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Investigation note

Stability of static biodynamic compost from regional crop residues

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Abstract

The preparation of composts from agricultural waste allows generating an alternative in the production of organic fertilizers. Traditionally the constant turning, makes this system onerous, so the production of static composts associated with the application of biodynamic preparations (PB), promotes the development of sustainable alternatives. The objective of the present work was to evaluate the inclusion of PB (fundamental basis of biodynamic agriculture) in static compost of prickly pear and moringa remains as main substrates, establishing an experiment with a completely randomized design and bifactorial arrangement, in Zuazua, Nuevo Leon. Four treatments were considered: T1, prickly pear+PB; T2, moringa+PB, T3, prickly pear and T4, moringa. Also, the stability of the compost was evaluated during a year; through, of the behavior of 16 variables (physical, chemical and biological). The significant interactions showed that the use of prickly pear and application of PB in the compost, promoted in general a greater mineralization, temperature and lower humidity. According to the statistical significance of the main factors, in PB treatments the maximum values of UFC of bacteria were found and in treatments with prickly pear the highest values of organic matter, C:N ratio and hydrogen. The concentration of macro- and microelements increased in each treatment at the end of the evaluated period, with the exception of N, K and Cu. The decomposition of the main regional substrates used in the static piles was favored by the inclusion of PB.

Keywords: *Moringa oleifera* Lam., *Opuntia ficus indica* L. Mill.; biodynamic agriculture.

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The population increase during the last decades leads to an increase in the demand for food, causing in turn larger amounts of organic waste from the agricultural or industrial sector. The uncontrolled management of these leads to a process of contamination, including groundwater, atmosphere and soil, due to the leaching of unwanted minerals, greenhouse gases or chemicals contained in the waste. Composting is one of the strategies for the management of organic matter, defined as the transformation of this into more stable compounds in a controlled process and under aerobic conditions (Hubbe *et al*., 2010). In addition, the conditions within the composting piles reduce the potential of pathogenic microorganisms (Storino *et al*., 2016), the product obtained is of high value and works as an amendment of the soil by improving its physical, chemical and biological characteristics.

Within the composting methods, the management as static batteries can achieve the greatest reduction in energy and costs, due to the fact that turning is not necessary (Hubbe *et al*., 2010; Nasini *et al*., 2016). The management and efficient use of compost is not only the basis of soil fertility in sustainable agriculture, but is part of the set of essential components managed within the biodynamic agriculture approach (Demeter International, 2004).

Biodynamics (AB) emerged during the first half of the 1920s (Steiner, 1988), considered as a form of alternative agricultural production, under a closed system, where the inclusion of farm animals and plants is necessary to obtain biofertilizers and soil amendments. The use of biodynamic preparations (PB) and compost are considered as the fundamental basis of AB. The six PBs that are used in the compost, go through a fermentation period of six months to a year and are subsequently applied in proportions of 5-15 cm^3 for 14 t of raw material (Steiner, 1988; Zaller and Köpke, 2004). Composts with PB show higher nitrogen contents, temperatures, enzymatic dehydrogenase activity, higher microbial activity, nutrient retention capacity, microorganisms population, in contrast to untreated compost (Carpenter-Boggs *et al*., 2000; Reeve *et al*., 2010; Sradnick *et al*., 2013).

The AB considers the use of regional resources for agricultural production and takes as a basis the conservation of soil fertility. Therefore, the purpose of the present investigation was to evaluate the inclusion of PB in the static composting process, of prickly pear (*Opuntia ficus indica* L. Mill.) and moringa (*Moringa oleifera* Lam.) residues.

The experiment was carried out in the organic farm “Zu-Nopalito” (certified by BioAgriCert), located in Zuazua, Nuevo Leon (25° 53’ North latitude, 100° 02’ West longitude). It is around 355 meters above sea level and an annual rainfall of 520 mm. The prickly pear and moringa used as main substrates in the composting process were obtained from the organic farm ‘Zu-Nopalito’ and from the greenhouses of the Faculty of Agronomy of the Autonomous University of Nuevo Leon (FAUANL), respectively. The PB were acquired from the certified Demeter farm ‘El Equimite’ (Demeter International, 2004).

