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Net mineralization nitrogen and soil chemical changes with application of organic wastes with 'Fermented Bokashi Compost'

Cácio Luiz Boechat[1*], Jorge Antonio Gonzaga Santos[2] and Adriana Maria de Aguiar Accioly[3]

*[1]Departamento de Ciência do Solo, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 7712, 91540-000, Porto Alegre, Rio Grande do Sul, Brazil. [2]Centro de Ciências Agrárias Biológicas e Ambientais, Universidade Federal do Recôncavo da Bahia, Cruz das Almas, Bahia, Brazil. [3]Empresa Brasileira de Pesquisa Agropecuária, Centro Nacional de Pesquisa de Mandioca e Fruticultura, Cruz das Almas, Bahia, Brazil. *Author for correspondence. E-mail: clboechat@hotmail.com*

ABSTRACT. The use of organic wastes in agricultural soils is one of the possible ways to employ these materials. The aims of this study were to evaluate the effectiveness of organic wastes and Fermented Bokashi Compost (FBC), to establish the most efficient use of organic wastes for a soil, changing the net nitrogen mineralization and soil chemical properties. The experimental design was completely randomized in a 6 x 2 x 5 factorial, being five organic wastes plus an control (soil without waste), with or without FBC, evaluated at 0, 7, 42, 70 and 91 days of incubation, with three replicates, under laboratory conditions. The organic wastes enhanced the soil chemical properties and increased nitrogen concentration in soil. However, the net nitrogen mineralization was affected by C/N ratio of wastes and incubation time. The FBC mixed with the wastes accelerated and enhanced organic matter degradation, resulting in quickly available quantity of net nitrogen. The wastes can be considered potentially useful as organic fertilizer but their usefulness appears to depend on knowing the C/N ratio of each one. The FBC can be used when one wants a more accelerated degradation, resulting in a quicker quantity of available nutrients to the plants.

Keywords: efficacy of microorganisms, sewage sludge, degradation, fertility.

Mineralização líquida de nitrogênio e mudanças químicas no solo com a aplicação de resíduos orgânicos com 'Composto Fermentado Bokashi'

RESUMO. O uso de resíduos orgânicos nos solos é uma das maneiras possíveis para empregar estes materiais. Os objetivos deste estudo foram avaliar a eficácia de resíduos orgânicos e do composto fermentado Bokashi (FBC) e estabelecer o uso mais eficiente dos resíduos, alterando a mineralização líquida de nitrogênio e as propriedades químicas do solo. O delineamento experimental foi inteiramente casualizado, em fatorial 6 x 2 x 5, sendo cinco resíduos mais um controle (solo sem resíduo), com ou sem FBC, avaliados aos 0, 7, 42, 70 e 91 dias de incubação, com três repetições, em condições de laboratório. Os resíduos orgânicos melhoraram as propriedades químicas e aumentaram a concentração de nitrogênio no solo. No entanto, a mineralização líquida do nitrogênio foi afetada pela relação C/N dos resíduos e o tempo de incubação. A mistura do FBC com os resíduos acelera e melhora a degradação da matéria orgânica, resultando em uma quantidade de nitrogênio líquido rapidamente disponível. Os resíduos estudados podem ser considerados potenciais adubos orgânicos, contudo sua utilidade parece depender do conhecimento da relação C/N de cada um. O FBC pode ser usado quando se deseja uma degradação mais acelerada, resultando em rápida quantidade de nutrientes disponíveis para as plantas.

Palavras-chave: eficácia dos microorganismos, lodo de esgoto, degradação, fertilidade.

Introduction

The use of organic wastes from production processes or in biofertilizer form as a source of plant nutrients in agricultural soils is one of the ways to employ these materials, as they increase fertility, and improve soil characteristics and physic-chemical properties, and also microbial activity (BRADY; WEIL, 2002).

One of the world's most commonly used biofertilizers in this context is the so-called 'Effective microorganisms' (EM), referring to an undisclosed mixture of naturally occurring microorganisms that supposedly has beneficial properties in a wide range of applications (HIGA, 2002).

Bokashi is the Japanese term for 'fermented' organic matter and is equivalent to compost used in traditional organic farming which is mostly prepared with the addition of EM. The Fermented Bokashi Compost is a mixture of several types of organic matter subjected to predominantly lactic fermentation. It can be prepared under complete anaerobic or aerobic conditions. The latter means that partial anaerobic conditions occur in the middle of the compost pile while the outer layers remain aerobic. The preparation of Anaerobic Bokashi is prepared in closed vessels, while aerobic Bokashi is prepared similarly to traditional composting with additional usage of a cover such as a jute bag, straw mat, or similar material (KYAN et al., 1999).

