Nitrogen fertilization of coffee: organic compost and *Crotalaria juncea* L.[1]

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ABSTRACT

Information concerning the response of coffee to organic fertilizers is scarce. This study evaluates the effect of different doses of compost and *Crotalaria juncea* L. on growth, production and nitrogen nutrition of coffee trees. The treatments consisted of compost at rates of 25, 50, 75 and 100% of the recommended fertilization, with or without the aerial part of *C. juncea*. *C. juncea* was grown with NH_4-N (2% ^{15}N) and applied to coffee. The use of *C. juncea* increased growth in height and diameter of the coffee canopy. In the first year, the percentage of N derived from *C. juncea* reached 8.5% at seven months and 4.1% at fifteen months after fertilization. In the second year, the percentage of N derived from *C. juncea* reached 17.9% N at the early harvest, five months after fertilization. Increased rates of compost increased pH , P , K , Ca , Mg , sum of bases , effective CEC, base saturation and organic matter and reduced potential acidity. ^{15}N allowed the identification of the N contribution from *C. juncea* with percentage of leaf N derived from *Crotalaria juncea* from 9.2 to 17.9%.

Key words: *Crotalaria juncea* L., green manure, organic fertilizer, ^{15}N.

RESUMO

Adubação nitrogenada de cafeeiros com composto e crotalária

A resposta do cafeeiro aos adubos orgânicos é pouco estudada e, por isso, objetivou-se, neste trabalho, avaliar o efeito de diferentes doses de composto e de *Crotalaria juncea* L. sobre o crescimento, a produção e a nutrição nitrogenada dos cafeeiros. Os tratamentos foram: composto orgânico, nas doses de 25, 50, 75 e 100% da adubação recomendada, com ou sem a parte aérea de C. juncea. A *C. juncea* foi cultivada com N-NH_4 (2% de ^{15}N) e aplicada nos cafeeiros. A crotalária promoveu maior crescimento em altura e diâmetro de copa do cafeeiro. No 1º ano, o percentual de N derivado da crotalária atingiu 8,5% aos sete meses e 4,1%, aos quinze meses após a adubação. No 2º ano, foram atingidos 17,9% de N derivado da crotalária no início da colheita, cinco meses após a adubação. O aumento das doses de composto promove a elevação do pH, P, K, Ca, Mg, Soma de bases, CTCefetiva, saturação de bases e matéria orgânica, e redução da acidez potencial. O uso do isótopo ^{15}N permite a identificação da contribuição do N derivado da crotalária para o cafeeiro, com percentuais foliares de N derivado de *Crotalaria juncea* de 9,2 a 17,9%.

Palavras-chave: *Crotalaria juncea* L., adubação verde, adubação orgânica, ^{15}N.

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INTRODUCTION

Green manure and compost fertilizations are common practices in agro-ecological coffee production, but despite the potential benefits of organic fertilizers (Ricci *et al*., 2005; Bergo *et al*., 2006), there is little information on the response of coffee trees to these fertilizers. Compost increases foliar N with increasing rates (Araujo *et al*., 2007). It also replaces N and K from mineral sources in coffee during the formation phase, promoting growth similar to the mineral fertilization in number of nodes and branches, leaf area and leaf dry matter (Araujo *et al*., 2008) .

The legume production in situ allows the complementation of fertilization by the input of N-BNF (N from Biological Nitrogen Fixation) in the productive system. This complementation with *C. juncea* was reported for corn (Silva *et al*., 2006) and sugarcane (Ambrosano *et al*., 2011) and wit early or late legume species in grapevine (Ovalle *et al*., 2010).

N levels are also influenced by legume species. There are reports of lower leaf N content in coffee intercropped with *Crotalaria juncea* compared with the monocrop (Ricci *et al*., 2005), as well as similar leaf N in coffee fertilized with gray velvet bean (aerial parts) and ammonium sulfate, although the application of leucaena, pigeon pea, perennial peanut, brachiaria or sorghum has resulted in lower levels than those obtained with application of ammonium sulfate (Fidalsky & Chaves, 2010).

The application of legumes (aerial parts) produced in other areas allows the nutritional study and fertilizing potential without the interference effect of the intercropping (Fidalsky & Chaves, 2010; Vilela *et al.,* 2011). There are reports of increased growth and yield of coffee trees that received legume biomass compared with those obtained with ammonium sulfate (Fidalsky & Chaves, 2010; Vilela *et al* , 2011).

Although green manure is known as N source, studies that determine the percentage of N present in coffee derived from legumes are scarce. Snoeck *et al*., (2000) reported that 42.3% of N in coffee was originated from *Leucaena leucocephala* (Lam) de Wit. There are reports of legume contribution of legumes to nitrogen nutrition in other crops. The application of *C. juncea* in maize resulted in 45.4% of N derived from the aerial part of the legume used as the sole fertilizer and 23.4 to 16.5% when supplemented with different doses of urea (Silva *et al*., 2009a). In grapevine, 14 to 20% of leaf N derived from early and late intercropped pulses, respectively (Ovalle *et al*., 2010).

