Nutritional characteristics of maize cultivated with vermicompost
Características nutricionales de maíz cultivado con vermicomposta

María Ángela Oliva-Llaven[1,†], Gabriela Palacios-Pola[2,†], Miguel Abud-Archila[3], José Alexander Hernández-Solis[4], Víctor Manuel Ruíz-Valdiviezo[3], and Federico Antonio Gutiérrez-Miceli[3‡]

[1] Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Chiapas. Carretera Emiliano Zapata km 8, Del Frigorífico. 29060 Tuxtla Gutiérrez, Chiapas, México.
[2] Facultad de Ciencias de la Nutrición y Alimentos, Universidad de Ciencias y Artes de Chiapas. Libramiento Norte Poniente 1150. Col. Lajas Maciel. 29016 Tuxtla Gutiérrez Chiapas, México.
[3] Tecnológico Nacional de México, Instituto Tecnológico de Tuxtla-Gutiérrez. Carretera Panamericana km 1080, Col. Terán. 29020 Tuxtla Gutiérrez, Chiapas, México.
[‡] Corresponding author (fgmiceli@gmail.com)
[4] Facultad de Agronomía, Universidad Autónoma de Chiapas. Carretera Ocozocoautla-Villaflores km 84.5. Apartado Postal no. 78. 30470 Villaflores, Chiapas, México.
[†] Both authors contributed equally in this work.

SUMMARY

This work was conducted with the objective to evaluate the effect of vermicompost application on chemical characteristics, energetic parameters and amino acids profile of hybrid race corn grain cultivated under open-field and rained conditions. The experiment was accomplished under a randomized complete design with three repetitions. Three treatments were evaluated: 1) Maize after inoculation with a commercial mycorrhizal arbuscular fungi mixture (Tec Myc 60®) plus vermicompost (V+M); vermicompost (V) and chemical fertilization (CF). Starch content in grain was 1.9% higher in V+M treatment in comparison with chemical, whereas crude protein, ether extract, crude fiber, acid detergent fiber, neutral detergent fiber, total phosphorous and phytic phosphorous were not different between treatments. Energetic parameters were not different between three treatments. 17 amino acids were evaluated of wich only tryptophan, leucine, valine, histidine and aspartic acid were higher in CF and V treatments in comparison with V+M treatment. In conclusion, it is possible to cultivate maize using vermicompost as fertilizer because chemical characteristics, energetic parameters and amino acids profile in maize grain were not affected compared with the maize cultivated with vermicompost added with biofertilizers (V+M) or with corn cultivated with chemical fertilizers (CF).

Index words: *amino acid profile, chemical proximal analysis, cow manure vermicompost, energetic parameters.*

RESUMEN

Este trabajo tuvo como objetivo evaluar el efecto de la aplicación de vermicomposta sobre las características químicas, parámetros energéticos y perfil de aminoácidos de híbridos de maíz bajo condiciones de campo y con lluvia de temporal. El diseño experimental fue completamente al azar con tres repeticiones. Se evaluaron tres tratamientos: 1) maíz después de inoculación con una mezcla de hongos micorrízicos arbusculares (Tec Myc 60®) más vermicomposta (V + M); vermicomposta (V) y fertilización química (CF). El contenido de almidón en los granos fue 1.9% más elevado en el tratamiento V+M en comparación con el tratamiento con fertilización química, mientras que la proteína cruda, extracto etéreo, fibra cruda, fibra detergente ácida, fibra detergente neutra, fósforo total y fósforo fítico no fueron diferentes entre los tratamientos. Los parámetros energéticos no fueron diferentes entre

Recommended citation:
Oliva-Llaven, M. Á., G. Palacios-Pola, M. Abud-Archila, J. A. Hernández-Solis, V. M. Ruíz-Valdiviezo, and F. A. Gutiérrez-Miceli. 2019. Nutritional characteristics of maize cultivated with vermicompost. Terra Latinoamericana 37: 407-413.
DOI: https://doi.org/10.28940/terra.v37i4.534

Received: April 12, 2019.
Accepted: June 21, 2019.
Published in Terra Latinoamericana 37: 407-413.

los tres tratamientos. De los 17 aminoácidos, solo triptófano, leucina, valina, histidina y ácido aspártico fueron más elevados en los tratamientos CF y V en comparación con V+M. En conclusión, es posible cultivar maíz usando vermicomposta como fertilizante porque las características químicas, parámetros energéticos y perfil de aminoácidos en los granos de maíz no son diferentes a los obtenidos en maíz cultivado con vermicomposta y biofertilizantes (V+M) o con maíz cultivado con fertilización química (CF).