The construction of the batteries was based on the main criterion of initial C:N ratio 20:1. Each of the two main substrates was mixed with cow manure/chicken manure (1:1), as a source of nitrogen. The dimensions per pile were approximately 2.25, 0.90 and 1.30 m long, high and wide, respectively. For the passive ventilation system, PVC pipes (3” diameter), with holes (3/4” inch) every 10 cm, placed transversely at the base of the compost piles, were used. For the experiment, four piles of compost, two of prickly pear and two of moringa, were constructed as main substrates. Of the piles with the same substrate, one was given the PB treatment and the other one worked as a control, without PB (T1, Prickly pear+PB, T2, Moringa+PB, T3, Prickly pear, T4, Moringa).

Sixteen variables were monitored over time (October 2016-October 2017). For sampling the average depth and the total length of the piles it was considered.

The main substrates and the composted material (one year) were analyzed obtaining a composite sample (five subsamples) and quantified in triplicate. In addition, the irrigation water was analyzed in order to determine the nutritional contribution by it.

For the analysis of carbon (C) and hydrogen (H), the samples were dried at a constant temperature of 60 °C for 24 h and determined by the Dumas method (dry combustion), using a TruSpec analyzer (LECO, 2016). Organic matter (MO) was obtained by multiplying the organic C by a factor of 1.72 (Vos *et al.*, 2007). Total nitrogen (N) was quantified with the Kjeldahl digestion procedure (Vos *et al.*, 2007). The determination of the phosphorus content (P) was made by the vanadato-molybdate method and the use of a Spectronic® spectrophotometer, model Helios Epsilon (USA) (Krey *et al*., 2013). Potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), iron (Fe) and manganese (Mn) were determined by atomic absorption spectroscopy (UNICAM Solar®, model 9626).

The temperature and humidity were monitored weekly during the first 14 weeks, considering five samples per compost. For temperature recording, five thermometers were placed for measurement at the center and along the piles. The percentage of humidity was determined after drying at a constant temperature of 105 °C for 24 h (Escudero *et al*., 2012).

The populations of bacteria and fungi/yeast were quantified every four weeks during the most active phase of the composting process (14 weeks). Five samples were taken from the center and along each pile and then stored at 4 °C until analysis. The samples were prepared in dilutions of $1{:}10^6$ and $1{:}10^7$ to quantify the growth of fungi/yeast and bacteria, respectively. Inoculation of 1 mL per sample was performed on 3M™ Petrifilm™ plates. For fungi/yeast, 3M Petrifilm RYM plates were incubated at 28 °C ±2 °C for five days. For bacteria, 3M Petrifilm AC plates were incubated at 35 °C ±2 °C for 48 h.

The experiment was established under a completely randomized design with a 2 x 2 factorial arrangement, one of the main factors being the use of PB with two levels (with, without PB) and the other factor the type of substrates with two levels (prickly pear, moringa). The data obtained from the variables in the different sampling points were subjected to a one-way analysis of variance (Anva). If necessary, the arcsine transformation prior to Anva was carried out. The mean comparison was made using the honesty test of Tukey’s significant difference ($p< 0.05$). Additionally, some principal components analysis (ACP) was carried out to find the relationship between the physical, chemical and biological variables in the composting process and its association with the different treatments. The statistical analyzes were performed through the statistical package SPSS 17.0.

By means of the Anva, highly significant interaction of the evaluated factors was found (PB x Substrate) for the variables temperature, K, Mg, Cu, Fe, Mn and a significant interaction for humidity, N, P, Ca and Zn. The application of the PB in the composts induced the increase of temperature, reduction of humidity and in general, the decrease in the final concentration of the aforementioned elements (Figure 1).

