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Growth, production and nutrients in coriander cultivated with biofertilizer

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ABSTRACT

The aim of this study was to evaluate the effect of doses of a biofertilizer, formulated with a mix of plants (BMV), on the growth, production and nutrients in coriander cultivar Verdão. The BMV was prepared with crushed parts of the species *Flemingia macrophylla*, *Musa* sp. and *Azolla* sp. The trial was carried out in a greenhouse, in Yellow Argissol, with medium texture (V= 36.4%). The experimental design was of randomized blocks with six replicates. Besides BMV doses (0, 5, 10, 15 and 30%, in water), an additional treatment with bovine manure biofertilizer was added (10% in water). Inorganic ingredients blended into biofertilizers as chicken manure were incorporated in soil of growing-beds. The evaluated traits responded to BMV doses linearly. A decrease in green mass (GM) of plants, from 1.43 to 0.88 kg/m², which is the commercial product, and plant height, from 31.33 to 24.02 cm, was attributed to the astringency of *Musa* sp. in the biofertilizer, together with N shortage. The plant aerial part dry mass (DM) increased from 11.29 to 13.75 g/100 g due to fibrous stems under nitrogen deficiency. Nutrient contents increased (B and Zn), did not range (N, S, and Cu) or decreased (P, K, Ca, Mg, Fe and Mn) and accumulation increased (N, S, K, B, Zn and Cu), decreased (Fe) or did not change (P, Ca, Mg and Mn). The analysis of the principal components showed DM and accumulations of P, K, Ca, Mg and S in the same direction and antagonism of N with Ca and Mg, attributed to loss of N at alkaline pH, by natural phosphate (FN) in BMV. And also, DM, B, Cu and Zn accumulations increased concomitantly while accumulations of Fe and Mn did not compete. The manure biofertilizer surpassed the BMV in GM (1.38 and 1.21 kg/m², respectively), as well as accumulations of N and K.

Keywords: *Coriandrum sativum*, organic manure, alternative fertilizer.

RESUMO

Crescimento, produção e nutrientes no coentro cultivado com biofertilizante

Objetivou-se avaliar o efeito de doses de um biofertilizante de materiais vegetais (BMV) sobre o crescimento, produção e nutrientes no coentro 'Verdão'. O BMV foi preparado com partes trituradas das espécies *Flemingia macrophylla*, *Musa* sp. e *Azolla* sp. O ensaio foi conduzido em cultivo protegido, em Argissolo Amarelo textura média (V%= 36,4). O delineamento experimental foi de blocos ao acaso com seis repetições. Além das doses do BMV (0, 5, 10, 15 e 30% em água), foi adicionado um tratamento com biofertilizante de esterco bovino (10% em água). Os biofertilizantes receberam ingredientes inorgânicos e foi incorporado esterco de galinha ao solo. As características avaliadas responderam às doses do BMV linearmente. Houve decréscimo da massa verde (GM) de plantas, de 1,43 a 0,88 kg/m², que é o produto comercial, e da altura de planta em 31,33 a 24,02 cm, atribuídos à adstringência conferida pela *Musa* sp. ao biofertilizante, junto com escassez de N. A massa seca da parte aérea (DM) incrementou de 11,29 a 13,75 g/100 g devido às hastes mais fibrosas sob carência de N. Os teores dos nutrientes aumentaram (B e Zn), não variaram (N, S e Cu) ou decresceram (P, K, Ca, Mg, Fe e Mn) e os acúmulos incrementaram (N, S, K, B, Zn e Cu), decresceram (Fe) ou não se alteraram (P, Ca, Mg e Mn). A análise de componentes principais evidenciou a DM e os acúmulos de P, K, Ca, Mg e S com o mesmo sentido, além de antagonismo do N com o Ca e o Mg, atribuído à perda de N em pH alcalino, pelo fosfato natural no BMV. A DM e os acúmulos de B, Cu e Zn aumentaram concomitante ao passo que os acúmulos de Fe e de Mn não competiram. O biofertilizante de esterco superou o BMV em GM (1,38 e 1,21 kg/m², respectivamente), assim como, nos acúmulos de N e K.

Palavras-chave: *Coriandrum sativum*, adubação orgânica, fertilizante alternativo.

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Coriander (*Coriandrum sativum*, Apiaceae) originates from the territories of the Mediterranean Basin. In Brazil, this herb was introduced at the beginning of colonization (Melo *et al.*, 2009), having great socioeconomic importance, especially in the Northern and Northeastern regions. The green mass of the leaves is used *in natura* as a condiment. The dry fruits, besides

being used as condiments, are used in pharmaceutical and cosmetics industries (Daflon *et al.*, 2014). The plant is a good source of calcium, iron, vitamin C and pro-vitamin A (Melo *et al.*, 2009). In addition, it is a host of predators which control populations of phytophagous pests of vegetables (Resende *et al.*, 2012).

