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Grasses and legumes as cover crop in no-tillage system in northeastern Pará Brazil

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ABSTRACT

Studies to select one or more species of coverage plants adapted to Amazonian soil and climate conditions of the Amazon are a promising strategy for the improvement of environmental quality, establishing no-till agricultural systems, and thereby reducing the impacts of monoculture farming. The aim of this study was to assess the persistence time, half-life time, macronutrient content and accumulation, and C:N ratio of straw coverage in a Ultisol in northeastern Pará. Experimental design was randomized blocks with five treatments and five replicates. Plants were harvested after 105 days, growth and biomass production was quantified. After 84 days, soil coverage was 97, 85, 52, 50, and 15% for signalgrass (*Brachiaria brizantha*) (syn. *Urochloa*), dense crowngrass (*Panicum purpurascens*), jack bean (*Canavalia ensiformes*), pearl millet (*Pennisetum americanum*) and sunn hemp (*Crotalaria juncea,*), respectively. Signalgrass yielded the greatest dry matter production (9,696 kg ha^{-1}). It also had high C:N ratio (38.4), long half-life (86.5 days) and a high persistence in the field. Jack bean also showed high dry matter production (8,950 kg ha^{-1}), but it had low C:N ratio (17.4) and lower half-life time (39 days) than the grasses. These attributes indicate that signalgrass and jack bean have a high potential for use as cover plants in no-till agricultural systems in the State of Pará.

KEYWORDS: Half-life, persistence of plant biomass, recycling nutrients, C / N ratio

Gramíneas e leguminosas como plantas de cobertura para o sistema de plantio direto no nordeste do estado do Pará

RESUMO

Estudos que visem à seleção de espécies, ou de grupos de espécies de plantas de cobertura do solo adaptadas as condições edafoclimáticas amazônicas parece ser uma estratégia viável para a melhoria da qualidade ambiental por propiciar o estabelecimento do SPD atenuando problemas relacionados ao monocultivo. O objetivo foi avaliar o comportamento de plantas de cobertura, no Nordeste paraense, quanto a persistência, tempo de meia vida, teor e acúmulo de macronutrientes e relação C/N na palhada, em Argissolo Vermelho Amarelo. O delineamento experimental foi em blocos ao acaso, com cinco tratamentos e cinco repetições. As plantas foram cultivadas a partir do mês de julho e cortadas aos 105 dias de cultivo e então foi feita a avaliação da produção. Ao final dos 84 dias a percentagem de cobertura do solo correspondeu a 97, 85, 52, 50 e 15%, para a braquiária (*Brachiaria brizantha*) (syn. *Urochloa*), capim colônia (*Panicum purpurascens*), feijão de porco (*Canavalia ensiformes*), milheto (*Pennisetum americanum*) e crotalária (*Crotalaria juncea,*), respectivamente. A braquiária apresentou maior produção de matéria seca (9.696 kg ha^{-1}), elevada relação C/N (38,4), alto tempo de meia vida (86,5 dias) e grande persistência no campo. O feijão de porco apresentou alta produção de matéria seca (8.950 kg ha^{-1}), porém menor relação C/N (17,4) e tempo de meia vida (39 dias), quando comparada as gramíneas. Por estas características, a braquiária e o feijão de porco são espécies com potencial utilização como plantas de cobertura no SPD no estado do Pará.

PALAVRAS-CHAVE: Tempo de meia vida, persistência de biomassa vegetal, reciclagem de nutrientes, relação C/N.

INTRODUCTION

Sound agricultural practices requires environmental preservation and sustainable use of natural resources, the improvement of quality of agricultural soils, and reduction of production costs. No-tillage system is part of this context. The absent of periodic tillage allows reduction of working time and fuel consumption. In terms of soil quality, the maintenance of plant biomass over the soil promotes erosion control and soil moisture conservation. Besides increasing organic matter and enhancing soil biological activity (Topakci *et al*. 2011), no-tillage can reduce weed competition and improves the yield of rice (*Oryza sativa*) (Marenco *et al*. 1999).

