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Nitrogen, phosphorus, and potassium content of six biofertilizers used for fertigation in organic production system

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Abstract

This research tracked N, P and K content of six biofertilizers during the fermentation process. The experiment consisted of six biofertilizers and five fermentation times (3, 7, 15, 22 and 30 days after preparation [DAP]). The biofertilizers were prepared on the same basis for fermentation, adding (in 15 L of water): T1 = castor bean cake (2 kg), T2 = blood meal (2 kg), T3 = hoof and horn powder (2 kg), T4 = bone meal (2 kg), T5 = blood meal (1 kg); T6 = bone meal (1 kg). The experimental design was a randomized block design with three replications. The biofertilizer hoof and horn powder were higher N content than the others, reaching 6.77 g L^{-1}, whereas the bone meal (1 and 2 kg) had the lowest content, reaching 1.43 and 1.93 g L^{-1}, respectively. At all fermentation times, the castor bean cake (3.23 g L^{-1}) and hoof and horn powder (2.61 g L^{-1}) biofertilizers showed higher P content than bone meal (1 and 2 kg) biofertilizers. Castor bean cake biofertilizer had higher K content (2.49 g L^{-1}) than hoof and horn powder (1.86 g L^{-1}), blood meal (1.69 and 1.60 g L^{-1}), bone meal (1.57 to 1.68 g L^{-1}) biofertilizers. Regardless of the type of biofertilizer, the K content had no change, the N content and the electrical conductivity increased, and the P content reduced during fermentation time until 30 DAP.

Keywords: Blood meal, bone meal, castor bean cake, hoof and horn powder, electrical conductivity

Introduction

Fertigation is the process of applying fertilizers with the irrigation water in order to provide the nutrients required by the plant at the appropriate time, with the possibility of more efficient adjustment to the different phenological phases of the plants (Trani et al., 2011).

For organic systems, the fertigation can be considered a suitable fertilization method, since according to article 96 of IN 46/2011, as amended by IN 17/2014, irrigation and the application of inputs must be carried out in a way that avoids waste and pollution of surface water or groundwater (Brasil, 2014). In this way, fertigation, in organic systems is carried out with the joint application of water and biofertilizers, which are natural products obtained from the fermentation of organic materials with water, containing the nutrients necessary for plant nutrition. The use of biofertilizers may favor a greater richness of microorganisms and promote better availability of nutrients to the roots. Several authors have demonstrated the beneficial effects of biofertilizers used via soil in improving of plant development (Ludke, 2009; Pereira et al., 2011; Marrocos et al., 2012).

The chemical and microbiological composition of the biofertilizers can be highly complex and variable, according to the preparation method, with the ingredients used in their elaboration, as well as may vary throughout the fermentation time (Marrocos et al., 2012). Reports of biofertilizers with similar raw material bases have been analyzed and show high variation in nutritional contents such as Supermagro (NPK - 1.43, 0.26, 1.01 g L^{-1}), Agrobio (NPK - 0.04, 0.08, 1.41 g L^{-1}), Bioembrapa (NPK - 1.5, 0.17, 1.89 g L^{-1}), bovine manure biofertilizers (NPK - 0.5, 0.7 g L^{-1}), chicken (NPK - 0.78, 2.54 g L^{-1}), compost (NPK - 0.02, 0.11, 3.07 g L^{-1}) (Ludke, 2009, Marrocos et al., 2012).

Rice bran, molasses and microorganisms are a common basis for various biofertilizer recipes, as they

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provide energy for the decomposing microorganisms. Castor bean cake, bone meal, blood meal and hoof and horn powder have been organic fertilizers for over 60 years studied in Brazil (Chacón et al., 2011; Silva et al., 2012), and they have been used as the main source of nitrogen, potassium and phosphorus in different studies of organic fertilization in several vegetables (Ferreira et al., 2012; Martins et al., 2013; Candian, 2018).

Although many authors report the chemical composition of different biofertilizers, few studies demonstrate the effect of fermentation time on nutritional characteristics. Thus, the objective of this research was to track the nitrogen, phosphorus and potassium content and the electrical conductivity of six biofertilizers used for fertigation in organic production systems, throughout the fermentation process.

