategia para la recuperación integral de suelos salino-sódicos en la región de estudio.

Palabras clave: Enmiendas orgánicas, recuperación de suelo, salinidad, sodicidad.

Introduction

Desertification, erosion and salinization are the main threats to soil fertility in tropical areas; salinization, for example, causes negative effects on the physical, chemical and biological soil properties (Mogollon et al, 2010, 2014. Torres *et al.*, 2006). The areas of soil degraded by salt and sodium problems are widely distributed in the world, but are most common in arid and semi-arid areas that have been subjected to intensive agriculture.

The salinization processes of soils can be classified into two groups; on the one hand, the natural salinity, favored by major climate changes, geomorphological processes of sedimentation, erosion and redistribution of materials and changes in surface and groundwater hydrology (Lamz and Gonzalez, 2013). On the other, the anthropogenic salinity which has primarily been the result of inadequate irrigation and drainage practices (Yurtseven Öztürk and Avci, 2014).

In soils of the arid zone of Falcon State there is a clear process of degradation due to effects of salinization, as a result of inappropriate agricultural practices. In this State, one of the agricultural areas most affected by this process is the Cebollal de Coro, known for its high production of vegetables (Rodríguez *et al.*, 2009).

The management of fertilization and irrigation and the use of vermicompost are some of the methodologies proposed for the rehabilitation of land affected by salt excess (Chaoui *et al.*, 2003).

Therefore, the present study aims to evaluate the effect of the addition of vermicompost in the rehabilitation of saline-sodic soils The Cebollal sector, Falcon State, under controlled laboratory conditions, using as indicators of changes in pH, electric conductivity and exchangeable sodium percentage (ESP).

Materials and methods

Area of study and sample collection

Soil samples were collected from the series El Jebe, classified as Typic Haplargids, of clay texture and high salt contents (Rodríguez *et al.*, 2009) in the farm Los Hurtados (1.255.647.95 N and415.918.77 W) with 5386 ha dedicated to vegetable crops. Weather is characterized by high temperatures during most part of the year and low rainfall at the end of the year (372 mm/year) and annual potential evapotranspiration between four and eight times higher than the precipitation (2162 mm/year). The evaluated variables were electric conductivity (EC), pH, exchangeable cations (Ca, Mg, Na and K) and the exchangeable sodium percentage (ESP).

For the analysis, in places with visible signs of salinization (pH > 8, $EC_{1:2}$ > 2 dS/m) 18 subsamples of soil were taken between 0 and 20 cm of depth in a plot of approximately 1 ha. With the subsamples a sample of 50 Kg was formed after drying, sieving on 2 mm sieve and homogenizing, and it was used in the laboratory for the corresponding chemical analysis.

As background, during the 1980s and 1990s, the farm was exploited with irrigated horticultural crops, mainly onion and melon, in which large amounts of fertilizers and other agrochemicals of synthesis, as herbicides and insecticides, were applied; parallel to this, an overuse of aquifers for irrigation occurred (Rodríguez, 2002); as result of the soil salinization, the exploitation has been used for 10 years without any commercial crops.

Vermicompost

The vermicompost used came from the farm El Pozón located in the municipality Petir, Falcon State. For its elaboration was used Californian red worm (*Eisenia foetida*) and residues of food, coffee solid waste, banana pseudostems and horse manure were used as substrate, previously pre-composted for 20 days and then subjected to vermicomposting for 60 days.

Experimental design

Vermicompost evaluation was done in the lab under controlled conditions of humidity and temperature. For this, in a completely randomized design 1, 5 and 10% (w/w) doses and twelve replicates were evaluated on the variables associated with salinity (pH, EC, exchangeable cations, ESP); additionally a control treatment without vermicompost was evaluated. The experimental unit consisted on a plastic container with 100 g of mix soil: vermicompost, which were placed in the incubator at 28 °C and at 80% of field capacity. To ensure this condition, each 4 days weight of each experimental unit was measured and to compensate the weight lost distilled water was added. Incubation was done for 28 days, time during which four measurements were taken at

7, 14, 21 and 28 days. Measurement of the studied variables were performed in three experimental units for each treatment.

