Decomposition and release of nutrients from species of tropical green manure

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ABSTRACT

Decomposition processes and mineralization are essential to determine the time to deploy and manage species in consortia or rotations. The aim of this article was study the dynamics of biomass decomposition and release of macronutrients of plant residues of Fabacea. The species used were: jack bean *(Canavalia ensiformis),* pigeon pea *(Cajanus cajan),* dwarf mucuna *(Mucuna deeringiana)* and sunn hemp *(Crotalaria juncea).* The experiment was conducted in the field in a randomized block design, 4 x 5 factorial, four species of green manure and five times (0, 30, 60, 90, and 120 days). In the results, sunn hemp and pigeon pea had lower decomposition and release of C, N, K, and Mg. All species, K and P showed similar half-lives ($t_{1/2}$). For N, sunn hemp presented the lowest coefficient of mineralization (*k*), 0.0040 g g^{-1} dia^{-1}, associated with highest $t_{1/2}$ (173.3 days), already, jack bean showed the highest *k* (0.0122 g g^{-1} dia^{-1}) associated with the lowest $t_{1/2}$ (56.8 days). In edaphoclimatic conditions, use of the jack bean and the dwarf mucuna is recommended for supply of nutrients in shorter periods of time for subsequent crops. However, sunn hemp and pigeon pea are recommended for greater persistence of mulch on the soil.

Keywords: nutrient cycling; mineralization; Fabaceae.

INTRODUCTION

In agricultural and natural systems, the processes of decomposition and nutrient release from organic residues added in the soil are controlled by three main factors: (1) physical-chemical conditions of the environment, which are controlled by the climate and soil characteristics of the environment; (2) the type of vegetation that influences the quality of the organic material and its degradability; and (3) the nature of the decomposition community, micro-organisms and soil fauna (Perin *et al.*, 2010). In similar climate and managements conditions, the variables that control the process of decomposition are the soil decomposition community and chemical quality of plant residues added to the soil (Brito, 2003).

The use of green manure plants, mainly from the Fabaceae family, set in rotation, succession, or consortium with crops of economic interest, is a viable option in the maintenance or recovery of soil quality by providing nutrients (e.g., N) to subsequent cultures, which reduces dependence on mineral fertilizers in agroecosystems (O'Dea *et al.*, 2015). This is attributed to the ability of these species to incorporate atmospheric N through biological nitrogen fixation (BNF), recycle and mobilize nutrients from subsurface soil layers to surface horizons, increase the soil organic matter content, and consequently favor the edaphic

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biological activity (Sharma & Behera, 2009).

The qualitative characteristics of plant residues (e.g., contents of C, N, lignin, hemicellulose, and polyphenols) strongly influence the dynamics of decomposition and release of nutrients in the soil (Swift *et al.*, 1979; Palm, 1995; Mafongoya *et al.*, 1998; Monteiro & Gama-Rodrigues, 2004). Several studies have identified the influence of Fabaceae plant residue quality on decomposition rates and the release of nutrients in the soil (Palm & Sanchez, 1991; Cobo *et al.*, 2002a; Cobo *et al.*, 2002b; Gama-Rodrigues *et al.*, 2007; Mahama *et al.*, 2016; Pereira *et al.*, 2016; Veras *et al.* 2016). A study on cover crops with contrasting chemical characteristics showed that the pigeon pea (*C. cajan*) had higher lignin content (32%) in the period chosen for its pruning compared to other species (Carvalho *et al.*, 2011). Due to the high recalcitrance level of the lignin molecule (Swift *et al.*, 1979), the largest content in pigeon pea explains the lower rate of decomposition of the plant shoot of this Fabaceae. Carvalho *et al.* (2010) demonstrated that cellulose content of sunn hemp (*C. juncea*) was higher compared to other Fabaceae species and similar to wheat (*Triticum spp.,* Poaceae family). In the same study, the lignin in the shoots of pigeon pea (*C. cajan*) was 71% higher compared to *Urochloa humidicola* (Poaceae family). These results reflected in lower rates of decomposition for sunn hemp and pigeon pea compared to other Fabaceae species studied.

To evaluate decomposition rates and nutrient release, several trials have been conducted in the field with Fabaceae and other species that do not realize the biological nitrogen fixation (Espindola *et al.*, 2006; Pleguezuelo *et al.*, 2009; Meyer *et al*, 2011). The coefficient *k* expresses the weight loss kinetics of decomposing organic materials, and through this index, ecosystems in many regions were studied (Olson, 1963; Forey *et al.*, 2015). In a study of the decomposition of plant species, *k* values vary with latitude, temperature, precipitation, concentration of nutrients, and the C/N ratio of the species (Zhang *et al.*, 2008).

In addition to the amounts of biomass and nutrients accumulated by Fabaceae, it is of fundamental importance to know the dynamics by which these nutrients become available in order to identify the best management for the use of these green manure (Matos *et al.*, 2011). Therefore, it is imperative to know indices related to the decomposition processes and release of nutrients in different situations in order to determine, among other issues, the most appropriate time to deploy and manage these fertilizer species (Matos *et al.*, 2008). This knowledge improves crops of economic interest like Robusta coffee (*Coffea canephora*), a crop of great economic and social importance to the state of Espirito Santo, Brazil (Fassio & Silva, 2007). It is noteworthy that studies of this type with Fabaceae at conditions in this Brazilian state are unknown. The objective of this work was to study the dynamics of decomposition and release of accumulated macronutrients in species of tropical green manure.

