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Agronomic performance of sweet potato crop in succession to leguminous plants in monocropping and intercropped with corn

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ABSTRACT

This study aimed to evaluate sweet potato performance in succession to annual herbaceous leguminous plants, in monocropping or intercropped with corn, under agroecological management, under Baixada Fluminense conditions. The experimental design was randomized blocks, with five treatments and four replicates. The treatments consisted of pre-cropping with the following species: crotalária (*Crotalaria juncea*) under monocropping system, crotalária intercropped with corn (*Zea mays*), jack bean (*Canavalia ensiformis*) under monocropping system, jack bean intercropped with corn and spontaneous vegetation. The results showed that monocropped crotalária reached the greatest dry biomass accumulation during two consecutive years of succession. In the second year, this treatment provided greater accumulated amounts of N, K and Mg in plant biomass. Growing sweet potatoes in succession to the pre-cropping of crotalária is advantageous, as it provided an increase in vegetable productivity in the second year of succession.

Keywords: *Ipomoea batatas*, *Crotalaria juncea*, *Canavalia ensiformis*, *Zea mays*, green manuring, organic agriculture.

RESUMO

Desempenho agrônômico de batata-doce em sucessão a leguminosas em monocultivo ou consorciadas ao milho

O objetivo deste estudo foi determinar o desempenho de batata-doce em sucessão a leguminosas herbáceas anuais, em monocultivo ou consorciadas com milho, sob manejo agroecológico, em condições da Baixada Fluminense. O delineamento experimental empregado foi de blocos ao acaso, com cinco tratamentos e quatro repetições. Os tratamentos envolveram pré-cultivos com as seguintes espécies: crotalária (*Crotalaria juncea*) em monocultivo, crotalária consorciada ao milho (*Zea mays*), feijão-de-porco (*Canavalia ensiformis*) em monocultivo, feijão-de-porco consorciado ao milho e vegetação espontânea. Os resultados demonstraram que a crotalária em monocultivo apresentou maior acúmulo de biomassa seca em dois anos consecutivos da sucessão. No segundo ano, esse tratamento proporcionou maiores quantidades acumuladas de N, K e Mg na biomassa vegetal. O cultivo de batata-doce em sucessão ao pré-cultivo de crotalária é vantajoso, pois proporcionou aumento de produtividade da hortalíça no segundo ano da sucessão.

Palavras-chave: *Ipomoea batatas*, *Crotalaria juncea*, *Canavalia ensiformis*, *Zea mays*, adubação verde, agricultura orgânica.

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Sweet potato (*Ipomoea batatas*) is a vegetable which belongs to botanical family Convolvulaceae. It is from Central and South Americas, where approximately 50 genera and more than 1,000 species can be found (Lebot, 2009). This crop plant is grown in all Brazilian states, using intense tillage, involving plowing and harrowing (Rós, 2017). Propagation is carried out through vine from healthy plants and planting, in general, performed in windrows to make it easy for rooting and harvest.

According to IBGE (2018), the planting area in Brazil covers

approximately 53,024 hectares, with an average yield of 13.99 t ha⁻¹. In Brazil, South and Northeast Regions show the largest planted areas, whereas the Midwest region has the smallest cultivated area. In relation to consumption, in Brazil, sweet potato is the fourth most consumed vegetable, showing a great social importance since it is an energy-rich, high-complex carbohydrate food (Leonardo *et al.*, 2014).

The investment on sweet potato crop is low. The lack of investment in technology is justified by the fact that this is a low profit margin crop,

due to its small individual production volume (Silva *et al.*, 2008). The same authors point out that producers still tend to cultivate sweet potatoes as a marginal crop, with the reasoning that, spending the minimum, whatever the crop produces, it represents an additional gain.

Results obtained from some studies, carried out throughout the years, show the productive potential of this crop when submitted to organic fertilization. Santos *et al.* (2010), evaluating the effect of organic fertilization on sweet potato total production, concluded that total production (18.03 t ha⁻¹) of sweet potato

roots responded linearly and positively to increasing doses of poultry litter and that fertilizer application increased the total production of sweet potato roots.