Palabras clave: *perfil de aminoácidos, análisis químico proximal, vermicomposta, parámetros energéticos.*

INTRODUCTION

Cultivation of maize has increased in the world and its value as a cost-effective ruminant and chicken feed is one of the main reason farmers grow it. Maize originates from Mexico and is still the main staple crop in large parts of the country. Sustainable agriculture became a major issue of global concern, so more and more farmers in Mexico are now cultivating their land without using chemical products, pesticides and herbicides. Vermicomposting is the non-thermophilic biodegradation of organic material through the interaction between earthworms and microorganisms (Arancon *et al*., 2004; Bhat *et al*., 2018). Application of organic fertilizers to agricultural soils is an important practice for increasing crop yield (Saldaña-Hernández *et al.,* 2014), whereas composts can improve soil physical and chemical properties (Sarwar *et al*., 2008) and biological soil attributes. The addition of vermicompost to the soil have a positive effect on physical properties (field capacity, real density and porous spaces); in terms of chemical properties, there were positive results in the availability of phosphorus, potassium, iron and manganese, as well as in the pH (Ramos-Oseguera *et al*., 2019). However, the effect of vermicompost on yield of crops is not clear, Ramos-Oseguera *et al.* (2019) reported that the use continuous of vermicompost in soils cultivated with *Arachis hypogeae* L. could to stabilize their physical properties, chemical and their productive capacity. Arbuscular mycorrhiza (AM) have a significant positive effect on maize development (Deng *et al*., 2017). Maize plants with AM had a significantly higher uptake of N, P, Mg and Zn and also greater shoot weight. However, few studies have been carried out to determine the effect of vermicompost and AM on maize composition in field. i. e. Zhu *et al*. (2016) reported that arbuscular mycorrhiza maize plants had higher amino acid concentrations than the non-AM plants, but not analysis were carried out on maize grains. For that, the aim of this study was to determine the effect of a commercial mycorrhizal arbuscular fungi mixture (Tec Myc 60®) and cow manure vermicompost on proximate chemical composition, energetic parameters and amino acid profile in maize (*Zea mays* L.) grains.

MATERIALS AND METHODS

Experiment Location

The experiment was conducted during 2017 in "Caprico divino" farm, in Suchiapa, Chiapas, México, located at 6° 37' 30" N and 93° 6' 0" W and at an altitude of 500 m. The climate is warm sub-humid with periodic rains with average annual precipitation of 956 mm.

Maize Cultivar and Microorganisms

Maize (*Zea mays)* cv "Tuxpeño" hybrid seeds were obtained from PROASE (Productores Asociados de Semillas, Chiapas, México). For vermicompost plus mycorrhizal arbuscular fungi (V+M) treatment, seeds were submerged in commercial mycorrhizal arbuscular fungi mixture (Tec Myc 60®) for one hour and further sun-dried. For vermicompost and chemical treatments, seeds were submerged in water also for one hour and sun-dried before soaking. Plant to plant and row to row distances were maintained at 20 and 40 cm respectively. At maturity, plants were harvested manually and grains were used for the study of proximate chemical composition and amino acid profile analysis.

Cow Manure Vermicompost and Soil Characterization

Soil was collected in the experimental field. Five random subsamples of the entire field were taken, then the subsamples were mixed to obtain a composite sample that was used to perform the analyses. Soil and vermicompost were characterized in terms of pH, organic C, organic matter, total N, and available phosphorus as reported by Contreras-Ramos *et al.* (2004).

Both soil and vermicompost total N contents were used to calculate the amount of chemical and vermicompost fertilization. In the chemical treatment, fertilization was done with a mixture of N-P-K 150 kg ha^{-1} of 46-00-00, 200 kg ha^{-1} of 18-46-00 and 100 kg ha^{-1} of 00-00-60 after 15 days of plant emergence. In the vermicompost treatment, the fertilization was done after 15 days of plant emergence using 1600 kg ha^{-1} of vermicompost.