Chemical analysis

pH was determined with pHmeter on a soil: water 1:2 ratio (Bates, 1973). EC was measured in the same soil:water ratio (1:2) using a conductimeter (Dellavalle, 1992). The organic carbon (OC) was determined by the Walkley-Black method (1934). Total nitrogen (Nt) was obtained by the Kjeldahl method, with previous digestion of the sample. Exchangeable cations were extracted with ammonium acetate 1N; sodium (Na^+) and potassium (K^+) cations were determined by flame photometry (Thomas, 1982); and calcium (Ca^{2+}) and magnesium (Mg^{2+}) cations were obtained by the complexometric method (Abadía *et al.*, 1981). To calculate the exchangeable sodium percentage (ESP) the following equation was used:

$$ESP = Na/\sum(Ca, Mg, K, Na) * 100$$

Data analysis was done by variance and Tukey test for mean comparison using the Infostat version 1.1 software (Infostat, 2002).

Results and discussion

Physico-chemical characterization of soil and vermicompost

Soil

In Table 1 the average values of the chemical properties of soil and vermicompost are displayed; in addition of the sand, silt and clay fractions, and the textural class. The original soil had a pH of 8.40, an ESP 67.2% and EC of 3.48 dS/m. According to Fuentes (1999) saline-sodic soils are characterized by a $EC_{1:2}$ >1.6 dS/m and a ESP > 15%.

The high values of sodicity found in this soil are related to the previous management characterized by excessive use of synthetic chemical inputs (fertilizers and pesticides), high mechanization and use of irrigation water with high levels of salinity) (Rodríguez *et al.*, 2009).

The cationic ratio refers to the relative proportion of basic cations in the soil. Generally, it is expected that in soils with good conditions for plant growth, the cation content corresponds to the following order: $Ca^{2+} > Mg^{2+} > K^+ > Na^+$ (Casanova, 2005), however, in the soils of this study the ratio was inverse: $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$. The sodium content compared to calcium and magnesium absorbed in the clay can determine the dispersion of these particles, causing loss of aggregates and alteration of porosity (Le Bissonnais, 2006).

Table 1. Physico-chemical characterization of the used soil and vermicompost.

Parameters	Soil	Vermicompost
pH	8.30	6.80
Electric Conductivity (dS/m) (1:2)	3.43	0.48
Organic Matter (g/kg)	3.0	325.0
Organic Carbon (g/kg)	2.50	188.50
Total N (g/kg)	0.20	17.50
C/N ratio	12.50	10.77
Ca^{2+} ($Cmol_+$/kg)	1.18	62.50
Mg^{2+} ($Cmol_+$/kg)	0.25	54.25
K^+ ($Cmol_+$/kg)	0.28	12.86
Na^+ ($Cmol_+$/kg)	3.35	4.50
Exchageable Sodium Percentage (%)	67.17	4.10
% sand	34	-
% clay	42	-
% silt	24	-
Texture	Clay	-

The OC content was low (2.50 g/kg) which is typical in semiarid conditions and it is lower than the one found by Acosta *et al.* (2008) (6.40 g/kg) in the Paraguana Peninsula, Falcon State. The soil Nt (0.2 g/kg) was low as well, as expected in semiarid regions.

Vermicompost

The vermicompost used as amendment had pH values of 6.80 and EC of 0.48 dS/m (Table 1) indicating that is a non-saline organic product of neutral reaction. These values are in the expected range in stabilized and mature compost (Duran and Henriquez, 2010). It is important to state that the chemical properties of vermicompost are variable depending on the type and state of decomposition and storage time of the subproducts used for its elaboration (Durán and Henríquez, 2007).

The OC had values of 188.5 g/kg, which was in the range considered as adequate in this type of compost (144 - 300 g/kg) (Ravera and De Sanzo, 2000). The C/N ratio was 10.77, indicating that is a vermicompost stable and mature, since according to some authors (Castillo *et al.*, 2010; Acosta *et al.*, 2004) it meets the established value for this characteristic (C/N = 15 or less). This is a direct estimation of the biological degradable fractions of C and N in the organic substrates (Defrieri *et al.*, 2005), plus it is an index for celerity of substrate decomposition and later mineralization of their components (De La Cruz *et al.*, 2010).