Coriander is not a demanding plant

in relation to soil and it is tolerant to acidity; however, the herb responds to organic and mineral fertilization (Filgueira, 2008). At the end of the crop cycle, leafy vegetable nutritional requirement becomes more intense, since, in the beginning of the cycle, the dry matter accumulation is slow. In soils with optimum artificial levels of fertility, macronutrients accumulation

rates in coriander were from 30 to 35 days after sowing, with total extraction up to 40 DAS (descending order: K, Ca, N, Mg and P), higher K accumulation and lower accumulation of P (Grangeiro *et al.*, 2011). In hydroponic cultivation, the macronutrient extraction by the coriander vegetative parts represented 85% (N); 79.9% (P), 89.2% (K); 86.4% (Ca); 77.8% (Mg) and 82.3% (S), in relation to total (Donegá, 2009). Identically, the authors verified that total accumulation of micronutrients by coriander at 30 days after emergency in seedbeds, following the order: Fe, Zn, Mn, B and Cu, which corresponded to 18.402; 0.876; 0.816; 0.55 and 0.141 mg/plant (Haag *et al.*, 1988). Given the above, an adequate supply of these nutrients is necessary, in any different coriander production system, in order to avoid nutritional deficiencies. Especially, the N supply, which is of decisive importance for growth and development of herbaceous vegetables (Filgueira, 2008; Echer *et al.*, 2012), being the second most accumulated nutrient (Haag *et al.*, 1988), besides, its deficiency affects the uptake of P, K, Ca and Mg (Araújo *et al.*, 2016), among others.

In leafy vegetables, limiting nutrients are conventionally supplied through the application of mineral fertilizers and organic residues, in planting and top dressing application of N. Thus, the coriander grown using poultry manure and NPK produced more green mass than the cultivation without these fertilizers (Santos, 2009). However, agroecological approaches recommend reducing and rationalizing the use of synthetic inputs, so that the organic fertilizers are likely to become of central importance to soil. Animal manures are good suppliers of N, P and K (Bergo *et al.*, 2005) and used in vegetables even in organic production system, in which also, some mineral sources can be applied, through compost or biofertilizer.

Biofertilizers result from the fermentation of manures, which can be enriched with other organic residues and mineral components, in water, under anaerobic or aerobic process (Souza & Alcântara, 2007). They also result

from exclusive digestion of organic material, with or without minerals (Bergo *et al.*, 2005; Medeiros *et al.*, 2007), being possible to use several organic residues. Banana industry waste is a potential substrate for anaerobic digestion processes (Souza *et al.*, 2010), for its important content of K (Moreira & Fageria, 2009), as well as, water hyacinths and aquatic plants (Guazelli *et al.*, 2012), since they are free of water contaminants. Otherwise, N content will increase if N-rich species are used (Souza & Resende, 2003), such as leguminous plants.

Biofertilizers are supposed to have multiple effects; even if they do not own a standard formula. Coriander production was benefited by using a biofertilizer formulated, on a volume basis, with 50% of cattle manure and 50% of water (Silva *et al.*, 2007). However, the biofertilizer prepared with plant residues could be a safer option for leafy vegetables, following Good Agricultural Practices (GAPs) criteria. Thus, this work aimed to evaluate the effect of a biofertilizer formulated with plant material and enriched with mineral sources on growth, production and acquisition of nutrients in coriander.

MATERIAL AND METHODS

The experiment was carried out from July 17 to August 27, 2013, in a greenhouse, chapel type, with open sides, covered with 150 μm -thick polyethylene film of low density, at Experimental Station of Embrapa Amazonia Oriental, Iranduba, Amazonas State, Brazil ($3^{\circ}15'13''\text{S}$; $60^{\circ}13'36''\text{W}$; altitude 51 m). The soil is classified as Yellow Argissol, with medium texture, showing signs of indigenous anthropogenic action, presenting the following chemical attributes (0-20 cm): pH= 5.2; Al= 0.0; MO= 22.0 g/kg; P= 48 mg/dm³; K= 26 mg/dm³; Ca= 1.9 cmol/dm³; Mg= 1.0 cmol/dm³ and V%= 36.4.

The main treatments were doses of a biofertilizer prepared with plant materials (BMV): 0%, 5%, 10%, 15% and 30% in water, besides an additional treatment with bovine manure biofertilizer (BEB), 10% in water. The

experimental design was of randomized blocks, with six replicates. Each plot consisted of five double rows (10 cm among them) of coriander cultivar Verdão, as direct sowing was carried out in beds (15 cm high and 1.2 m wide), being a row on each side of the drip tape (0.25 m among them). The three central double rows (1 m) were the useful area (0.75 m²). As a basis, the planting beds received 1.5 kg/m² of poultry manure [(g/kg) = N (31.0); P (19.1); K (25.0); Ca (26.0); Mg (6.2); S (5.9); and (mg/kg) = B (44.2); Cu (67.3); Fe (1024.5); Mn (332.6); Zn (533.0)].