Material and Methods

This research was carried out in an organic farm located in the city of Botucatu-SP, Brazil. The biofertilizers were obtained of the same base of ingredients for the fermentation, composed of 1 kg of rice bran (Nori Cerealist, Itapolis, SP, BRA), 250 mL of molasses (Coopercitrus, Itapolis, SP, BRA), and 250 mL of microorganisms (Embiotic Line, Korin, Sao Paulo, SP, BRA). For this common base, one ingredient was added. Biofertilizer 1 was added 2 kg of castor bean cake (A. Azevedo Oil Industry and Trade Ltda., IBD N. I0046 SP, Itupeva, SP, BRA); biofertilizer 2, 2 kg of blood meal (Nossa Senhora Aparecida Cattle Slaughtering, Pocos de Caldas, MG, BRA); biofertilizer 3, 2 kg of hoof and horn powder (Cobecrina, Bovine By-products, Jacarezinho, PR, BRA); biofertilizer 4, 2 kg of bone meal (Nutrissafra Fertilizer Ltda., Barueri, SP, BRA); biofertilizer 5, 1 kg of blood meal; and biofertilizer 6, 1 kg of bone meal was added. After the prepared of biofertilizer, five times of fermentation were also evaluated, 3, 7, 15, 22, and 30 days.

The bone meal, blood meal, hoof and horn powder and castor bean cake were sent for analysis of content of N, P and K. The following percentages were obtained: bone meal: 1.4, 18.7 and 0.1 %; blood meal: 11.3, 0.3 and 0.2 %; hoof and horn powder: 13.0, 0.7 and 0.2 % and castor bean cake: 5.6, 1.5 and 0.8 % of N, P and K, respectively. After the preparation, every day the biofertilizers were mixed until they formed a vortex to one side and then to the other. For each fermentation time, samples were collected shortly after this mixing.

Experiment evaluated six different mixing of biofertilizer and five times of fermentation. Thirty treatments were evaluated in split-plot design where the biofertilizers were the main plot and dating after prepared were subplot. The experimental design was in randomized blocks, with three replicates. Each replicate consisted of one bucket with a capacity of 30 liters.

In each plot, electrical conductivity (EC) and N, P, and K contents were measured. The EC was measured with a conductivity meter (resolution 0.01 $mS.cm^{-1}$), put directly inside of the liquid. Then, 80 mL of the biofertilizer was collected from each plot and stored in a glass bottle, identified with the treatment and the replicate, which was stored in a freezer (T = 0 °C) until the analyzes of the macronutrients N, P and K are performed.

The experiment data were analyzed using Sisvar Software (Ferreira, 2011). The main plot (biofertilizer) was compared by the Tukey test ($p> 0.05$), while the subplot (times of fermentation) was compared by regression analyzes.

Results and Discussion

In the analysis of variance, only for the N content the interaction between biofertilizers and preparation time was significant by the F test. The hoof and horn powder biofertilizer (2 kg) presented, in almost all samples, a higher N content than all others, except at 15 DAP, when it did not differ from the biofertilizer made with blood meal (2 kg) (Table 1). On the other hand, biofertilizers made with bone meal (1 kg and 2 kg) had the lowest N content, although not always statistically inferior to all other biofertilizers. Probably, these results are related to the original percentage of N of their ingredients being higher and lower, for hoof and horn powder (13 % N) and bone meal (1.4 % N), respectively.

Table 1. Nitrogen contents in the six biofertilizers throughout the fermentation time.

Biofertilizer / Main Ingredient	Days after preparation				
	3	7	15	22	30
	g L^{-1}				
Castor bean cake (2 kg)	1.5 b*	1.9 bc	2.0 bc	2.5 b	3.3 b
Blood meal (2 kg)	1.7 b	2.7 b	2.9 ab	2.6 b	3.0 bc
Hoof and horns powder (2 kg)	3.8 a	4.2 a	3.9 a	5.1 a	6.8 a
Bone meal (2 kg)	1.4 b	1.6 bc	1.6 c	1.8 bc	1.9 cd
Blood meal (1 kg)	1.5 b	1.6 bc	1.4 c	1.8 bc	2.0 cd
Bone meal (1 kg)	1.2 b	0.8 c	1.1 c	1.2 c	1.4 d

*Means followed by the same letter in each column do not differ by Tukey test at 5% probability.