The cationic rations in vermicompost was $Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$. In this conditions, it is expected that in function to the high Ca^{2+}contents, once it is added to the soil a substitution process in Na^{+} ions occurs, favoring the washing off of this ion.

Soil pH

No differences were found in the treatment 1 (T1) that corresponds to the control (incubated soil without vermicompost) along the 28 days of incubation. In a general, the results showed a significant reduction in soil pH as higher doses are applied (Table 2). T4 (10% vermicompost) after 28 days showed significant differences in pH ($P < 0.05$) in comparison with the control treatment, being the values 7.5 and 8.3, respectively.

Table 2. pH variation in the soil during the incubation experiment.

Treatments	Dates of Measurement			
	7 days	14 days	21 days	28 days
T1 (control)	8.27 (0.06) ^{Aa}	8.23 (0.15) ^{Aa}	8.27 (0.06) ^{Aa}	8.30 (0.10) ^{Aa}
T2 (1% V)	7.83 (0.03) ^{Ba}	7.75 (0.05) ^{Ba}	7.77 (0.06) ^{Ba}	7.75 (0.05) ^{Ba}
T3 (5% V)	7.77 (0.06) ^{Ca}	7.67 (0.06) ^{Bb}	7.62 (0.03) ^{Cb}	7.60 (0.05) ^{Cb}
T4 (10% V)	7.72 (0.03) ^{Ca}	7.62 (0.03) ^{Bb}	7.55 (0.05) ^{Cc}	7.50 (0.05) ^{Cc}

Upper case letters indicate differences between treatments by date of measurement; lower case letters indicate differences for the same treatment during the incubation. Letters differ with a probability ≤ 0.05% according to Tukey´s test; in parenthesis, the standard deviation.

This reduction in pH is associated with a higher number of resulting hydrogen ions from the ionization of the various radicals present in the organic matter in vermicompost (Duran and Henriquez, 2009) and due to the production of organic acids from the compost mineralization or by nitrification that takes place during the mineralization of organic matter (Azarmi *et al.*, 2008).

Electric conductivity

In Table 3 are shown the soil EC values. The dynamics of this variable is shown for each treatment after the monitoring dates together with the statistical differences between treatments for each sampling date.

In all treatments was found a significant reduction ($P < 0.05$) of soil EC. The lowest values were observed in T4, in which the initial soil EC (3.48 dS/cm) has a reduction of 62% at the end of the experiment with a value of 1.33 dS/cm. Similar results were found by Mahmoud and Ibrahim (2012) who observed a 46% reduction in the soil EC with addition of 10% vermicompost. Nonetheless, Ayyobi *et al.* (2014) studies show that when the application of vermicompost is not continuous in time, the soil EC could increase since most of the amendments have high salinity values.

Table 3. Variation of soil EC (dS/m) during the incubation experiment.

Treatments	Dates of Measurement			
	7 days	14 days	21 days	28 days
T1 (control)	3.42 (0.03) ^{Aa}	3.42 (0.08) ^{Aa}	3.47 (0.08) ^{Aa}	3.40 (0.05) ^{Aa}
T2 (1% V)	3.47 (0.03) ^{Aa}	2.57 (0.15) ^{Bb}	2.50 (0.05) ^{Bb}	2.38 (0.03) ^{Bc}
T3 (5% V)	2.68 (0.13) ^{Ba}	2.00 (0.18) ^{Cb}	1.63 (0.08) ^{Cc}	1.58 (0.08) ^{Cc}
T4 (10% V)	2.53 (0.08) ^{Ba}	1.75 (0.05) ^{Db}	1.53 (0.08) ^{Cc}	1.33 (0.13) ^{Dd}

Upper case letters indicate differences between treatments by date of measurement; lower case letters indicate differences for the same treatment during the incubation. Letters differ with a probability ≤ 0.05% according to Tukey´s test; in parenthesis, the standard deviation.

