Colegio de Postgraduados

# Bioconversion of poultry waste as growth enhancers and nutritional content in sugarcane

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**Citation**: Rosas-Martínez, V., Rodríguez-Lagunes, D. A., Llarena-Hernández, R. C., Pastelín-Solano, M. C., Bulbarela-Marini, J. E., Marín-Garza, T., Vivar-Vera, G., Castillo-Morán, A., & Castañeda-Castro, O. (2025). Bioconversion of poultry waste as growth enhancers and nutritional content in sugarcane. *Agro Productividad*. https://doi.org/10.32854/bzfarx91

**Academic Editor**: Jorge Cadena Iñiguez
**Associate Editor**: Dra. Lucero del Mar Ruiz Posadas
**Guest Editor**: Juan Francisco Aguirre Medina

**Received**: February 5, 2025.
**Accepted**: November 25, 2025.
**Published on-line**: December XX, 2025.

*Agro Productividad, 18*(11). November. 2025. pp: 41-52.



## ABSTRACT

**Objective**: Different doses of compost made from poultry residues and filter cake from sugarcane juice were evaluated, combined with mineral fertilizer, to determine the nutritional status and growth in sugar cane.

**Design/methodology/approach**: The agricultural yield of sugarcane and the concentration of minerals were studied through foliar analysis; the nitrogen content was determined through the micro-Kjeldahl method, while phosphorus, potassium, calcium, magnesium, iron, copper, zinc, manganese, and boron were quantified through inductively coupled plasma optical emission spectrophotometry and wet digestion spectrophotometry.

**Results**: The results show that the application of compost made from chicken manure presented the highest yield (120 t ha$^{-1}$), number of stems, and content of macronutrients, while nutrition with chemical fertilizers provided the highest content of micronutrients in sugarcane plants.

**Findings/conclusions**: This study has shown that the use of poultry waste compost favors the morphological development and nutritional content of the sugarcane crop.

**Keywords**: Compost, poultry sector, *Saccharum*.

## INTRODUCTION

The increase in anthropogenic activities has resulted in the generation of various residues of animal and plant origin that have an impact on the quality of the environment (Carnicer *et al*., 2018). The poultry sector has increased the amount of organic solid waste associated with the formation of lixiviates that carry toxic substances and contaminate water sources and soil, causing eutrophication and degradation, and releasing greenhouse gases (Fernández-Nieto and Betancourt-González, 2019; Asses *et al*., 2019).

Poultry production is the fastest growing sector in history (Molaey *et al*., 2018). According to data from the United States Department of Agriculture (USDA), production in 2023 was 103.5 millions of t of chicken meat worldwide (FIRA, 2024). Furthermore, in Mexico

the poultry industry continues to be the most dynamic livestock activity, with a production of 3,9 millions of t of chicken meat and a growth of 2.7% compared to 2022 (3,781,735.284) (SIAP, 2024).

Poultry waste is a source of essential nutrients, nitrogen (N), phosphorus (P), potassium (K), for agricultural production (Thomas *et al.*, 2020; Wan *et al.*, 2020); however, if these are applied directly to the soil without previous treatment, they can bring with them pathogenic microorganisms, antibiotics, and compounds that interact with the endocrine system (steroidal hormones, phytoestrogens, pesticides and herbicides) which can be transferred to the crop, livestock, and the food chain with health risks. The direct application of manure to the ground can reach the water table (Pinos-Rodríguez *et al.*, 2012).

Considering the composting is a degradation process that can transform the organic substrates of agricultural residues into stabilized organic matter, which can inactivate the pathogenic microorganisms present and in thus, the nutrients will be more available to be absorbed by the crops (Fuquene and Yate, 2017; Freitag *et al.*, 2018). Bayrakdar *et al.* (2017) and Wang *et al.* (2017) mention that poultry waste generates environmental damage since they are considered sources of infection and are vectors of diseases that can spread through the soil, water, or air, which also causes a risk to nearby areas, as well as high emission of toxic gases to the atmosphere.