In hot and humid regions with heavy rainfalls during the wet period, plant biomass maintenance on the soil surface is benefit, once those conditions accelerate residue decomposition (Timossi *et al*. 2007). Selection of plant species for use in no-tillage as cover crops depends on both their adaptation to the weather conditions of each region and grower interest (Silva and Rosolem 2008). In the Amazon, high humidity and temperature leads to an accelerated decomposition of organic matter. Thus, no-tillage consolidation in this region depends on several factors, including plant species capable of producing large amount biomass, long persistence of biomass in the soil and the storage of high nutrient amounts in the residues.

Legumes and grasses have distinct behavior in no-tillage treatments. Legume plant residues decompose rapidly due to their low C/N ratio, as they have high nitrogen and water-soluble carbon contents (Aita *et al*. 2003). Legumes release great part of nutrients during the first 30 days after shoot deposition in the soil (Da Ros and Aita 1996). Grasses, on the other hand, are characterized by a high C/N ratio in plant residues and longer persistence on the soil surface as a result of low decomposition rate. Hence, there is a minor amount of nutrient release, particularly N (Borkert *et al*. 2003). Species like signalgrass and pearl millet cultivated under no-tillage system increase the yield of the next soybean culture and its phosphorus content due to high biomass production and increased availability of soil P (Veronese *et al*. 2012). In the Cerrado region of Maranhão State, Brazil, signalgrass and pearl millet cultivated under no-tillage system increased P, K, Ca, and Mg contents both in soil and organic matter (Bressan *et al*. 2013).

In the Amazon region, empirical and scientific attempts to implement and maintain no-tillage system with species previously used in other Brazilian regions have faced low production of crop residues and low quality of residues as the mains obstacles. Hence no-tillage systems success in the Amazon region depends entirely on the identification of cover crops with potential to produce great amount of lasting residues, and able to endure the high temperatures and humidity of this region. The objective of this study was to evaluate the potential of grasses and legumes as no-tillage crops, in the northeastern mesoregion of Pará, Brazil.

MATERIALS AND METHODS

The experiment was conducted in 2004, at the Farm School of Federal Rural University of Amazon (Ufra), located in Igarapé-Açú, Pará State (01º07'33" S and 47º37'27" W, 39 m of altitude).

Regional climate is humid mesothermal, Ami type according to the Köppen classification, i.e., it is a rainy and humid tropical climate, with a short dry season, and mean temperature of 25 ºC. Annual rainfall in 2004 (experimental period) was 2,500 mm, with heavy concentration from January to June. Air relative humidity was around 85% (Table 1). Maximum and minimum air temperatures were 32.2 and 21.4 °C, respectively (Embrapa 2007).

The soil of experimental area is classified as Ultisol (Embrapa 2013). Soil samples were collected from 0.0-0.2 m depth for chemical and physical analyses. All analyses were performed according to the methodology described by Embrapa (2009). The soil had a sandy-clayey texture in the A horizon, with 668 g kg^{-1} of sand, 141 g kg^{-1} of silt, and 191 g kg^{-1} of clay. Results from the chemical attributes were: pH 5.5 (in water); organic matter, 14.9 g kg^{-1} soil; P, 10.2 mg dm^{-3}; K, 0.05; Ca, 1.6; Mg, 1.2; and base saturation, 45.3% $cmol_c$ dm^{-3}.

The experimental design was arranged in randomized blocks, with five treatments: 1) legumes jack bean [*Canavalia ensiformes* (L.) DC], 2) sunn hemp (*Crotalaria juncea* L.), and grasses 3) dense crowngrass (*Panicum purpurascens* Mez.), 4) signalgrass (*Brachiaria brizantha*) (syn. *Urochloa*), 5) pearl millet (*Pennisetum americanum* L. Leeke). There were five replications, resulting in 25 plots. Each plot, of 25 m^2 (2.5 x 10 m), was composed by six planting lines of 10 m length each, with 0.5 m spacing among lines and plants.

Species were first cultivated in 2003 on the same soil type, in a contiguous area. From the cultivated species, those that showed greatest potential for dry matter production (Teixeira *et al*. 2006) were used in this experiment. Seed sowing was manually made in July (period after harvest of

Table 1. Maximum and minimum temperatures and rainfall during the experimental period.