However, Tiruo Higa suggested a very broad application range of EM preparations and has reported beneficial effects in different environments such as soils, plants and water. It has been proposed that EM preparations help to produce substances acting as antioxidants, such as inositol, ubiquinone, saponin, low-molecular polysaccharides, polyphenols and chelating agents. These substances may inhibit harmful microbial species enhance the proliferation of beneficial microorganisms and detoxify harmful substances simultaneously (HIGA, 2001 apud MAYER et al., 2010).

Only small and often contradictory effects of the application of EM preparations on crop yields and plant development have been reported (KHALIQ et al., 2006; OKORSKI et al., 2008; VAN VLIET et al., 2006). EM-applications have also been found to have no effect (KHALIQ et al., 2006; VAN VLIET et al., 2006). Similar results were found by Schenck zu Schweinsberg-Mickan and Müller (2009) to N mineralization and microbial biomass C and N in soil without amendments and with application of wheat straw and coarse meal of yellow lupins. Few effects have been observed related to the EM carrier substrate molasses. Okorski and Majchrzak (2007) observed the highest soil fungal diversity when EM was applied together with pesticides in a field experiment planted with peas.

Many studies have been performed to investigate the effect of organic wastes on the physicochemical characteristics of soil (ARAUJO, 2011; DE MARIA et al., 2010), their biological properties (BUENO et al., 2011) and crop yields (ARAUJO, 2011; PIGOZZO et al., 2008).

There are only a few studies on the effects of EM on decomposition of organic wastes in soil and on soil quality in general. Our aim was to verify whether the application of Fermented Bokashi Compost mixed with five different types of organic wastes, promotes soil chemical improvement and higher net nitrogen mineralization under laboratory conditions.

Material and methods

Soil and wastes characterization

Standard quality assurance chemical analyses data for the soil and wastes was obtained from Embrapa Laboratory, in Brazil. Some chemical analysis according to Embrapa (1999) and total C, ammonium nitrogen, nitrate nitrogen and total N were analyzed using a methodology cited by Tedesco et al. (1995).

The soil was an Oxisol Ustox (USDA, 1999) or according to the Brazilian System of Soil Classification 'Latossolo Amarelo distrófico' (EMBRAPA, 2006) with 172, 754 and 74 g kg^{-1} clay, sand and silt respectively in the 0–20 cm layer. The chemical analysis results are shown in Table 1. Before soil incubation with treatments, about 100 kg of soil were sieved (Ø ≤ 4.75 mm), homogenized, moistened (70% of field capacity) and stored in dark plastic bags at room temperature for 21 days to restore the microbial communities.

The organic wastes used in the experiment were: Treated pulp mill sludge (PMS) - The raw material for this industry is newspaper, books, bank and office composts and other recyclable paper. The organic wastes were treated using physical, chemical and biological activated sludge processes to remove biochemical oxygen demand and concentration of resin with the addition of lime (CaO) in order to eliminate pathogens and promote organic waste stabilization.

Petrochemical complex sludge (PS) - Sludge derived from wastes generated by industries located in a petrochemical complex. The industrial sludge is derived from aerated biological treatment and treatment to reduce heavy metal concentrations.

Treated urban sewage sludge (USS) – This organic waste was the result of sewage treatment that used physical processes to remove coarse solids, biological activated sludge to reduce biochemical oxygen demand, plus the addition of lime (CaO), aiming at eliminating pathogens and stabilizing wastes.

Treated dairy industry sewage sludge (DSS) - Organic waste generated by the dairy industry to manufacture cheese, and to process butter and milk. The organic wastes are aerated in a pond to reduce the organic load and eliminate pathogens, and chemical stabilization is performed applying lime (CaO).

Organic compost from the fruit pulp industry (FPW) - Organic compost derived from the remains of fruit peel and seeds for frozen fruit pulp production. The organic composts piled for primary fermentation processes and partial decomposition of the material and stabilization of organic load for three years.

The chemical properties of the organic composts can be seen in Table 2.

Table 1. Chemical characteristics of soil used in the experiment.

pH[a]	pH[b]	P	Ca	Mg	CEC[c]	N- NH_4^+	N- NO_3^-	SOC[d]	SOM[e]	N-Kjeldahl	C/N ratio
.....	.....	g dm^{-3}	— cmol$_c$ dm^{-3} —			— mg kg^{-1} —		——— g kg^{-1} ———			.....
5.20	4.18	0.002	1.12	0.23	2.97	57.12	100.80	3.53	6.08	1.05	3.36

[a]In H2O (ratio 1:2.5); [b]In CaCl2; [c]Cation exchange capacity; [d]Soil organic carbon and [e]Soil organic matter.

Table 2. Chemical characteristics of organic wastes used in the experiment.