Exchangeable sodium (Na^{+})

Vermicompost application reduced the exchangeable Na^{+} contents in the soil ($P < 0.05$) (Table 4). These differences were observed from the 14 days of incubation in the T4 and after 21 days in T2 and T3.

After 28 days of incubation the lowest values for Na^{+} were found in soils treated with 5 and 10% of vermicompost, the values were 2.02 and 1.77 $Cmol_{+}$/kg, respectively. The percentage of reduction was 40% for T3 and 47% for T4.

Sodicity reduction in the soil due to vermicompost application can be due to the supply of Ca^{2+} and Mg^{2+}, cations that favor the substitution of exchangeable Na^{+} in the soil solution, that additionally improves formation of stable aggregates (Mahmoud and Ibrahim,

Table 4. Variation of soil Exchangeable Sodium ($Cmol_{+}$/Kg) during the incubation experiment.

Treatments	Dates of Measurement			
	7 days	14 days	21 days	28 days
T1 (control)	3.42 (0.03) ^{Aa}	3.42 (0.08) ^{Aa}	3.47 (0.08) ^{Aa}	3.40 (0.05) ^{Aa}
T2 (1% V)	3.47 (0.03) ^{Aa}	2.57 (0.15) ^{Bb}	2.50 (0.05) ^{Bb}	2.38 (0.03) ^{Bc}
T3 (5% V)	2.68 (0.13) ^{Ba}	2.00 (0.18) ^{Cb}	1.63 (0.08) ^{Cc}	1.58 (0.08) ^{Cc}
T4 (10% V)	2.53 (0.08) ^{Ba}	1.75 (0.05) ^{Db}	1.53 (0.08) ^{Cc}	1.33 (0.13) ^{Dd}

Upper case letters indicate differences between treatments by date of measurement; lower case letters indicate differences for the same treatment during the incubation. Letters differ with a probability ≤ 0.05% according to Tukey´s test; in parenthesis, the standard deviation.

2012). On the other hand, it is known that the application of organic matter in soils affected by salt promotes flocculation of clay minerals, an essential condition for the aggregation of particles and increased pore space which, in turn, promotes the Na^+ washing and soil EC reduction (Lakhdar *et al.*, 2010).

Exchangeable Sodium Percentage

The ESP is the measurement of the saturation degree of the exchange soil complex with sodium. In this study, after 14 days of incubation with vermicompost in the soil, a reduction of this parameter was found ($P < 0.05$) for all the treatments (Table 5).

The lowest values for ESP (33.27%) were found in T4 at 28 days of incubation. The reduction percentage compared to the initial content was 50% for this treatment.

Although the ESP values were higher than 15%, which is considered as critical value for a sodic soil (Biswas and Biswas, 2014), it is evident the benefits from the use of vermicompost as buffer of the exchangeable Na^+ levels on a relatively short time of incubation of 28 days.

Table 5. Variation in the soil Exchangeable Sodium Percentage (ESP) during the incubation experiment.

Treatments	Dates of Measurement			
	7 days	14 days	21 days	28 days
T1 (control)	65.69 (0.85)^{Aa}	66.65 (0.59)^{Aa}	65.80 (0.97)^{Aa}	66.53 (0.62)^{Aa}
T2 (1% V)	63.20 (0.27)^{Ba}	59.88 (0.52)^{Bb}	55.85 (1.56)^{Bc}	54.28 (0.61)^{Bc}
T3 (5% V)	48.23 (2.13)^{Ca}	44.93 (0.65)^{Cb}	42.67 (1.14)^{Cc}	41.18 (0.55)^{Cc}
T4 (10% V)	43.02 (0.67)^{Da}	35.67 (0.56)^{Db}	34.17 (0.09)^{Dc}	33.27 (0.77)^{Dc}

Upper case letters indicate differences between treatments by date of measurement; lower case letters indicate differences for the same treatment during the incubation. Letters differ with a probability ≤ 0.05% according to Tukey´s test; in parenthesis, the standard deviation.