However, only the highest N content in the raw material is not enough to guarantee a higher N content in the biofertilizer. The blood meal (11.3 % N) presents almost twice the N content of the castor bean cake (5.6 % N). However, the N content in the biofertilizer based on blood meal is almost equal to that of the biofertilizer based on castor bean cake (Table 1). Therefore, regardless of the amount of original N, the release of N may vary for each ingredient and only the original content is not a guarantee of greater availability.

In the case of a fertirrigation aiming a higher supply of N to the plants, the biofertilizer with hoof and horns proved to be the most adequate, because in all samples dates it has made N more available than the other biofertilizers.

All the biofertilizers had an increase in the N content with the fermentation time (Figure 1), confirming Marrocos et al. (2012) who stated that the composition of the biofertilizers varies throughout the fermentation time. Lopez et al. (2016) also observed an increase in N content in the biofertilizer Supermagro in the first four weeks of preparation, varying the content until the ninth week, when there was a stabilization in the N content. As there was a continuous increase of N and there was no stabilization during the 30 DAP, it is suggested that the N mineralization process has not yet been completed, demonstrating that the biofertilizers did not stabilize with 30 days of fermentation.

In the biofertilizers based with bone meal (1 and 2 kg) and blood meal (2 kg) the increase was linear (Figure 1), with continuous increases in the N content with the fermentation time, with increases estimated to be 0.015 ; 0.017 and 0.033 g L^{-1} for each day of fermentation, respectively. Therefore, in spite of having the same linear trend, the biofertilizer based on blood meal (2 kg) presented a much higher daily increase, which can be explained by the fact that the blood meal has an original N content much higher than the bone meal and greater ease in its release during fermentation.

N contents during the fermentation time in the biofertilizers based on castor bean cake (2 kg), hoof and horn powder (2 kg) and blood meal (1 kg) adjusted to the quadratic model (Figure 1), with higher increases in the last samples. However, Marrocos et al. (2012) reported reduction of N content in biofertilizers with fermentation time. For these authors, the bovine manure biofertilizer started with N content of 0.3 g L^{-1} at 0 DAP and ended with 0.1 g L^{-1} at 30 DAP and chicken manure started at 1.8 g L^{-1} and ended with 1.1 g L^{-1} at 30 DAP. All values reported by these authors were lower than those obtained in this study at 30 DAP.

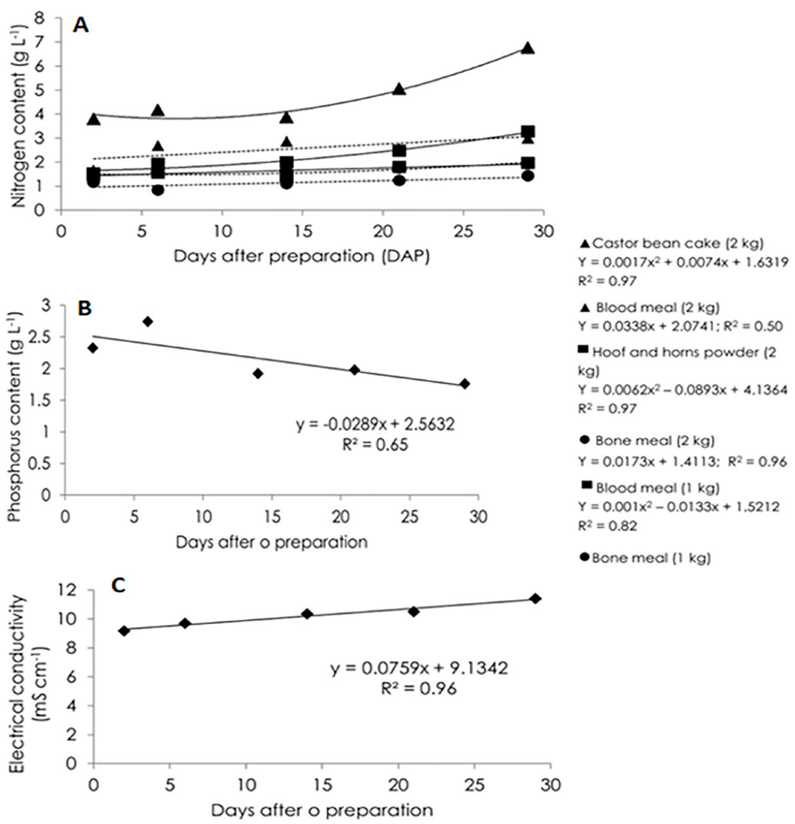

Figure 1. Nitrogen (A) and phosphorus (B) content, and electrical conduction (C) during fermentation time (days after preparation).