MATERIALS AND METHODS

Area of study and treatments

The experiment was setup on a farm located in the city of Cachoeiro de Itapemirim, in the southern of the Espirito Santo state (latitude 20º 45’ 11” South and longitude 41º 17’ 39” West). The climate is Cwa, having rainy summers and dry winters according to the Köppen classification, with the highest rainfall occurring in March, November, and December (Figure 1).

The soil was classified as a Udox (Soil Survey Staff, 2010), and the physical and chemical characterization is detailed in Table 1.

The experimental design was a randomized block design (RBD) in a 4x5 factorial using four species of green manure and five data collection times (0, 30, 60, 90 and 120 days), with three replications. The plant material used was the shoot of the jack bean (*Canavalia ensiformis* (L.) DC.), pigeon pea (*Cajanus cajan* var. flavus DC.), dwarf mucuna (*Mucuna deeringiana* (Bort) Merr.), and sunn hemp (*Crotalaria juncea* L.).

The samples of plant material were placed in individual decomposition bags (litterbags) in the form of green material. Each sample consisted of 30 g of Fabaceae plant shoot material proportional to the percentage of leaves/ flowers and stems/ branches of each species. The decomposition bags were made of polyethylene screen with 1.5 mm mesh openings and dimensions of 0.2 m x 0.2 m. The experiment was setup in February 2010, with the decomposition bags distribution on the soil surface of a *Coffea canephora* plantation.

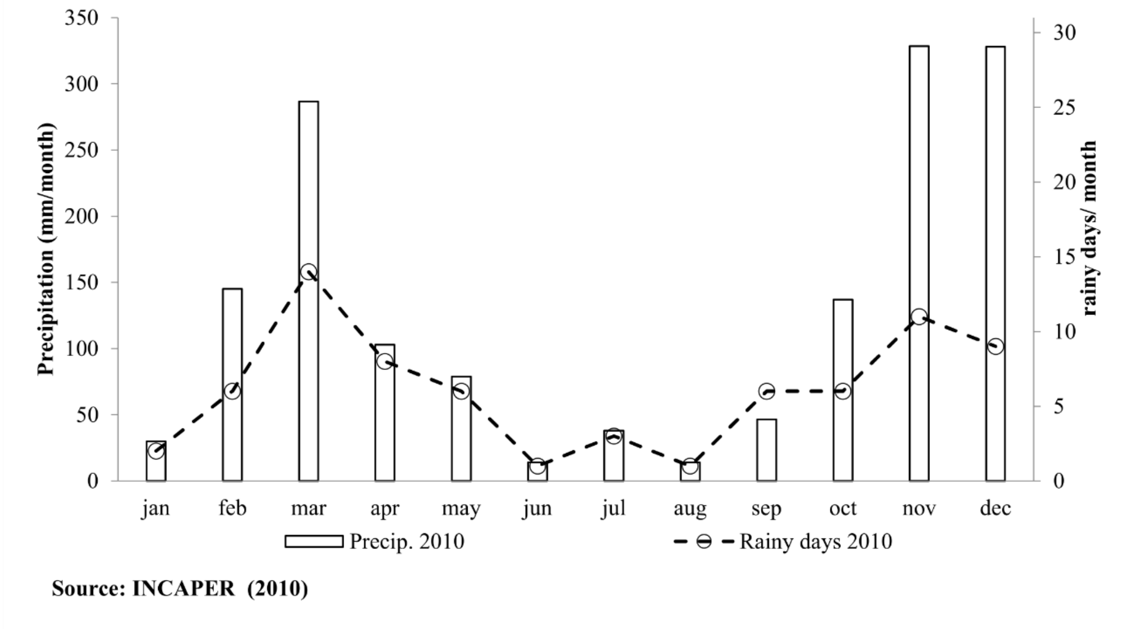


Figure 1: Monthly rainfall and number of rainy days during 2010, Cachoeiro de Itapemirim, Espirito Santo.

Table 1: Physical and chemical characterization of the Oxisol at a depth of 0 to 20 cm

Sand	Silt	Clay	pH(H_2O)	C	P	K	Ca	Mg	Al^{3+}	H + Al
	g kg^{-1}			g kg^{-1}	mg kg^{-1}			cmol$_c$ kg^{-1}		
601	49	350	5.90	13.80	20.42	90.84	1.98	0.56	0.00	2.82

Laboratory evaluations

Samples of the four species of Fabaceae collected on the day of experiment setup (time zero) and bags in each collection time were dried in an oven at 65 °C to constant weight. Later, the samples were weighed to determine the dry matter and ground to determine the contents of K (flame photometry), P (spectrophotometry with blue-molybdenum), and Ca and Mg (atomic absorption spectrophotometry) (Silva, 2009). The contents of C and N were determined by dry combustion in an elemental analyzer.