BMV was produced from parts of the species *Flemingia macrophylla*, *Musa* sp. and *Azolla* sp., using herbaceous branches and leaves; only leaves and leaves and roots, respectively. These parts were crushed and, then mixed in the following volumetric ratios: 40, 60 and 20 L, respectively. This material was put in a 310-liter polyethylene tank, and then added 160 L of well water, Arad natural phosphate (FN) [(2.8 kg); P₂O₅= 33%; Ca= 37% and S= 1%]; potassium sulfate (1.4 kg); magnesium sulfate (700 g) and micronutrients, in the form of fritted trace elements (FTE) [(280 g) S= 3.2%; B= 1.8%; Cu= 0.8%; Mn= 2%; Mo= 0.1% and Zn= 9%]; borax (140 g) and zinc sulfate (70 g); soluble content in the neutral ammonium citrate (CNA) + water (1:1): Cu (0.48%); Mn (1.2%); soluble content of citric acid (2%) of: B (1.09%); Mo (0.06%) and Zn (5.4%). In BEB, the mixture of fresh manure and well water (v/v = 1/1) was also put in a 310-liter polyethylene tank; and the same nutrient sources and amounts were added proportionally to its volume.

Both biofertilizers resulted from anaerobic fermentation. Into BMV, there was addition of cow milk (5 L) with natural yogurt (110 g) and 1.0 kg of sugar (Bergo *et al.*, 2005), to supply microorganisms. This was not applied to BEB due to the microbial population which is ordinary in ruminants (Guazelli *et al.*, 2012). At 30 days, these biofertilizers were sampled, by a register at the bottom of the tank, in order to analyze the liquid part, resulting in the following composition of the plant material and the bovine manure biofertilizers, respectively

[(mL/L): P= 0.11 and 4.21; K= 0.52 and 2.32; Ca= 0.40 and 4.18; Mg= 0.75 and 1.98 and S= 0.09 and 0.11; ($\mu\text{L/L}$): Cu= 1.0 and 10.50; Fe= 66.50 and 823.0; Mn= 70.0 and 202.50 and Zn= 97.0 and 275.73]. The sieved biofertilizers (1 mm mesh) and diluted in water, according to the treatments, were applied manually (1.5 L/m) among the double rows (6.0 L/plot), weekly, totalizing four applications. Irrigation, with drip emitters, spaced every 10 cm from the drip tape, with a flow rate of 10.6 L/h/meter, was monitored by using sensor Irrigas®. Weeding was carried out with the use of hoe, when necessary. No phytosanitary damage was noticed in plants.

Harvest was carried out at 40 days

after sowing. Next traits were evaluated: the green mass of the whole harvested plants per plot (the roots were washed in order to remove the soil particles); plant height (average of three random measurements of plant packs, using a milimetric ruler, from the base of the plant up to the apex); aerial part dry mass [average between two plant packs (100 g each, without the roots) per plot, which were put in a greenhouse (65°C), in paper bags, until constant mass]. Afterwards, the contents of macronutrient and micronutrient were determined and calculated the accumulation per 100 g of aerial part green mass (GMap) too (g/100 g of GMap; mg/100 g of GMap, respectively).

The obtained data were submitted

to analyses of variance (F test) and regression, besides contrasts with additional treatment (F test), using the program IRRISTAT 5.0. Also the main components analysis was applied with aerial part dry mass and nutrient accumulation, for the main treatments, using the *Facto Mine* R package (Lê *et al.*, 2008) for R v.3.2.1 (R Foundation for Statistical Computing, 2015).

RESULTS AND DISCUSSION

Green mass, dry mass and plant height

The green mass of the plants (GM) decreased linearly with the growing doses of the biofertilizer (BMV) (Figure

Table 1. Regression equations of contents and accumulations of macro and micronutrients in the coriander's aerial part with doses of biofertilizer prepared with a mix of plants. Manaus, Embrapa Amazônia Ocidental, 2013.

Nutrient	Regression equations of macronutrient contents (g/kg)	Amplitude (0%↔30%) (g/kg)	Reference values ^{1,2} (g/kg)
N; S	$\bar{y} = 21.74; 1.34$	-	31.8 and 57.2; 1.5 and 2.49
P	$y = 5.08 - 0.0187^{\Delta}x \text{ R}^2 = 0.40$	5.08↔4.52	2.0 and 5.59
K	$y = 57.72 - 0.1755^{**}x \text{ R}^2 = 0.88$	57.72↔52.46	46.0 and 49.4
Ca	$y = 13.56 - 0.0729^{\Delta}x \text{ R}^2 = 0.58$	13.56↔11.37	5.4 and absent
Mg	$y = 3.99 - 0.0216^{**}x \text{ R}^2 = 0.77$	3.99↔3.35	3.6 and 2.36
Macronutrient accumulations (g/100g of GMap)			
N	$y = 0.234 + 0.0027^{**}x \text{ R}^2 = 0.98$	0.234↔0.3251	-
P; Ca; Mg	$\bar{y} = 0.059; 0.155; 0.046$	-	-
K	$y = 0.651 + 0.0023^{**}x \text{ R}^2 = 0.72$	0.651↔0.7204	-
S	$y = 0.015 + 0.0001^{**}x \text{ R}^2 = 0.72$	0.015↔0.018	-
Micronutrient contents (mg/kg)			
B	$y = 14.739 + 7.335^{**}x \text{ R}^2 = 0.98$	14.739↔234.79	39.0
Zn	$y = 36.084 + 0.2339^{\Delta}x \text{ R}^2 = 0.77$	36.084↔43.19	63.3
Cu	$\bar{y} = 9.495$	-	10.3
Fe	$y = 866.57 - 12.735^{\Delta}x \text{ R}^2 = 0.96$	866.57↔484.52	1347.5
Mn	$y = 61,324 - 0,6839^{**}x \text{ R}^2 = 0,96$	61.324↔40.81	61.8
Micronutrient accumulations (mg/100g of GMap)			
B	$y = 0.095 + 0.1028^{**}x \text{ R}^2 = 0.96$	0,095↔3,18	-
Zn	$y = 0.405 + 0.0061^{**}x \text{ R}^2 = 0.94$	0.405↔0.5881	-
Cu	$y = 0.107 + 0.0008^{\Delta}x \text{ R}^2 = 0.94$	0.107↔0.1308	-
Fe	$y = 9.754 - 0.0966^{\Delta}x \text{ R}^2 = 0.85$	9.754↔6.8558	-
Mn	$\bar{y} = 0.643$	-	-