Rós *et al.* (2014), studying the influence of the use of fertilizer sources and doses in sweet potato productivity, verified that the crop responds to soil fertilization, with increases in total and commercial productivity through application of biofertilizers and poultry manure, as well as the combination of both fertilizers. Leonardo *et al.* (2014) also reported that fertilizing with bovine manure increased N efficiency, the characteristics of sweet potato production, besides the fact that the combined application of N top-dressing and bovine manure increased the commercial sweet potato productivity in 5.7 t ha⁻¹ of roots, when compared with plantation without any nutrient inputs.

Another management system which favors sweet potato productivity and other crops of economic interest is cultivation in succession with green manure. Green fertilizer contributes to improving or maintaining the soil fertility, increasing organic matter level throughout the years (Silva *et al.*, 2014). This management provides N to the system when the area was previously cultivated with legume (Pereira *et al.*, 2013), giving soil greater resistance against agents which can cause erosion (Teodoro *et al.*, 2011), as it also can reduce incidence of nematodes (Dias *et al.*, 2010).

Green manure using green velvet (*Mucuna pruriens* var. *utilis*) provides an increase in agronomic performance of cabbage, submitted to organic management, when compared with corn pre-cropping, considering this management able to substitute organic top-dressing fertilization with no decrease in the vegetable productivity (Cordeiro *et al.*, 2018).

In order to evaluate the performance of sweet potato in corn succession intercropped with legumes, Risso (2007) verified that sweet potato production was not influenced by the presence of legumes grown with corn. However, an increased supply of organic matter and incorporation of N in the system was verified. In another study, Espindola *et*

al. (1998) observed an increase in sweet potato productivity when grown in succession with velvet bean cultivation. They also observed greater amount of accumulated doses of N, P and K in the shoots of jack bean and velvet bean in relation to other pre-cropping.

In this context, this study aimed to determine the performance of sweet potato in succession to annual herbaceous legumes, in monocropping or intercropped with corn in an agroecological management system.

MATERIAL AND METHODS

The experiment was carried out at Embrapa Agrobiologia experimental field, located in the municipality of Seropédica, in the Metropolitan Region of Rio de Janeiro (22°46'S, 43°41'W, 33 m altitude). The soil in the experimental area was classified as Red Yellow Argisol (Santos *et al.*, 2018), the chemical properties in 0 to 20 cm layer are: pH= 5.78; Al⁺⁺⁺= 0.0 cmol/dm⁻³; P= 44.94 mg/L; K= 31,00 mg/L; Ca= 1.86 cmol/dm⁻³; and Mg= 0.95 cmol/dm⁻³, analyzed according to the methodology described by Nogueira & Souza (2005).

The experimental design used was randomized blocks with five treatments and four replicates. During the two agricultural years, the plots were kept in the same place, with dimensions of 6.5x5.0 m, covering an area of 32.5 m². Pre-cropping treatments were: spontaneous vegetation, monocropped crotalária (*Crotalaria juncea*); crotalária intercropped with corn, (*Zea mays*) monocropped jack bean (*Canavalia ensiformis*), jack bean intercropped with corn, using BRS Eldorado corn. The spontaneous vegetation in the first year of cultivation consisted mainly of "anileira" (*Indigofera hirsuta*). In the second year of cultivation, besides the "anileira", the presence of crabgrass (*Digitaria horizontalis*) and *Euphorbia heterophylla* (wild poinsettia) was also observed.

Before installation, the experimental area had been under fallow for approximately 10 years. Plowing and harrowing were performed before this

experiment installation. Then, furrows (spaced 50 cm) were opened. In the two years of agriculture, we performed corn and vegetable sowing at the same time, in November. Corn crop was sown in simple rows alternating with vegetables. The vegetables seeds were inoculated with bacteria of the genus *Rhizobium*, strain BR 2003 (SEMIA 6156), of the crop collection of Embrapa Agrobiologia, and, then, the seeds were sown in densities of 10-30 seeds per linear meter for jack beans and crotalária, respectively. Corn crop was sown in density of 10 plants per linear meter. Afterwards, these plants were thinned to five plants.

The total area was fertilized at the same time corn and vegetables were sown. We applied 80 kg ha⁻¹ P₂O₅ as thermophosphate source, and 80 kg ha⁻¹ K₂O, using potassium sulfate. The thermophosphate used in this experiment showed 180 g kg⁻¹ and potassium sulfate 480 g kg⁻¹ K₂O.