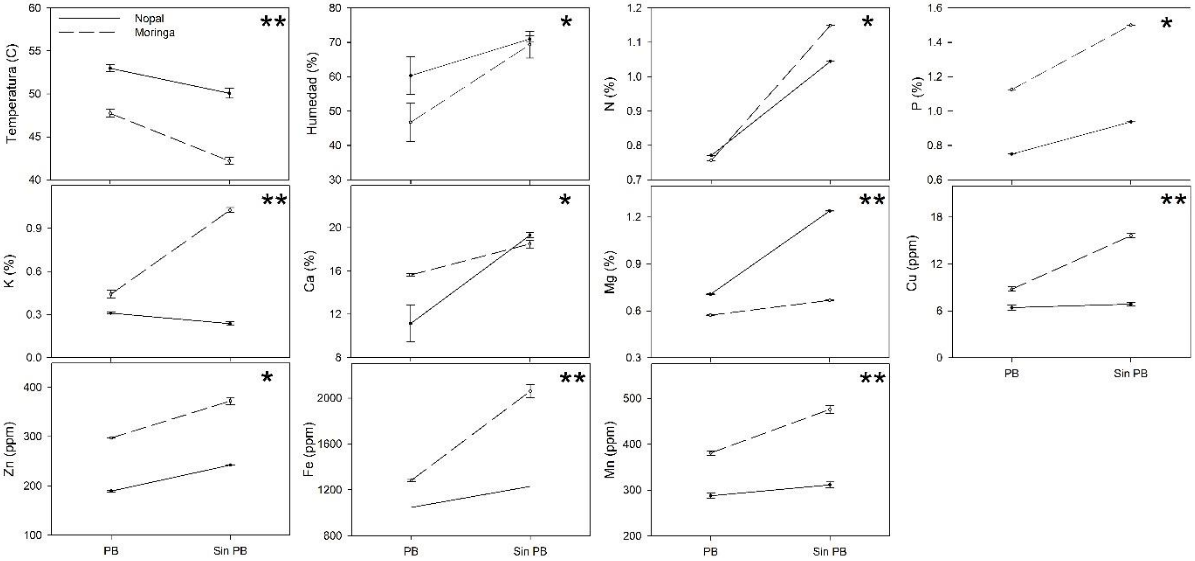

Figure 1. Physical and chemical variables with significant interaction ($^{*}p< 0.05$) and highly significant ($^{**}p< 0.01$) in the evaluated factors (biodynamic preparations x substrate). Source: data obtained from field and laboratory (FAUANL), 2016-2017. Processor: SigmaPlot 10.0.

In the case of the main factor -PB-, a highly significant difference was found for the bacteria variable and only significant for the C:N ratio, where the treatments including PB showed the maximum values. For the main factor -substrate-, a highly significant difference was found for MO, C:N and H ratio, where the prickly pear treatments showed the maximum values (Table 1). The variable fungi/yeast did not present significant statistical difference between treatments ($4.97x10^{9}$ ±$1.53x10^{9}$, $4.75x10^{9}$ ±$1.83x10^{9}$, $6.77x10^{9}$ ±$8.99x10^{8}$ and $5.18x10^{9}$ ±$6.11x10^{8}$ total UFC, for T1, T2, T3 and T4, respectively).

Table 1. Variables with significant difference ($^{*}p< 0.05$) and highly significant ($^{**}p< 0.01$) in the main factors (biodynamic preparations and substrate).

Anva factor	Inclusion PB/substratum	Bacterias (totals UFC)	C:N	MO (%)	H (%)
PB	With PB	$1.61x10^{8}$ ±$2.05x10^{7}$ a**	11.66 ±4.59 a*	24.08 ±5.1 a	1.62 ±0.35 a
	Without PB	$1.27x10^{8}$ ±$1.64x10^{7}$ b	9.3 ±3.18 b	26.96 ±4.92 a	1.81 ±0.27 a
Substratum	Prickly pear	$1.54x10^{8}$ ±$1.92x10^{7}$ a	13.78 ±2.25 a**	29.65 ±2.64 a**	1.92 ±0.16 a**
	Moringa	$1.37x10^{8}$ ±$2.87x10^{7}$ a	7.18 ±0.85 b	21.4 ±2.64 b	1.42 ±0.24 b

Means with equal letters by factor and column are not statistically different (Tukey, 0.05). UFC= Colony forming units; C:N= Carbon:nitrogen ratio; MO= Organic material; H= Hydrogen. Source: data obtained from FAUANL laboratory (2017).

The temperature results obtained agree with Zaller and Köpke (2004); Reeve *et al*. (2010), who reported higher temperatures in batteries inoculated with PB, compared to controls (without PB). In addition, they indicate greater microbial activity in the former, suggested by the greater activity of the enzyme dehydrogenase. The increase in temperature is the product of the decomposition of the organic matter, as a reflection of the microbial activity, which in turn decreases the humidity and the concentration of elements, such as C, H and O (Singh *et al*., 2016).

The MO values at the end of the period evaluated showed no significant difference between treatments with and without PB (Table 1). However, the percentage of carbon loss (throughout the evaluation period) reflected the greater decomposition activity of the organic material in those piles with PB (54 and 64% for T1 and T2, respectively), in contrast to the piles without PB (50 and 57% for T3 and T4, respectively).