Direct determination of N derived from legumes uses isotopic enrichment of green manure, which allows increasing the ^{15}N concentration above the natural abundance of ^{15}N in the air and, thus, to use the isotope as a tracer. The labeling strategy is to grow the green manure in a controlled environment in order to inhibit the biological fixation and uptake of the ^{15}N-fertilizer to achieve the desired isotopic labeling (Ambrosano *et al*., 2003).

Despite some recent studies, little is known about the effect of different organic fertilizer rates and their complementation with green manure. Therefore, we aimed to evaluate the initial growth, yield and content of N derived from green manure (NfGM) in Arabic coffee fertilized with different rates of compost, supplemented with *Crotalaria juncea*.

MATERIALS AND METHODS

The experiment was conducted at the Federal University of Viçosa, MG, located at 20° 45' 14'' S and 42° 52' 53'' O, 650 m altitude. The region has a cold and dry winter, hot and rainy summer with average temperature of 19.4 °C (maximum 26.4 °C and minimum 14.8 °C) and average rainfall of 1.221 mm per year.

The experimental design was a 4x2 factorial arrangement with four levels of organic fertilizer (25, 50, 75 and 100%) and two rates of *Crotalaria juncea* (0 and 450 g/plant) in a randomized block design with four replications. The plots contained nine plants, considering seven useful plants.

Seedlings of *Coffeea arabica* cv. Oeiras were planted in February 2009 in a spacing of 2.0 x 0.75 m. Initially, the soil characteristics were: 1.4 g kg^{-1} of organic matter; pH (H_2O) 5.2; 8.0 mg dm^{-3} P; 50 mg dm^{-3} K; 2.0 cmol$_c$.dm^{-3} Ca^{2+}; 0.8 cmol$_c$.dm^{-3} Mg^{2+}; 0.3 cmol$_c$.dm^{-3} Al^{3+} ; 3.80 cmol$_c$.dm^{-3} H + Al^{3+}; 2.93 cmol$_c$.dm^{-3} sum bases; 3.23 cmol$_c$.dm^{-3} effective CEC; 6.73 cmol$_c$.dm^{-3} total CEC; 44% of base saturation and 32.6 mg L^{-1} P-rem. Planting holes received 0.165 kg of lime, 0.286 kg of Gafsa rock phosphate, 0.03 kg of FTE BR 11. The rate of 100% chicken manure at transplanting corresponded to 0.07 kg/hole of N. Poultry litter had pH (H_2O) of 7.69; 52.9% moisture; C/N ratio 10.4 and levels of 20.74 g kg $^{-1}$ of organic carbon (OC); 19.9 g kg^{-1} N; 14.4 g kg^{-1} P; 28.8 g kg^{-1} K; 35.3 g kg^{-1} Ca; 6.4 g kg^{-1} S, which were determined according to Silva (2009c).

Production of labeled C. juncea (^{15}N-Cj) and unlabeled C. juncea (Cj)

Cj was grown in the field, without lime and fertilizers, spaced 0.5 m apart with 30 seeds per meter. The first cultivation took place from 22/11/2009 to 25/01/2010 and the second, from 05/10/2010 to 22/12/2010.

^{15}N-Cj was grown in a greenhouse in the same period, in 500-L fiberglass boxes. The seeds were immersed in 1% sodium hypochlorite for 5 minutes, then 70% ethanol for 1 minute, washed with distilled water and sown. Each box was filled with 260 L of the substrate washed sand and vermiculite 1:1, fertilized with 300 mg dm^{-3} of P_2O_5, 29 mg dm^{-3} K and 130 mg dm^{-3} (N ammonium sulfate with 2% ^{15}N a.e.). The ratio of Ca and Mg was 3:1. The application of N and K was split at 5, 12 , 19 , 25 , 33 , 37 , 41 and 57 days after sowing. Micronutrients were applied via Hoagland and Arnon (1950) solution, according to Martinez & Clemente (2011), in the following formulation: B = 46 µmol L^{-1}; Cu = 0.3 µmol L^{-1}; Fe + EDTA = 45 µmol L^{-1}; Mn = 12.6 µmol L^{-1}; Mo = 0.1 µmol L^{-1} and Zn = 1.3 µmol L^{-1}, completing the volume to 1000 mL with distilled water, applying 0.5 mL dm^{-3} substrate.

Four samples of ^{15}N-Cj and Cj were weighed at harvest, dried in an oven at 65 °C to constant biomass and ground. N content was determined by the Kjeldahl method. ^{15}N-Cj samples were powdered in a rolling mill for 24 hours for ^{15}N determination using a biomass spectrometer (Finnigan Mat Delta Plus), Nitrogen Laboratory of Embrapa Agrobiology.

C. juncea decomposition

Fresh matter samples of 0.20 kg of *C. juncea* were placed on the ground under the coffee canopy, covered with 0.30 x 0.30 m screens of 4 x 4 mm mesh and collected after 0 , 3 , 7, 12 , 18, 25, 32 , 40 and 60 days. The samples were collected and dried at 65 ° C up to constant mass in an oven with forced air circulation, weighed, ground and N content was determined by the Kjeldahl method.