On the other hand, the cultivation of sugarcane is one of the most important resources in the world since it constitutes the main raw material to produce sugar. Consequently, worldwide in 2024, around a production of 183 million t of sugar cane and an agricultural yield of 72.6 t $ha^{-1}$ (STATISTA, 2024). In Mexico, the sugar agribusiness is of great commercial importance and is the sixth largest sugar producer worldwide, having 50 active sugar mills distributed throughout the territory, which together represented a total of 5.3 4.7 million t of sugar and a cultivated area of 783 741 thousand hectares, of which 98% of the production is handled by small producers, obtaining a total yield of 63.4 t $ha^{-1}$ (CONADESUCA, 2024).

However, the low productivity of the sugarcane crop is also due to the immoderate use of fertilizers, the extraction of nutrients by the stems, the burning of harvest residues, and the compaction from the use of heavy machinery (Araujo *et al.*, 2016). According to Rahmad *et al.* (2019), chemical fertilization with N, P and K is no longer able to maintain the optimal production of the sugarcane crop, since their intensive use reduces soil fertility and its capacity to provide essential nutrients is not sufficient (Shulka *et al.*, 2016). Nevertheless, to produce sugar cane, residues from the sugar industry have been applied; the so-called cachaza or filter cake, which is obtained as a result of the clarification process of the cane juices, is applied as organic fertilization for sugarcane production contributing to improve the soil and the environment (Velasco-Velasco, 2014). From this by-product of sugarcane, 30 to 50 kg per t of processed sugarcane is obtained (Salgado *et al.*, 2003).

However, with the application of organic fertilizer, greater benefits can be obtained in the development of plants compared to chemical fertilization in some growth and nutrition parameters, which also depends on the quality of the organic fertilizer (Bernui *et al.*, 2016; Maradiaga-Rodriguez *et al.*, 2019). The nutrition of the sugarcane crop is important because it requires thirteen essential elements for its production; six macronutrients where N, P, and K are called primary, calcium (Ca), magnesium Mg), and sulfur (S) secondary, and seven others, including boron (Bo), zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), molybdenum (Mo), and chlorine (Cl), which correspond to microelements (Kingston, 2014). Therefore, it is of utmost importance to implement and develop sustainable nutritional programs, as well as to improve productivity and profitability for the producer, without neglecting the quality of the raw material and the improvement of soil conditions (SIAP, 2018). Thus, the objective of this work was to evaluate different doses of organic fertilizers obtained from poultry waste and filter cake on the development and yield of the sugarcane crop.

## MATERIAL AND METHODS

**Study area and location**. The study was carried out in the supply area of Ingenio Central El Potrero, S. A. de C. V. The unit is located 20 km. from the City of Cordoba, Veracruz, Mexico. The agricultural field is located at 520 masl, 18° 53' 37.2" north (N) and 96° 47' 07.6" west (W). Its climate is warm subhumid with rains in summer (40%), with a minimum temperature of 16.8 °C and a maximum of 43.0 °C, its average annual rainfall ranges from 1400 to 1600 mm (SMN 2023).

**Plant material**. The CP 72-2086 sugarcane variety was used.

**Composting material**. The materials used to make the compost were: chicken manure with rice husk used as bedding for the birds from the "La Primavera 1" farm, located in Cuitlahuac, Veracruz, Mexico; incubator residues which contained empty shells, unhatched eggs, and dead chicks from the incubation plant located in Cordoba, Veracruz, Mexico, which belongs to Grupo Pecuario San Antonio SA de C. V; and finally filter cake from the storage unit of the Ingenio Central El Potrero sugar mill in the state of Veracruz, Mexico.

**Composting**. Composting was carried out for nine months following the methodology described by Román *et al.* (2013), at the Colegio de Postgraduados, Campus Cordoba, located at 650 masl, 18° 50' north (N) and 96° 51' west (W). From the selected organic residues, three mixtures were prepared; (T1) chicken manure, (T2) chicken manure and filter cake 1:1 (W/V), and (T3) incubator residues with filter cake 3:1 (W/V). One t piles were made, measuring 1 m high, 1 m wide and 2 m long; they were kept covered with transparent plastic, airing was done by hand turning every eight days. The temperature was measured every third day with a Traceable Model 4371 Digital Thermometer, Control Products, USA. The pH was verified by the method of Jackson (1979) every eight days. Water was added every eight days and humidity was measured through gravimetry taking 25 g samples; they were dried in a model 3488M Imperial V oven (Lib-line, IL, United States) at 70 °C for 72 hours.