Month	Maximum temperature (°C)	Minimum temperature (°C)	Rainfall (mm)
July	31.7	21.8	228.6
August	31.9	21.8	443.4
September	32.4	21.7	476
October	33.2	21.6	50
November	33.7	21.4	11.2
December	33.7	22.6	79

economic plant species), in holes, with the exception of dense crowngrass, which seeds were not viable so seedlings were used. Two legume and three grass plants were cultivated per hole, resulting in a stand of 80,000 and 120,000 plants per hectare, respectively. Fertilization was equally performed for all species, in the holes, with the application of 5 g NPK 10-28-20 that corresponded to 400 kg ha^{-1}.

Harvest of the shoot part was carried out manually, cutting the plant at 0.05 m from the soil surface, after 105 days of growth, when plants were in initial flowering stage. Harvesting period was determined following cultivation of the same species performed in 2003, in same farm area. Harvested area of each plot was 2.0 x 2.5 m, where all biomass was spread on the soil surface.

To determine the amount of dry matter of cover crops in each plot, plant residues were collected from an inner plot area of 0.09 m^2, using a 0.30 by 0.30 m square frame at two random locations (Stott *et al.* 1990). The collected material was dried in an oven with forced air circulation at 65 ºC, until constant mass. Final values were transformed to ton per hectare, considering plant stand.

To determine time persistence of plant residue over the soil surface after biomass harvesting, percentage of soil coverage was measured on non-disturbed spread plant residue, in five different periods: on harvesting day and 21, 42, 63, and 84 days after shoot harvesting. The method used was "graded string" or linear transect, described by Hartwig and Laflen (1978) and Alves *et al.* (1998). On a nylon string, 50 points were marked with 6 cm spacing among them. At each evaluation time, the string was diagonally stretched at each plot so it provided two readings. Coverage percentage was measured according to the number of times that the string points were over the residue. Results from both readings were aggregated in order to obtain the coverage percentage value.

Description of residue decomposition and half-life time ($t^{1/2}$) was performed using the exponential mathematical model described by Thomas and Asakawa (1993), according to the equation $X = X^{0-kt}$, where: X is the remaining dry matter amount in a t time, in days; X^0 is the initial dry matter amount; and k is the decomposition constant. From the final k decomposition constant, $t^{1/2}$ is calculated according to the equation $t^{1/2} = ln^2/k$.

To determine macronutrient content in plant tissues, plants were randomly collected, washed with distilled water, and placed in an oven with forced air circulation at 65 ºC, until constant mass. Plant material was then ground in a Wiley grinder (sieve with a 0.33 mm mesh). Nitrogen was determined according to the Kjeldahl method; for other macronutrients, the nitropercloric digestion was applied; P was determined by colorimetry, K by flame photometry, Ca and Mg by atomic absorption spectrometry (Malavolta 2006). Carbon content was assessed by a modified Walkley Black method (Tedesco *et al.* 1995).

Nutrient content was multiplied by the produced dry mass to obtain the accumulated macronutrient content. Dry mass results were submitted to analysis of variance and means were compared by the Duncan test ($p < 0.05$). Regression analysis was performed for evaluation of residue persistence on soil surface.

RESULTS

Dry mass greatest production of aerial part (DMAP) was obtained by signalgrass (9,696 kg ha^{-1}) and jack bean (8,950 kg ha^{-1}), with no difference between them ($p < 0.05$) (Figure 1). The other species had significantly lower dry mass production, their percentages in comparison with signalgrass were 41% for pearl millet, 51.6% for sunn hemp and 54% for dense crowngrass.

The species differ on residues soil coverage after biomass deposition. Signalgrass had the highest coverage level, reaching 100% at the harvesting day and 97% after 84 days of plant deposition on soil surface (Figure 2). After the 21st day after harvesting, sunn hemp was the species with minor coverage (30%) and, by the end of the experimental period, it reached only 15%. Furthermore, it was the species that had the fastest decomposition rate. Although jack bean was one of the largest dry mass producers, it showed a high decomposition rate, as coverage ranged from 81% at the beginning of the evaluation (harvesting day) to 52% after 84 days, when the evaluation ended.

Contents of C in the DMAP, with the exception of dense crowngrass that had the lowest value, did not vary among species (Table 2). Still, legumes had higher N contents than grasses and, consequently, lower C/N ratio.