Among the cultural practices we performed, top-dressing nitrogen doses in the corn crop stood out. We used an equivalent dose of 100 kg ha⁻¹ N, in the form of castor cake containing 50 g N kg⁻¹ in the composition, being splitted in two applications, at 15 and 30 days after sowing. The intercropped crotalária was pruned, at 35 days after sowing. Pruning was performed when corn and crotalária reached the same height. The crotalária was pruned at 30 cm below the main ear insertion or approximately 1/3 of its total height. During pruning, biomass samples were collected in a 2-m² useful area (2x1) from the plots of crotalária intercropped with corn, to quantify the fresh biomass productivity obtained from pruning. A subsample was removed and taken to the oven with forced air circulation at 65°C, to determine dry mass productivity and nutrient content, which were added to the total dry biomass and nutrient accumulation in intercropped crotalária. Cartridge caterpillar (*Spodoptera frugiperda*) was controlled in the corn crop, by applying *Bacillus thuringiensis* at 10 g L⁻¹ from the first moment the insect was detected.

Corn harvest was done using 6 m² samples of useful area per plot, collected

from the two central rows, in order to evaluate green corn productivity. At 120 days after sowing, we collected samples from 2 m² area per plot (2x1), of corn, intercropped vegetables, monocropped vegetables, and also 1 m² per plot of spontaneous vegetation, in order to determine the fresh biomass of the species used for pre-cropping, removing one subsample which was taken to an oven with forced air circulation at 65°C to determine dry biomass and the nutrient contents. The contents and accumulation of the nutrients were described for spontaneous vegetations and vegetables. The procedure for analyzing N in the biomass was based on Kjeldahl method, P was analyzed through colorimetric method, K by flame photometry, Ca and Mg were determined by atomic absorption method, according to the procedures described by Nogueira & Souza (2005).

After collecting samples, in order to determine fresh and dry biomasses, contents and accumulation of nutrients, we cut the pre-cropping and biomass was incorporated to soil with the aid of a harrow. The authors planted the sweet potato one week after the cutting management of the pre-cropping. During the planting, windrows were built in a field measuring 5 meters long, 0.5 m wide and 0.3 m high, spacing 1 meter between the windrows, totalizing six windrows per plot. Planting of sweet potato cv. Rosinha do Verdan was performed in March in the two years of agriculture, spacing 20 cm between vines. Vines were selected through segments of the end of the matrix plant measuring approximately 30 cm long, from the experimental field of Embrapa Agrobiologia.

The harvest was performed five months after planting, with samples of six square meters per plot, collected from the useful area of the two central windrows of the plots, discarding the border rows. The roots were classified according to the categories proposed by Silva *et al.* (1991): Extra A (251 to 500 g), Extra (151 to 250 g), Diverse (80 to 150 g) and tubers weighing 10 to 79 g. The roots belonging to Extra and Diverse categories are considered marketable roots.

Dry biomass accumulation data (t ha⁻¹), contents (g kg⁻¹) and accumulation

(kg ha⁻¹) of the nutrients N, P, K, Mg of the pre-cropping species and productivity of the sweet potato (t ha⁻¹), in two years of agriculture (2012 and 2013) were submitted to variance analysis by F test and the averages were compared using Scott-Knott test ($p \leq 0.05$). Pearson's correlation coefficients (r) between the values of the total productivity of sweet potato and macronutrient obtained in two years were also obtained. R software (R Core Team, 2020) was used to perform these analyses.

RESULTS AND DISCUSSION

Corn intercropped with crotalária obtained productivity of 5.80 and 7.24 t ha⁻¹ of green ears in the first and in the second years, respectively, whereas corn intercropped with jack beans reached 6.34 and 7.53 t ha⁻¹. These productivities are similar to the ones obtained by Guedes *et al.* (2010) studying corn-cowpea intercropping under similar climatic conditions. We highlight that corn crop can be considered one facilitating element during the insertion of green manures, since during this period in addition to the biomass production from legumes and corn, we could also verify green ear production, which allows income earning during the period of green fertilization, without reduction in productivity.