Data analyses

To evaluate the decomposition and nutrient release of Fabaceae after analysis of variance (ANOVA), contrasts were established for the absolute values of the remaining biomass (dry matter), residual levels of macronutrients, and C/N and C/P; the results were grouped according to Alvarez & Alvarez (2006). The first contrast (C1) was between jack bean, pigeon pea, and dwarf mucuna against sunn hemp. This contrast was established to verify differences between sunn hemp, the species with the largest remaining dry mass (DM) and C/N and C/P ratios, and others Fabaceae. The second contrast (C2) was established between the dwarf mucuna against the others three Fabaceae. The third contrast (C3) compared the less fibrous herbaceous species, jack bean and dwarf mucuna, against the more fibrous Fabaceae, sunn hemp and pigeon pea. The significance of contrasts was evaluated by an F test ($P < 0.01$ to $P < 0.10$), with the aid of SAEG software (Universidade Federal de Viçosa, 2005).

The study of the dynamics of decomposition and release of nutrients was followed by the simple exponential model (Rezende *et al.*, 1999): $X = X0\ e - kt$, where X is the amount of dry matter or nutrient remaining after a period of time t in days; X_0 is the amount of dry matter or initial nutrient content; and k is the decay constant, which can be obtained by the equation: $k = -ln(X/X0)/t$. The coefficients of the regression models were tested using the t test at 1 and 5%.

The half-life ($t_{1/2}$) was also estimated as it expresses the time required for half of the residue to decompose or for half of the nutrients contained in such residue to be released. It is possible to calculate the half-life time by the equation: $t1/2 = ln(2)/k$, where: $t_{1/2}$ is the half-life of the dry material or nutrients; ln (2) is a constant value; and k is the constant of decomposition described above (Rezende *et al.*, 1999). The decomposition constant k was subjected to ANOVA F test, and when significant, we used the t test at 5% probability according Thönnissen *et al.* (2000). The statistical analysis was performed with the aid of SAEG software (Universidade Federal de Viçosa, 2005).

RESULTS

Chemical characteristics of Fabaceae residues

The initial N content in the plant species residues ranged from 19.1 to 40.7 g kg^{-1}, being lower for sunn hemp and higher for dwarf mucuna (Table 2). For K, the range was 6.9 to 12.8 g kg^{-1}, with sunn hemp having the lowest value and jack bean as the highest. As for the P, the variation was 3.3 to 5.4 g kg^{-1}.

The C/N ratio ranged from 9.9 to 21.3, dwarf mucuna having the lowest value and sunn hemp having the largest (Table 2). For the C/P ratio, the dwarf mucuna had the lowest value (76), while pigeon pea and jack bean obtained the highest ratios, with 121 and 122, respectively.

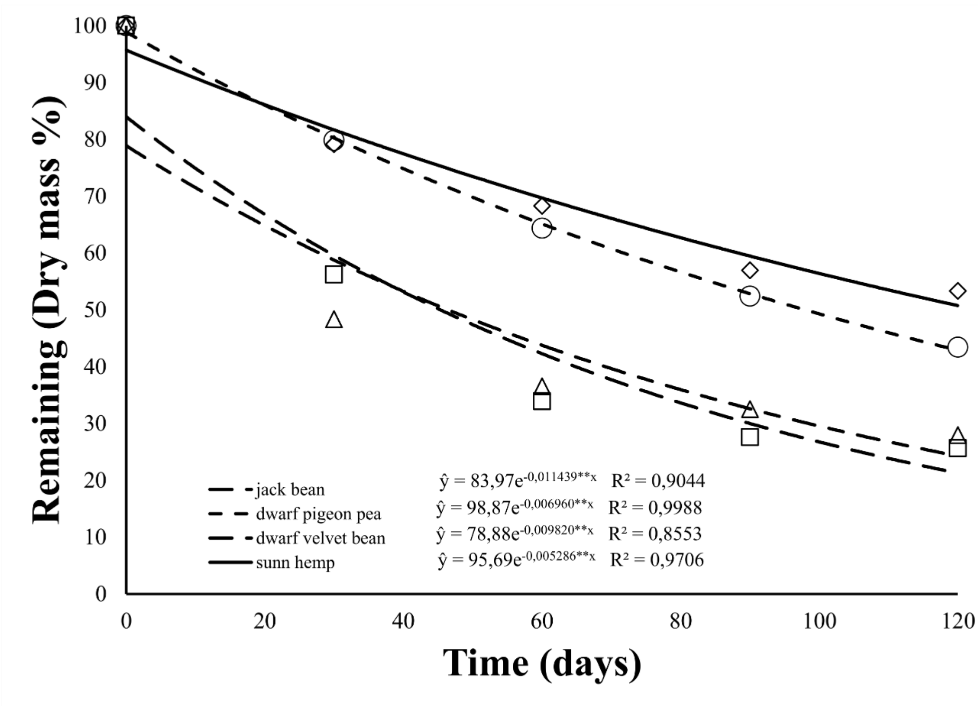
Decomposition of green manure residues

The production of dry matter (DM) of shoots ranged from 3.9 to 12.5 Mg ha^{-1}, being lower for dwarf mucuna and greater for sunn hemp (Mangaravite *et al.*, 2014). The DM decomposition kinetics of these residues showed a similar behavior between the four species with exponential decay over time (Figure 2).