**Chemical analysis of composts**. The N concentration was carried out by the micro-Kjeldahl method (Bremner, 1965); P, K, Ca, Mg, and Na were analyzed following the methodology described by Alcántar and Sandoval (1999), by means of inductively coupled plasma optical emission spectrophotometry, in a Model 725 ICP-OES equipment (Agilent; Mulgrave, Australia).

**Evaluation morphological development**. These variables were quantified following the methodology described by the IMPA (1983). At 9 months of age of the crop, 5 points were marked in a quincunx pattern, each 2 linear meters in every treatment and replicate; 10 stems were randomly selected for each point and the height and diameter of stems were recorded. For the number of stems, all the milling stems present at each point were counted.

**Agricultural yield**. At the time of harvest, rolls of 20 milling stems were formed from the four central rows and leaving two rows from the edge standing. Later, each roll per treatment was weighed and the yield was calculated.

**Leaf mineral analysis**. The concentration of N in leaf was performed by the micro-Kjeldahl method (Bremner, 1965) and the nutrients P, K, Ca, Mg, Fe, Cu, Zn, Mn, and B were quantified inductively coupled plasma optical emission spectrophotometry in an ICP-OES model 725 equipment (Agilent; Mulgrave, Australia), following the methodology described by Alcántar and Sandoval (1999).

**Experimental design**. Fourteen treatments were carried out with application of 4, 6, and 8 t ha$^{-1}$ of compost, alone or in combination with mineral fertilizer, and an absolute control (Table 1). A completely randomized block design was used, with four replicates.

**Table 1**. Fertilization treatments, with composts, in template cycle of the CP 72-2086 variety of sugar cane cultivated for nine months.

| Treatment | Dose |
|---|---|
| 0 | Absolute control |
| 1 | 8 t ha$^{-1}$ chicken manure compost |
| 2 | 6 t ha$^{-1}$ chicken manure compost |
| 3 | 8 t ha$^{-1}$ chicken manure compost and filter cake 1:1 (W/V) |
| 4 | 6 t ha$^{-1}$ chicken manure compost and filter cake 1:1 (W/V) |
| 5 | 8 t ha$^{-1}$ incubator residues compost and filter cake 3:1 (W/V) |
| 6 | 6 t ha$^{-1}$ incubator residues compost and filter cake 3:1 (W/V) |
| 7 | Mineral fertilizer by recommended dose (400 kg ha$^{-1}$ of 20-10-10 and 20-00-30 during the first and second applications, each). |
| 8 | Mineral fertilizer by soil analysis (400 kg ha$^{-1}$ of 92-120-2 and 46-60-2 during the first and second applications, each). |
| 9 | 4 t ha$^{-1}$ chicken manure compost+200 kg ha$^{-1}$ mineral fertilizer 20-10-10 and 20-00-30 during the first and second application, each. |
| 10 | 4 t ha$^{-1}$ chicken manure compost and filter cake+200 kg ha$^{-1}$ mineral fertilizer 20-10-10 and 20-00-30 during the first and second application, each. |
| 11 | 4 t ha$^{-1}$ incubator residues compost and filter cake+200 kg ha$^{-1}$ mineral fertilizer 20-10-10 and 20-00-30 during the first and second application, each. |
| 12 | 4 t ha$^{-1}$ chicken manure compost+200 kg ha$^{-1}$ mineral fertilizer 92-120-2 and 46-60-2 during the first and second application, each. |
| 13 | 4 t ha$^{-1}$ chicken manure compost and filter cake+200 kg ha$^{-1}$ mineral fertilizer 92-120-2 and 46-60-2 during the first and second application, each. |
| 14 | 4 t ha$^{-1}$ incubator residues compost and filter cake+200 kg ha$^{-1}$ mineral fertilizer 92-120-2 and 46-60-2 during the first and second application, each. |

W/V (weight/volume), kg ha$^{-1}$ ( kilogram per hectare).

**Statistical analysis**. An analysis of variance (ANOVA) and Tukey means comparison tests ($p \leq 0.05$) were done with the SPSS V. 25 statistical software.