*** Δ Significant by F test ($p < 0.01$, $p < 0.05$ and $p < 0.1$, respectively). Amplitude (0%↔30%) nutrient content or accumulation with neighboring doses at the interval (0%↔30%) using the respective regression equation; \bar{y} = average; GMap= aerial part green mass. ¹Macronutrients: Haag *et al.* (1988), in soil and Daflon *et al.* (2014), in nutrient solution, respectively; ²Micronutrients: Haag *et al.* (1988).

1A). Probably, the roots were damaged, particularly, the finest roots affecting water absorption, besides nutrients, damaging the chain of reactions which culminate in the production of the green mass. Damage to the roots should be related to the astringent sap of banana leaves in the BMV, since Costa *et al.* (2014) state that this sap is an effective healing. Moreover, mass accumulation in leafy vegetables is positively influenced by water content and by N supply. Thus, the GM production ranged from 1070.8 g/plot (1.43 kg/m²)

to 658.75 g/plot (0.88 kg/m²), according to the lowest to the highest dose, coherent with the gradual reduction of plant size, which also, in regular visual inspections, showed progressively paler green color. This change in color is due to the lack of N, which is related to unfavorable interactions between BMV and the reactions of this nutrient in soil. Therefore, water stress and N deficiency determined the decreasing of GM.

Aerial part dry mass (DM) increased linearly (Figure 1B), ranging from 11.29 g/100 g of GMap (0% BMV) to 13.75 g/100 g of GMap (30% BMV)

13.75 g/100 g of GMap (30%). DM may increase by the greater number of stems, to the detriment to leaf expansion. Also, N-deficient plants may show thin and fibrous stems, due to carbohydrates excess which could not be used in the synthesis of amino acids and other nitrogenous compounds (Taiz & Zeiger, 2006).

Plant height (PH) decreased with the doses (Figure 1C), as well as GM, ranging from 31.33 cm (0% BMV) to 24.02 cm (30%). Oliveira *et al.* (2002), using cattle manure and NPK