Table 2: Chemical characteristics of the tropical Fabaceae used in the study

Green manure	N	P	K	Ca	Mg	C/N	C/P
	g kg^{-1}						
C. ensiformis	30.5	3.3	12.8	11.3	1.2	12.2	122
C. cajan	27.1	3.5	7.4	2.4	0.8	15.6	121
M. deeringiana	40.7	5.4	10.7	7.8	1.5	9.9	76
C. juncea	19.1	4.4	6.9	2.8	1.0	21.3	92

Jack bean (*Canavalia ensiformis),* pigeon pea *(Cajanus cajan),* dwarf mucuna *(Mucuna deeringiana)* and sunn hemp *(Crotalaria juncea).*



*, ** = significant at 5% and 1% probability, respectively, by the t test.

Figure 2: Decomposition of the biomass of the four green manure plants, in the period 120 days, in percentage data. Jack bean (*Canavalia ensiformis),* pigeon pea *(Cajanus cajan),* dwarf mucuna *(Mucuna deeringiana)* and sunn hemp *(Crotalaria juncea).*

The same pattern of biomass decomposition was observed between the two more fibrous species, pigeon pea and sunn hemp, and the two less fibrous species, jack bean and dwarf mucuna. The less fibrous Fabaceae showed loss of dry matter (DM) mass of over 40% in the first 30 days of the experiment, while the more fibrous species lost only 20% in this period. It should be noted, therefore, that pigeon pea and sunn hemp species had larger amounts of DM over the whole period of decomposition.

The constant of decomposition *k* increased in the following order: sunn hemp < pigeon pea < dwarf mucuna < jack bean, which resulted in differences for the half-life time ($t_{1/2}$) being 130.8, 99.0, 70.7, and 60.8 days, respectively (Table 3).

Table 3: Estimation of the parameters (X_0, k) of the decomposition and nutrient release equation and the half-life ($t_{1/2}$) for the green manure species

Green manure	X_0 (g)	*k* (g g^{-1} day^{-1})	R^2	$t_{1/2}$ (days)
		dry matter		
C. ensiformis	5.810	0.0114 ns	0.904	60.8
M. deeringiana	5.138	0.0098 ns	0.855	70.7
C. cajan	11.742	0.0070 ns	0.999	99.0
C. juncea	9.066	0.0053 ns	0.971	130.8
		Nitrogen		
C. ensiformis	0.169	0.0122 *	0.890	56.8
M. deeringiana	0.192	0.0097 *	0.762	71.5
C. cajan	0.265	0.0093 *	0.883	74.5
C. juncea	0.111	0.0040 *	0.178	173.3
		Phosphor		
C. ensiformis	0.030	0.0201 **	0.875	34.5
M. deeringiana	0.036	0.0215 **	0.951	32.2
C. cajan	0.041	0.0227 **	0.912	30.5
C. juncea	0.026	0.0238 **	0.806	29.1
		Potassium		
C. ensiformis	0.037	0.0273 **	0.762	25.4
M. deeringiana	0.030	0.0225 **	0.698	30.8
C. cajan	0.044	0.0196 **	0.734	35.4
C. juncea	0.026	0.0190 **	0.595	36.5
		Calcium		
C. ensiformis	0.072	0.0071 **	0.957	97.6
M. deeringiana	0.050	0.0058 **	0.958	119.5
C. cajan	0.030	0.0057 **	0.958	121.6
C. juncea	0.014	0.0060 **	0.243	115.5
		Magnesium		
C. ensiformis	0.007	0.0111 **	0.924	62.4
M. deeringiana	0.008	0.0100 **	0.875	69.2
C. cajan	0.008	0.0082 **	0.948	84.5
C. juncea	0.006	0.0084 **	0.586	82.5

**, * = significant at 0.01 and 0.05, respectively, by the t test. ns = non-significant by the t test. R^2 = coefficient of determination. Jack bean (*Canavalia ensiformis),* pigeon pea *(Cajanus cajan),* dwarf mucuna *(Mucuna deeringiana)* and sunn hemp *(Crotalaria juncea).*

In contrast C2, it is evident that the dwarf mucuna shoot residue showed more effective decomposition of DM compared to others Fabaceae (Table 4). Moreover, contrast C1 demonstrates that the sunn hemp species had a lower DM decomposition rate.

Nutrient release

The less fibrous Fabaceae, jack bean and dwarf mucuna, compared with sunn hemp and pigeon pea, demonstrated higher rates of release of N, C, K and Mg in contrast C3 (Table 4). The remaining values for P did not appear as different between the more fibrous and less fibrous species (C3 contrast).

