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Research

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Agronomic efficiency of fermented composts in organic fertilization management of butterhead lettuce and green leaf lettuce

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ABSTRACT

This work aimed to evaluate the agronomic efficiency of fermented composts formulated with brewery waste (RC) with castor bean bran (FM) or *Gliricidia sepium* leaf bran (FG) in the fertilization of butterhead lettuce and green leaf lettuce grown in succession. The experimental design was in randomized blocks in a 2x5 factorial scheme, consisting of two fermented composts and five N doses (0, 50, 100, 200, and 400 kg/ha). The composts were formulated by combining 60 RC+40 FM and 60 RC+40 FG considering the % of dry matter after moisture correction. We verified that the phytotechnical performance of the butterhead lettuce, in relation to fertilization, is influenced by the applied dose; no difference regarding the composts was noticed, though. The doses of 272.2 and 248.71 kg/ha of N enabled the maximum yield of 78.01 and 87.79 t/ha, respectively, 60 RC+40 FM and 60 RC+40 FG. The fermented compost containing FM, in the range of the stipulated doses, showed a residual effect on the main phytotechnical traits of the green leaf lettuce, and the magnitude of the effect is directly proportional to the dose applied in the previous crop.

Keywords: *Lactuca sativa*, bokashi, organic farming.

RESUMO

Eficiência agronômica de compostos fermentados na fertilização de alfaces tipo americana e crespa em sistema orgânico

Objetivou-se avaliar a eficiência agronômica de compostos fermentados formulados com o resíduo de cervejaria (RC) conjugado ao farelo de mamona (FM) ou ao farelo de folhas de *Gliricidia sepium* (FG) na fertilização de alfaces do tipo americana e crespa cultivada na sucessão. O delineamento experimental foi em blocos casualizados em esquema fatorial 2x5, constando de dois compostos fermentados e cinco doses de N (0, 50, 100, 200 e 400 kg/ha). Os compostos foram formulados por meio da combinação de 60 RC+40 FM e 60 RC+40 FG considerando o percentual de matéria seca após a correção de umidade. Constatou-se que o desempenho fitotécnico da alface americana em função da fertilização é influenciado pela dose aplicada, todavia, não foram detectados efeitos diferenciados quanto aos compostos. As doses estimadas de 272,2 e 248,71 kg/ha de N possibilitaram o alcance máximo de produtividade de 78,01 e 87,79 t/ha, respectivamente, 60 RC+40 FM e 60 RC+40 FG. O composto fermentado contendo o FM, no intervalo das doses estipuladas, apresentou efeito residual nas principais características fitotécnicas da alface crespa, e a magnitude do efeito é diretamente proporcional à dose aplicada no cultivo antecessor.

Palavras-chave: *Lactuca sativa*, bokashi, agricultura orgânica.

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The fermented compost (bokashi) is widely used as a fertilizer source in vegetable production system, satisfactorily meeting the nutritional demand as it also has potential to improve physical (Olle, 2020) and biological (Hata *et al*., 2020) traits of the soil. Another relevant aspect is that it is simple and easy to be made, since it can be formulated and produced by farmers themselves under different technological levels (Aragão *et al*., 2020).

Therefore, the formulations are adapted according to the regional or local raw materials availability, to make its use in farmings easier (Oliveira *et al*., 2014). In Rio de Janeiro, wheat bran is commonly used as the main energy source, together with castor bean bran which has a high nitrogen content (Xavier *et al*., 2019). However, these inputs have high cost, which can be difficult to be used by the farmers, especially family-based ones. In addition, wheat bran, in Brazil, is a foreign commodity, which shows constant price fluctuations (Tomáz & Monteiro, 2023).

In this sense, in line with the concepts of circular economy, the use of abundant agro-industrial residues, with emphasis on malt bagasse as an energy source in formulations of fermented compounds, can be an alternative for farmers, mainly because it is a low-cost input commercialized on a large scale

(Tombini *et al*., 2021). Moreover, malt bagasse has higher nitrogen contents when compared with wheat bran, able to provide agronomic efficiency for vegetable fertilization (Pian, 2019).

The use of bran from the phytomass of fabaceous leaves produced *in situ* can be a viable alternative to replacing castor bean bran, notably tree species adapted to tropical environments such as gliricidia, which is easily propagated and produces high amounts of nutrient-rich phytomass, especially nitrogen (Chaves *et al*., 2022). Simultaneously, the use of fabaceous phytomass enhances ecological processes such as photosynthesis and the biological nitrogen fixation.