Parameter	Unit	Organic wastes[a]				
(Total value)		PMS	PS	USS	DSS	FPW
pH[b]	.....	8.30	7.40	5.67	6.90	5.40
P	g dm^{-3}	0.28	4.04	9.49	15.00	0.51
Ca	cmol$_c$ dm^{-3}	190.23	116.80	59.86	198.20	28.20
Mg	cmol$_c$ dm^{-3}	16.61	5.48	27.18	13.05	18.50
Organic carbon	g kg^{-1}	236.40	34.40	235.00	161.60	232.40
Organic matter	g kg^{-1}	407.55	59.31	405.14	278.60	400.60
N-Ammonium	mg kg^{-1}	263.20	750.12	8619.80	6182.40	460.60
N-Nitrate	mg kg^{-1}	171.08	855.40	421.12	36.96	881.72
N-Kjeldahl	g kg^{-1}	3.72	4.49	32.63	19.20	19.50
Cu	mg kg^{-1}	162.20	373.20	334.02	141.79	101.72
Fe	mg kg^{-1}	3,240.86	7,640.86	7,364.59	11,752.69	701.08
Mn	mg kg^{-1}	50.34	83.58	113.39	292.28	68.43
Ni	mg kg^{-1}	0.70	1.10	0.77	1.13	0.27
Cd	mg kg^{-1}	0.11	0.12	0.12	0.12	0.10
Pb	mg kg^{-1}	37.61	32.48	8.55	44.44	3.42
Cr	mg kg^{-1}	6.22	4.22	3.82	6.83	0.60
C/N ratio	.....	63.55	7.66	7.20	8.42	11.92

[a]Based on dry mass; [b]In H2O (ratio 1:2.5); DSS - Treated dairy industry sewage sludge; USS - Treated urban sewage sludge; PS - Petrochemical complex sludge; PMS - Treated pulp mill sludge and FPW - Organic compost from the fruit pulp industry.

Incubation experiment

A 91 days incubation experiment was conducted aiming to evaluate soil chemical changes and measure N mineralization of five wastes at application rates of 27.0 (PMS), 22.2 (PS), 3.0 (USS), 5.2 (DSS) and 5.2 (FPW) Mg ha^{-1} dry weight (defined based on the supply of 100 kg N ha^{-1} calculated based in the N- Kjeldahl), associated or not with organic compost enriched with effective microorganisms (EM-4) called Fermented Bokashi Compost (FBC) at an application rate of 1.5 Mg ha^{-1} (MOKITI OKADA FUNDATION, 1998). The FBC chemical analysis results were pH $_{(H2O)}$ 7.6, total N, P, K, Ca and Mg; 12.0, 4.5, 5.8, 20.5, 2.9 mg kg^{-1}, respectively.

Treatments consisted of 150 g dry weight of sieved soil samples placed in small plastic cups. Organic wastes were mixed added to soils at desired application rates, mixed vigorously for 2 min. to ensure uniformity within and between samples, and deionized water was added to moisten soils to 70% of field capacity.

Cups were then placed in a BOD incubator in the absence of light, at controlled temperature (25 ± 0.20°C) and humidity maintained close to 70% of field capacity. The moisture content was checked every two days by weighing and adjusted with deionized water. The experimental units were evaluated at 0, 7, 42, 70 and 91 days after hatching, with three replications. The chemical soil analysis was performed after the last day of incubation.

Measurements of net nitrogen mineralization

The mineral N (NH_4^+ and NO_2^- + NO_3^-) and some chemical attributes were determined immediately after assembly treatment (time 0).

The following equations were used to estimate (a) Net Nitrogen mineralization (NNm) and (b) Net Nitrogen mineralization accumulated (Nma), which represents the amount of organic N of the wastes that were mineralized and the sum for all dates:

$$NNm = ((Nres2 - Nres1) - (Nt2 - Nt1) / Nad) * 100 \quad (a)$$

$$Nma = \text{date } 0\ (NNm) + \text{date } 1\ (NNm) + + \text{date } n\ (NNm) \quad (b)$$

where: NNm (%) corresponds to N mineralization; Nres1 and Nres2 (mg 100 g^{-1}) quantities of soil mineral N in the treatments with organic waste at the beginning and end of each evaluation interval, respectively; Nt1 and Nt2 (mg 100 g^{-1}) quantities of soil mineral N in control (Blank soil) at the beginning and end of each evaluation interval, respectively, Nad (mg 100 g^{-1}) organic N added by waste; Nma (%) corresponds to accumulated N mineralization and date is the time interval between incubation followed analysis.

Analysis of data

Treatments and time effects data were analyzed as a completely randomized design in a factorial 6 x 2 x 5, being five organic wastes incorporated into the soil plus control, with or without FBC, evaluated at 0, 7, 42, 70 and 91 days of incubation and soil data were evaluated at initial and final time of incubation, with three replicates, under laboratory conditions. All data were analyzed using analysis of variance (ANOVA) in the SAS program (SAS, 2004). When differences between treatments were significant, means were compared by Tukey test at the 0.01 probability level.