Maize Grain Chemical Analysis

The crude fiber content (%) was determined by following Soxhlet extraction method (AOAC, 1995) in which two grams of maize grain ground powder was extracted with petroleum ether. The maize grain ground powder was transferred to 1 L beaker and then 200 mL boiling 1.20% sulfuric acid, 1 g of freshly prepared asbestos, bumping chips and one drop of diluted antifoam were added. After that beaker was placed on the digestion apparatus with pre-adjusted hot plate and boiled for 30 min. Finally, beaker was removed and the contents were filtered and dried 2 h at 135 °C, cooled and weighed, ignited for 30 min at 600 °C in the oven, cooled and reweighed. Finally, crude fiber (CF) in maize (%) was calculated using the following equation.

CF = (Loss in weight on ignition – loss in weight of asbestos blank) × 100 (1)

For ash content two grams of the dried sample was weighed into a dry porcelain dish and then heated in a muffle furnace at 600 °C for 6 h. It was cooled in desiccators and weighed. The percentage ash content was calculated by using the following equation.

Ash (%) = (weight after ignition – weight of asbestos blank) × 100 (2)

The crude protein contents in maize grain was determined by Kjeldahl method and it was calculated using the following equation.

Crude Protein (%) = nitrogen content × 6.25 (*factor for cereals) (3)

Energetic Parameters and Amino Acid Quantification

Gross energy (GE), available energy for growth pigs (EDCE), digestible energy in female pigs (EDC), metabolizable energy for growth pigs (EMCC), gross energy for growth pigs (ENCC), net energy in female pigs (ENC) and apparent metabolizable energy (EMA) were determined with near-infrared reflectance spectroscopy (NIRS). NIRS was also used to quantify essential amino acids (De Oliveira-Pereira *et al*., 2018).

Experimental Design and Statistical Analysis

The experiment was accomplished under a randomized complete design. Three treatments were evaluated: 1) Maize seeds inoculated with a commercial mycorrhizal arbuscular fungi mixture (Tec Myc 60®) plus vermicompost (V+M). In this treatment, two kg of maize seeds were soaked in 1 L of Tec Myc 60® for one hour and then they were dried in the sun before planting them. Vermicompost and chemical fertilization were additionated to soil after 15 d of plant emergence 2) vermicompost (V) and 3) chemical fertilization (CF). All treatments were carried out by triplicate. 250 plant were used for each treatment and 15 corn cob were sampled for chemical analysis, energetic parameters and amino acid quantification. All determinations were realized by duplicate.

Significant differences were determined by analysis of variance (ANOVA). Mean comparisons were made using the least significant difference (Fisher test) with a significance of 5%. The general linear model procedure was used (PROC GLM SAS Institute, 1989).