In relation to dry biomass accumulation of green manures, monocropped crotalária reached the highest value of accumulation, in the

two years of cultivation, whereas the treatment with spontaneous vegetation showed the lowest value of biomass accumulation (Table 1). We highlight that the spontaneous vegetation, besides presenting less accumulation of biomass, was constituted mainly by anileira (*Indigofera hirsuta*), which is an herbaceous legume, and also by grasses and euphorbia, which results in an inferior quality biomass comparing with the other treatments. In different populational arrangements, Amabile *et al.* (2000) reported, for crotalária, dry biomass productivity of 17.26 t ha⁻¹ during spring-summer season, whereas Pereira *et al.* (2005) obtained, for the same season, 10.7 t ha⁻¹ and in autumn-winter season, 6.8 t ha⁻¹. Other authors showed dry biomass production for this vegetable ranging from 2.64 t ha⁻¹ (Medina *et al.*, 2013) to 9.83 t ha⁻¹ (Suzuki & Alves, 2006). The results found in literature showed a wide range considering the dry biomass productivity of this vegetable, showing that the biomass can vary in relation to planting season, plant density and cultivation under variable climatic conditions.

The intercropping of crotalária and jack beans with corn, probably due to the lower plant density, resulted in lower biomass productivity in relation to the respective monocropping systems. However, intercropping provides extra income with the production of green ears; this can contribute with green manure management in production units, mainly those ones considered family farms.

Table 1. Total dry biomass accumulation of pre-cropping in two consecutive cycles. Seropédica, Embrapa Agrobiologia, 2012, 2013.

Pre-cropping	Dry biomass (t ha ⁻¹)					
	1 st year			2 nd year		
	Vegetables	Corn	Total	Vegetables	Corn	Total
Spontaneous	-----	-----	4.79 C ¹	-----	-----	2.37 D
Crotalária	13.04	-----	13.04 A	15.84	-----	15.84 A
Crotalária + corn	6.04	4.74	10.78 B	8.15	3.68	11.84 B
Jack beans	9.43	-----	9.43 B	11.75	-----	11.75 B
Jack beans + corn	4.87	4.79	9.66 B	4.38	3.31	7.70 C
CV (%)	-----	-----	14.05	-----	-----	22.96

¹Averages followed by the same letter do not differ from each other by the Scott-Knott test at 5% probability.

The nutrient contents present in dry biomass of vegetables and spontaneous vegetation did not differ in the first year for N and K. Contents of P and Ca were superior in treatments with monocropped jack beans and jack beans intercropped with corn, (*Zea mays*) though. Jack bean

pre-cropping intercropped with corn and spontaneous vegetation showed higher values for Mg contents (Table 2). We highlight that, probably, no difference in N contents between spontaneous vegetation and vegetables was noticed, due to the predominance of anileira as

a component of spontaneous vegetation in the experimental area. Cavalcante *et al.* (2012), studying different vegetables, verified that no difference regarding to N contents was observed. These values were superior to spontaneous vegetation, though. In the second year of cultivation, higher N contents were observed in monocropped vegetables and intercropped with corn, in relation to spontaneous vegetation, as well as, higher Ca contents in jack beans intercropped with corn. The highest K contents were associated with treatments with monocropped crotalária, crotalária intercropped with corn and spontaneous vegetation. Mg content was inferior in dry biomass of jack beans when intercropped with corn. Similar results of macronutrient levels in different kinds of green manures in monocropping or intercropping systems were described by Rodrigues *et al.* (2012). Cavalcante *et al.* (2012), studying under different climatic conditions, obtained similar results for all macronutrients which did not differ statistically, except for Ca, which showed a higher content in the dry biomass of the jack bean.

In relation to accumulated macronutrients in dry biomass of vegetables and spontaneous vegetation, the authors verified that, in the first year, treatments crotalária and jack beans under monocropping system showed higher quantities of N, P and K, whereas monocropped jack beans provided higher quantity of accumulated Ca. In the second cultivation cycle, the authors observed that pre-cropping of monocropped crotalária showed, when compared with other treatments, higher quantities of N, K and Mg accumulated in the biomass, whereas for P and Ca, higher accumulated quantities were observed in monocropped crotalária and jack beans (Table 3). Jack bean is a species which tends to show a higher Ca accumulation, which is confirmed by the results described by Heinrichs *et al.* (2005) in two cycles, obtaining superior accumulated quantities of Ca when compared with other pre-cropped species. Similar results were described by Padovan *et al.* (2011), showing that even from flowering, jack bean accumulates significant amounts of biomass and nutrients, mainly N, K

Table 2. Nutrient contents in the shoot part of vegetables and spontaneous vegetation obtained in two consecutive cycles. Seropédica, Embrapa Agrobiologia, 2012, 2013.