The percentage of humidity reached is within the adequate range for microbial activity (Tang *et al*., 2006), this is a critical parameter for the optimization of these systems (Luo *et al*., 2008), which depends on the correct selection and mixing ratio of the materials. The maximum points of temperature reached were 58, 55, 59 and 56 °C for T1, T2, T3 and T4, respectively. Such values guarantee the control of pathogens for humans (Storino *et al*., 2016).

In Table 1 it is observed that the C:N ratio of the four treatments was maintained between values of 7:1 and 14:1. Nair and Delate (2016) suggest values between 10-15:1, as optimal for mature compost to be applied in the field. The adjustment of the initial C:N ratio in the composts of the present investigation (20:1) was calculated according to the initial values of the main substrates, these being 24.88, 36.67, 8.02 and 13.77 for prickly pear, moringa, poultry manure and bovinaza, respectively. This parameter is one of the most important for the development of a composting process (Guo *et al*., 2012).

The most active period of the composting process (mesophilic and thermophilic phase) was during the first 14 weeks. Period where the maximum values of temperature, UFC of bacteria and fungi/yeast were obtained.

In Figure 2, the comparison of the concentrations of elements of the initial mixes and mature compost piles (one year) is observed. The concentration of N decreased toward the end of the process in all treatments, as did the values of K and Cu (except for T4). The concentration of P, Ca, Mg, Zn, Fe and Mn in mature compost increased, due to the characteristic decrease in the volume of the decomposing material (Oliveira *et al*., 2017) and the contribution of macroelements by irrigation water (Ca, 11.48 meq L^{-1}; Mg, 7.71 meq L^{-1}). In T4 the lowest concentration of microorganisms and temperature was found, therefore, a lower degree of decomposition and mineralization, keeping the minerals fixed in the original material.

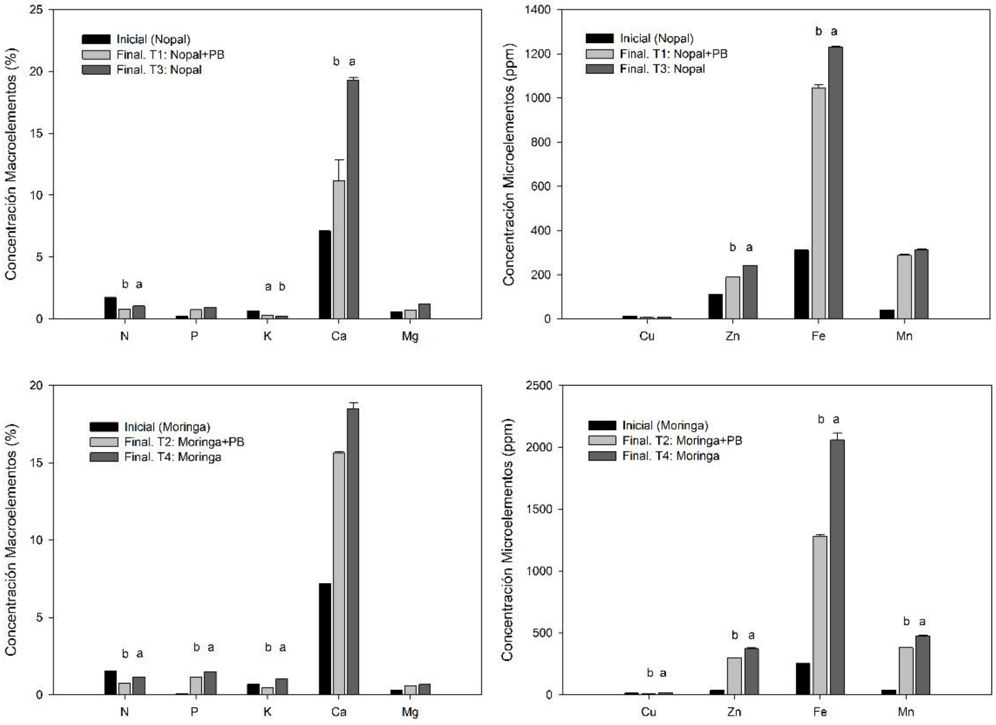

Figure 2. Initial and final concentration (one year) of macro and microelements in static compost, considering prickly pear and moringa as main substrates and the inclusion of biodynamic preparations (PB). Statistical comparison only between final concentrations. Bars without letters are statistically equal (Tukey, 0.05). Source: data obtained from the laboratory (FAUANL), 2016-2017. Processor: SigmaPlot 10.0.