RESULTS AND DISCUSSION

Cow Manure Vermicompost and Soil Characteristics

Soil had an organic carbon (13.2 g kg^{-1}), organic matter (22.8 g kg^{-1}), total nitrogen (1.86 g kg^{-1}) and available phosphorus (61.7 g kg^{-1}). Ruíz-Valdiviezo *et al*. (2010) and Ruíz-Valdiviezo *et al*. (2013), found similar values in different soil types of the state of Chiapas. Also, these values indicate that these soils may be suitable for the establishment of different types of crops such as maize. A very important factor that determines the quality and fertility of the soil has been the C/N ratio. This ratio has been reported high for soils that have not been cultivated or plowed (Fan and Guo, 2010). The C/N ratio had a value of 7.1, which indicates that the soil in this study has a low level of organic matter. Values between 10 and 14 correspond to a mineralization and rapid rupture of tissues, since the microbial activity is stimulated, there are enough nutrients for the microorganisms and for the vegetables (Gamarra *et al*., 2018). The content and the decomposition of soil organic matter has been rapid due to the high content of N (Ostrowska and Porebska, 2015), and possibly the nitrogen is mineralized due that with low C/N values the native microorganisms have been more efficient in the decomposition of organic matter. Phosphorus content in the studied soil was higher (6.17 g kg^{-1}) compared to the P content (4 g kg^{-1}) in another Chiapas soil studied by Abud-Archila *et al*. (2018). Likewise, the P soil content is an important factor for the best plant yield, since it has been reported directly influences the growth of the plant and the colonization of AM fungi (Deng *et al*., 2017). On the other hand, cow manure vermicompost had an organic C content of 163 g kg^{-1}, a total N content of 11.4 g kg^{-1}, available phosphorus was 0.35 g kg^{-1}, an electrical conductivity (EC) of 5.37 mS cm^{-1}, a CEC of 37 $cmol_c$ kg^{-1} while the pH was 8.818. In relation to these results obtained for the physical-chemical characterization of vermicompost of cow manure, it was found that the pH and EC of the vermicompost was 8.18 and 5.37 mS cm^{-1}, respectively, corresponding to an organic material or substrate that has been used as organic fertilizer, as reported by Méndez-Moreno *et al*. (2012) and Doan *et al*. (2013) when they applied vermicompost with these characteristics to maize crops. The C/N ratio was 14.29 for vermicompost. It is known (Aalok *et al*., 2008) that vermicompost with C/N ratio >12 have a mature composting and have been suitable for use as organic fertilizer, favouring the increase of the organic matter of the soil (Zerzghi *et al*., 2010; Yu *et al*., 2019).

Proximate Chemical Composition of Maize Grains

Starch content in grain was 1.9% higher in V+M treatment in comparison with CF, whereas crude protein, ether extract, crude fiber, acid detergent fiber, neutral detergent fiber, total phosphorous and phytic phosphorous were not different between treatments (Table 1). In relation to crude protein content, our values were lower than De-Oliveira Pereira *et al.* (2018) who reported values of 9.86% and 9.28% for maize produced by conventional and organic culture. The crude fiber values varied between 2.04 and 2.14%, however values lower than 2.51% were reported by De-Oliveira Pereira (2018). The ether extract content varied between 3.62 and 4% for all treatments, and, no significantly differences can be observed among treatments (Table 1). In our case, no significant differences were obtained for crude protein content in maize produced by conventional and organic agriculture management. These results are important because it indicates that this "Tuxpeño" hybrid of maize can be cultivated with vermicompost

Table 1. Proximate chemical composition of maize (*Zea mays* L.) grains obtained from plants cultivated with vermicompost (V), vermicompost plus commercial mycorrhizal arbuscular fungi, Tec Myc 60® (V+M) and chemical fertilization (CF).

Treatment	Chemical composition									
	CP†	EE	CF	ADF	NDF	Ash	Starch	Sugars	TP	PP
	%								mg g^{-1}	
V+M	7.52±0.93a§	3.62±0.37a	2.10±0.12a	3.06±0.21a	10.5±0.38a	1.22±0.13a	65.4±1.2a	1.0±0.16a	2.06±0.19a	1.54±0.14a
V	7.99±0.89a	3.76±0.71a	2.04±0.11a	3.02±0.23a	10.8±0.82a	1.24±0.11a	64.4±1.4ab	0.92±0.11a	2.07±0.21a	1.55±0.16a
Chemical	8.56±0.62a	4.0±0.41a	2.14±0.09a	3.14±0.27a	11.2±0.91a	1.30±0.10a	63.5±1.2b	0.9±0.31a	2.14±0.17a	1.60±0.12a
LSD‡ (0.05)	1.14	0.71	0.15	0.33	1.02	0.17	1.78	0.29	0.26	0.195

† CP = crude protein; EE = ether extract; CF = crude fiber; ADF = acid detergent fiber; NDF = neutral detergent fiber; TP = total phosphorous; PP = phytic phosphorous. ‡ Least Significative Difference (0.05); § Values in columns with the same letter are not significantly different among treatments.

in substitution of the chemical fertilizers without the grains of maize being of lower nutritional quality. The results could be explained because the amount of vermicompost applied per plant was calculated by matching the nitrogen content that was applied to it with chemical fertilizer (De-Oliveira Pereira *et al.*, 2018).