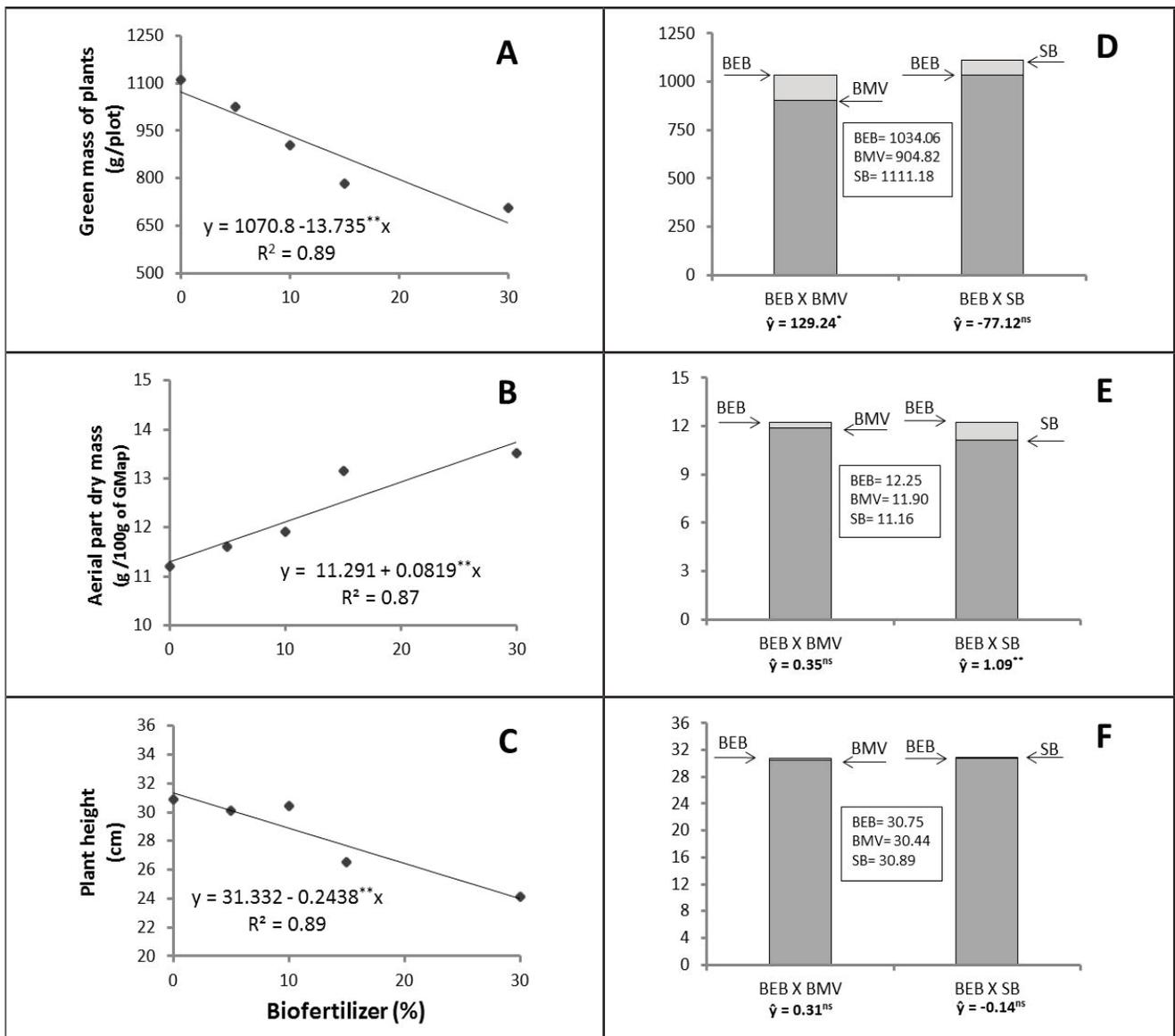


Figure 1. Green mass of plants (A), aerial part dry mass (B) and plant height (C) of coriander grown with BMV using different doses and contrasts BEB versus BMV and BEB versus SB, respectively (D, E and F). BMV=biofertilizer prepared with vegetal material; BEB= bovine manure biofertilizer; SB= without biofertilizer, GMap= aerial part green mass. Useful area of the plot (0.75 m²). **significant by F test (p<0.05 and p<0.01, respectively); ^{ns}= non-significant.

obtained maximum PH, 35 cm. N is the nutrient which most limits plant growth (Marschner, 2012), therefore its scarcity does not help PH and the same factors affected the responses for GM and PH.

Contrasts between treatments (BEB versus BMV and BEB versus SB (bovine manure in the absence of biofertilizer) were studied for GM (Figure 1D), DM (Figure 1E) and PH (Figure 1F). BEB surpassed BMV for GM ($\hat{y}=129.24^*$) also SB for DM ($\hat{y}=1.09^{**}$), showing no significance for the other traits. BEB showed, in the liquid part, highest contents for all macronutrients, whereas, for the BMV were attributed effects related to root injury, to the detriment of water and nutrient uptake, as well as a low N. Thus, BEB was more effective in relation to GM yield, that is the commercial product. Alike, it is reasonable that the BEB provided conditions for greater production of DM than SB has.

Contents and nutrients accumulations in the plant's aerial part

BMV doses affected distinctly concentrations and accumulations of

nutrients in the aerial part of coriander plant, with significant responses adjusting to different linear functions; thus, the amplitudes of their contents in DM were calculated, using the lowest and the highest dose of the interval studied (0%↔30%), in order to be compared to reference values (Table 1).

N contents did not range according to the doses, whereas accumulations increased linearly, which did not reflect in GM, possibly, because the increase (0.0027 g/100 g of GMap), per each unit applied to BMV, was little expressive. Nitrogen is fundamental to increase vegetative growth in leafy vegetables (Echer *et al.*, 2012); therefore, there was N scarcity or depreciation on the acquisition of this nutrient. S also showed significance only for accumulation, which showed inexpressive linear increase (0.0001 g/100 g of GMap, per unit of BMV), concluding that the addition of sulphates (K and Mg) into BMV had little impact in acquisition of S by coriander. SO_4^{2-} is absorbed in low amounts and speed depends on the accompanying cation (Vitti *et al.*, 2006): $Ca^{2+} < Mg^{2+} < NH_4^+ < K^+$. In both cases,

the average of contents was lower than the reference values (Haag *et al.*, 1988; Daflon *et al.*, 2014).