Results and discussion

Chemical properties of soil

Comparison of means showed that chemical attributes of the soil were affected by organic waste treatments compared to control (Table 3). The soil chemical characterization initially showed that soil presented a higher acid pH and lower P, K, Ca, Mg, Al and organic matter concentrations (TOMÉ JÚNIOR, 1997). The FBC added to the wastes affected soil chemical attributes. After 91 days of incubation, the PMS, PS and DSS treatments in the presence or not of FCB, increased the soil pH. The initial treatment of these wastes basically consists of a biological process with limestone or lime ($CaCO_3$ or CaO) addition to eliminate pathogens and promote organic waste stabilization, so that carbonate reacts with hydrogen ions present in soil solution (liquid phase of the soil) to form water and CO_2 molecules, in addition to increasing Ca and Mg concentrations and P availability (Table 3).

The USS and FPW treatments did not present significant pH changes, mainly due to their chemical characteristics (Table 2). The pH in the treatments did not change statistically in the presence of FBC or not. Moreira and Fageria (2010) studying alfalfa (*Medicago sativa L.*) under tropical conditions, affirm that optimum acidity indices for maximum dry matter yield were pH 5.4, base saturation 57%, Ca saturation 40%, and Mg saturation 24%. Therefore, to waste application rates, an initial study of soil pH neutralization power and Ca and Mg saturation index should be performed to soil system analysis. Soil pH ranged between 4.10 and 7.6, where 4.10 and 4.27 (USS and FPW) didn't differ of pH of control (blank soil) with FBC and without FBC ranged between 4.30 and 6.44, where 4.30 (FPW) didn't differ of pH of control (Table 3). However, when the results of both blank soil pH were compared, no significant difference was observed with FCB, as reported by Zydlik and Zydlik (2008). Moreover, concentrations of Ca and Mg are very important in the analysis to ensure complete neutralization of exchangeable Al in the soil. How was observed to PMS, PS and DSS.

The average concentrations of available P in PMS, PS, USS, DSS and FPW treatments with FCB were 2.25, 6.6, 4.55, 4.25 and 2.75 times higher than the control, respectively, and without FCB they were 4.28, 12.85, 4.35, 6.9 and 3.03 times higher, respectively (Table 3). However, in the presence of FCB the concentrations of P available follow the decreasing order; PS > DSS = USS > PMS = FPW > control and quantities of P available in the absence of FCB were observed in the following decreasing order: PS > DSS > PMS = USS = FPW > control (Table 3).

The differences between initial concentration of P in USS and the difference between P available found in USS treatment with FBC and without FBC are associated with the pH in the solution. They occurred because some microorganisms present in Fermented Bokashi Compost are more adaptable to acid conditions than native microbes resulting in higher degradation and P available in the soil (SHEN et al., 2011).

Table 3. Chemical characteristics changes of soil treated with organic wastes from different sources (based on dry mass) mixed or not with Fermented Bokashi Compost after incubation for 91 days.

Attribute	pH[b]	P	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	Na^+	H+Al[c]	SOM[d]
Unit	.....	mg dm^{-3}				cmol$_c$ dm^{-3}			g kg^{-1}
With Fermented Bokashi Compost									
Blank soil	4.23[a] cA	6.67 dA	0.063 bA	0.30 cB	0.30 abA	0.53 aA	0.020 bA	2.75 aA	6.55 abA
PMS	7.60 aA	15.00 cA	0.057 bA	3.00 aB	0.20 bA	0.0 cA	0.043 aB	0.0 cA	8.97 aA
PS	6.00 bA	44.00 aB	0.057 bA	2.00 bA	0.30 abA	0.0 cA	0.030 bA	0.88 bA	7.07 abB
USS	4.10 cA	30.33 bA	0.060 bA	0.47 cA	0.33 aA	0.50 abA	0.023 bA	2.31 aA	7.04 abB
DSS	6.10 abA	28.33 bA	0.060 bA	2.23 bA	0.30 abA	0.0 cA	0.030 bA	0.81 bA	6.35 cB
FPW	4.27 cA	18.33 cA	0.090 aA	0.33 cA	0.30 abA	0.40 bA	0.023 bA	2.27 aA	7.42 bA
Without Fermented Bokashi Compost									
Blank soil	4.28 bA	4.30 cA	0.042 bB	0.33 cA	0.22 bcA	0.43 aB	0.014 bA	2.60 aA	5.45 cB
PMS	6.40 aA	18.41 bcA	0.041 bA	3.45 aA	0.17 cA	0.0 bA	0.061 aA	0.08 cA	7.77 bB
PS	6.44 aA	55.24 aA	0.042 bA	2.14 bA	0.30 bA	0.0 bA	0.022 bB	1.11 bA	7.95 abA
USS	4.69 abA	18.70 bcB	0.051 abA	0.54 cA	0.41 aA	0.44 aB	0.021 bA	2.85 aA	8.71 aA
DSS	5.55 abA	29.67 abA	0.041 bB	2.25 bA	0.21 bcA	0.0 bA	0.027 bA	0.92 bcA	7.68 bA
FPW	4.30 bA	13.03 bcB	0.066 aB	0.38 cA	0.33 abA	0.41 aA	0.018 bA	2.65 aA	7.80 bA
C.V.[e] (%)	10.98	36.63	22.45	34.53	15.39	31.28	18.66	27.80	11.52