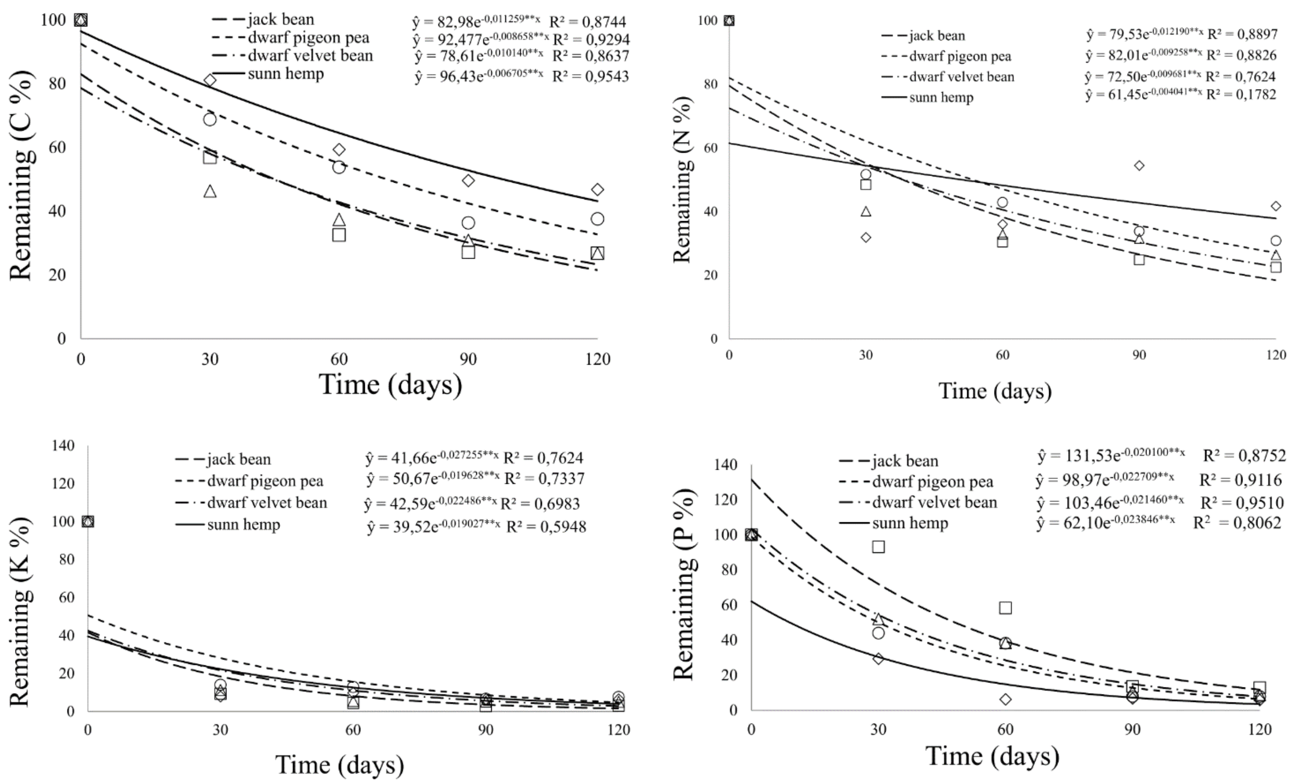
The release curves for K showed uniform pattern and were similar between the four Fabaceae (Figure 3). Regardless of species, 80% of K was released within the first 30 days of plant material exposure, which demonstrates the high initial rate of release of this element.

The *k* mineralization constant for the K ranged from 0.0190 to 0.0273 g $g^{-1}dia^{-1}$ for sunn hemp and jack bean, respectively. This behavior was reflected in higher and lower $t_{1/2}$ of K for sunn hemp and jack bean as values of 36.5 and 25.4 days, respectively (Table 3).

Table 4: Values and significance by the F test for the contrasts C1, C2 and C3, established between means of the variables DM, N, P, K, C, Ca, Mg, C/N and C/P, relative to remaining residuals of the decomposition of shoot of the Fabaceae species used as green manure