## RESULTS AND DISCUSSION

### Chemical composition of composts

Table 2 shows that there were statistically significant differences between the treatments from the effect of the organic residue and chemical fertilizer factors on the concentration of macronutrients. Composts made from chicken manure have the highest concentration value. Thus, the highest contents of N, K, Ca, and Na are found in the compost made from chicken manure, while the compost resulting from chicken manure and filter cake had the highest P and Mg contents.

The results of the present study showed that the chemical composition of the composts in treatments T1 (100% chicken manure) exhibited the highest content of N (4.30 g $kg^{-1}$), K (9.17 g $kg^{-1}$), and Na (3.93 g $kg^{-1}$), while T2 (poultry manure compost with the addition of 50% of sugar cane residues) reported the highest concentrations of P (12.49 g $kg^{-1}$) and Mg (10.81 g $kg^{-1}$). The higher N content in the chicken manure compost is likely due to the fact that chicken manure has a higher nitrogen content than other livestock manures (Zhu *et al.*, 2019). According to observations by Li *et al.* (2022), chicken manure compost has a higher nitrogen conversion because the characteristic microorganisms present in chicken manure are responsible for decomposing organic matter and fixing nitrogen during the composting stages. The higher P concentration observed in T2 may be due to the fact that filter cake has a higher P content than chicken manure (Suhartini *et al.*, 2020). Gonçalves *et al.* (2021) and Wongkoon *et al.* (2014) found that filter cake compost contains approximately 2.25 and 3.9 g $kg^{-1}$ of P; therefore, the combination of filter cake with chicken manure likely increased the P concentration in T2.

Haroon *et al.* (2018) obtained high values of N, P, Ca, and Mg in chicken manure and cypress residues compost. This indicates that the chicken manure compost is rich in nutrients and their concentration increases as the degradation time increases; this is attributed to the effect of nutrient concentration due to losses from aerobic volatilization. Accordingly, stabilized poultry residues can be used in agriculture due to their high content of N, P, K, and beneficial microorganisms present (Hernández-Rodríguez *et al.*, 2013; Wan *et al.*, 2020).

**Table 2**. Effect of the organic residue factors on the concentration of macronutrients in compost.

| Compost | N | P | K | Ca | Mg |
|---|---|---|---|---|---|
| | g $kg^{-1}$ | | | | |
| T1 | 4.30±0.08a | 11.99±0.03b | 9.17±0.10a | 4.51±0.25a | 9.24±0.34b |
| T2 | 2.22±0.12b | 12.49±0.09a | 8.58±0.20b | 4.40±0.16a | 10.81±0.15a |
| T3 | 3.80±0.17a | 0.71±0.02c | 2.94±0.02c | 1.79±0.10b | 4.35±0.17c |

Means ± DE whit different letters in each column indicate significant statistical differences ($P \leq 0.05$). g $kg^{-1}$ (gram per kilogram).

**Morphological development**

These variables showed a different behavior due to the interaction of climatic factors, mainly rainfall, presenting a dry period from January to May with an average of 20 mm, and subsequently from June to November the rains averaged 200 mm. The highest number of sugarcane stems (13.58±0.03) was obtained in treatment 1, made up of chicken manure (8 t ha$^{-1}$), while treatment 12, comprised of 4 t ha$^{-1}$ of chicken manure compost + 200 kg ha$^{-1}$ of mineral fertilizer (92-120-2 and 46-60-2), showed the greatest height and diameter of stems. Finally, the highest yield (120.79±0.23) was obtained with treatment 2, made up of 6 t ha$^{-1}$ of chicken manure compost (Table 3).

In T1, the highest number of shoots is observed, probably because chicken manure compost contains a high N content, one of whose functions is structural (Cárdenas-Navarro *et al.*, 2004); an example of this is that Rengel *et al.* (2011) observed that during tillering, sugarcane plants increased N absorption, obtaining 24.9% higher stalk production. Another function of N is related to the crop yield of sugarcane in the field; field yield is observed in T2 (Sosa *et al.*, 2015). Treatment T2 is composed of composted chicken manure, which showed the highest N concentration, coinciding with Salgado-García *et al.* (2017), where sugarcane cultivars increased their yields as the N dose increased. The application of P to the sugarcane crop causes an increase in its growth (Patil *et al.*, 2020).