Conclusions

With the application of 10% of vermicompost in an incubation period of 28 days, it was possible to partially buffer the sodicity of a saline-sodic soil from Cebollal de Oro, Falcon State, Venezuela, as result of reduction on electric conductivity.

Adding 10% of vermicompost significantly reduced the soil pH after 28 days of incubation.

With application of vermicompost in 5 and 10% doses, the soil exchangeable sodium was reduced in values equivalent to 40 and 47%, respectively.

References

Abadía, A., Millán, E., and Abadía, J. (1981). Determinación de calcio y magnesio en extractos de saturación de suelos. An. Aula Dei., 15(3-4),273-280.

Acosta, Y., Paolini, J., and Benítez, E. (2004). Índice de humificación y prueba de fitotoxicidad en residuos orgánicos de uso agrícola potencial. Rev. Fac. Agron., (UCV). 21(4),1-6.

Acosta, Y., Paolini, J., Flores, S., El Zauahre, M., Reyes, N., and García, H. (2008). Fraccionamiento de metales y materia orgánica en un suelo de la Península de Paraguaná, estado Falcón, Venezuela. Multiciencias, 8 (extraordinario), 39-47.

Albiach, R., Canet, R., Pomares, F., and Ingelmo, F. (2000). Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. Biores. Technol, 75(1),43-48.

Arumugam, K., Muthunarayanan, V., Ganasen, S., Sugumar, S., and Vivek, S. (2013). Dynamics of biological, physical and chemical parameters during vermicomposting of market waste mixed with cow dung. Int. J. Pl. An. and Env. Sci, 3(4), 187-192.

Ayyobi, H., Hassanpour, E., Alaqemand, S., Fathi, J.A., and Peyvast, G. (2014). Vermicompost Leachate and Vermiwash Enhance French Dwarf Bean Yield. Intl. J. Veg. Sci., 20(1), 21–27.

Azarmi, R., Giglou, M., and Taleshmikail, D. (2008). Influence of vermicompost on soil chemical and physical properties in tomato (Lycopersicum esculentum) field. Afri. J. Biotechnol., 7(14), 2397-2401.

Bates, R.G. (1973). Determination of pH: Theory and Practice. (pp. 479) New York, USA: John Wiley.

Biswas, A., and Biswas, A. (2002). Comprehensive approaches in rehabilitating salt affected soils: a review on Indian perspective. Open Transactions on Geosciences, 1(1), 13-24.

Casanova, E. (2005). Introducción a las Ciencias del Suelo. (pp. 487) Caracas: CDCH UCV.

Castillo, H., Hernández, A., Dominguez, D., and Ojeda, D. (2010). Effect of Californian red worm (Eisenia foetida) on the nutrient dynamics of a mixture of semicomposted materials. Chil. J. Agr. Res., 70(3),465-473.

Chaoui H., Zibilske, L., and Ohno, T. (2003). Effects of earthworm cast and compost on soil microbial activity and plant nutrient availability. Soil Biol. Biochem., 35(2),295-302.

Defrieri, R., Jiménez, M., Effron, D., and Palma, M. (2005). Utilización de parámetros químicos y microbiológicos como criterios de madurez durante el proceso de composteo. AgriScientia, 22(1):25-31.

Dellavalle, N.B. (1992). Determination of specific conductance in supernatant 1:2 soil:water solution. (pp. 40-43). Athens, USA: Handbook on Reference Methods for Soil Analysis.

De La Cruz, E., Osorio, R., Martínez, E., Lozano, A., Gómez, A., and Sánchez, R. (2010). Uso de compostas y vermicompostas para la producción de tomate orgánico en invernadero. Interciencia., 35(5),363-368.

Durán, L., and Henríquez, C. (2010). El Vermicompost: su efecto en algunas propiedades del suelo y la respuesta en planta. Agron. Mesoam., 21(1),85-93.

Durán L., and Henríquez, C. (2009). Crecimiento y reproducción de la lombríz roja (Eisenia foetida) en cinco sustratos orgánicos. Agron. Costarric., 33(2),275-281.