In Brazil, the most consumed vegetable is lettuce. Lettuce is grown by family farmers whose resources are limited in terms of investment in the crop. Considering the above, the use of agroindustrial or agricultural residues abundant in fermented compounds formulations can be an alternative to farmers concerning fertilization. Thus, the aim of this study was to evaluate the agronomical efficiency of the fermented composts formulated with brewery residue and castor bean bran or *Gliricidia sepium* leaf bran for fertilizing butterhead lettuce and green leaf lettuce in succession.

MATERIAL AND METHODS

The experiment was carried out from July to November 2019, at Fazendinha Agroecológica km 47, located in the municipality of Seropédica-RJ (22°46'S, 43°41'W, 33 m altitude). The soil was classified as Red Yellow Latosol (Santos *et al*., 2018), the chemical properties in the 0-20 cm layer were: pH = 6.3; Al^{+++}= 0.0 $cmol_c/dm^3$; Ca^{++}= 2.9 $cmol_c/dm^3$; Mg^{++}= 0.9 $cmol_c/dm^3$; K^+= 180 mg/dm^3; available P = 187 mg/dm^3, analyzed using the methodology proposed by Nogueira & Souza (2005).

The soil was plowed and harrowed, and the seedbeds were built up with the aid of a seedbed tiller. The experimental design was randomized blocks, in a factorial scheme 2x5, with four replicates, being the factor levels related to two fermented composts and five N doses (0, 50, 100, 200 and 400 kg/ha), considering the total N content in the respective composts (Table 1). The composts were formulated mixing 60% RC+40% FM and 60% RC+40% FG, considering the dry matter (%) after moisture correction in a forced ventilation oven at 65°C. Based on fixed doses of N, the authors estimated the total amount of the fermented composts applied and concentrations of P, K, Ca and Mg (Table 2). The composts were applied five days before the transplant, being uniformly distributed and incorporated into the superficial layer (0-5 cm) with the aid of a hoe.

Brewery residue and castor bean bran were obtained from the regional market. Glyricidia bran, tender branches and leaflets were collected from biomass production banks established at Fazendinha Agroecológica km 47. This material was dried, crushed and sieved through a 2 mm mesh. During preparation of the composts, the materials were manually mixed, homogeneously, in the respective proportions, moisturized and inoculated with an activated solution of the commercial product Embiotic®, containing, initially, 10^4 UFC/mL of *Lactobacillus plantarum* and 10^3 UFC/mL of *Saccharomyces cerevisiae*, respectively. To prepare the active solution, we used 50 mL of the commercial product, 50 g brown sugar and 400 mL water, packaged in a plastic bottle for seven days. The activated solution was diluted in water (1% v/v) during preparation of the compost. The solution was added into the mixtures in order to reach moisture contents ranging from 35 to 40%, verified by manual compression of a portion of the mixture

Table 1. Macronutrient contents and C/N ratio of the raw-materials and fermented composts used in fertilizing butterhead lettuce and green leaf lettuce. Seropédica, Fazendinha Agroecológica km 47, 2019.

Raw-material	N	P	K	Ca	Mg	C/N
			(g/kg)			Ratio
Brewery residue	54.6	5.3	0.4	3.8	1.2	7.70
Castor bean bran	70.8	8.1	10.2	6.2	5.0	5.90
Gliricidia bran	29.3	1.8	10.8	14.5	4.4	14.3
Fermented compost						
60% RC+40% FM	61.8	7.8	4.4	3.9	2.7	6.8
60% RC+40% FG	44.4	5.1	5.3	4.1	2.5	9.5

Table 2. Amounts of fermented composts used in the experiment (QACF) and nutrients for fertilizing butterhead lettuce and green leaf lettuce. Seropédica, Fazendinha Agroecológica km 47, 2019.

QACF	Applied nutrients				
	RC + FM				
	N	P	K	Ca	Mg
			(kg/ha)		
1618.12	100	12.62	7.11	6.31	4.36
3236.24	200	25.24	14.22	12.62	8.82
4854.36	300	37.86	21.33	18.93	13.08
6472.48	400	50.48	28.44	25.24	17.44
			RC + FG		
2252.25	100	11.48	11.94	9.23	5.63
4504.50	200	22.96	23.88	18.46	11.26
6756.75	300	34.44	35.82	27.69	16.89
9009.00	400	45.92	47.76	36.92	22.52

until obtaining a stable clod without crumbling or liquid runoff. The mixtures were packaged in 20 dm^3-capacity airtight plastic buckets, for a minimum period of 21 days.