Decomposition rates of dry matter and N mineralization of the green manure were determined by nonlinear regression models, as described by Wieder & Lang (1982), as cited by Aita & Giacomini (2003). The asymptotic model has the following equation:

$$DMR \text{ or } NR = A\, e^{-kat}$$

where: DMR and NR correspond to the percentage of dry matter and nitrogen remaining at time t; t is the sampling time from 0 to 60 days; ka is the constant rate of decomposition of dry matter and N mineralization. DMR and NR were calculated relative to DM and N at time zero for each sampling time. From the decomposition constants of DMR or NR, it was calculated the half-life ($t_{1/2}$) required for 50% of the dry matter or N to be mineralized to the soil, using the equation ($t_{1/2}$) = ln 0.5/k, according to Paul & Clark (1996). The rainfall for the period was 58 mm (Jan), 45 mm (Feb) and 185 mm (Mar) and 28 mm (Apr).

Fertilization with *C. juncea*

Cj was applied to the useful plants of the plot and ^{15}N-Cj was applied to microplots containing two coffee trees on 29/01/2010 and 21/12/2010 (Figure 1). Each plot had two microplots (M1 and M2), one for each year of the application of labeled *C. juncea*. The plots were fenced with galvanized steel plates, 0.5 m high, buried 0.45 m deep, in an area of 2.0 x 1.5 m. The level of N-Cj was 13.41 g kg^{-1} of N in the 1st crop year (2009/2010) and 17.45 g kg^{-1} in the 2nd crop year (2010/2011).

Topdressing

The organic compost was prepared in 60% elephant grass, 20% of coffee husk and 20% of poultry litter. The application was in a single dose. In November 2009 (Figure 1), the rate 100% of compost corresponded top 0.03 kg/plant N according to the recommendation of Guimarães *et al*. (1999) and, in November 2010, it was calculated for the expected production of 20 bags ha^{-1} (1200 kg ha^{-1}), which corresponded to 0.021 kg/plant of N. The compost used in November 2009 had pH (H_2O) 9.13; 17.95 C/N; 226.5 g kg^{-1} organic carbon; 12.6 g kg^{-1} N; 16.2 g kg^{-1} P; 24.0 g kg^{-1} K; 77.0 g kg^{-1} of Ca; 5.2 g kg^{-1} Mg; 4.8 g kg^{-1} S, wich were determined according to Silva (2009c). The compost used in November 2010 had pH (H_2O) 9.46; 168.3 g kg^{-1} organic carbon; C/ N 8.05; 20.9 g kg^{-1} N; 24.4 g kg^{-1} P; 25.6 g kg^{-1} K; 110.3 g kg^{-1} Ca; 7.6 g kg^{-1} Mg; and 7.0 g kg^{-1} S.

Growth evaluation

Total growth of coffee trees was evaluated through height (H) and crown diameter (CD). The upper crown was evaluated: a tape was used to mark the second internode from the apex of the plant. Above the marked internode, we measured height (Hm), the number of plagiotropic branches (NPBm) and nodes of the orthotropic branch (NNOm). In the plagiotropic branches of the marked internode we measured length (LPBm) and recorded the number of nodes (NNPm), reproductive nodes (NRNm) and leaves (NLPm). Markers were placed on 24/04/2010 and measurements of H, Hm, NPBm, NNOm and CD were taken on 7/11/10 and 19/04/11 (Figure 1), while LPBm, NNPm, NRNm and NLPm were taken on 20/11/10 and 22/04/11.

Coffee harvest and soil characteristics

Harvest was carried out in May and June 2011, in coffee trees with over 50% of ripe fruit (visual evaluation). Samples of 2.0 kg of each picking were placed in jute bags, dried in a shed drying patio to 12% moisture and processed. Soil samples were collected (0-0.20 m deep) in the canopy projection of the coffee trees, in September 2011. The composite samples were obtained from seven subsamples, corresponding to the useful plants of each plot. The analyses were performed according to Silva (2009c).

Leaf sampling

Samples of the 3rd or 4th pair of leaves were collected from the apex of the plagiotropic branch in the middle third of the coffee tree in April, June and December 2010 and in April 2011 (Figure 1). Drying of leaves and determinations of N and N derived from green manure NfGM were the same as described for *C. juncea*. The estimated recovery of NfGM was obtained by the following equation:

NfGM % = (% ^{15}N a.e. in coffee / % ^{15}N a.e. in leg) x 100,

Where: ^{15}N % a.e. in coffee is the atom percent excess in coffee leaves and % ^{15}N a.e. in leg is the atom percent excess in *C. juncea*.

Statistical analyzes

Data of growth, production, soil, N content and the percentages of NfGM were subjected to analysis of variance at 5% probability. The response to the factor rates of compost and the variables of *C. juncea* decomposition were analyzed by regression analysis.