Energetic Parameters and Amino Acid Profile

Gross energy (GE), available energy for growth pigs (EDCE), digestible energy in female pigs (EDC), metabolizable energy for growth pigs (EMCC), gross energy for growth pigs (ENCC), net energy in female pigs (ENC) and apparent metabolizable energy (EMA) were not different between treatments (Table 2). Therefore, maize can be cultivated with vermicompost in substitution of the chemical fertilizers without that the grains of maize are of lower energetic parameters quality. From the point of view of soil ecology, it is better to fertilize the soil with vermicompost than with chemical fertilizers. In addition, the results show that maize can be produced to feed pigs at various stages of growth, for the commercialization of organic meat.

Results shown that only tryptophan, aspartic acid, valine and histidine amino acids content were higher for chemical fertilization treatment that for vermicompost and V+M treatments (Table 3). However, amino acid content of corn in treatment V+M were not different with respect to plants fertilized with vermicompost (V) for the rest of amino acids of Table 3. However, it was observed than no significant differences ($P \geq 0.05$) can be observed between chemical, V and V+M fertilization treatments. These results are different to reported by De Oliveira-Pereira *et al*. (2018) who reported that the organic management showed lower levels ($P < 0.05$) of methionine, threonine, arginine, isoleucine, leucine, valine, histidine and phenylalanine, compared with conventional culture of a hybrid maize. Our results are according with Tejada and Benítez (2011) who found no significant differences between the organic amendment based on vermicompost and compost in maize. These results can be explained also, because the amount of vermicompost applied per plant was calculated by matching the nitrogen content that was applied to it with chemical fertilizer. The higher content of tryptophan, aspartic acid, valine and histidine obtained with chemical fertilization could be explained by the availability of phosphorus that is more immediate when using chemical fertilizer than using compost.

CONCLUSION

Vermicompost and mycorrhizal arbuscular fungi treatment increased the starch content compared to chemical fertilization but, tryptophan, leucine, valine, histidine and aspartic acid contents were smaller than in CF and V treatments. Then, it is possible to cultivate maize using only vermicompost as soil amended because the quality of the grain was not affected compared with the maize cultivated with vermicompost added with biofertilizers or with maize cultivated with chemical fertilizers.

Table 2. Energetic parameters analysis of maize (*Zea mays* L.) seeds obtained from plants cultivated with vermicompost (V), vermicompost plus commercial mycorrhizal arbuscular fungi, Tec Myc 60® (V+M) and chemical fertilization (CF).

Treatment	GE†	EDCE	EDC	EMCC	ENCC	ENC	EMA
	- kcal kg^{-1} DM basis -						
V+M	3909±28 a§	3463±26 a	3601±27 a	3380±25 a	2703±17 a	2803±17 a	3320±10 a
V	3921±40 a	3463±26 a	3602±27 a	3380±26 a	2697±15 a	2797±15 a	3326±26 a
CF	3934±22 a	3457±24 a	3596±25 a	3374±23 a	2687±17 a	2787±18 a	3329±17 a
LSD‡ (0.05)	45	36	38	35	23	23	27

† GE = gross energy; EDCE = available energy for growth pigs; EDC = digestible energy in female pigs; EMCC = metabolizable energy for growth pigs; ENCC = gross energy for growth pigs; ENC = net energy in female pigs; EMA = apparent metabolizable energy. ‡ Least significative difference (0.05). § Values in columns with the same letter are not significantly different among treatments.

Table 3. Amino acids content in maize (*Zea mays* L.) seeds obtained from plants cultivated with vermicompost (V), vermicompost plus commercial mycorrhizal arbuscular fungi, Tec Myc 60® (V+M) and chemical fertilization (CF).