[a]Mean values followed by the same lower letter do not differ between wastes and by the same capital letter do not differ between with or without Fermented Bokashi Compost within the same waste (Tukey test, $p < 0.01$); [b]In H2O (1:2.5); [c]Exchangeable acidity; [d]Soil organic matter; [e]Coefficient of variation; DSS - Treated dairy industry sewage sludge; USS - Treated urban sewage sludge; PS - Petrochemical complex sludge; PMS - Treated pulp mill sludge and FPW - Organic compost from the fruit pulp industry.

The soil K contents in soil treated with wastes increased in lowest proportion on both dates, FPW treatment being the highest concentration found, however K concentrations still remained low (TOMÉ JÚNIOR, 1997). In order to use organic wastes with successfully in agriculture will be necessary to apply K fertilizer or another element source (MELO; MARQUES, 2000).

The Na concentration in the FCB presence or not, increased only in PMS treatment (Table 3). The exchangeable acidity was relatively higher in the control (blank soil), USS and FPW treatments. As discussed previously, it was related to reduced pH capacity. Most Oxisols in Brazil are acidic and present low fertility (FAGERIA; BALIGAR, 2008). Theoretically, soil acidity is quantified on the basis of pH and Al^{3+} concentrations in soils (MOREIRA; FAGERIA, 2010).

The SOM degradation in the treatments was closely related to the C/N ratio, organic carbon quality (labile fractions) and quantity of each organic waste added to soil. Schenck zu Schweinsberg-Mickan and Müller (2009) found same behavior working with different EM and organic composts. Reductions in soil organic matter were observed using treatments PS, USS and DSS in the presence of FCB, compared to without FCB.

The C/N ratio of these treatments is lower and their organic fractions may be more labile and thus easier for the microorganisms to take up. Further, according to Zydlik and Zydlik (2008) the EM accelerates organic matter degradation.

The control and PMS treatments were better without FCB; this may occur because there are less or not specialized microorganisms, resulting in a higher quantity of available nitrogen and lower nitrogen competition by native microorganisms to degradation of the high quantity of carbon. In the FPW treatment no statistical differences with or without FCB were observed. Possibly, this occurred because FPW is an organic waste composted in piles for three years and it may have higher concentrations of stable or humified organic matter.

Net nitrogen mineralization

As expected, the organic wastes added to soil led to differences in net mineral nitrogen contents and reflected differences in the quality of the materials. The application of organic wastes increase net mineral nitrogen significantly ($p < 0.01$) over control and Fermented Bokashi Compost (FBC) accelerated the mineralization of nitrogen making available in the mineral form an higher amount of N in the first 7 days of incubation, coming to be higher without FBC, only 70 days after start incubation (Table 4). However, observed that the mineralization of nitrogen in the soil was highly enhanced when the organic waste was amended with FCB. Aryal et al. (2003) reported that performance of organic materials and effective microorganisms present in FCB was not as expected when they were applied alone.

When FCB was applied with PMS, a decrease of 5.71 times in net nitrogen quantity was recorded as compared to nitrogen quantity found in the PMS without FCB after 7 days of incubation. This probably occurred because the high C/N ratio (Table 2) of this waste stimulated the microorganisms present in FCB together with native microorganisms to use the mineral nitrogen in waste degradation occurring a net immobilization during decomposition of the added organic waste in the treatment PMS with FCB. However, observed a better nitrogen mineralized distribution over time with FBC application (Table 4).

Table 4. Net nitrogen mineralized (NNm) of treatments with organic wastes from different sources (based on dry mass) with or without Fermented Bokashi Compost during incubation period.