T3 consists of chicken manure and filter cake compost, resulting in a higher Mg content that influences the growth of sugarcane plants, because Mg is an element that forms part of molecules and has a structural function in plants; one of the main functions of Mg is as a constituent element of chlorophyll (Alcántar-González and Trejo-Téllez, 2007).

**Table 3**. Effect of organic residue factor on the morphological development of sugar cane cultivated for nine months and yield at harvest time.

| Treatment | Stems (number) | Height (m) | Diameter (cm) | Yield (t ha$^{-1}$) |
|---|---|---|---|---|
| 0 | 10.22±0.02e | 1.70±0.03h | 2.31±0.03i | 87.58±0.11i |
| 1 | 13.58±0.03a | 1.85±0.03ef | 3.10±0.03c | 93.86±0.13g |
| 2 | 12.22±0.06b | 1.90±0.005de | 2.62±0.02gh | 120.79±0.23a |
| 3 | 12.08±0.08b | 2.02±0.01a | 3.04±0.02c | 110.07±0.06c |
| 4 | 11.42±0.02c | 1.96±0.05bc | 2.77±0.01f | 103.03±0.20e |
| 5 | 12.33±0.05b | 1.92±0.03cd | 2.91±0.01de | 107.20±0.48d |
| 6 | 11.51±0.01c | 1.73±0.08h | 2.95±0.05d | 96.92±0.48f |
| 7 | 10.84±0.08d | 1.96±0.03bc | 2.57±0.03h | 107.03±0.29d |
| 8 | 12.30±0.20b | 1.97±0.05bc | 2.61±0.01gh | 89.97±0.19h |
| 9 | 11.30±0.02c | 1.83±0.05fg | 2.85±0.03ef | 103.25±0.12e |
| 10 | 11.61±0.01c | 1.95±0.05bc | 2.77±0.05f | 106.33±0.11d |
| 11 | 12.33±0.08b | 1.98±0.05b | 2.66±0.08g | 107.16±0.19d |
| 12 | 11.66±0.03c | 2.02±0.02a | 3.42±0.01a | 112.41±0.11b |
| 13 | 10.46±0.03e | 1.80±0.03g | 2.55±0.03h | 89.93±0.06h |
| 14 | 11.46±0.03c | 1.97±0.00bc | 3.32±0.03b | 107.07±0.48d |

Means ± DE with different letters in each column indicate significant statistical differences (P≤0.05). m (meter), cm (centimeter), kg ha$^{-1}$ (kilogram per hectare).

During the rapid growth development of the sugar cane crop, the period between 3 to 12 months of age (SADER, 2019), a positive effect was seen in the height variable in treatment T12 (chicken manure and fertilizer) with a height of (2.02±0.02 cm). This is probably due to the fact that chicken manure compost is rich in P, but it is highly soluble and leachable during application to the soil; however, if added with mineral fertilizers, the nutrient content increases and stabilizes in the soil, resulting in a balance of macro- and micronutrients and organic matter, which increases plant development (Mažeika *et al.*, 2021).

This coincides with the report by Nawaz *et al.* (2017), who mention that the application of compost and mineral fertilizer positively affects the growth of sugarcane. For their part, González *et al.* (2018) point out that stem height is an important growth parameter for sugarcane production since it depends on optimal edaphic conditions to estimate growth and development. Regarding stem diameter (3.32±0.03 cm) in treatment 14 (incubator residues and filter cake), it is considered a normal parameter, when compared with studies carried out by Unigarro *et al.* (2013), who report results with a diameter value between 2.75 and 2.97 m, which indicates adequate results for this variable. It should be noted that all treatments were superior to the control (without any treatment) presenting a diameter of 2.31±0.03. In this context, the number of stems is largely determined by the content of minerals present in the soil, being treatment 1 (chicken manure compost at 8 t $ha^{-1}$) the one thatpresented the highest number of stems (13.58±0.03). These results coincide with those mentioned by Rahmad *et al.* (2019), who say that when applying compost, nutrients necessary for growing sugarcane are added.

**Macronutrients concentration in leaves**

The results shown in Table 4 indicate a significant difference between treatments, with treatments 3 and 14 showing high N content, treatment 8 with P; however, treatment 1 had the highest concentrations of K, while treatment 7 had the highest concentrations of Ca, and Mg.