Pre-cropping	Nutrient contents in biomass (g kg ⁻¹) (1 st year)				
	N	P	K	Ca	Mg
Spontaneous	17.7 A ¹	1.67 B	16.37 A	11.13 B	3.33 A
Crotalária	17.2 A	1.22 B	10.31 A	4.46 C	2.17 B
Crotalária+corn	19.3 A	1.60 B	12.68 A	5.36 C	2.51 B
Jack beans	27.2 A	2.15 A	15.25 A	15.80 A	2.27 B
Jack beans + corn	21.9 A	2.07 A	9.93 A	18.95 A	3.47 A
CV (%)	34.25	18.03	30.70	24.38	25.42
Pre-cropping	Nutrient contents in biomass (g kg ⁻¹) (2 nd year)				
	N	P	K	Ca	Mg
Spontaneous	13.0 B	1.70 A	15.06 A	6.0 B	4.66A
Crotalária	24.9 A	1.68 A	8.37 A	9.66 B	5.16 A
Crotalária+corn	24.1 A	1.72 A	9.37 A	10.18 B	4.75A
Jack beans	21.2 A	1.57A	7.25 B	12.91 B	2.56 B
Jack beans + corn	22.2 A	1.76 A	8.68 B	20.55 A	3.92 A
CV (%)	41.26	18.12	28.46	26.10	14.59

¹Averages followed by the same letter do not differ from each other by the Scott-Knott test at 5% probability.

Table 3. Nutrient accumulation in the shoot part of vegetables and spontaneous vegetation obtained in two consecutive cycles. Seropédica, Embrapa Agrobiologia, 2012, 2013.

Pre-cropping	Nutrient accumulation (kg ha ⁻¹)(1 st year)				
	N	P	K	Ca	Mg
Spontaneous	84.87 B ¹	7.83 B	77.88 B	51.62 B	15.85 A
Crotalária	223.45 A	15.79 A	133.24 A	57.37 B	28.12 A
Crotalária+corn	115.12 B	9.51 B	74.32 B	31.39 B	15.15 A
Jack beans	250.59 A	20.21 A	139.65 A	151.60 A	21.48 A
Jack beans + corn	112.77 B	10.47 B	47.18 B	93.55 B	17.47 A
CV (%)	40.58	27.40	26.29	41.23	32.32
Pre-cropping	Nutrient accumulation (kg ha ⁻¹) (2 nd year)				
	N	P	K	Ca	Mg
Spontaneous	30.08 C	4.25 C	33.62 C	14.07C	11.30 C
Crotalária	381.90 A	25.79 A	130.20 A	148.70 A	79.70 A
Crotalária+corn	199.70 B	14.25 B	75.39 B	85.00 B	39.31 B
Jack beans	244.60 B	18.40 A	80.17 B	148.9 A	30.36 B
Jack beans + corn	98.25 C	7.68 C	35.79 C	91.99 B	17.61 C
CV (%)	33.32	22.69	23.79	32.31	25.61

¹Averages followed by the same letter do not differ from each other by the Scott-Knott test at 5% probability.

and Ca.

In relation to total and marketable productivity of sweet potato (Figure 1), the authors observed high productivity in all treatments in the first year of cultivation. That may have happened due to the fact that this area had been in

extended fallow period, approximately 10 years, before the experiment installation. In the second year of cultivation, the authors observed that the treatment with monocropped crotalária provided the best performance of the sweet potato, reaching a productivity of

19.9 t ha⁻¹. Similar result was reported by Souza *et al.* (2019) under similar climatic conditions and with the same cultivar. Quantifying performance of fourteen accessions of sweet potato evaluated in four different environments, Daros & Amaral Júnior (2000) obtained, for cultivar Rosinha do Verdan, maximum productivity of 24.1 t ha⁻¹ and minimum of 9.25 t ha⁻¹.

Correlation analysis showed that in the first year of cultivation, Ca showed positive correlations with total productivity of sweet potato, whereas, in the second year of cultivation, macronutrients K and Mg correlated positively with the total sweet potato productivity, allowing the authors to infer that the supply of these nutrients was one of the factors which were responsible for the beneficial effect on the productive yield of this vegetable in the second year of succession (Table 4). Espindola *et al.* (1998) verified positive correlations between sweet potato production and quantities of nutrients provided by pre-croppings, mainly when pre-cropping with velvet bean, which ensured greater supply of N and recycling of P and K, reaching an estimated sweet potato yield of 20 t ha⁻¹ under similar climatic conditions.