The butterhead lettuce (cv. Angelina) was transplanted on July 29, 2019 into a 20 cm spacing between plants and 25 cm between rows in 1.0 x 1.0 m plots, totalizing 20 plants per plot. Plants were harvested at 45 days after transplant using six central plants as useful area, corresponding to an area of 0.3 m^2. After 10 days of the butterhead lettuce harvesting, the seedlings of the green leaf lettuce (cv. Vera) were transplanted. No new fertilization was carried out in order to enable the quantification of the residual effect of the application of fermented composts. The crop was cultivated in succession in the same spacing and sampling area of the first cycle, and the harvest took place 40 days after transplanting. Cultural practices were done during the experiment, spontaneous vegetation was controlled through manual weeding. Drip irrigation was performed using drip tapes, 20 cm spacing between valves and 1.6 L/hour water flow. For butterhead lettuce, we evaluated average head diameter, number of commercial leaves, leaf area, productivity and accumulated amounts of N, P, K, Ca and Mg in leaf tissues, according to the methods described by Nogueira & Souza (2005). In relation to green leaf lettuce, we evaluated productivity, leaf area and accumulated amounts of N, P, K, Ca and Mg. The obtained data were submitted to analyses of variance by F test, at 5% probability and regression analyses using Sisvar software (version 5.6) (Ferreira, 2019).

RESULTS AND DISCUSSION

We verified significant effects in relation to N doses for all the components of butterhead lettuce production, in which the quadratic polynomial model provided the best mathematical adjustment of the observed data (Figure 1). The fertilization using RC+FM compost provided the highest head diameter (18.25 cm) at the estimated dose of 340 kg/ha of N, whereas the highest diameter (15.64 cm) was observed when RC+FG compost was used at the estimated dose of 228 kg/ha of N. This demonstrates the potential of using shoot phytomass (gliricidia) in fermented compost formulations, as it allows to use a reduced quantity of the fertilizer, obtaining the maximum response when compared to the compost formulated with castor bean bran. The head diameters were similar to the ones reported by Souza *et al*. (2013) using mineral fertilization, proving the potential of fermented compost in fertilizing the butterhead lettuce.

For number of leaves, the maximum responses, 18.37 and 18.04, were obtained at estimated doses of 253.33 and 208.12 kg/ha of N, respectively, RC+FM and RC+FG. The described results were superior to the ones reported by Brzezinski *et al*. (2017) for the same cultivar using a N fertilizer (urea) in field conditions, in which the authors reported 16.58 leaves/plant. An increase in number of leaves in relation to the minimum dose was noticed, which is not in accordance with Oliveira *et al*. (2004), who reported that the number of leaves per plant shows little difference with fertilization since this is an inherent trait of the cultivar. For leaf area, the maximum responses, 3453 cm^2 and 3210 cm^2/plant, were achieved with the estimated doses of 232 and 229 kg/ha of N, respectively, RC+FM and RC+FG. The results for leaf area obtained by applying fermented composts allowed similar results to the ones reported by Zuffo *et al*. (2016) for Rafaela cultivar and superior to the ones reported by Pantano *et al*. (2015) for Angelina cultivar.

In relation to productivity, we verified that the maximum response to fertilization 78.01 t/ha, using RC+FM compost, was obtained with the estimated dose of 272.2 kg/ha of N, whereas RC+FG compost provided the maximum response to fertilization 87.79 t/ha with the estimated dose of 248.71 kg/ha of N. The productivities mentioned above, using the fermented composts, are superior to the ones reported by Yuri *et al*. (2017) for the same cultivar and other cultivars derived from this study. The butterhead lettuce