Regarding agricultural performance, the application of chicken manure compost showed the highest value, which is related to that reported by Liu *et al.* (2018), who mention that the application of compost increases productivity and improves soil conditions for the growth of sugarcane. Specifically, it coincides with what was stated by Nawaz *et al.* (2017) where they mention that a balanced fertilization based on compost or chemical fertilizer, not only guarantees the production of crops, but also provides greater benefits to producers, so compost application is the best option to counteract the effect of nutrient losses due to volatilization into the environment.

In any case, if the manure is applied to the soil, less than 10% of the N content is present as nitrate and ammonia (inorganic form), not in an organic form, which must be mineralized to be available for plants (Espinoza *et al.*, 2018). Another impact is on the quality of water, air, and soil as a result of the nutrient content (Chen *et al.*, 2018; Xiao *et al.*, 2019), affecting acidification, eutrophication, and ozone depletion, as mentioned by Skunca *et al.* (2015). Moreover, manure contains bacteria that can be spread to agricultural

**Table 4**. Effect of organic residue factor on macronutrients concentration in leaves of sugarcane cultivated over nine months.

| Treatment | N | P | K | Ca | Mg |
|---|---|---|---|---|---|
| | g kg$^{-1}$ | | | | |
| 0 | 1.71±0.019g | 0.27±0.003ef | 1.04±0.011h | 0.25±0.002f | 0.11±0.001f |
| 1 | 2.21±0.024a | 0.29±0.003ab | 1.23±0.013a | 0.32±0.003b | 0.12±0.001cd |
| 2 | 1.91±0.021d | 0.27±0.003cd | 1.12±0.012ef | 0.32±0.003b | 0.13±0.001c |
| 3 | 2.25±0.025a | 0.29±0.003b | 1.17±0.013bc | 0.27±0.003e | 0.12±0.001de |
| 4 | 1.96±0.021c | 0.26±0.003fg | 1.09±0.012g | 0.26±0.003e | 0.11±0.001fg |
| 5 | 1.78±0.019ef | 0.27±0.003def | 1.22±0.013a | 0.29±0.003d | 0.11±0.001g |
| 6 | 2.01±0.022b | 0.27±0.003ef | 1.18±0.013b | 0.24±0.002g | 0.11±0.001f |
| 7 | 2.23±0.024a | 0.28±0.003c | 1.07±0.012g | 0.33±0.003a | 0.14±0.001a |
| 8 | 2.00±0.022bc | 0.30±0.003a | 1.08±0.012g | 0.25±0.002f | 0.12±0.001de |
| 9 | 1.63±0.018h | 0.26±0.003fg | 1.07±0.012g | 0.24±0.002g | 0.10±0.001e |
| 10 | 1.49±0.016i | 0.27±0.003cde | 1.09±0.012fg | 0.27±0.003e | 0.10±0.001e |
| 11 | 1.82±0.020e | 0.27±0.003def | 1.15±0.012de | 0.29±0.003d | 0.11±0.001g |
| 12 | 1.77±0.019f | 0.25±0.002h | 0.99±0.011i | 0.27±0.003e | 0.13±0.001c |
| 13 | 1.64±0.018h | 0.25±0.002i | 1.15±0.012cd | 0.23±0.002g | 0.12±0.001e |
| 14 | 2.25±0.025a | 0.26±0.002gh | 1.01±0.011i | 0.30±0.003c | 0.13±0.001b |

Means ± DE with different letters in each column indicate significant statistical differences ($P \leq 0.05$). g kg$^{-1}$ (gram per kilogram).

soils with its application as an organic fertilizer (Li *et al.*, 2020; Fang *et al.*, 2018; Zhang *et al.*, 2020). Because of this, manure is considered an important source of pathogens (Neill *et al.*, 2018), and hence should not be applied to agricultural soils.

## Micronutrients concentration in leaves

In the Regarding the content of micronutrients, in Table 5, the highest concentrations of Fe (88.5 mg kg$^{-1}$) and Mn (67.23 mg kg$^{-1}$) were observed in treatment 7, and Cu (5.0 mg kg$^{-1}$) in treatment 14. However, Zn (13.33 mg kg$^{-1}$) stood out in treatment 3. Finally, the highest concentration of B (8.41 mg kg$^{-1}$) was that in treatment 1. This showed significant differences between treatments.