	Period in days			
Treatment	7	42	70	91
(%)	With Fermented Bokashi Compost			
Blank soil[a]	0.96[b] cA	-0.30 cA	1.62 cA	-1.21 eB
PMS	-24.73 dB	2.34 bA	9.37 bB	21.95 aA
PS	24.30 bA	18.94 aA	7.99 bB	6.28 dA
USS	50.53 aA	-6.10 dB	-8.36 dB	9.24 cA
DSS	54.12 aA	-16.94 eB	21.13 aB	5.27 dA
FPW	24.52 bA	-14.55 eB	3.44 cB	13.45 bA
	Without Fermented Bokashi Compost			
Blank soil	-0.21 cA	0.38 cA	-0.72 eB	1.49 aA
PMS	-4.33 dA	-4.92 dB	31.08 cA	-27.09 dcB
PS	9.16 bB	-2.34 dB	56.24 aA	-29.32 dB
USS	-14.93 eB	41.87 aA	24.00 dA	-25.94 cB
DSS	12.43 aB	10.21 bA	34.89 bA	-11.34 bB
FPW	11.38 abB	2.70 cA	33.21 bcA	-27.83 cdB
C.V.[c]	17.11			

[a]Soil without wastes; [b]Mean values followed by the same lower letter do not differ significantly on the same date and followed by the same capital letter do not differ significantly with or without Fermented Bokashi Compost (Tukey test, $p < 0.01$); [c]Coefficient of variation; DSS - Treated dairy industry sewage sludge; USS - Treated urban sewage sludge; PS -Petrochemical complex sludge; PMS - Treated pulp mill sludge and FPW - Organic compost from the fruit pulp industry.

On the other hand, application of FCB in PS treatment resulted in a better distribution of mineral nitrogen on all dates, showing the degradation capacity of the microorganism present in FCB working together with native microorganisms (Table 4). It was expected because FCB is a mixture of different microorganisms. However, in the PS treatment without FBC, the mineral nitrogen mineralization occurred only at 7 and 70 days of incubation. In the DSS and USS treatments an increase was observed on all dates in the presence of FCB, except at 42 and 70 days of incubation. The increase in FPW treatments with FCB was observed at 7 and 91 days of incubation. The relatively low response of FPW to FCB, only responds well in the presence of sufficient labile organic matter. This compost was stabilized by three years in typical aerated fermentation piles and probably has a most recalcitrant carbon fraction or the lack of labile carbon components (SONG et al., 2011).

A preliminary field study at the University of Fort Hare did not detect a substantial contribution to crop yield by the recommended application of EM in combination with commercial compost (FATUNBI; NCUBE, 2009). This was attributed to the low quality C constituent in the compost used, which is typical of most matured compost. Composted organic wastes are low in soluble C and may not be able to effectively support proliferation of a decomposer community (FATUNBI; NCUBE, 2009).

Therefore, the net N mineralization and immobilization observed in these organic waste soils are in accordance with the common understanding of turnover of organic materials characterized by high and low C/N ratios (PALM et al., 2001; SENEVIRATNE, 2000).

The results do not agree with those reported by Schenck zu Schweinsberg-Mickan and Müller (2009). These authors detected no effect related to the addition of added living microorganisms (EM) in soil fertility and increased plant growth under a specific experimental condition, where authors related characteristics of the organic waste with time of incubation.

In Figure 1, observed that in the presence of FBC the net nitrogen mineralized accumulated (Nma) was higher after 7 days of incubation for all wastes, except PMS. However, were obtained without FBC high amounts of Nma only after 70 days of incubation (Figure 2).

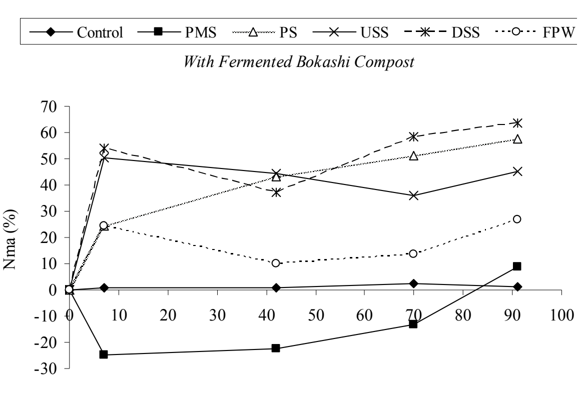

Figure 1. Net nitrogen mineralized accumulated (Nma) of treatments with organic wastes with Fermented Bokashi Compost during incubation period; DSS - Treated dairy industry sewage sludge; USS - Treated urban sewage sludge; PS - Petrochemical complex sludge; PMS - Treated pulp mill sludge and FPW - Organic compost from the fruit pulp industry.

This corroborates the hypothesis that FBC accelerates the nitrogen availability. Sahain et al. (2007) observed that Fermented Bokashi Compost called of biostimulant increased the values of soil elements as compared with the untreated soil. This treatment produced the highest significantly values of N, P, K, Fe, and Zn and while the control treatment was significantly the lowest values.

