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Mineralization and efficiency index of nitrogen in cattle manure fertilizers on the soil

Mineralização e índice de eficiência do nitrogênio de fertilizantes de esterco bovino no solo

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ABSTRACT

This research aimed to evaluate the mineralization of nitrogen (N) and to define the efficiency index (EI) of N after the addition of organic fertilizers based on cattle manure on the soil under laboratory conditions. A completely randomized statistical design with four replicates was used. The treatments were set as follows: T1) Soil (control); T2) Soil + vermicompost of cattle manure (CMV); T3) Soil + cattle manure and straw compost (CMS); and T4) Soil + cattle manure (CM). Experimental units were constituted by acrylic flasks with 5 x 5cm (height x diameter). Each flask was added with 135g of wet soil and 2.20, 2.45 and 2.27g of CMV, CMS and CM, respectively. Treatments were incubated at 25°C and the amount of mineral N from the soil (N-NH_4^+ and N-NO_2^- + N-NO_3^-) was determined at the beginning of the experiment and after 7, 14, 28, 56 and 112 days of incubation. The highest concentration of N-NO_2^- + N-NO_3^- in the soil were observed within the CMS treatment. The EI of N was of 27, 23 and 22% for CMS, CMV and CM, respectively. The mineralization of N from organic fertilizers based on cattle manure occurs on its vast majority within the first 28 days after its addition to the soil. The EI of N from the organic fertilizers based of cattle manure was higher for CMS>CMV>CM and achieved only 80% of what expected for organic fertilizers derived from cattle manure.

Key words: *vermicompost, organic fertilizer, cattle manure, composting.*

RESUMO

Este trabalho teve como objetivo avaliar em condição de laboratório a mineralização do nitrogênio (N) e determinar o índice de eficiência (EI) do N após adição de fertilizantes orgânicos a base de esterco bovino no solo. Foi utilizado o delineamento inteiramente casualizado com quatro repetições. Os tratamentos avaliados foram: T1) Solo (testemunha); T2) Solo + vermicomposto de esterco bovino (CMV); T3) Solo + composto de palha e esterco bovino (CMS); e T4) Solo + esterco bovino (CM). As unidades experimentais foram frascos de acrílico com 5cm de altura e 5cm de diâmetro. Em cada frasco, foram adicionados 135g de solo úmido e 2,20, 2,45 e 2,27g de CMV, CMS e CM, respectivamente. Os tratamentos foram acondicionados em incubadora a 25°C e os teores de N mineral do solo (N-NH_4^+ e N-NO_2^- + N-NO_3^-) foram determinados na data de instalação, aos 7, 14, 28, 56 e 112 dias de incubação. Os maiores teores de N-NO_2^- + N-NO_3^- no solo foram observados no tratamento CMS. O EI do N foi de 27, 23 e 22% para CMS, CM e CMV, respectivamente. A mineralização do N dos fertilizantes orgânicos a base do esterco bovino ocorre em sua grande maioria nos primeiros 28 dias após sua adição ao solo. O EI do N dos fertilizantes orgânicos a base de esterco bovino foi maior para CMS>CMV>CM e atingem apenas 80% do esperado para fertilizantes orgânicos oriundos de esterco bovino.

Palavras-chave: *vermicomposto, adubos orgânicos, dejetos bovinos, compostagem.*

INTRODUCTION

The raise of the Brazilian *per capita* income and the opening of new external markets resulted in an increasing demand for animal origin foodstuff. In order to supply such demand an intensive production of animals in confinement is required, thus resulting in a high production of animal wastes

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(CAMPOS et al., 2003; ASSENHEIMER, 2007). Commonly, these wastes are applied directly into the soil without treatment, as a disposal and source of nutrients for the plants. This may lead to a reduced agronomical efficiency and environmental problems (LUNA et al., 2009). To promote the adequate use of such residues an adequate treatment is recommended before its addition to the soil, with the aim of making them sanitary inactive and biologically stable. Among the treatment procedures for organic residues, composting and vermicomposting are outstanding, once they reduce the volume of residues, contamination potential (DOMÍNGUEZ & GÓMEZ-BRANDÓN, 2010) and concentrate nutrients into the resulting compost (DORES-SILVA et al., 2013).