Variables	DM	N	P	K	C	Ca	Mg	C/N	C/P
	g sample^{-1}								
Contrast	C1 = (1/3 CE +1/3 CC + 1/3 MD) – (1CJ) - Three other Fabaceae against *Crotalaria juncea*								
CE/3	1.124	0.032	0.004	0.007	0.420	0.017	0.001	5.255	126.243
CC/3	2.693	0.056	0.006	0.008	0.991	0.007	0.002	7.274	278.245
MD/3	1.065	0.041	0.005	0.006	0.421	0.012	0.002	4.079	117.396
CJ	6.779	0.095	0.012	0.017	2.559	0.012	0.004	36.522	1448.449
C1 Values	-1.897	0.033	0.002	0.004	-0.727	0.025	0.001	-19.914	-926.565
Significance	**	**	ns	**	**	**	°	**	**
Contrast Fabaceae	C2 = (1 MD) - (1/3 CE + 1/3 CC + 1/3 CJ) - *Mucuna deeringiana* against the three other								
CE/3	1.124	0.032	0.004	0.007	0.420	0.017	0.001	5.255	126.243
CC/3	2.693	0.056	0.006	0.008	0.991	0.007	0.002	7.274	278.245
MD	3.196	0.122	0.015	0.018	1.262	0.037	0.005	12.236	352.188
CJ/3	2.260	0.032	0.004	0.006	0.853	0.004	0.001	12.174	482.816
C2 Values	-2.881	0.002	0.001	-0.003	-1.002	0.009	0.0003	12.468	535.116
Significance	**	ns	ns	**	**	**	ns	°	ns
Contrast Fabaceae	C3 = (1/2 CE +1/2 MD) - (1/2 CC + 1/2 CJ) - Less fibrous Fabaceae against the more fibrous								
CE/2	1.686	0.048	0.006	0.011	0.629	0.025	0.002	7.883	189.364
CC/2	4.039	0.084	0.008	0.012	1.487	0.011	0.003	10.911	417.368
MD/2	1.598	0.061	0.007	0.009	0.631	0.018	0.002	6.118	176.094
CJ/2	3.390	0.048	0.006	0.008	1.279	0.006	0.002	18.261	724.225
C3 Values	-4.144	-0.022	-0.001	-0.001	-1.506	0.027	-0.0004	-15.171	-776.135
Significance	**	**	ns	°	**	**	°	**	**
CV %	8.37	17.39	22.47	19.00	11.47	16.26	21.26	22.47	43.34

CE = *Canavalia ensiformis*, CC = *Cajanus cajan*, MD = *Mucuna deeringiana*, CJ = *Crotalaria juncea*, DM = dry matter, N = nitrogen, P = phosphor, K = potassium, C = carbono, Ca = calcium, Mg = magnesium, C/N = ratio between C and N, C/P = ratio between C e P. **, *, ° = significant at 0.01, 0.05, and 0.10 respectively, by the F test. ns = non-significant by the F test. CV = coefficients of variation. Jack bean (*Canavalia ensiformis),* pigeon pea *(Cajanus cajan),* dwarf mucuna *(Mucuna deeringiana)* and sunn hemp *(Crotalaria juncea).*



*, ** = significant at 5% and 1% probability, respectively, by the t test.

Figure 3: Evolution of the release of C, N, K and P, from the biomass of four green manure plants, over 120 days. Jack bean (*Canavalia ensiformis),* pigeon pea *(Cajanus cajan),* dwarf mucuna *(Mucuna deeringiana)* and sunn hemp *(Crotalaria juncea).*

The four Fabaceae followed a similar P release pattern, especially from 90 days (Figure 3). These results are supported by the nearly *k* mineralization values ranging from 0.0201 to 0.0238 g $g^{-1}dia^{-1}$ and the half-lives ($t_{1/2}$), which ranged from 34.5 to 29.1 days for the jack bean and sunn hemp, respectively (Table 3).

For N, the jack bean species had the highest release coefficient (k = 0.0122 g g^{-1} dia^{-1}) associated with the lowest $t_{1/2}$ value of 56.8 days (Table 3 and Figure 3). This indicates that release of 50% of N from this species occurred until the beginning of April 2010. After 120 days, in mid-June, the remaining N in this species was 18.4% (i.e., 81.6% of N was mineralized).

Among the studied nutrients, Ca showed the lowest rate of release between jack bean, dwarf mucuna, and pigeon pea, as evidenced by reduced *k* values and high half-life values ($t_{1/2}$) (Table 3).

The Mg release pattern of the four Fabaceae had a behavior similar to N and K, with the highest release in the first 30 days (Figure 4). However, the $t_{1/2}$ values for Mg are greater than those observed for K (Table 3). The $t_{1/2}$ Mg values of the two most herbaceous Fabaceae, jack bean and dwarf mucuna were similar, while the same occurred with the two shrub species, pigeon pea and sunn hemp, with 84.5 values and 82 5 days, respectively (Table 3).

DISCUSSION

Chemical characteristics of Fabaceae residues

Organic residues with concentrations greater than 20 g kg^{-1} and 2.5 g kg^{-1} for N and P, respectively, can be considered high quality (Mafongoya *et al.*, 1998); however, for example, lignin and polyphenols can control the availability of these nutrients (Gentile *et al.*, 2008). Taking the N and P contents into account, except for the sunn hemp N, the Fabaceae of our study are within the limit and, therefore, considered high quality.

Organic residues with initial C/N ratios < 20 and C/P ratios < 200 are considered high quality, being the predominant mineralization process to increase the availability of nutrients (Stevenson, 1986). For C/P ratios, all of the Fabaceae fit in the category of high quality as suggested by Stevenson (1986), and only the sunn hemp C/N ratio did not fit in high quality threshold.