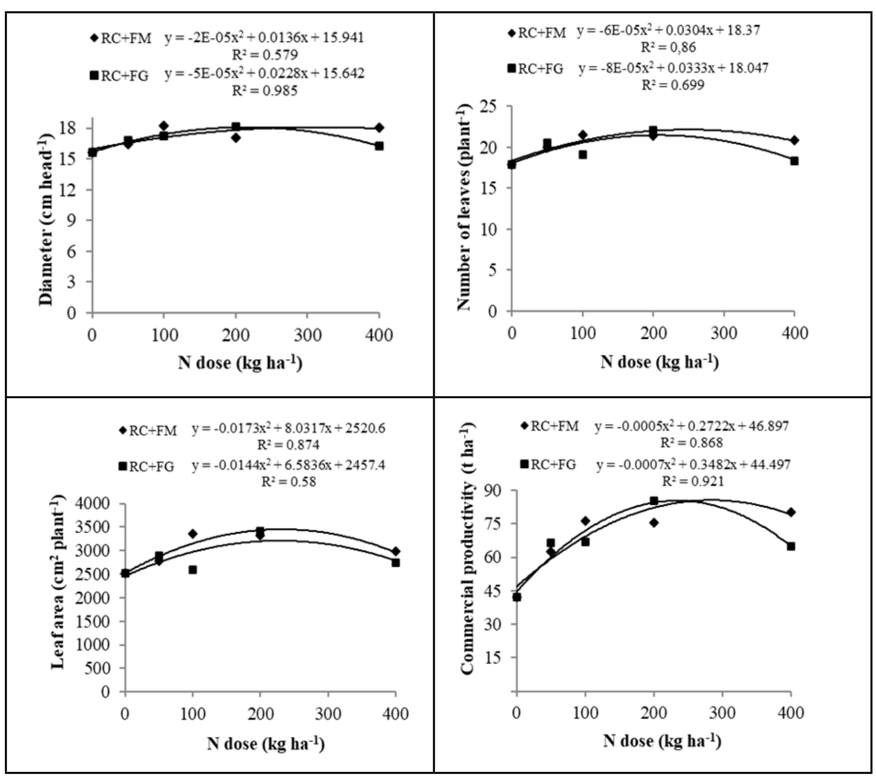

Figure 1. Diameter of heads, number of leaves, leaf area and productivity of butterhead lettuce submitted to fertilization with different doses of fermented composts. Seropédica, Fazendinha Agroecológica km 47, 2019.

reached the maximum productivity using RC+FG compost at lower dose when compared with RC+FM compost. This can be justified by a greater potassium supply in the presence of fabaceae phytomass as observed in Table 2, considering that, this nutrient is required in greater amounts by different lettuce cultivars (Grangeiro *et al*., 2006; Petrazzini *et al*., 2014). This fact was also shown by Lobo & Grassi Filho (2023) in four consecutive cycles of butterhead lettuce.

The accumulation rates of N, P, K, Ca and Mg adjusted to the quadratic polynomial model for the two evaluated composts (Figure 2). RC+FM compost provided a greater response to N accumulation at the estimated dose of 343 kg/ha of N where the accumulation was 167 kg/ha, whereas RC+FG compost showed a greater response at the estimated dose of 292 kg/ha of N, accumulating 160 kg/ha of the nutrient. We highlight that N is the second nutrient most extracted by the crop, being responsible by the highest plant development and, consequently, an increase in crop productivity (Filgueira, 2012; Sediyama *et al*., 2016). Moreover, when N is supplied in appropriate doses, it promotes the expansion of the active photosynthetic area, in addition to providing more commercially attractive colored leaves (Nascimento *et al*., 2017).