RESULTS

C. juncea *decomposition*

At day 60, the remaining dry matter of *C. juncea* corresponded to 66.4% of the original mass (Table 1) and $T_{1/2}$ was estimated at 96.3 days. $T_{1/2}$ of N was estimated at 33.3 days and 69.1% of N was mineralized up to 60 days, which corresponds to the release of 20.2 kg ha^{-1} and 27.8 kg ha^{-1}, respectively.

Growth and production

There was a significant effect of *C. juncea* fertilization between November 2010 and April 2011 on H, Hm and CD ($p < 0.05$), both in total growth, until April 2011 (B), and in the increase between November 2010 and April 2011 (BA) (Table 2). There was significant effect ($p < 0.05$) of compost on CD, with an increase of almost 0.1 cm for every 1.4 kg N ha^{-1} (Table 1). There was no significant effect of compost rates and *C. juncea* on coffee yield ($p \leq 0.05$), with mean of 7.9 bags ha^{-1} (s = 2.94 - 7.9 bags = 474 kg).

Soil Characteristics

There was effect of compost for all variables of *C. juncea*, on the H+Al content and interaction of factors on total CEC ($p < 0.05$) (Table 3). Increased rates of compost increased pH, P, K, Ca, Mg, sum of bases, effective CEC, base saturation and organic matter and reduced the potential acidity (Table 1). There was effect of compost unfolding for each level of *C. juncea* ($p < 0.05$) on total CEC, with linear increase of the levels without *C. juncea* (Table 1). The unfolding of the *C. juncea* rate within each level of compost showed an increase in total CEC with addition of *C. juncea* at the rates 25 and 75% of compost (Table 3). The use of *C. juncea* biomass decreased the potential acidity from 2.03 to 1.84 cmol$_c$ cm^{-3}, indicating that the legume promoted the increase of bases in the soil exchange complex, since the aluminum content of the soil was null (Table 1).

Leaf N at sampling dates

There was significant effect ($p < 0.05$) in Apr/2010 due to *C. juncea*, in Jun/2010 and Apr/2011 due to the compost

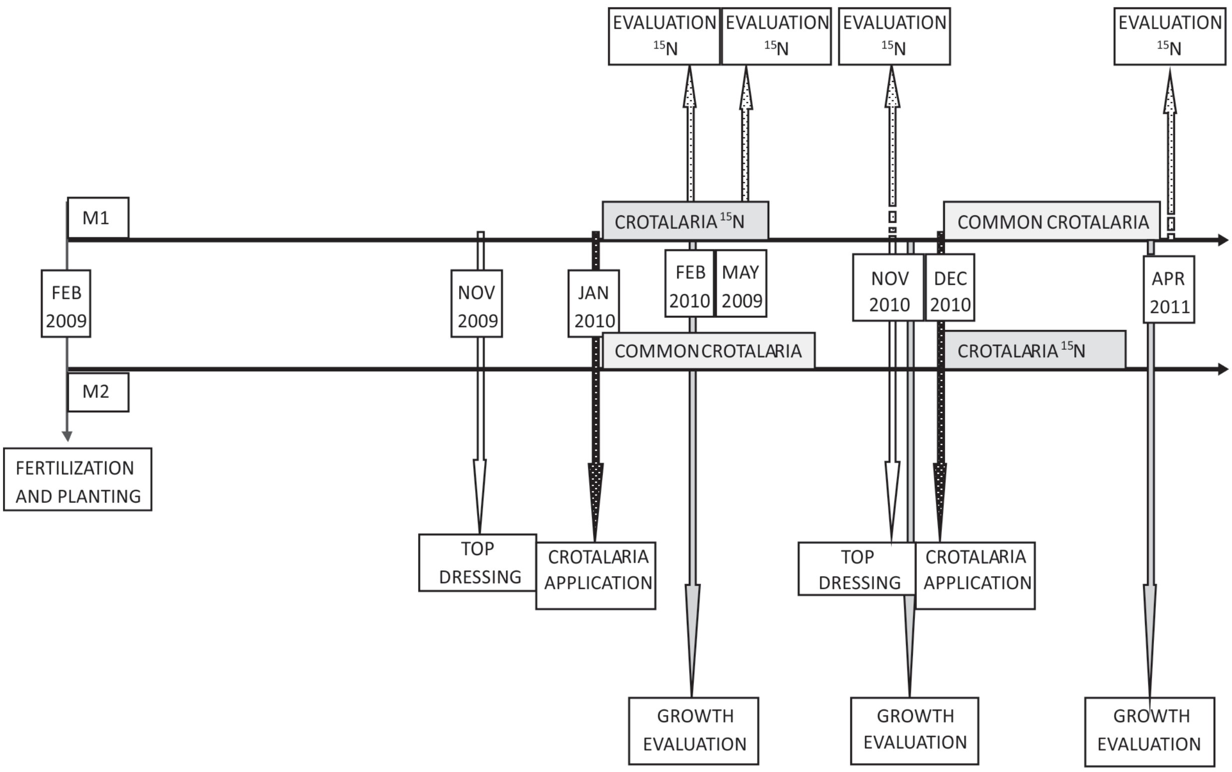

Figure 1. Chronology of organic fertilizer application at planting and topdressing, *Crotalaria juncea* conventional or labeled with ^{15}N to microplots in the years 1 and 2 (M1 and M2) and the evaluation times.

and in Dec/2010, because of the interaction of the factors (Table 4). In April 2010, leaf N concentration was higher with *C. juncea*, indicating a supplementary effect to the compost, which did not occur on the following dates. Leaf contents increased with compost rates, from 2.47 to 2.82% in June 2010 and 1.91 to 2.22% in April 2011 (Table 4), promoting increases of 14 and 17%, respectively.