In relation to marketable productivity, the authors observed that crotalária intercropped with corn provided higher productivity of marketable-standard tubers in the first year; no difference was noticed in the second year of cultivation.

Considering the obtained data, monocropped crotalária obtained the highest productivity of dry biomass in the two consecutive cycles. In the second year of succession, it showed higher accumulated amounts of N, K and Mg in plant biomass. The cultivation of sweet potatoes in succession to the pre-cropping of crotalária is advantageous, as it provided an increase in vegetable productivity in the second year of succession.

The authors highlight the advantages of intercropping crops for organic agriculture management, as in addition to the production of biomass of the two species, the farmers can obtain additional income from the production of green ears, which may contribute

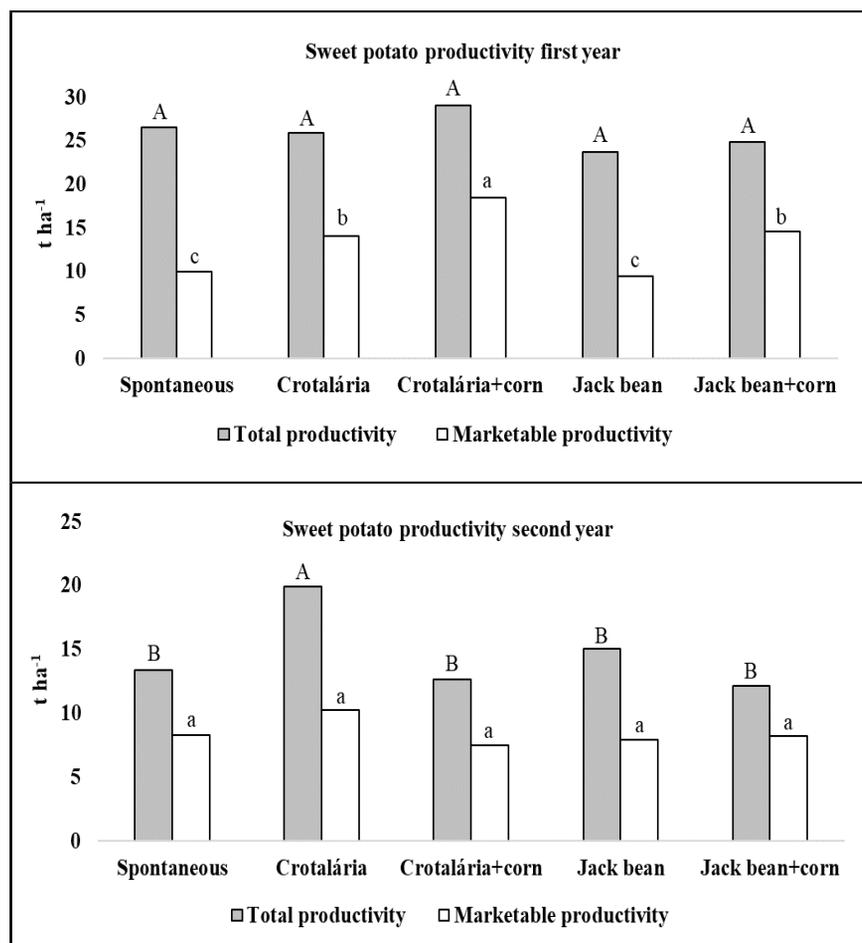


Figure 1. Total and marketable productivity of sweet potato obtained in two consecutive cycles. Averages followed by the same letter, uppercase for total productivity and lowercase for marketable productivity do not differ from each other by the Scott-Knott test at 5% probability. Seropédica, Embrapa Agrobiologia, 2012, 2013.

Table 4. Pearson's correlation coefficients (r) which relate the macronutrients accumulated by green manures with the total productivity of sweet potatoes in two consecutive cycles. Seropédica, Embrapa Agrobiologia, 2012, 2013.

Macronutrient	Year 1	Probability of significance	Year 2	Probability of significance
N	0.56	0.3247	0.85**	0.0714
P	0.66	0.2266	0.85**	0.0689
K	0.38	0.5244	0.89*	0.0438
Ca	0.89*	0.0441	0.62	0.2633
Mg	0.43	0.4667	0.88*	0.0431

Probability of significance: *significant values at 5% and **significant values at 10%.

to the adoption of green manure in production units.

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