Treatment	Methionine	Cysteine	Lysine	Threonine	Tryptophan	Arginine
			%			
V+M	0.129±0.009 a	0.152±0.011 a	0.212±0.024 a	0.266±0.031 a	0.057±0.006 b	0.353±0.049 a
V	0.144±0.019 a	0.156±0.009 a	0.219±0.013 a	0.285±0.029 a	0.061±0.004 ab	0.363±0.034 a
CF	0.143±0.012 a	0.152±0.006 a	0.269±0.089 a	0.303±0.023 a	0.064±0.004 a	0.378±0.029 a
LSD‡ (0.05)	0.019	0.013	0.075	0.039	0.006	0.053
	Isoleucine	Leucine	Valine	Histidine	Methionine	Glycine
V+M	0.262±0.032 a	0.903±0.128 a	0.361±0.038 b	0.214±0.021 b	0.372±0.057 a	0.286±0.027 a
V	0.283±0.036 a	0.984±0.155 a	0.387±0.041 ab	0.229±0.024 ab	0.401±0.056 a	0.299±0.020 a
CF	0.304±0.025 a	1.067±0.103 a	0.412±0.029 a	0.243±0.015 a	0.438±0.041 a	0.314±0.017 a
LSD‡ (0.05)	0.043	0.18	0.05	0.028	0.071	0.03
	Serine	Proline	Alanine	Aspartic acid	Glutamic acid	
V+M	0.372±0.049 a	0.668±0.073 a	0.566±0.074 a	0.490±0.065 b	1.359±0.199 a	
V	0.396±0.048 a	0.715±0.087 a	0.611±0.082 a	0.522±0.053 ab	1.471±0.207 a	
CF	0.422±0.033 a	0.735±0.058 a	0.66±0.054 a	0.565±0.042 a	1.579±0.136 a	
LSD‡ (0.05)	0.061	0.102	0.098	0.075	0.252	

‡ Least significative difference (0.05). Values in columns with the same letter are not significantly different among treatments.

ACKNOWLEDGEMENT

This research was funded by Tecnológico Nacional de México, Project 6843.18-P.

REFERENCES

Aalok, A., A. Tripathi, and P. Soni. 2008. Vermicomposting: A better option for organic solid waste management. J. Human Ecol. 24: 59-64. doi: 10.1080/09709274.2008.11906100.

Abud-Archila, M., A. K. Espinosa-Arrioja, T. González-Soto, V. F. Gutiérrez-Oliva, V. M. Ruíz-Valdiviezo, D. González-Mendoza, L. Rodríguez-Hernández, and F. A. Gutiérrez-Miceli. 2018. Growth and biochemical responses of moringa (*Moringa oleifera* L.) to vermicompost and phosphate rock under water stress conditions. Phyton 87: 209-215.

Arancon, N. Q., C. A. Edwards, R. Atiyeh, and J. D. Metzger. 2004. Effects of vermicomposts produced from food waste on the growth and yields of greenhouse peppers. Bioresour. Technol. 93: 139-144. doi: 10.1016/j.biortech.2003.10.015.

AOAC (Association of Official Analytical Chemists International). 1995. Official methods of analysis of the AOAC international, 16th ed. Method 970.12. Association of Official Analytical Chemists International. Washington, DC, USA.

Bhat, S., J. Singh, and A. Vig. 2018. Earthworms as organic waste managers and biofertilizer producers. Waste Biomass Valorizat. 9: 1073-1086. doi: 10.1007/s12649-017-9899-8.

Contreras-Ramos, S. M., E. M. Escamilla-Silva, and L. Dendooven. 2004. Vermicomposting of biosolids with cow manure and oat straw. Biol. Fertil. Soils 41: 190-198. doi: 10.1007/s00374-004-0821-8.

De Oliveira-Pereira, D. C., R. Henriques-Longaresi, G. do Valle Pereira, D. Pelizari, S. K. Homma, and L. C. Demattê Filho. 2018. Organic maize: Changes in amino acid composition. Braz. J. Sustain. Agr. 8: 74-78. doi: https://doi.org/10.21206/rbas.v8i1.479.

Deng, Y., G. Feng, X. Chen, and C. Zou. 2017. Arbuscular mycorrhizal fungal colonization is considerable at optimal Olsen-P levels for maximized yields in an intensive wheat-maize cropping system. Field Crops Res. 209: 1-9. doi: https://doi.org/10.1016/j.fcr.2017.04.004.

Doan, T. T., P. T. Ngo, C. Rumpel, B. V. Nguyen, and P. Jouquet. 2013. Interactions between compost, vermicompost and earthworms influence plant growth and yield: A one-year greenhouse experiment. Sci. Hortic. 160: 148-154. doi: https://doi.org/10.1016/j.scienta.2013.05.042.