Composting is a controlled process of aerobic microbial degradation (INÁCIO & MILLER, 2009), while in vermicomposting the degradation proceeds with the aid of earthworms that accelerate organic material's degradation (AMORIN et al., 2005; DOMÍNGUEZ & GÓMEZ-BRANDÓN, 2010). After composting or vermicomposting the resulting material is used as a source of nutrients for plants as well as physical improving, chemical and biological quality of the soil (KIEHL, 1985). Unlike mineral fertilizers, the majority of nutrients contained in fertilizers from organic origin, among them nitrogen (N), are not readily available for plants. Thus, they need to be mineralized by the action of microorganisms, in order to become available for absorption by plant roots. Moreover, at this point they become more susceptible to lixiviation or vaporization. In this manner, it is essential to know and understand the dynamics of the N mineralization in the soil and the efficiency index (EI) of the N from organic fertilizers, in order to make feasible to establish agronomic recommendations concerning the correct dosages and period of adhibition (MELO et al., 2008). In this manner, it will be possible to increase the absorption efficiency of N by plants and decrease the environmental impacts related with N.

The efficiency index (EI) expresses the percentage of mineralized N compared with the total quantity of N added to the soil by organic fertilizers. Currently, to calculate the quantity of organic fertilizers to be applied, N concentration and EI are used as parameter. The chapter entitled "Organic Fertilization" from the "Fertilization and Liming Manual", for the States of Rio Grande do Sul and Santa Catarina, in Brazil (CQFS RS-SC, 2004), was intended as a guidance for such practice and may be one of the publications that contributes and aggregates the most about this topic (FIOREZE et al., 2012). In this manual, recommendations are based in fixed coefficients, obtained from a still restricted number of studies focusing productivity and higher profits (GIACOMINI & AITA, 2006), that may result in under or super-estimation of dosages to be applied. Thus, the objective of his study was to evaluate the mineralization of N and to determine the EI of N after the addition of organic fertilizers based in cattle manure to the soil, under laboratory conditions.

MATERIALS AND METHODS

The present study comprehends an incubation experiment performed during 112 days at the Soil and Environmental Microbiology Laboratory from the Soil Department, at the Universidade Federal de Santa Maria (UFSM), RS – Brazil. The soil used for the incubation experiment was collected in an area of native grassland, without previous addition of fertilizers or liming, form a 0-10cm soil layer and was classified as a loamy red distrophyc soil (EMBRAPA, 2006), with the following characteristics: pH in water (1:1) = 5.8; SMP index = 6.6; Total N = 0.09mg kg^{-1}; $N\text{-}NH_4^+$ = 1.45mg kg^{-1}; $N\text{-}NO_2^-$ + $N\text{-}NO_3^-$ = 4.44mg kg^{-1}; Base Saturation = 70.5%; Organic Matter = 14g kg^{-1}; Clay = 130g dm^{-3}; P (Melich-1) = 37.0mg dm^{-3}; K (Melich-1) = 0.286mg dm^{-3}; H+Al = 2.2$cmol_c$ dm^{-3}; Ca = 3.8$cmol_c$ dm^{-3}; Mg = 1.2$cmol_c$ dm^{-3}. Soil was sifted in a 4mm mesh, homogenized and stored in plastic bags at 25ºC until the incubation started.

Cattle manure used in the organic fertilizer production was collected form beef cattle under feedlot conditions, where animal feces and urine were mixed. This material was designated as cattle manure (CM). The compost was produced by mixing CM and straw (natural field grass), submitted to a forced air composting system during 75 days. This fertilizer was designated as compost of straw and cattle manure (CMS). The vermicompost was produced by composting cattle manure with earthworms during 40 days. This fertilizer was designated as cattle manure vermicompost (CMV). Subsequently, all these fertilizers were dried at 65ºC and milled. The pH value, as well as C, N, P, K total contents and concentration of mineral N, $N\text{-}NH_4^+$ and $N\text{-}NO_2^-$ + $N\text{-}NO_3^-$ were determined according TEDESCO et al. (1995) (Table 1). The results were expressed as percentage of dry matter (DM).

The experiment was performed under a completely random statistical design with four replicates. The treatments consisted in: T1) Soil only (control); T2) Soil + CMV; T3) Soil + CMS; and T4)

Table 1 - Preliminary chemical characterization of the vermicompost of cattle manure (CMV), compost of cattle manure and straw (CMS) and cattle manure (CM).