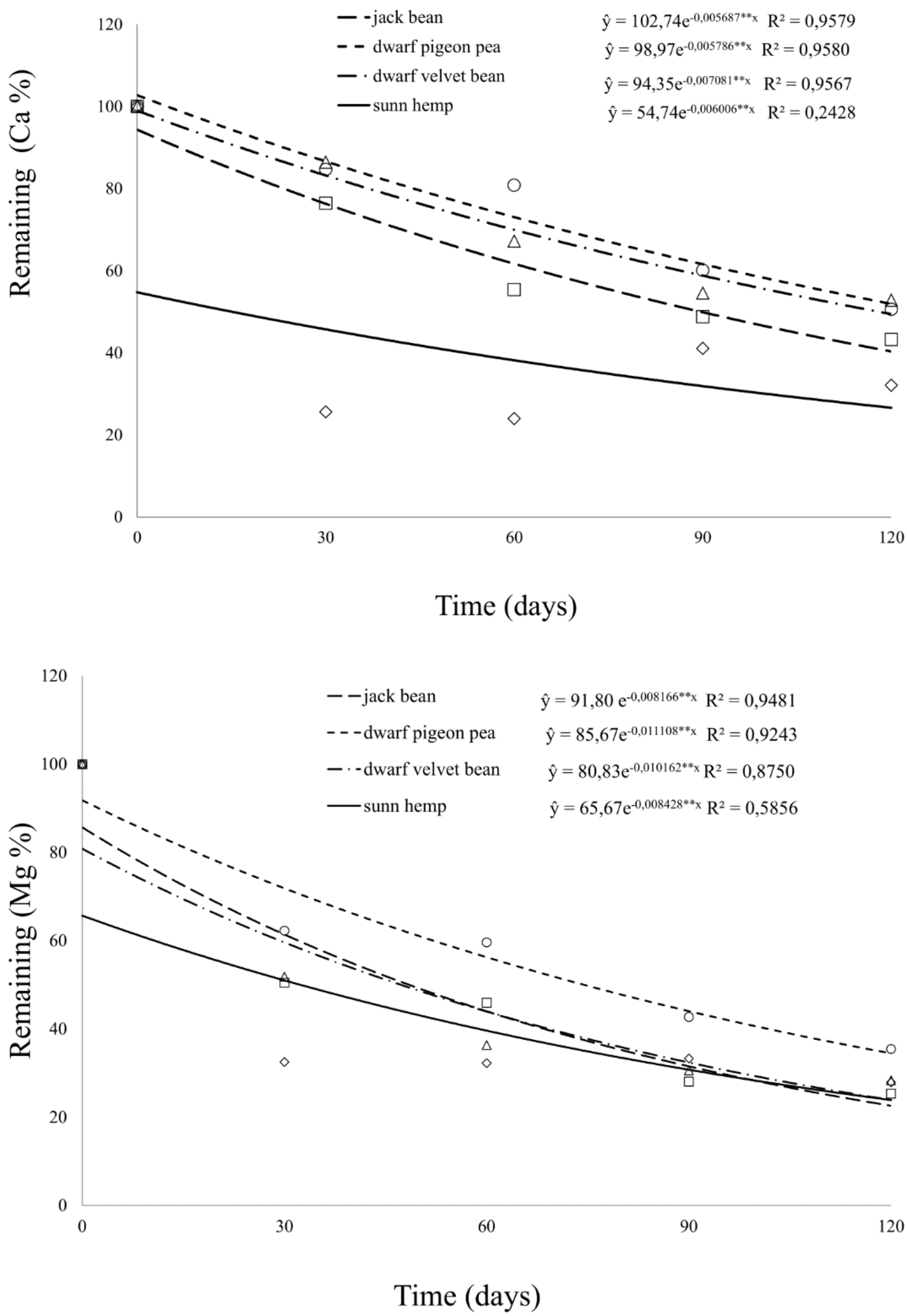


Figure 4: Evolution of the release of Ca and Mg from the biomass of four legumes with green manure, over 120 days. Jack bean (*Canavalia ensiformis),* pigeon pea *(Cajanus cajan),* dwarf mucuna *(Mucuna deeringiana)* and sunn hemp *(Crotalaria juncea)*. *, ** = significant at 5% and 1% probability, respectively, by the t test.

Decomposition of green manure residues

The climate has a strong influence on the decomposition rates of plant residues between geographic regions; however, the chemical composition of the residue (e.g., C, N, cellulose, hemicellulose, polyphenols and lignin) is the best descriptor of decomposition locally (Adl, 2003). In this sense, the C/N and C/P are important variables that locally influence the decomposition of plant residues added to the soil (Moreira & Siqueira, 2006). In our study, the biomass of sunn hemp and pigeon pea had higher initial C/N relations compared to others Fabaceae, which may have contributed to the greater accumulation of their biomasses throughout the experimental period.

The chemical composition of plant species used in our study are well described and ratified in the literature (Gama-Rodrigues *et al.*, 2007; Carvalho *et al.* 2011; Veras *et al.*, 2016). For the same period evaluated, for example, the levels of lignin, cellulose and polyphenols were higher in shoot residues of sunn hemp and pigeon pea compared to jack bean and the dwarf mucuna. This causes sunn hemp and pigeon pea residues to have slower decomposition, making it able to form a stable mulch able to protect the soil against erosion, besides of contribute to the increase of soil organic matter.

The decomposition rates of organic residues in tropical soils are higher compared to temperate regions (Adl, 2003). In our study, we observed higher rates of decomposition for dwarf mucuna and jack bean. Therefore, we can infer that the sunn hemp and pigeon pea residues have great potential for use as mulch in tropical soils due to the lower rates of decomposition and greater accumulation in the soil over time.