In the unfolding of *C. juncea* levels, within each compost rate, the supplementary fertilization with *C. juncea* reduced leaf N in the rates 25% and 50% of compost N, and increased leaf N in the rate 100% (Table 4). In the unfolding of the effect of compost rates, within each level of *C. juncea* in November 2010, the leaf N concentration decreased with increasing compost rates (Table 1),

Table 1. Regression equations and coefficients of determination for estimates of dry matter and N remaining from *Crotalaria juncea*, crown diameter, soil variables, leaf N and leaf N percentage derived from green manure (NfGM) in coffee fertilized with different rates of organic compost (x)

Variables	Date	Equation	r^2
Remaining dry matter	——	$\hat{y} = 102.2243\ e^{-0.0071x}$	0.7960
Remaining nitrogen	——	$\hat{y} = 113.3307\ e^{-0.0217x}$	0.9280
Crown diameter (cm)	Apr/2011	$\hat{y} = 91.52 + 0.4665^{**}x$	0.8882
pH	Jan/2012	$\hat{y} = 6.3687 + 0.00570^{**}\ x$	0.8664
P (dag kg^{-1})	Jan/2012	$\hat{y} = 104.2500 + 3.66000^{**}x$	0.9606
K (dag kg^{-1})	Jan/2012	$\hat{y} = 414.4375 + 2.22000^{**}x$	0.9373
Ca ($cmol_c\ dm^{-3}$)	Jan/2012	$\hat{y} = 2.5062 + 0.01180^{**}x$	0.9775
Mg ($cmol_c\ dm^{-3}$)	Jan/2012	$\hat{y} = 0.5187 + 0.00225^{**}x$	0.8224
H+Al ($cmol_c\ dm^{-3}$)	Jan/2012	$\hat{y} = 2.3375 - 0.00620^{**}x$	0.8196
SB and t ($cmol_c\ dm^{-3}$)	Jan/2012	$\hat{y} = 4.0125 + 0.02030^{**}x$	0.9876
CEC_{total} (without *C. juncea*) ($cmol_c\ dm^{-3}$)	Jan/2012	$\hat{y} = 5.8625 + 0.02210^{**}x$	0.8287
CEC_{total} (with *C. juncea*) ($cmol_c\ dm^{-3}$)	Jan/2012	$\hat{y} = 7.5025$	——
V (%)	Jan/2012	$\hat{y} = 60.5625 + 0.16500^{**}x$	0.9476
OM (mg dm^{-3})	Jan/2012	$\hat{y} = 1.69375 + 0.00790^{**}x$	0.9986
N (%)	Jul/2010	$\hat{y} = 2.3583 + 0.0218^{**}x$	0.9254
N without *C. juncea* (%)	Dec/2010	$\hat{y} = 3.0645 – 0.0355^{**}x$	0.8276
N with *C. juncea* (%)	Dec/2010	$\hat{y} = 2.5111$	——
NfGM	Apr/2011	$\hat{y} = 1.803 + 0.0198^{**}x$	0.9227

** Significant at 1% probability by t test.
N doses of the organic compound in Nov/2010 : 5.25 , 10.50 , 15.75 and 21.00 g/plant.

Table 2. Coffee growth under two rates of *Crotalaria juncea* aerial parts, 24/April/2010, evaluations in November/2010 (A) and April/2011 (B), and increase between the two dates (B-A)

C. juncea[1] (g/plant)	H (cm)	Hm (cm)	NPBm	NNOm	CD (cm)	LPBm (cm)	NRNm	NLPm
				A: Apr-Nov/2010				
0	55.51 a	10.95 a	8.58 a	5.66 a	58.97 a	12.18 a	5.60 a	9.91 a
450	56.01 a	10.99 a	9.00 a	5.75 a	59.48 a	12.12 a	5.42 a	10.01 a
CV (%)	9.65	16.47	12.23	7.81	13.45	12.48	7.17	8.23
				B: Nov-Apr/2011				
0	84.84 a	42.97 a	21.52 a	13.35 a	94.33 a	37.13 a	11.44 a	16.44 a
450	89.93 b	48.32 b	22.78 a	13.78 a	100.96 b	37.49 a	11.68 a	16.79 a
CV (%)	5.95	9.35	10.12	6.46	5.24	18.55	8.19	16.48
				B-A				
0	29.33 a	32.03 a	12.94 a	7.69 a	35.36 a	24.95 a	5.84 a	6.52 a
450	33.91 b	37.33 b	13.77 a	8.03 a	41.48 b	25.36 a	6.26 a	6.78 a
CV (%)	18.60	13.70	17.84	12.82	18.46	8.34	12.37	37.61