P contents decreased linearly with the doses and the accumulations were not responsive. P utilization is lower even with the application of the fertilizer (Araújo & Machado, 2006). Damages to roots and precipitation of Ca^{++} , as well as FN, under the highest doses of BMV, probably interfered with its acquisition. K contents also decreased linearly with doses; on the other hand, the accumulations increased linearly. By the angular coefficient of functions, respectively, the highest negative value for K contents (0.1755) compared to the positive value of the accumulation (0.0023), shows a decrease of K in DM, by dilution. P was the least accumulated nutrient in coriander, whereas K was the most absorbed nutrient (Grangeiro *et al.*, 2011); thus, compared to reference values in soil and nutrient solution, P contents were the most consistent with the nutrients obtained in nutrient solution, whereas K contents were higher in both conditions.

Ca and Mg contents decreased linearly with the doses and there was no significance for accumulations of these nutrients which was similar to P. In the irrigation water, phosphates are incompatible with Ca and Mg (Borges & Silva, 2011) and FN added into BMV, by its composition (Ca=37%; $P_2O_5=33\%$), may have affected the acquisition of these nutrients. Moreover, Ca delivered by FN may have decreased Mg absorption rate (Vitti *et al.*, 2006), which was practically a third of what was verified for Ca. Under these conditions, Ca contents were more than double of those recorded by Haag *et al.* (1988), whereas Mg contents were close. Grangeiro *et al.* (2011) verified that Ca accumulation (20.4 mg/plant) practically double the Mg content (10.18 mg/plant).

The contrast between BEB versus BMV was significant only for contents of K and S ($\hat{y}=-1.73^*$; -0.17^* , respectively), being BMV superior (Table 2). For BEB x SB, the significance occurred for the K content ($\hat{y}=-1.71^*$), which was higher in SB; thus, this fact can be an effect of concentration since DM was higher than

Table 2. Treatment averages and contrasts estimates (\hat{y}) of biofertilizer of bovine manure (BEB) versus biofertilizer prepared with a mix of plants (BMV) and BEB versus without biofertilizer (SB) for contents and accumulations of macronutrients in the coriander's aerial part. Manaus, Embrapa Amazônia Ocidental, 2013.

Macronutrients	Averages			\hat{Y}	
	BEB	BMV	SB	BEB x BMV	BEB x SB
Contents (g/kg)					
N	20.71	21.89	21.60	-1.18 ^{ns}	-0.89 ^{ns}
P	5.12	5.34	4.84	-0.22 ^{ns}	0.28 ^{ns}
K	55.41	57.14	57.12	-1.73*	-1.71*
Ca	14.25	13.75	13.17	0.50 ^{ns}	1.08 ^{ns}
Mg	4.09	4.00	3.90	0.09 ^{ns}	0.19 ^{ns}
S	1.31	1.48	1.33	-0.17*	0.02 ^{ns}
Accumulations (g/100 g of GMap)					
N	0.38	0.26	0.24	0.12 ^{**}	0.14 ^{**}
P	0.055	0.064	0.054	-0.009*	0.0003 ^{ns}
K	0.77	0.68	0.64	0.09 ^{**}	0.13 ^{**}
Ca	0.10	0.16	0.15	-0.06 ^{**}	-0.04 ^{**}
Mg	0.035	0.048	0.044	-0.013 ^{**}	-0.008*
S	0.019	0.018	0.015	0.001 ^{ns}	0.004 ^{**}

*** Significant by F test ($p < 0.01$ and $p < 0.05$, respectively) and ^{ns} Non-significant; GMap= aerial part green mass.

BEB, inversely, by diluting its content. Cattle manure shows considerable contents of K (23.5 g/kg), being able to raise the K⁺ of the biofertilizer.

In relation to accumulations, the contrast BEB versus BMV, with no significance for S, indicated higher values of N and K in BEB, which is consistent with its greater production of GM (Figure 1D) and with invariable DM in this contrast (Figure 1E). On the other hand, the highest accumulations of P, Ca and Mg in BMV may occur due to the fact that their organic acids decreased P fixing (Benites *et al.*, 2005), particularly, solubilizing the probable phosphates of Ca. Moreover, synergism between P and Mg in the absorption (Silva & Trevizam, 2015) may have increased both nutrients in the aerial part. In BEB x SB, significance occurred for the accumulation of all the macronutrients, except for P. Greater accumulations of N, K and S were observed with BEB, and of Ca and Mg with SB. The highest accumulation of Ca and Mg in SB may indicate undesirable effect of BEB on its acquisition, and this may be related to the effect of the triad P, Ca and Mg.

The increasing doses of BMV increased linearly the contents of

B and Zn and their accumulations. B uptake can be excessive when its content in the solution is high (Dechen & Nachtigall, 2006), and it is verified, from the 10% dose, that the contents reach higher values than the comparison references, considering the marked angular coefficient of the function (+7.335). However, in the amplitude of Zn contribution, the values were lower than the reference used. For Zn, values lower than 25.0 mg/kg are considered deficient.