Fan, P. and D. Guo. 2010. Slow decomposition of lower order roots: a key mechanism of root carbon and nutrient retention in the soil. Oecologia 163: 509-515. doi: https://doi.org/10.1007/s00442-009-1541-4.

Gamarra, C., M. I. Díaz Lezcano, M. Vera de Ortíz, M. P. Galeano y A. J. N. Cabrera-Cardús. 2018. Relación carbono-nitrógeno en suelos de sistemas silvopastoriles del Chaco paraguayo. Rev. Mex. Cienc. For. 9: 1-25. doi: https://doi.org/https://doi.org/10.29298/rmcf.v9i46.134.

Méndez-Moreno, O., N. S. Leon-Martínez, F. A. Gutierrez-Miceli, R. Rincon-Rosales, and J. D. Álvarez-Solis. 2012. Effect of earthworm humus application in the maize growth and grain yield. Gayana Bot. 69: 49-54.

Ostrowska, A. and G. Porebska. 2015. Assessment of the C/N ratio as an indicator of the decomposability of organic matter in forest soils. Ecol. Indicat. 49: 104-109. doi: https://doi.org/10.1016/j.ecolind.2014.09.044.

Ramos Oseguera, C. A., A. E. Castro Ramírez, N. S. León Martínez, J. D. Álvarez Solís y E. Huerta Lwanga. 2019. Lombricomposta para recuperar la fertilidad de suelo franco arenoso y el rendimiento de cacahuate (*Arachis hypogaea* L.). Terra Latinoamericana 37: 45-55. doi: 10.28940/terra.v37i1.331.

Ruíz-Valdiviezo, V. M., M. Luna-Guido, A. Galzy, F. A. Gutiérrez-Miceli, and L. Dendooven. 2010. Greenhouse gas emissions and C and N mineralization in soils of Chiapas (México) amended with leaves of *Jatropha curcas* L. Appl. Soil Ecol. 46: 17-25. doi: https://doi.org/10.1016/j.apsoil.2010.06.002.

Ruíz-Valdiviezo, V. M., L. D. Mendoza-Urbina, M. Luna-Guido, F. A. Gutiérrez-Miceli, M. R. Cárdenas-Aquino, J. A. Montes-Molina, and L. Dendooven. 2013. Emission of greenhouse gases and dynamics of mineral N in soils amended with castor bean (*Ricinus communis* L.) and piñón (*Jatropha curcas* L.) seed cake. Plant Soil Environ. 59: 51-56.

Saldaña Hernández, M. I., R. Gómez A., M. C. Rivera Cruz, J. D. Álvarez Solís, C. F. Ortiz y J. M. Pat Fernández. 2014. Efecto de abonos orgánicos en la dinámica microbiológica del suelo y producción de *Alpinia purpurata* (Vieill) K. Schum. Interciencia 39: 809-815.

Sarwar, G., H. Schmeisky, N. Hussain, S. Muhammad., M. Ibrahim, and M. Ehsan Safdar. 2008. Improvement of soil physical and chemical properties with compost application in rice-wheat cropping system. Pak. J. Bot. 40: 275-282.

Tejada, M. and C. Benítez. 2011. Organic amendment based on vermicompost and compost: differences on soil properties and maize yield. Waste Manage. Res. 29: 1185-1196. doi: 10.1177/0734242X10383622.

Yu, H., B. Xie, R. Khan, and G. Shen. 2019. The changes in carbon, nitrogen components and humic substances during organic-inorganic aerobic co-composting. Bioresour. Technol 271: 228-235. doi: https://doi.org/10.1016/j.biortech.2018.09.088.

Zerzghi, H., J. P. Brooks, C. P. Gerba, and I. L. Pepper. 2010. Influence of long-term land application of class B biosolids on soil bacterial diversity. J. Appl. Microbiol. 109: 698-706. doi: 10.1111/j.1365-2672.2010.04698.x.

Zhu, X., F. Song, and F. Liu. 2016. Altered amino acid profile of arbuscular mycorrhizal maize plants under low temperature stress. J. Plant Nutr. Soil Sci. 179: 186-189. doi: 10.1002/jpln.201400165.