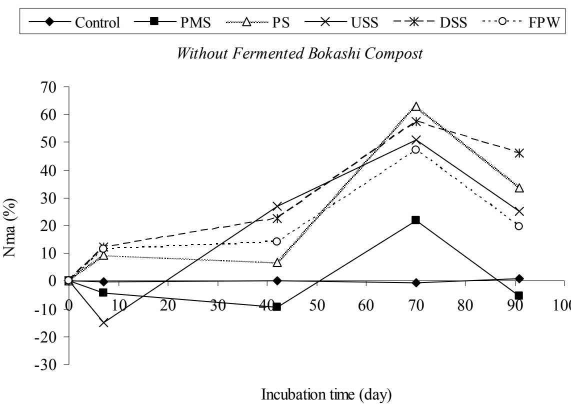

Figure 2. Net nitrogen mineralized accumulated (Nma) of treatments with organic wastes without Fermented Bokashi Compost during incubation period; DSS - Treated dairy industry sewage sludge; USS - Treated urban sewage sludge; PS - Petrochemical complex sludge; PMS - Treated pulp mill sludge and FPW - Organic compost from the fruit pulp industry.

Conclusion

The expectation that Fermented Bokashi Compost with 'effective microorganism' (EM-4) would increase and accelerate organic waste degradation was confirmed here. Positive effects of Bokashi on net N mineralization and soil fertility evolution could be identified as a combination with the organic waste quality effects. Possible suppressive effects of a higher C/N ratio in soil microbial biomass and activity are observed.

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References

ARAUJO, F. F. Disponibilização de fósforo, correção do solo, teores foliares e rendimento de milho após a incorporação de fosfatos e lodo de curtume natural e compostado. **Acta Scientiarum. Agronomy**, v. 33, n. 2, p. 355-360, 2011.

ARYAL, U. K.; XU, H. L.; FUJITA, M. Rhizobia and AM fungal inoculation improve growth and nutrient uptake of bean plants under organic fertilization. **Journal of Sustainable Agriculture**, v. 21, n. 3, p. 29-41, 2003.

BRADY, N. C.; WEIL, R. R. **The nature and properties of soils**. 13th ed. New Jersey: Prentice Hall, 2002.

BUENO, J. R. P.; BERTON, R. S.; SILVEIRA, A. P. D.; CHIBA, M. K.; ANDRADE, C. A.; DE MARIA, I. C. Chemical and microbiological attributes of an Oxisol treated with successive applications of sewage sludge. **Revista Brasileira de Ciência do Solo**, v. 35, n. 4, p. 1461-1470, 2011.

DE MARIA, I. C.; CHIBA, M. K.; COSTA, A.; BERTON, R. S. Sewage sludge application to agricultural land as soil physical conditioner. **Revista Brasileira de Ciência do Solo**, v. 34, n. 3, p. 967-974, 2010.

EMBRAPA-Empresa Brasileira de Pesquisa Agropecuária. **Manual de análises químicas de solos, plantas e fertilizantes**. Brasília: Embrapa, 1999.

EMBRAPA-Empresa Brasileira de Pesquisa Agropecuária. **Sistema brasileiro de classificação de solos**. Brasília: Embrapa Produção de informação; Rio de Janeiro: Embrapa Solos, 2006.

FAGERIA, N. K.; BALIGAR, V. C. Ameliorating soil acidity of tropical Oxisols by liming for sustainable crop production. **Advances in Agronomy**, v. 99, p. 345-431, 2008.

FATUNBI, A. O.; NCUBE, L. Activities of effective microorganism (EM) on the nutrient dynamics of different organic materials applied to soil. **American-Eurasian Journal of Agronomy**, v. 2, n. 1, p. 26-35, 2009.

HIGA, T. **Revolution to save the earth**: with Effective Microorganisms (EM) to solve the problems of our world. Kevelaer: OLV (Organic Farming Verlag), 2002.

KHALIQ, A.; ABBASI, M. K.; HUSSAIN, T. Effects of integrated use of organic and inorganic nutrient sources with effective microorganisms (EM) on seed cotton yield in Pakistan. **Bioresource Technology**, v. 97, n. 8, p. 967-972, 2006.

KYAN, T.; SHINTANI, M.; KANDA, S.; SAKURAI, M.; OHASHI, H.; FUJISAWA, A.; PONGDIT, S. **Kyusei nature farming and the technology of effective microorganisms, guidelines for practical use**. Bangkok: APNAN; Atami; INFRC, 1999.

MAYER, J.; SCHEID, S.; WIDMER, F.; FLIEßBACH, A.; OBERHOLZER, H. How effective are 'Effective microorganisms® (EM)'? Results from a field study in temperate climate. **Applied Soil Ecology**, v. 46, n. 2, p. 230-239, 2010.