Fertilizer	Total N[1]	NH_4^+	$NO_2^- + NO_3^-$	K	P	Total C	C/N	pH
	-----------	-----------	-----------% of DM	-----------	-----------	-----------		
CMV	1.97	0.01	0.18	1.45	1.65	22.8	11.5	8.3
CMS	1.99	0.02	0.17	2.01	1.97	23.2	11.6	7.0
CM	2.22	0.02	0.17	2.49	1.08	30.5	13.7	8.4

[1]N = Nitrogen; NH_4^+ = Ammonium; NO_2^- = Nitrite; NO_3^- = Nitrate; K = Potassium; P = Phosphorus; C = Carbon; C/N = C/N ratio; pH = Hydrogenionic potential; DM = Dry matter.

Soil + CM. Humidity of the soil and the mixtures were set to 80% of the field capacity. The experimental units were acrylic flasks with 5x5cm (height x diameter), with 110mL capacity. The quantity of organic fertilizer added to the acrylic flasks was of 2.20, 2.45 and 2.27g for treatments T2, T3 and T4, respectively, equivalent to the addition of 360mg of N kg^{-1} dry soil. Inside each acrylic flask, 135g of soil with a gravimetric humidity of 14.7% (equivalent to 117.8g of dried soil at 105°C) were loaded in two steps. In the first step, 67.5g of humid soil and half of the total quantity of the organic fertilizers were added and compressed to a level of 2.5cm in the acrylic flask. In the second step, the remaining soil and organic fertilizer were added and then compressed to a level of 5cm. Each flask was filled with only one of the organic fertilizers. In this manner, a density of 1.2g cm^{-3} was attained. Four acrylic flasks without cover within each treatment were introduced into glass containers with 2,000ml capacity and covered. Glass containers, hermetically closed, were placed inside an incubator chamber without illumination at a controlled temperature of 25±1ºC. Glass containers were open weekly during 10 minutes in order to avoid O_2 deficiency and to determine soil humidity by weighting the experimental units and, when the weight loss was higher than 0.5%, distilled water was added to the soil surface of the acrylic flasks.

Concentration of mineral N, that is, ammonium (N-NH_4^+) and nitrite (N-NO_2^-) + nitrate (N-NO_3^-) were evaluated within the soil of each experimental unit soon after the setting of the experimental treatments, time 0, as well as 7, 14, 28, 56 and 112 days after the incubation started. The mineral N was extracted by adding 25g of wet soil to a 100mL KCl 1mol L^{-1} and shaking during 30 minutes in a mechanical horizontal shaker. Then, the solution was set to rest for 30 minutes before an aliquot of 20mL of supernatant was collected, to determine the contents of N-NH_4^+ and N-NO_2^- + N-NO_3^- as described by TEDESCO et al. (1995). The results were expressed in mg of N kg^{-1} dry soil.

From the values of N-NH_4^+ and N-NO_2^- + N-NO_3^-, values for the mineral N (N_{min}) in the soil were obtained (Equation 1):

$$N_{min} = N\text{-}NH_4^+ + N\text{-}NO_2^- + N\text{-}NO_3^- \quad \text{(Equation 1)}$$

Then, with the values of N_{min} and N_{tot} (Total N in the soil = total quantity of N added via organic fertilizers + total N quantity naturally occurring in the soil of each treatment), the efficiency index (EI) for the different organic fertilizers was calculated (Equation 2):

$$IE\ (\%) = (N_{min}/N_{tot})*100 \quad \text{(Equation 2)}$$

The results underwent analysis of variance and the mean values form the treatments were compared by the Tukey test at 5% probability using the Software STATISTICA (version 9.0).

RESULTS AND DISCUSSION

Content of nutrients within the different organic fertilizers are showed in table 1. In a general manner, these results are similar to the ones obtained by HIGASHIKAWA et al. (2010) and SCHULZ et al. (2012). In our study, CM showed higher contents of total C and N, K and C/N ratio when compared with CMV and CMS. However, DORES-SILVA et al. (2013), when comparing the efficiency of composting and vermicomposting in the stabilization of organic residues, reported higher contents of N in the final compost. Probably the total N was reduced within CMV and CMS due to the N losses during the transformation processes of organic matter, in the form of gas as nitrous oxide (N_2O), elementary N (N_2) or due to volatilization of ammonia (NH_3) (SÖRENSEN, 2001).