Release of nutrients

The behavior observed for the decomposition rates of dry biomass reflected the release rates of C, N, K, and Mg. The release rates of these elements were higher, in general, for the jack bean and dwarf mucuna compared with sunn hemp and pigeon pea. Plant residues with lower C/N ratios that are associated with lower levels of recalcitrant organic molecules (e.g., lignin) and have higher nutrient mineralization rates (Swift *et al.*, 1979; Monteiro & Gama-Rodrigues, 2004) can provide large quantities of nutrients for subsequent crops (Espindola *et al.*, 2005). In the tropical conditions of this study, you should choose to use jack bean or dwarf mucuna residues rather sunn hemp or pigeon pea residues if the intention is the supply of nutrients (e.g., subsequent crops) in smaller periods time.

High K release values from biomass in various cover crops (Fabaceae) was also observed in other studies conducted in various soil and climatic conditions (Giacomini *et al.*, 2003; Espindola *et al.*, 2006; Gama-Rodrigues *et al.*, 2007; Pereira *et al.*, 2016). K is the most abundant ion in plant cells (Marschner, 1997), and its high speed of release can be attributed to the fact that it is present in ionic form, not being attached to any structural component of plant tissue (Gama-Rodrigues & Barros, 2002; Costa *et al.*, 2005; Gama-Rodrigues *et al.*, 2007; Taiz & Zeiger, 2009). This rapid release of K to the soil suggests that the period of implementation of agricultural crops in succession to green manure should be reduced in order to reduce losses of K, seeking their greater use by subsequent crops. Furthermore, similar $t_{1/2}$ values for K and P in the four studied Fabaceae species may facilitate the synchronization of agricultural management for the supply of these nutrients for agricultural crops in succession.

Fabaceae residues, unless they contain high levels of lignin and polyphenols, easily release N from the biomass (Palm & Sanchez, 1991; Constantinides & Fownes, 1994; Palm, 1995; Cobo *et al.*, 2002a). A study conducted in tropical soil evaluating the decomposition and release of nutrients from Fabaceae and non-Fabaceae species residues found that the N release rate was higher for the jack beans compared to the other species tested. The values for the coefficient k and $t_{1/2}$ were similar to our study with 0.0162 g g^{-1} dia^{-1} and 43 days, respectively (Gama-Rodrigues *et al.*, 2007). These authors related these results to better chemical quality of the jack bean residue, due to higher levels of N, P, and Ca, as well as lower ratios of C/N and polyphenol/N.

The N released from jack bean until the half-life ($t_{1/2}$) and 120 days after the onset of decomposition corresponded to 102.4 and 167.1 kg ha^{-1}, respectively. For an expected yield of *Coffea canephora* fruits between 31-50 sacks ha^{-1}, it is recommended to perform nitrogen fertilization of 320 kg ha^{-1} N (Prezotti *et al.*, 2007). Thus, if the goal is synchronizing the partial supply of N for *C. canephora* from jack bean decomposition, it can be inferred that the values of N released by jack bean in $t_{1/2}$ and 120 days are, respectively, between 32 and 52% of the total N required to achieve that average yield of coffee.

The low release rate behavior of Ca of plant biomass is often reported in the literature for Fabaceae species and other non-Fabaceae (Cobo *et al.*, 2002b; Espindola *et al.*, 2006; Gama-Rodrigues *et al.*, 2007; Perin *et al.*, 2010). This behavior is associated with the fact that this nutrient is one of the middle lamella of the cell wall constituents and one of the most recalcitrant components of plant tissues (Taiz & Zeiger, 2009; Perin *et al.*, 2010).

The similarity of Mg and K in terms of the release dynamics during the first 30 days may be associated to the fact that Mg is also in ionic form within the plant tissue (Waters, 2011). It is noteworthy that over 70% of Mg diffuses freely in the cell suspension or is bound by ionic bonds to negatively charged components (e.g., proteins) (Dechen & Nachtigall, 2007). The N is part of proteins and together with Mg is a structural component of chlorophyll (Cantarella, 2007; Waters, 2011); this may be one of the explanations for similar behavior in the dynamic mineralization between Mg and N.

CONCLUSIONS

Among the species tested, sunn hemp showed the lowest rate of decomposition, next to the pigeon pea, inferring that shrub species have higher potential to accumulate organic matter and act as mulch in tropical edaphoclimatic conditions. On the other hand, jack beans and dwarf mucuna should be chosen if the objective is the supply of nutrients in shorter periods for subsequent crops because they demonstrated higher rates of decomposition and nutrient release during experiment.

The K and P for the four Fabaceae showed similar $t_{1/2}$ values, and for N, sunn hemp was the species that presented the lowest coefficient of mineralization (k = 0.0040 g g^{-1} dia^{-1}), associated with greater $t_{1/2}$ (173.3 days). On the other hand, jack bean was the species that showed the highest coefficient of mineralization for N (k = 0.0122 g g^{-1} dia^{-1}), associated with the lower half-life ($t_{1/2}$ = 56.8 days).

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