[1]Corresponding to N applications of 6.03 g/plant in Jan/2010 and 7.85 g/plant in Dec/2010
Total height (H); Height at the top of the canopy (Hm); number of plagiotropic branches (NPBm); nodes of the orthotropic branch above the marked internode (NNOm); crown diameter (CD). Length (LPB), number of nodes (NRNm) and number of leaves (NLPm) of the the marked plagiotropic branch.
Means followed by the same letter in the column are not significantly different by the F test ($p \geq 0.05$).

indicating a negative effect of the compost on the leaf contents in the month following the fertilization, without *C. juncea*. Leaf contents decreased by 20%, from 2.88 to 2.31%, from the lowest to the highest compost rate.

N derived from green manure (NfGM) - Evaluation in April and June 2010

There was significant effect ($p < 0.05$) of the isolated factors of compost and sampling time on NfGM. NfGM decreased with increasing compost rates (Table 5), with reduction of 38.9% at the highest compost rate. Between the 3rd and 5th months after fertilization with *C. juncea*, there was an increase in NfGM and leaf percentage: in June 2010 was 34% higher than in April 2010 (Table 5).

Evaluation in December 2010 and in April 2011

The N rate of the compost ranged from 25 to 100% and did not change the NfGM percentage, indicating that factors other than the amount of N applied interfered with leaf N of coffee. The NfGM percentage was higher in December 2010 compared with April 2011 (Table 5).

Effect of fertilization with labeled C. juncea in December 2010

The analysis of NfGM leaf percentage, as a function of compost rates, found no significant effect by the F test ($p \geq 0.05$), although the addition of N via compost has grown four-fold, from the lowest rate to the highest (Table 5).

DISCUSSION

C. juncea decomposition

The $T_{1/2}$ of N-Cj at 33.3 days is close to the results reported in the literature of 24 days (Diniz *et al*., 2007) and 28 days (Ribas *et al*., 2010) for gray velvet bean; 30, 56 and 32 days were reported for forage peanut, tropical kudzu and siratro, respectively (Espindola *et al*., 2006); and more than 15 days for *C. juncea* (Perin *et al*., 2006). Since 53% of the N is accumulated between February and May, during coffee bean development (Laviola *et al*., 2008), there may have been synchrony between *C. juncea* applied on January 29 and mineralization of 50 and 69.1% of N, respectively, in the first and second month of bean development.

Growth

The rates of compost and *C. juncea* did not exert different responses on the growth in the two initial years, suggesting that 25% of the compost rate, with 7.5 and 5.25 g N per plant were enough for coffee. However, in April 2011, at the end of the fruiting period, there was response of coffee to *C. juncea*, indicating that the

Table 3. Total CEC in soil cultivated with coffee and fertilized with compost and *Crotalaria juncea*

C. juncea	**Compost (%)**			
(g/plant)	**25**	**50**	**75**	**100**
	CEC total ($cmol_c$ dm^{-3})			
0	6.27 b	6.95 a	7.05 b	7.70 a
450	7.12 a	7.15 a	7.97 a	7.77 a

Means followed by the same letter in the column are not significantly different by the F test ($p \geq 0.05$).

Table 4. Leaf N in coffee trees fertilized with *Crotalaria juncea* dry matter, sampled in April, June and November, 2010 and April/2011 and N contents as function of compost and *Crotalaria juncea* rates sampled in November, 2010

C. juncea[1]	**Apr/2010**	**Jun/2010**	**Nov/2010**	**Apr/2011**
(g/plant)	**N (%)**			
450	2.67 a	2.70 a	2.51 a	2.12 a
0.0	2.41 b	2.58 a	2.60 a	2.01 a
CV (%)	9.45	7.59	8.84	7.22
	Compost[2]			
C. juncea	**25%**	**50%**	**75%**	**100%**
(g/plant)	**N (%)**			
450	2.46 b	2.43 b	2.44 a	2.72 a
0.0	2.81 a	2.84 a	2.41 a	2.34 b
CV (%)	8.84			

[1]450 g/plant corresponding to N supply of 6.03 g/plant in Jan/2010 and 7.85 g/plant in Dec/2010

[2]Rates corresponding to 7.5; 15.0; 22.5 and 30.0 g/plant of compost N applied in Nov/2010.

Means followed by different letters in the column are significantly different by the F test ($p < 0.05$).

compost only was not efficient to supply the nutritional demand. It is likely that the response to *C. juncea* fertilization was due to the increased demand during the fruiting period, with beans acting as strong nutrient sinks (Fenilli *et al*., 2007b; Laviola *et al*., 2008) and the plant simultaneously in vegetative and reproductive growth (Fenilli *et al*., 2007a).

Increased H, Hm and CD with *C. juncea* fertilization suggest that there was an effect of the split fertilization, because *C. juncea* was applied 49 days after the compost. This complementation was of 7.8 g/plant of N, compared with 21 g/plant at the highest compost rate.