The higher contents of available N-NH_4^+, especially in the CM treatment, were observed during the first 28 days of incubation (Figure 1a). There were no statistically significant differences among treatments CMS and CMV, except at 56 and 112

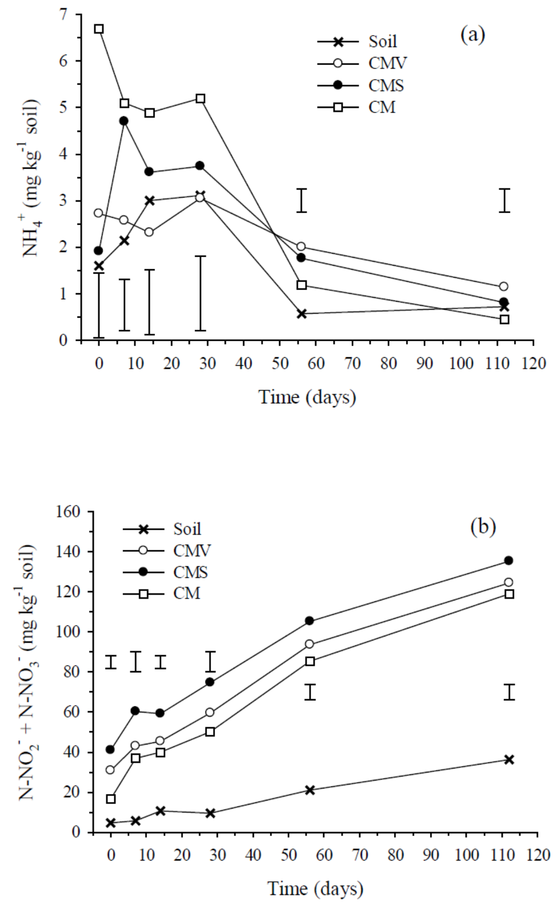

Figure 1 - Contents of $N\text{-}NH_4^+$ (a) and $N\text{-}NO_2^- + N\text{-}NO_3^-$ (b) in soil with the addition of organic fertilizers based on cattle manure. Control treatment (Soil), vermicompost of cattle manure (CMV), cattle manure and straw compost (CMS) and cattle manure (CM). Values shown represent the mean value from four replicates. Vertical bars represent the minimum significant difference between the mean value of each treatment in each evaluation date (Tukey, P<0.05).

days, when CMV showed higher contents of $N\text{-}NH_4^+$ than CMS. It is possible that such results are a consequence of the N contained in the most unstable organic fractions, being initially converted to $N\text{-}NH_4^+$ (ammonification). Normally, contents of $N\text{-}NH_4^+$ are higher in residues with greater contents of total N (MELO et al., 2008), and with lower degree of maturation (SANCHEZ-MONEDERO et al., 2001). Furthermore, the presence of urine mixed to the cattle feces may have contributed to the higher content of $N\text{-}NH_4^+$ in the CM treatment during the initial period of incubation. The high concentration of $N\text{-}NH_4^+$ reported within the CM during such period, may restrict the use of this organic fertilizer, once it may inhibit seed germination or limit the development of plant roots, thus impairing plant development (VARNERO et al., 2007). Therefore, its addition as a fertilizer in the soil must be implemented at lower dosages than the recommended standard or applied with antecedence to sowing.

During the period between 28 and 112 days a reduction in the contents of $N\text{-}NH_4^+$ in the soil was observed (Figure 1a), accompanied by the increase in contents of $N\text{-}NO_3^-$ (Figure 1b), because of the ammoniac N oxidation from the nitrifying bacterial wastes (nitrification). There were no significant differences between treatments CMS and CMV, though CMS showed always-higher contents of $N\text{-}NO_2^- + N\text{-}NO_3^-$, statistically differing form CM for all the evaluation periods (Figure 1b). Contents of $N\text{-}NO_2^- + N\text{-}NO_3^-$ constituted the most representative form of mineralized N during the whole period of incubation. At 112 days, these forms of N represented as far as 98% (116mg N kg^{-1} of soil), 99% (134mg N kg^{-1} of soil) and 99% (118mg N kg^{-1} of soil) of the total mineral N ($N\text{-}NH_4^+$ e $N\text{-}NO_2^- + N\text{-}NO_3^-$) on treatments CMV, CMS and CM, respectively. According to SCHULZ et al. (2012), the higher mineralization of $N\text{-}NO_2^-$ and $N\text{-}NO_3^-$ in the beginning of the development cycle of a crop, when the nutrient absorption capability of the plant is low, possibly leading to losses of this element in the soil.