At the end of the evaluations (30 DAP), the N contents found in this study were higher than the results obtained by Ludke (2009): 0.2 to 0.4 g L^{-1}. These lower N results reported by Ludke (2009) and Marrocos et al. (2012) in relation to the present study may be associated by the difference of the ingredients, by the amount of water proportionally to the solid ingredients, and by the fermentation conditions. Unfortunately, not all published research details the entire production process of the biofertilizers analyzed for a better comparison and discussion of the results obtained between different authors.

Independently of the sampling time, biofertilizers of hoof and horn powder (2 kg) and castor bean cake (2 kg) presented higher P availability than those of bone meal (1 and 2 kg) (Table 2), despite of the latter ingredient had the highest original percentage of P (18.7 %), than hoof and horn powder (0.7 %) and castor bean cake (1.5 %). Although rich in P, it is in the form of calcium phosphate, which has low solubility (Raij, 2011).

Regardless of the type of biofertilizer, the P content reduced with the fermentation time, with a mean reduction of 0.029 g L^{-1} per day of fermentation (Figure 1). According to Trani et al. (2011), the Ca content in bone meal is 23.2 %, whereas the hoof and horn powder and castor bean cake have 0.3 and 2.0 % of Ca, respectively. Over time, the increased availability of Ca of the medium in the fermentation process may have caused the precipitation of part of the P in the form of calcium phosphate and, therefore, the reduction of its availability with the time. According to Kiehl (2010), the pH index, the reaction with phosphate ions and those of calcium, magnesium, manganese, iron and aluminum oxides and the presence of microorganisms are factors responsible for the greater or lesser amount of phosphorus available. Marrocos et al. (2012) also reported a reduction in P during the fermentation time in a bovine manure.

Table 2. Phosphorus (P) and potassium (K) contents and electrical conductivity (EC) in six biofertilizers.

Biofertilizer / Main Ingredient	P	K	EC
	—— g L^{-1} ——		mS cm^{-1}
Castor bean cake (2 kg)	3.2 a*	2.5 a	9.5 b
Blood meal (2 kg)	2.3 ab	1.6 b	13.2 a
Hoof and horns powder (2 kg)	2.6 a	1.9 b	9.7 b
Bone meal (2 kg)	0.8 c	1.7 b	10.5 b
Blood meal (1 kg)	2.5 ab	1.7 b	9.3 b
Bone meal (1 kg)	1.5 bc	1.6 b	9.2 b

*Means followed by the same letter in each column do not differ by Tukey test at 5% probability.

At the end of the 30 DAP, the contents of P found in this research were different than the results obtained by Ludke (2009), for different biofertilizers (0.08 to 0.17 g L^{-1}), and that of Marrocos et al. (2012), for biofertilizers based on bovine (0.50 g L^{-1}) or chicken manure (0.78 g L^{-1}). Again, these lower P results reported by different authors in relation to the present study may be associated both by the difference of the ingredients, by the amount of water proportionally to the solid ingredients, and by the fermentation conditions.

In order to obtain a biofertilizer richer in P, it is advisable to ferment for the shortest possible time and, among the biofertilizers analyzed, the biofertilizers of hoof and horn powder and castor bean cake were the most suitable, since from the beginning of the process they have provided more P than the other biofertilizers.

Irrespective of the sampling time, the castor bean cake (2 kg) biofertilizer presented higher K content than all the others, which did not differ from each other (Table 2). This should be related to the original percentage of K in castor bean cake (0.8 %) higher than in bone meal (0.1 %), hoof and horn powder (0.2 %) and blood meal (0.2 %). In addition, the decomposition of castor bean cake is relatively fast, compared to other organic materials (Severino et al., 2004).