MELO, W. J.; MARQUES, M. O. Potencial do lodo de esgoto como fonte de nutrientes para as plantas. In: BETTIOL, W.; CAMARGO, O. A. (Ed.). **Impacto ambiental do uso agrícola do lodo de esgoto**. Jaguariúna: Embrapa Meio Ambiente, 2000. p. 45-67.

MOKITI OKADA FOUNDATION. **Microorganismos efetivos (EM) na agricultura**. São Paulo: Mokiti Okada Foundation, 1998.

MOREIRA, A.; FAGERIA, N. K. Liming influence on soil chemical properties, nutritional status and yield of alfalfa grown in acid soil. **Revista Brasileira de Ciência do Solo**, v. 34, n. 4, p. 1231-1239, 2010.

OKORSKI, A.; MAJCHRZAK, B. Fungi isolated from soil before the seeding and after harvest of pea (*Pisum sativum* L.) after application of bio-control product EM. **Acta Agrobotanica**, v. 60, n. 1, p. 113-121, 2007.

OKORSKI, A.; OLSZEWSKI, J.; PSZCZOKOWSKA, A.; KULIK, T. Effect of fungal infection and the application of the biological agent EM 1 on the rate of photosynthesis and transpiration in pea (*Pisum sativum* L.) leaves. **Polish Journal of Natural Sciences**, v. 23, n. 1, p. 35-47, 2008.

PALM, C. A.; GACHEGO, C.; DELVE, R.; CADISCH, G.; GILLER, K. E. Organic inputs for soil fertility management in tropical agroecosystems: Application of an organic resource database. **Agriculture, Ecosystems and Environment**, v. 83, n. 1-2, p. 27-42, 2001.

PIGOZZO, A. T. J.; LENZI, E.; LUCA JÚNIOR, J.; SCAPIM, C. A.; VIDIGAL FILHO, P. S.; COSTA, A. C. S. Reação do solo e disponibilidade de micronutrientes, em solo de textura média, tratado com lodo de esgoto e cultivado com milho. **Acta Scientiarum. Agronomy**, v. 30, n. 4, p. 569-579, 2008.

SAHAIN, M. F. M.; EL-MOTTY, E. Z. A.; EL-SHIEKH, M. H.; HAGAGG, L. F. Effect of some biostimulant on growth and fruiting of Anna apple trees in newly reclaimed areas. **Research Journal of Agriculture and Biological Sciences**, v. 3, n. 5, p. 422-429, 2007.

SAS-Statistical Analisys System. **SAS® 9.1.2 qualification tools user's guide**. Cary: SAS Institute, 2004.

SCHENCK ZU SCHWEINSBERG-MICKAN, M.; MÜLLER, T. Impact of effective microorganisms and other biofertilizers on soil microbial characteristics, organic-matter decomposition, and plant growth. **Journal of Plant Nutrition and Soil Science**, v. 172, n. 5, p. 704-712, 2009.

SENEVIRATNE, G. Litter quality and nitrogen release in tropical agriculture: a synthesis. **Biology and Fertility of Soils**, v. 31, n. 1, p. 60-64, 2000.

SHEN, J.; YUAN, L.; ZHANG, J.; LI, H.; BAI, Z.; CHEN, X.; ZHANG, W.; ZHANG, F. Phosphorus Dynamics: From Soil to Plant. **Plant Physiology**, v. 156, n. 3, p. 997-1005, 2011.

SONG, M.; JIANG, J.; XU, X.; SHI, P. Correlation between CO_2 efflux and net nitrogen mineralization and its response to external C or N supply in an alpine meadow soil. **Pedosphere**, v. 21, n. 5, p. 666-675, 2011.

TEDESCO, M. J.; GIANELLO, C.; BISSAN, C. A.; BOHNEN, H.; VOLKWEISS, S. J. **Análise de solo, plantas e outros materiais**. Porto Alegre: UFRGS, 1995.

TOMÉ JÚNIOR, J. B. **Manual para interpretação de análise de solo**. Guaíba: Agropecuária, Brasil, 1997.

USDA-Unites States Department of Agriculture. **Soil taxonomy**. A basic system of soil classification for making and interpreting soil survey. Washington D.C.: Soil Survey Staff, 1999.

VAN VLIET, P. C. J.; BLOEM, J.; GOEDE, R. G. M. Microbial diversity, nitrogen loss and grass production after addition of effective micro-organisms® (EM) to slurry manure. **Applied Soil Ecology**, v. 32, n. 2, p. 188-198, 2006.

ZYDLIK P.; ZYDLIK Z. Impact of biological effective microorganisms (EM) preparations on some physic-chemical properties of soil and the vegetative growth of apple-tree rootstocks. **Nauka Przyroda Technologie**, v. 2, n. 1, p. 1-8, 2008.

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