The EI showed always positive and increasing values in the course of incubation of the fertilizers (Figure 2), demonstrating that there was dominance of the mineralization process over the

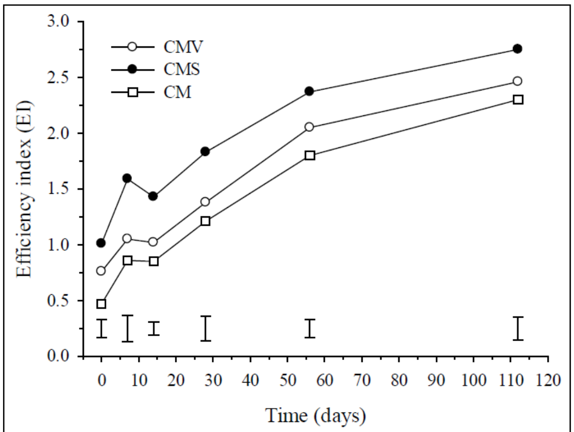

Figure 2 - Efficiency index (EI) of N from soil with the addition of organic fertilizers based on cattle manure. Control treatment (Soil), vermicompost of cattle manure (CMV), cattle manure and straw compost (CMS) and cattle manure (CM). Values shown represent the mean value from four replicates. Vertical bars represent the minimum significant difference between means of each treatment in each evaluation date (Tukey, P<0.05).

immobilization process, in all treatments during the incubation. It was also possible to observe that the longer the incubation period, higher was the content of mineralized N and consequently higher the EI (Equation 2). The higher efficiency indexes were reported in the soil that received the addition of CMS, statistically differing from CMV and CM in all dates evaluated. There were no significant differences of EI between CMV and CM. The EI was of 0.27 for CMS, 0.23 for CM and 0.22 for CMV at 112 days of incubation, all values lower to the value of 0.30 considered in the Fertilization and Liming Manual for the States of Rio Grande do Sul and Santa Catarina, Brazil (CQFS RS-SC, 2004), for fertilizers originated from cattle manure. Moreover, it is important to emphasize that the values of EI in the present study were obtained under laboratory conditions, that is, optimal conditions of humidity, temperature, granulometry and homogeneity of the mixture with the soil. These conditions propitiated to study the maximum potential of N mineralization from the organic fertilizers. However, these conditions are not typically reported in field environments, thus resulting in lower values of EI for the same organic fertilizers.

Conversely, we must consider that EI specified by the CQFS/RS-SC (2004) refers to a quantity of N made available during cropping, while in the present study mineralization was evaluated during a period of 112 days. Consequently, depending on the cycle of the species cultivated, the organic fertilizers may show higher or lower EI values. OLIVEIRA et al. (2012) when studying mineralization potential of N from 15 organic compounds during 28 days, among those some vermicompost, compost and cattle manure, observed EI values lower than 0.15. While studying EI form swine's liquid wastes and deep bedding poultry, FIOREZE et al. (2012) also reported lower values of EI than those preconized by the CQFS/RS-SC (2004) for those materials. The EI of swine liquid wastes varied from 0.26 to 0.41 and poultry deep bedding form 0.19 to 0.32 in 112 days of incubation, while the CQFS/RS-SC (2004) refers an EI of 0.8 for both organic fertilizers.

The utilization efficiency of these organic fertilizers, regarding the N supplying for the crops, will be higher as higher is the synchrony between the soil organic N mineralization process and the demand for mineral N by plants (KIEHL, 1985). Therefore, the utilization of N will be maximized when crop sowing is made as close as possible from the addition of such organic fertilizer to the soil, and when the crop has a long cycle, once the availability of N occurs slowly and continuously. However, additional studies must be carried out in order to enlarge the information sources concerning the potential of N releasing from organic fertilizers based on cattle manure and their EI for agricultural purposes, particularly, for its utilization in vegetables, where few information are available.

CONCLUSION

Mineralization of N from organic fertilizers based on cattle manure occurs mainly (0.5 or 50%) during the first 28 days after its addition to the soil.

The EI of the N from organic fertilizers based on cattle manure was higher in CMS>CMV>CM and reached only 80% of the expected value for organic fertilizers based on cattle manure.

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