Cu contents did not change with the doses of BMV, whereas contents of Fe and Mn decreased linearly. Mn accumulation was not affected either, Cu accumulation has increased and Fe accumulation has decreased linearly. The average contents of Cu and the relative amplitude of Fe were lower than the reference values. Mn referential values were the same; however, only without the biofertilizer (0%), decreased with an increase of doses. Despite appreciable supply of Fe by the soil with manure, BMV decreased the acquisition of Fe, probably, due to changes in pH and concentrations of P and Ca (Luchini, 2008), which interfere with the acquisition of this

nutrient. Since Mn was added into the effluent, an increase in contents proportionally to the doses would be expected. However, its absorption is basically controlled metabolically (Dechen & Nachtigall, 2006) and Mn extraction by the coriander is lower than Fe extraction (Haag *et al.*, 1988).

The contrasts BEB versus BMV and BEB versus SB (with no biofertilizer) were studied for contents and accumulations of micronutrients (Table 3). For the contrast BEB versus BMV, significance was only noticed for Fe contents (\hat{y} = -278.76 mg/kg), with superiority of BMV. On the contrast BEB versus SB, a significance was noticed only for Fe contents, with superiority of SB (\hat{y} = -476.06 mg/kg). In both situations, BEB was less impactful for Fe content, which accumulation stood out in BMV and in SB. Fe acquisition in plants is affected by the pH, concentration of Ca and P; balance Fe/Mn, among others (Dechen & Nachtigall, 2006). The contents of Ca and P in the liquid part of BEB were more accentuated, and Fe shows affinity to form phosphate binders and the slower speed of Fe³⁺ reduction at higher pH, phenomena which reduce the supply to the roots. In both contrasts, significance also occurred for B, considering that BEB surpassed BMV and SB. In the first, probably, due to the increased movement of B with transpiration flow, since BEB yielded more GM than BMV (Figure 1D). And due to the fact that BEB surpassed SB, the lowest yield of DM in SB (Figure 1E) can be emphasized, because it was verified that the accumulation of B followed the increase of DM.

Principal components analysis

The results of the principal components analysis (PCA), applied into DM correlation matrix (g/100 g of GMap) and macronutrient accumulations (g/100 g of GMap), demonstrated that, in the correlation circle, the first two axes explained 76.30% of total variability, being 48.91% in axis 1 and 27.39% in axis 2 (Figure 2). The principal component 1 (PC1), with distribution in axis 1, was influenced by dry mass of the aerial part (MS), P, K, Ca, Mg and S, all with positive eigenvectors

Table 3. Treatment averages and contrast estimates (\hat{y}) biofertilizer of bovine manure (BEB) versus biofertilizer produced with a mix of plants (BMV) and BEB versus without biofertilizer (SB) for contents and accumulations of micronutrients in the coriander's aerial part. Manaus, Embrapa Amazônia Ocidental, 2013.

Micronutrients	Averages			\hat{Y}	
	BEB	BMV	SB	BEB x BMV	BEB x SB
Contents (mg/kg)					
B	75.88	72.44	32.59	3.44 ^{ns}	43.29 ^{ns}
Zn	38.69	40.66	34.40	-1.97 ^{ns}	4.29 ^{ns}
Cu	9.11	9.94	9.56	-0.83 ^{ns}	-0.45 ^{ns}
Fe	415.29	694.05	891.35	-278.76 ^{**}	-476.06 ^{**}
Mn	55.04	56.58	61.03	-1.54 ^{ns}	-5.99 ^{ns}
Accumulations (mg/100 g of GMap)					
B	2.839	0.863	0.365	1.980 ^{**}	2.470 ^{**}
Zn	0.451	0.483	0.385	-0.032 ^{ns}	0.066 ^{ns}
Cu	0.109	0.118	0.107	-0.009 ^{ns}	0.002 ^{ns}
Fe	4.027	8.220	9.764	-4.190 ^{**}	-5.740 ^{**}
Mn	0.554	0.669	0.671	-0.115 ^{ns}	-0.117 ^{ns}

** Significant by F test ($p < 0,01$ and $p < 0,05$, respectively) and ^{ns} Non-significant; GMap= aerial part green mass.