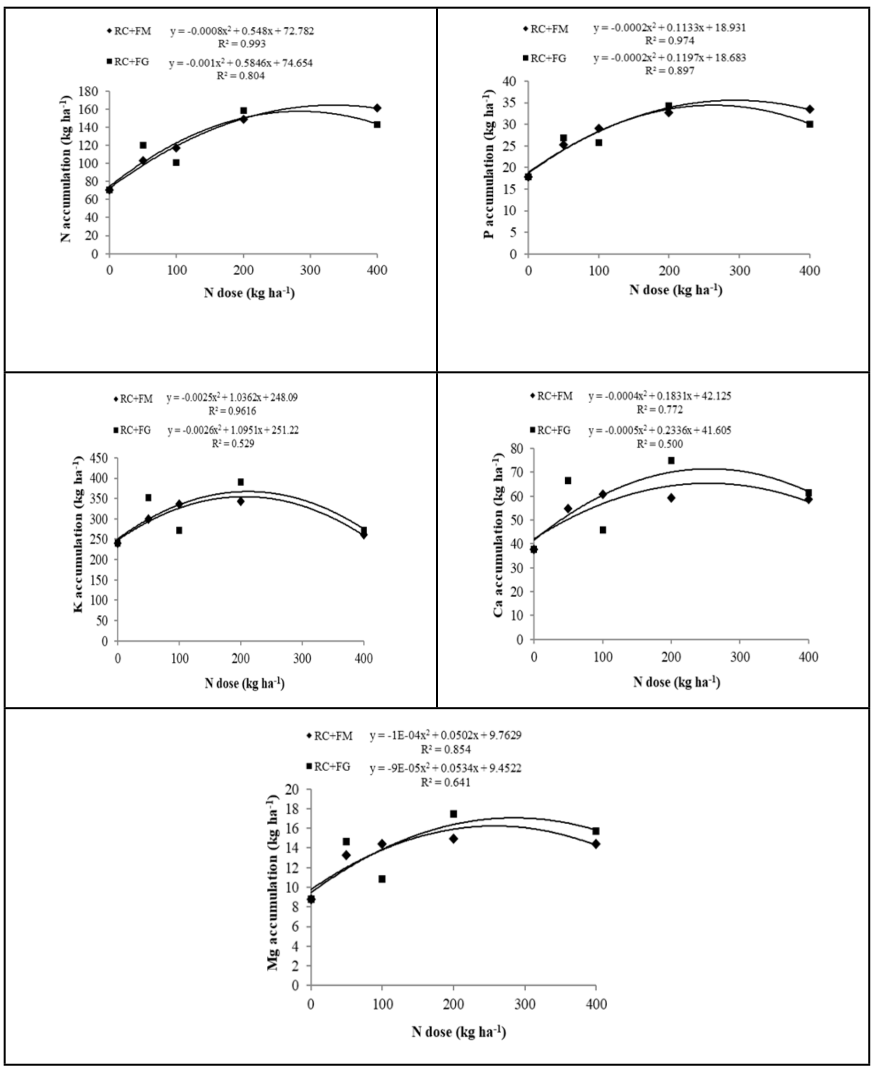

Figure 2. Amounts of N, P, K, Ca and Mg accumulation in the shoot phytomass of butterhead lettuce submitted to fertilization with different doses of fermented composts. Seropédica, Fazendinha Agroecológica km 47, 2019

In relation to P accumulation rate, RC+FM compost provided the maximum response at the estimated dose of 283 kg/ha of N, resulting in an accumulation of 35 kg/ha of P and, for RC+FG compost, the maximum response was obtained at the estimated dose of 299 kg/ha of N accumulating 37 kg/ha of P. For both composts, the amount of P accumulation was superior than the ones found by Sediyama *et al*. (2016) for Kaiser cultivar, fertilized with different organic composts. In relation to accumulated amounts of K, RC+FM compost provided the maximum response at the estimated dose of 207 kg/ha of N, an accumulation of 355 kg/ha of K. In relation to RC+FG compost, the maximum response was obtained at the estimated dose of 211 kg/ha of N, and an accumulation of 367 kg/ha of the nutrient.

The amounts of Ca and Mg accumulated in the shoot biomass of butterhead lettuce when fertilized with RC+FM compost, respectively, at the estimated doses of 229 and 251 kg/ha of N, were 63 and 16 kg/ha. On the other hand, in the presence of RC+FG compost, the maximum responses obtained at estimated doses of 234 kg/ha of N accumulating 69 kg/ha of Ca, and 297 kg/ha of N with accumulated amounted of 17 kg/ha of Ca.

In relation to green leaf lettuce grown in succession, the authors noticed no significant interaction regarding to fertilization in any evaluated phytotechnical variable (Figure 3). For dose, the residual effect of fertilizer with RC+FM compost was adjusted to the increasing linear model and provided productivities of fresh mass ranging from 18 to 29 t/ha, which did not differ between each other, and the same was observed for leaf area. Thus, the residual effect of the compost was not enough to achieve the maximum productive potential of the crop. Despite this, the productivity of lettuce obtained with residual fertilization was similar to that reported by Goulart *et al*. (2018), 27 t/ha, evaluating different cultivars submitted to fertilization with fermented compost and cattle manure. Martins *et al*. (2013), using the compost of distillery and castor bean cake, obtained a commercial productivity index of 25 t/ha.

In relation to N, P, Ca and Mg accumulation, in the green leaf lettuce shoot area, no significant interaction related to fertilization was observed (Figure 4). For RC+FG compost, no statistical differences were observed among the doses used in the amounts of nutrient accumulation in the shoot phytomass of the crop, with no mathematical adjustment for the evaluated variables. For RC+FM compost, the authors obtained one adjustment in the increasing linear model in relation to N, P, Ca and Mg accumulation; for K, no mathematical adjustment was noticed, though.