Araujo *et al*. (2008) reported higher vegetative growth with rates of organic compost ranging from 0.702 to 0.770 kg/pot, in 10 dm^3 pots. These rates corresponded to 64-70 g of N in 64 dm^3 holes, which were taken as reference values in this work. This correspondence was a high value for field conditions, because the application of 0.0175 kg/hole of N was not different from 0.07 kg/hole and is close to the recommendation for Minas Gerais, which ranges from 0.009 to 0.025 g/plant (Guimarães *et al*., 1999).

The initial yield of processed coffee in this work, 7.9 bags ha^{-1}, is close to that obtained by other authors in the 1st harvest, with 3.5 , 4.5 and 9.6 bags ha^{-1}, respectively in coffee fertilized with gray velvet bean, leucaena and sugarcane filter cake (Fidalsky & Chaves, 2010); 6.6, 9.1 and 12.1 bags ha^{-1} in conventional crops (Carvalho *et al*., 2006) and 4.8 bags ha^{-1} in irrigated conventional system with application of 280 kg ha^{-1} N (Fenilli, 2006).

Table 5. Percentage of leaf N derived from *Crotalaria juncea* (NfGM) applied in January 2010, in coffee fertilized with compost, at four sampling times

Compost[1]		*C. juncea* applied in Jan/2010	
		Evaluation times	
		Apr/2010	Jun/2010
Rate (%)	**N (g/plant)**	**NfGM %**	
25	7.5	8.15	11.56
50	15.0	8.35	10.77
75	22.5	4.98	6.76
100	30.0	5.93	7.62
Mean		6.85a	9.18 b
CV (%)		17.86	
		Dec/2010	**Apr/2011**
Rate (%)	**N (g/plant)**	**NfGM %**	
25	7.5	8.38	4.30
50	15.0	8.00	4.38
75	22.5	6.26	3.83
100	30.0	6.99	4.08
Mean		7.41 a	4.15 b
CV (%)		13.43	
		***C. juncea* applied in Dec/2010**	
Compost[2]		**Evaluation times**	
		Apr/2011	——
Rate (%)	**N (g/plant)**	**NfGM %**	
25	7.5	19.36	——
50	15.0	20.70	——
75	22.5	16.43	——
100	30.0	15.21	——
Mean		17.93	——
CV (%)		36.11	——

[1]Compost applied in November 2009

[2]Compost applied in November 2010.

Fertilization with *Crotalaria juncea* (450 g/plant) corresponding to the N rate of 6.03 g/plant in Jan/2010 and 7.85 g/plant in Dec/2010. Means followed by different letters in the same row are significantly different by the F test ($p < 0.05$).

Soil analysis

Despite improvements in all indicators of soil quality with increasing compost rates, there was no response of coffee to yield gains as a function of the rates. This fact shows that the lowest compost rate was enough for the coffee tree to reach its yield potential at the 1st harvest, at 27 months old.

The compost applied in 2010 was well cured and application of mature compost should be split, especially in perennial crops, to prevent leaching losses of ammonium and nitrate (Melo *et al*., 2008). In consequence, part of the compost N, especially at higher rates, may have been lost by leaching or immobilized by soil organisms, whose populations tend to grow with the addition of organic material to the soil (Balota & Chaves, 2010). Therefore, splitting of compost at higher rates might reduce potential losses and provide mineralized N at times of greatest demand, after flowering and at the pinhead stage, since the dry matter accumulation rate of beans increases up to the 3rd week of February (Fenilli *et al*., 2007b) and the highest N accumulation occurs at the stages of rapid expansion, between December and January, and bean-filling stage, between February and April (Laviola *et al*., 2008).

Leaf N

The highest leaf N content of coffee treated with *C. juncea* occurred only in April 2010 and can be related to rainfall distribution. Precipitation was lower in February 2010 (45.5 mm), increased in March (184.8 mm) and certainly enabled that the mineralized nutrients from organic matter were released to the soil and absorbed by the coffee tree.

After ten months (November 2010), following the *C. juncea* application, leaf concentrations of N-compost at the rates of 25 and 50% were higher without the legume. However, at the rate of 100%, the highest leaf N was recorded with *C. juncea*. Hence, there was a residual effect of *C. juncea* and a probable N immobilization by soil microorganisms to decompose this remaining organic matter, resulting in a reduction of leaf concentrations at the rates of 25 and 50%.

In maize grown in pots and fertilized with *C. juncea*, there was no N immobilization caused by the legume, because of the relatively low C/N (Ambrosano *et al*., 2003 and 2009). However, maize is an annual and short-cycle crop and would be less influenced by the remaining and more recalcitrant organic matter. In this study, at 60 days after the *C. juncea* cutting, the dry matter and N remaining were 66.4 and 30.1%, respectively, with N depletion in the remaining organic matter, which may have contributed to the N immobilization and reduced leaf content in December 2010.