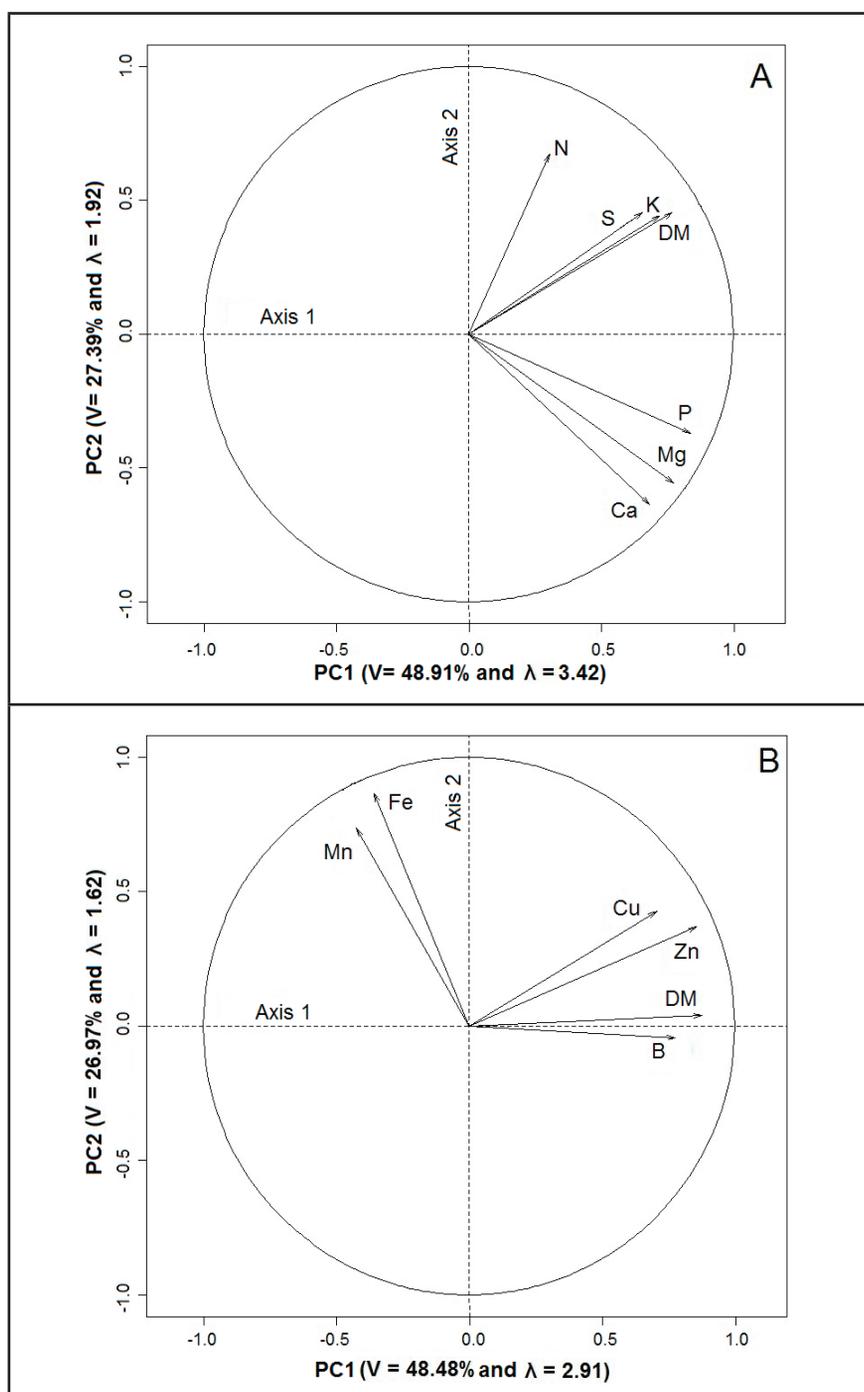


Figure 2. Correlation circle between accumulations of macro (A) and micronutrients (B) and aerial part dry mass (DM) of the coriander in two first principal components (PC1 and PC2). Variance (V) and eigenvalues of correlation matrix (λ). Manaus, Embrapa Amazônia Ocidental, 2013.

(0.725; 0.841; 0.770; 0.685; 0.775 and 0.658, respectively); therefore, the same occur with DM and with the acquisition of these macronutrients. PC2, in axis 2, demonstrates competition of N (0.674) with Ca (-0.636) and Mg (-0.556), by the opposite signals. Therefore, increasing N accumulation will decrease the

accumulation of Ca and Mg and vice-versa. This indicates losses of N through volatilization, which are favored, among other factors, by alkaline pH. In this case, due to contribution of FN in the biofertilizer raising the pH (Luchini, 2008), besides adding more Ca and Mg to the soil.

Evaluating PCA, which was applied to DM correlation matrix (100 g of GMap) and micronutrient accumulations (mg/100 g of GMap), it is possible to verify that, in the correlation circle, the first two axes explained 75.45% of total variance of the original traits, being 48.48% in axis 1 and 26.97% in axis 2 (Figure 2). PC1, in axis 1, represents DM (0.876) and the accumulations of B (0.776), Cu (0.710) and Zn (0.857), by the largest coefficients of the same signal, indicating that DM and the acquisition of these micronutrients increased concomitantly. In PC2, axis 2, it is easily verified that accumulations of Fe (0.867) and Mn (0.738), with positive eigenvectors, do not express competition. In general, PC1 can better explain the data; however, PC2 was additional on these metal micronutrients, which is important since Mn, and not Fe, was added into the biofertilizer.

In short, the increase of BMV concentrations (% in water) led a decrease in green mass yield of the coriander, which is a product with commercial value, as well as the plant height; however, the aerial part dry mass increased. On the other hand, the total amounts of nutrients in the aerial part of plants increased (N, S and K; B, Zn and Cu), decreased (Fe) or no responded (P, Ca and Mg; Mn). Interactions between BMV and N in soil, decreasing its availability, conditioned growth and production, since the results related to nutrients were not counterproductive. On the other hand, BEB surpassed BMV in relation to the green mass of the plants and to the accumulations of N and K. In short, it is inferred that *Musa* sp and FN in the composition of BMV have compromised its efficacy.

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