In general, lower concentrations of macro and microelements were observed in compost piles including PB and prickly pear. This behavior was due to the increase in decomposition and mineralization, promoted mainly by bacterial activity, which in turn increased the release of the elements to the environment, either by leaching and volatilization. Such an aspect is reflected as a disadvantage of the PB application. However, the correct capture or retention of the released elements, make the use of PB a method to increase the availability of the elements contained in the original materials, to the plants.

The final macro and microelement concentrations in the compost remain within the acceptable range and reported by several authors (Rasapoor *et al*., 2009; Nasini *et al*., 2016).

In the ACP, the first (61.77%) and second (27.01%) component values were selected, which explain approximately 89% of the total variance. The first component showed a correlation between the variables bacteria, temperature and C:N ratio, associated with T1, in addition to the correlation between N, P, K, Ca, Cu, Zn, Fe and Mn, associated with T4. The second component showed a correlation between fungi/yeast, MO, H, Mg and humidity, associated with T3 (Figure 3). The results of the ACP agree with what was presented previously, where the macro and microelement variables are correlated (except Mg), whose higher concentrations are associated with T4. In addition, the correlation of variables related to microbial activity (temperature, C:N, MO and bacteria, mainly) associated with T1 is confirmed. These behaviors reflect the increase in the decomposition process, fostered by the application of PB and the prickly pear substrate.

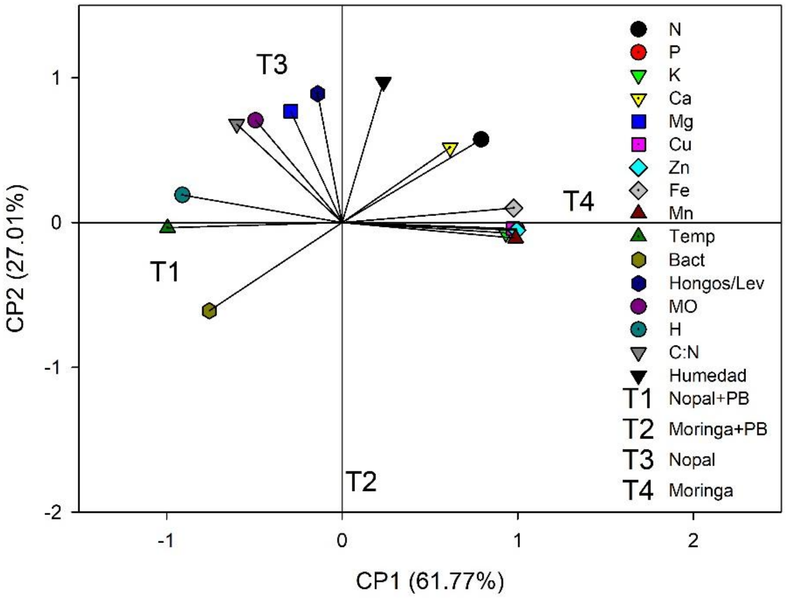

Figure 3. Analysis of the main components for the physical, chemical and biological variables of static compost. PB= biodynamic preparations; Temp= maximum temperature; Bact= total bacteria; fungi/Lev= fungi/total yeast; MO= organic matter; H= hydrogen, C:N: carbon:nitrogen ratio. Source: data obtained from field and laboratory (FAUANL), 2016-2017. Processor: SigmaPlot 10.0.

Conclusions

Through the significant interaction of the evaluated factors (PB x substrate), it is concluded that the combination of PB with prickly pear reached the highest temperature, humidity reduction and, in general, greater mineralization. The significant difference found in the main factors shows a higher bacterial activity in treatments with PB and higher MO, H and C:N ratio for treatments with the prickly pear substrate.

The decrease in the concentration of N and C and the increase of the elements evaluated during a year, reflects the characteristic behavior of the composting process. At the end of the evaluated period (one year), the values of the parameters are within the acceptable range for a mature final product.

The aeration of the compost by using the passive method promoted the microbial activity measured by the increase in population and variables related to it (temperature, mineralization, carbon content and nitrogen). The use of the main substrates evaluated promotes the use of regional resources and at the same time the recycling of the minerals and compounds contained in the biomass.

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