The compost applied in November 2010 had pH 9.5; C/N ratio of 8/1 and 168 g kg^{-1} of organic carbon. These values are close to those indicated for mature compost parameters, with alkaline pH, C/N ratio and organic carbon adequate to N mineralization (Herberts *et al*., 2005; Silva *et al*, 2008; Silva *et al*., 2009b). Nevertheless, there was reduction in leaf N in the month subsequent to fertilization with increasing compost rates, which may be due to the initial N immobilization caused by the increase in microbial biomass (Herberts *et al*., 2005).

Leaf N derived from C. juncea in the first year of growth

The decrease in NfGM of coffee leaves, from 9.96 to 6.08%, with increasing compost rates, in April 2010, indicated a dilution effect. The decrease was small, despite the N-Cj rate (6.03 g/plant) has varied from 45 to 17% of the total N applied with the N-compost. A greater variation was obtained in the aerial parts of maize fertilized with 1.0 g of N-Cj per pot, with NfGM decreasing from 44.6 to 14.0% at rates of urea from 0.0 to 2.25 g/pot (Smith *et al*., 2009b). The smaller variation in the percentage of NfGM with compost, in relation to urea, may be related to the increased availability of N-urea, which is totally soluble, and the application of compost in a single dose 49 days before *C. juncea*, compared with the results of Smith *et al*. (2009b), who applied *C. juncea* together with the first dose of urea. This same reasoning can be applied to the results of *C. juncea* application in December 2010, two months after the compost application, which resulted in 17.9% of NfGM regardless of the compost rate, indicating no dilution of the N-Cj by the N-compost.

The increase in leaf NfGM in June 2010 compared with April 2010, suggests an increase in the availability of N-Cj in the soil in relation to the organic compost. However, Ambrosano *et al*. (2009) reported values between 40 and 42.4% of N derived from aerial parts of *C. juncea* and velvet bean as the sole N source, in maize aerial parts at 20, 40, 60, 80 and 100 days after emergence. The differences observed are probably due to the two-month interval between the application of the compost and *C. juncea*, which increased the N available from *C. juncea*, the latest application.

Unlike what happens with green manure, in coffee fertilized with labeled ammonium sulfate, the leaf N from the fertilizer accounted for 24.4, 40.7, 44.8 and 49.6% of the total N at 63, 126, 182 and 263 days after anthesis (Fenilli *et al*., 2007a), indicating an increasing trend, which should be associated with the increased N availability in the soil after application of each portion of the fertilizer. These variations show that the separation of the application time of the compost and *C. juncea* can be beneficial for supplying N for coffee in a more distributed way.

Evaluation in the second year of growth (December 2010; April 2011)

The reduction of NfGM in April 2011 compared with December 2010, from 7.41% to 4.15%, is certainly related to the dilution of the ^{15}N applied in January 2010, with the beginning of the compost fertilization in November 2010 and the *C. juncea* application in December 2010. Similarly, Ambrosano *et al*. (2011) obtained 4.1% of N-Cj in sugarcane leaves in the 2nd harvest after *C. juncea* application, indicating the persistence of residual N in the soil. Fenilli *et al*., (2008) found in the litter and in the soil 46.3% of applied N after a year of application of marked ammonium sulfate in a coffee plantation.

Araujo *et al*. (2005) reported 12.8% of NfGM in wheat aerial parts, applying 100 kg N ha^{-1} of *C. juncea*. Ovalle *et al*. (2010) applied 68-194 kg N ha^{-1} with early and late legumes, respectively, supplementary to 40 kg ha^{-1} mineral N and found in grapevine leaves, 14 to 20% of NfGM. Ambrosano *et al*. (2011) obtained 10.9% of N derived from *C. juncea* in sugarcane leaves fertilized with 196 kg N-Cj ha^{-1}. The value found from the first application (6.85%) is below the values found in the literature, but 17.93% from the second application is close to the results reported. Despite the large difference between the levels of N supplied by legumes in many studies, the percentage of N derived from the legumes in the leaves does not show a direct relationship with the dose applied, leading us to believe that other factors predominate in the dynamics of N mineralization and absorption. However, the factor fertilization time may have led to large differences in the N levels in the two consecutive years. In the first year, the application was carried out at the end of January, near the period of decreasing N accumulation by the coffee (Fenilli *et al*, 2007b; Laviola *et al* , 2008), unlike the second year in which *C. juncea* was applied in December, in the early stage of rapid expansion and increasing N accumulation.

CONCLUSIONS

Until flowering, the coffee tree does not show increased growth in response to supplementation of organic compost with aerial parts of *Crotalaria juncea*.

After the onset of the reproductive phase, the coffee tree has higher growth rate with the fertilization with aerial parts of *Crotalaria juncea*, supplementing the compost fertilization.

The organic compost increases pH, P, K, Ca, Mg, sum of bases, effective CEC, base saturation and organic matter, and reduces the potential acidity.

The organic compound increases leaf N content in coffee trees.

When *Crotalaria juncea* is applied to coffee about two months after the organic compost, the ratio of leaf NfGM in coffee is independent of the compost rate.

The use of the isotope ^{15}N allows the calculation of the NfGM contribution to the coffee tree, with percentages of leaf N derived from *Crotalaria juncea* ranging from 9.2 to 17.9%.

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