Only RC+FM compost provided some residual effect, however, it was not sufficient to meet completely the nutritional demands of the green leaf lettuce in the second cycle. Oliveira (2015), evaluating the residual effect of fermented composts prepared with castor bean bran and gliricidia in arugula crop, pointed out the absence of apparent effects in the second cycle; the author also highlighted that the amount of N application and the requirements of the evaluated crops influence this effect. Considering the mentioned above, Resende *et al*. (2007) highlighted the importance of crop succession in organic farming systems, recommending growing leaf vegetables which are able to be grown repeatedly (in rotation) on the same land without organic fertilizer replacement.

The authors concluded that the phytotechnical performance of the butterhead lettuce in relation to fertilization is influenced by the dose applied, however, no differentiated effects of the applied composts were observed. The doses 272.2 and 248.71 kg/ha of N allowed the crop to reach the maximum productivity, 78.01 and 87.79 t/ha, respectively, 60 RC+40 FM and 60 RC+40 FG. The fermented compost with FM, within the range of stipulated doses, showed a residual effect on the main phytotechnical traits of the green leaf lettuce; the magnitude of the effect is directly proportional to the applied dose used in the previous crop.

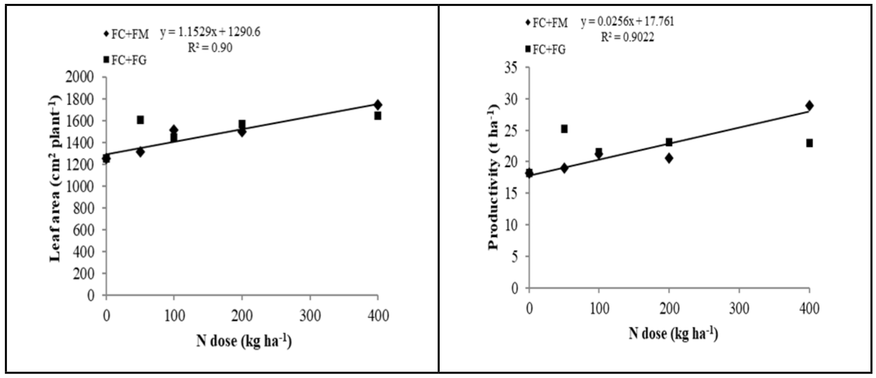

Figure 3. Leaf area and fresh productivity of the green leaf lettuce submitted to fertilization with different doses of fermented composts. Seropédica, Fazendinha Agroecológica km 47, 2019.

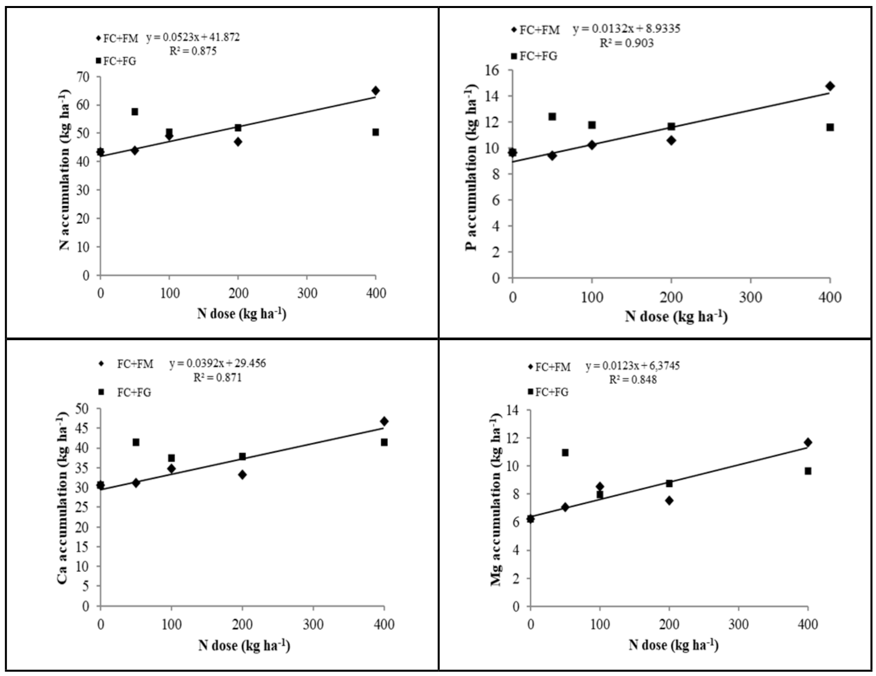

Figure 4. Amounts of N, P, Ca and Mg accumulation in the shoot phytomass of green leaf lettuce submitted to fertilization with different doses of fermented composts. Seropédica, Fazendinha Agroecológica km 47, 2019.

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