The contents of K did not change with the fermentation time, independently of the type of biofertilizer. This can be explained by the fact that potassium is not bound to the organic compounds in the cells, it is an active element, in free form, and is therefore readily released in the middle from the beginning of the process of organic matter decomposition (Kiehl, 2010). However, in the studies carried out by Marrocos et al. (2012), the K content in the biofertilizers based on bovine and chicken manure presented a quadratic curve, increasing up to 15 or 20 DAP and then reducing till 30 DAP.

In the case of a fertirrigation aiming at the supply of K to the plants, considering the use of the same amount of ingredients in the biofertilizer elaboration, the castor bean cake proved to be the most appropriate among the evaluated ones. Since there was no variation over time, if the objective is to provide K, it can be used with little fermentation time.

At the end of the 30 DAP, the K contents found in this study were higher than the results obtained by Ludke (2009) for the biofertilizer Agrobio (1.41 g L^{-1}), whereas only in the biofertilizer based on castor bean cake content was higher than the Bioembrapa (1.89 g L^{-1}) and all were smaller than the compound extract (3.07 g L^{-1}). On the other hand, the values obtained in this research are higher that related by Marrocos et al. (2012) in the biofertilizer based on bovine manure (0.70 g L^{-1}) and lower than the biofertilizer based on chicken manure (2.54 to 3.06 g L^{-1}). Differences in values obtained by different authors should be related to both the difference of the ingredients and the fermentation conditions.

The biofertilizer based on blood meal (2 kg) presented higher electrical conductivity (EC) than all the others that did not differ each other (Table 2). This result was not expected, since the biofertilizer of blood meal presented lower availability of nutrients than the biofertilizers of hoof and horn powder and castor bean cake, which presented higher availability of nitrogen and potassium, respectively. However, it is not only these nutrients that are responsible for the saline content of the solution, and the largest EC of the biofertilizer based on blood meal (2 kg) may be due to other ions available during the fermentation.

According to Trani et al. (2011), fertilizers generally contain salts that can raise the saline concentration of irrigation water. However, excess salts in the root zone impairs seed germination, plant development and productivity, and some species are more tolerant to salinity than others. In this way, once the CE of the biofertilizers is known, its correct dilution must be made so that the EC at the exit of the emitters is suitable for the culture. According to Salomão et al. (2012), the calculation is done by knowing the EC in the dilution of 1 gram of the fertilizer in 1 liter of water, then adjust the amount of fertilizer in relation to the total water to be applied. However, even if the EC at the exit of the emitters is suitable for the crop, the accumulation of salts in the soil occurs, and EC should be periodically monitored in the soil solution so that it does not exceed the maximum tolerated for each crop.

Regardless of the type of biofertilizer, the EC increased with the fermentation time (Figure 1). According to Carmo et al. (2016), the sum of the ions is a predictor of the EC, which is regulated by pH, together with the sum of the concentrations of cations, anions and C-soluble, so that EC increases when, simultaneously, pH reduction occurs and increases in the concentrations of ions (cations + anions) + C-soluble in the solution. In this case, it is suggested that the EC increase of the biofertilizers over time is related to the increase of the nitrate anion (NO^{3-}) content and other non-evaluated ions, since in the biofertilizers the N content increased, the content of K did not change and the P content decreased with time. Lopez et al. (2016) also observed a constant increase in the EC of the biofertilizer Supermagro, dissolved to 5 %, in the first four weeks of evaluation.

It is noticed that the concentration of a nutrient may vary according to the ingredients used in the formulation of the biofertilizer, as well as throughout the fermentation time. Thus, of the tested ingredients, it is recommended to use hoof and horn powder, with longer fermentation time if the objective is higher N content, while castor bean cake is more suitable to obtain higher contents of K. It is also recommended to evaluate the EC of the biofertilizers to avoid the salinization of the soil solution, being recommended the dilution according to the initial value and the species to be fertilized.

Conclusions

It is concluded that the biofertilizer based on hoof and horn powder (2 kg) presented higher N content than other biofertilizers; that biofertilizers of hoof and horn powder (2 kg) and castor bean cake (2 kg) presented higher P content than those of bone meal (1 and 2 kg); that the castor bean cake (2 kg) biofertilizer had a higher K content than the others; and that regardless of the type of biofertilizer, the contents of K did not change, those of P reduced and those of N and the EC increased until the 30 days of preparation.

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