Finally, a foliar analysis does not provide information for a given nutrient, but it does show the deficiencies to modify the fertilization program. Therefore, the values obtained in this study showed that mineral fertilization resulted in higher mineral content in foliar tissue. This could be due to the availability of nutrients and mineralization in the soil. Thus, these results are similar to those reported by Rangel *et al.* (2011), finding Fe, Mn, and B in greater quantity in leaf tissue and Cu and Zn deficiencies. For their part, Pérez *et al.* (2015) mention that the plant decreases nutrient absorption at 12 months of age due to the fact that it enters the maturation process, vegetative growth becoming slow. It is worth mentioning that minerals are elements with essential physiological functions for the metabolism of plants (Marín-Garza *et al.* 2018).

**Table 5**. Effect of organic residue factor on the concentration of micronutrients in leaves of sugarcane cultivated over nine months.

| Treatment | Fe | Cu | Zn | Mn | B |
|---|---|---|---|---|---|
| | mg kg$^{-1}$ | | | | |
| 0 | 71.9±0.80h | 1.37±0.015e | 11.4±0.12b | 46.29±0.51f | 5.01±0.056j |
| 1 | 84.7±0.94bc | 1.37±0.015e | 11.6±0.13b | 50.80±0.56c | 8.41±0.094a |
| 2 | 77.4±0.86fg | 1.25±0.014g | 11.47±0.12b | 47.01±0.52ef | 5.57±0.062g |
| 3 | 86.3±0.96b | 1.44±0.016d | 13.33±0.14a | 44.08±0.49g | 5.51±0.061gh |
| 4 | 69.7±0.77i | 1.25±0.014g | 10.97±0.12cde | 46.85±0.52ef | 7.32±0.081d |
| 5 | 82.2±0.91d | 1.50±0.016c | 10.42±0.11f | 47.48±0.53e | 6.87±0.076e |
| 6 | 79.5±0.88e | 1.50±0.015c | 10.91±0.12cde | 46.29±0.51f | 7.66±0.085c |
| 7 | 88.5±0.99a | 1.18±0.013h | 10.79±0.12de | 67.23±0.75a | 7.94±0.088b |
| 8 | 83.1±0.92cd | 1.75±0.019b | 10.91±0.12cde | 52.85±0.59b | 6.75±0.075e |
| 9 | 68.2±0.76ij | 1.44±0.016d | 9.92±0.11g | 41.00±0.45g | 5.35±0.059hi |
| 10 | 78.1±0.87ef | 1.31±0.014f | 11.04±0.12cd | 44.87±0.50g | 7.33±0.082d |
| 11 | 75.5±0.84g | 1.19±0.013h | 10.73±0.12e | 34.36±0.38i | 7.68±0.085c |
| 12 | 69.2±0.77i | 1.31±0.014f | 11.10±0.12c | 48.74±0.54d | 5.98±0.066f |
| 13 | 66.4±0.74j | 1.31±0.014f | 10.91±0.12cde | 34.44±0.38i | 5.29±0.059i |
| 14 | 83.2±0.93cd | 5.00±0.055a | 11.72±0.13b | 47.56±0.53de | 6.02±0.067f |

Means ± DE with different letters in each column indicate significant statistical differences ($P \leq 0.05$). mg kg$^{-1}$ (milligram per kilogram).

## CONCLUSIONS

The application of compost made from poultry residues, such as chicken manure, had a positive effect on the morphological development of the sugarcane crop, while chemical fertilization based on the result of soil analysis stimulated the concentration of nutrients in plants. So, it is recommended to apply compost from poultry residues, alone or in combination with filter cake, to increase the agricultural production of crops. It was also shown that the final compost had a high level of maturity and was not phytotoxic for the crop.

## ACKNOWLEDGMENTS

To Consejo Nacional de Ciencia y Tecnología (CONACYT) for their support through the doctoral grant No. 301506; Ciencias Agropecuarias, Universidad Veracruzana and the Grupo Pecuario San Antonio, S. A. de C. V., for the donation of material to produce compost; and the Ingenio Central El Potrero.

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