Durán, L., and Henríquez, C. (2007). Caracterización química, física y microbiológica de vermicompostes producidos a partir de cinco sustratos orgánicos. Agron. Costarric., 31(1),41-51.

Ewel, J., Madriz, A., and Tosi, J. (1976). Zonas de Vida de Venezuela. (pp. 265) Caracas: Fondo Nacional de Investigaciones Agropecuarias.

Fuentes, J. (1999). El Suelo y los Fertilizantes. (pp. 352)Madrid: Mundi-Presa.

Hidalgo, P., Sindoni, M., and Marín, C. (2009). Evaluación de sustratos a base de Vermicompost y enmiendas orgánicas líquidas en la propagación de parchita (Passiflora edulis v. flavicarpa) en vivero. Revista UDO Agrícola., 9(1),126-135.

INFOSTAT. (2002). InfoStat, versión 1.1. Manual del Usuario. Argentina: Grupo InfoStat, Universidad Nacional de Córdoba.

Lamz, A., and González, M. (2013). La salinidad como problema en la agricultura: la mejora vegetal una solución inmediata. Cultivos Tropicales., 34(4),31-42.

Lakhdar, A., Scelza, R., Scotti, R., Rao, M., Jedidi, N., Gianfreda, L., and Abdelly, C. (2010). The effect of compost and sewage sludge on soil biological activities in salt affected soil. R. C. Suelo Nutr. Veg., 10(1),40-47.

Le Bissonnais, Y. (2006). Aggregate breakdown mechanisms and erodibility. In Lal R (Ed.). Encyclopedia of Soil Science. (pp. 40-44.) USA:Taylor and Francis.

Mahmoud, E., and Ibrahim, M. (2012). Effect of vermicompost and its mixtures with water treatment residual on soil chemical properties and barley growth. J. Soil Sci. Plant Nutr.,12(3),431-440.

Mogollón, J.P., Martínez, A., and Rivas, W. (2014). Degradación química de suelos agrícolas en la Península de Paraguaná, Venezuela. Suelos Ecuatoriales. 44(1):22-28.

Ravera A., and De Sanzo, C. (2000). Como criar lombrices rojas californianas, Programa de Autosuficiencia Regional. Buenos Aires, Argentina. Available at: http://www.bajatec.net/pdfs/manual_lombricultura.pdf

Rodríguez, N., Florentino, A., Torres, D., Yendis, H., and Zamora, F. (2009). Selección de Indicadores de Calidad de Suelo en Tres Tipos de Uso de la Tierra en la Planicie de Coro estado Falcón. Rev. Fac. Agron. (LUZ) 26(3),340-361.

Rodríguez, N. (2002). Identificación y caracterización de indicadores de sostenibilidad de los tipos de uso de la tierra en las series El Patillal y San Isidro de la Llanura de Coro, estado Falcón. Tesis de Maestría en Ciencias del Suelo. (pp. 165). Maracay, Venezuela: Universidad Central de Venezuela

Romaniuk, R., Giuffré, L., and Romero, R. (2011). A soil quality index to evaluate the vermicompost amendments effects on soil properties. J. Environ. Protect., 2(5),502-510.

Thomas, G. (1982). Exchangeable cations. In: Black, C.A. et al. (ed). Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. Wisconssin: ASA-SSSA. p. 159-165.

Torres, D., Nectalí, R., Yendis, H., Florentino, A., and Zamora, F. (2006). Cambios en algunas propiedades químicas del suelo según el uso de la tierra en el sector El Cebollal, estado Falcón. Bioagro.,18(2), 123-128.

Yurtseven, E., Öztürk, H., and Avci. S. (2014). Mass balance criteria in soil salinity management: different irrigation water qualities and leaching ratios. J. Agr. Sci, 20(2).103-111.

Zhang Q., and Zak J. (1998). Effects of water and nitrogen amendment on soil microbial biomass and fine root production in a semi-arid environment in West Texas. Soil Biol. Biochem., 30(1), 39-45.