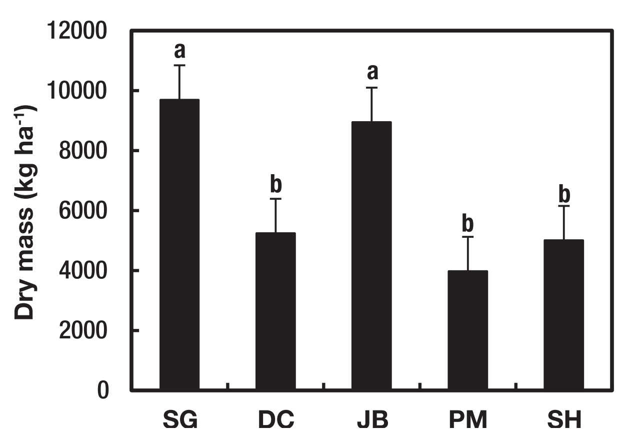

Figure 1. Production of dry mass of the aerial part (DMAP) of signalgrass (SG), dense crowngrass (DC), jack bean (JB), pearl millet (PM) and sunn hemp (SH). Letters represent differences by the Duncan test ($p < 0.05$).

Table 2. Macronutrient contents and C/N ratio in the dry mass of the aerial part of cover crops.

Treatment	C	N	C/N	P	K	Ca	Mg
	---------------------------------mg g^{-1}---------------------------------						
Sunn hemp	458 a	14.5 b	31.5 c	2.1 c	28.1 bc	6.9 b	3.2 c
Pearl millet	456 a	11.5 c	40.5 b	3.0 a	24.2 c	2.6 c	3.9 b
Jack bean	447 a	25.9 a	17.4 d	2.6 b	24.3 c	10.9 a	3.2 c
Signalgrass	439 a	11.5 c	38.4 b	2.1 c	31.5 ab	2.8 c	6.5 a
Dense crowngrass	400 b	8.0 d	51.3 a	1.7 d	33.8 a	3.0 c	3.9 b
CV (%)	6.3	11.2	12.4	12.2	9.8	18.8	11.5

Means followed by the same letters in the columns do not differ from each other by the Duncan test ($p < 0.05$).

Table 3. Accumulated values of macronutrients in the dry mass of the aerial part of cover crops.

Treatment	C	N	P	K	Ca	Mg
	---g m^{-2}---					
Sunn hemp	229.3 b	7.3 c	1.1 b	14.1 c	3.5 b	1.6 c
Pearl millet	181.3 b	4.6 c	1.2 b	9.6 d	1.0 d	1.6 c
Jack bean	400.1 a	23.2 a	2.3 a	21.8 bc	9.8 a	2.9 b
Signalgrass	425.7 a	11.2 b	2.0 a	30.5 a	2.7 bc	6.3 a
Dense crowngrass	209.7 b	4.2 c	0.9 b	17.7 bc	1.8cd	2.0 c
CV (%)	6.3	37.8	11.6	16.3	52.9	17.2

Means followed by the same letters in the columns do not differ from each other by the Duncan test ($p < 0.05$).

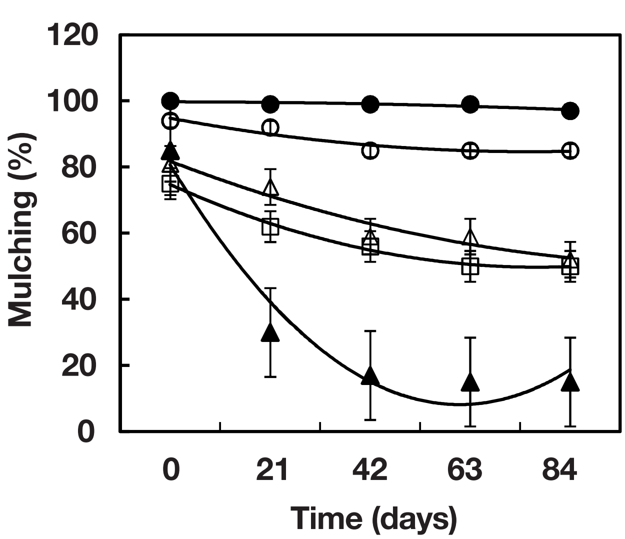

Figure 2. Soil coverage percentage of signalgrass (●), dense crowngrass (○), jack bean (Δ), pearl millet (□) and sunn hemp (▲) according to the time after havest.

ŷ (solid circle, ●) = $-0{,}1429x^2 + 0{,}2571x + 99{,}6$ $R^2 = 0{,}81$**

ŷ (circle, ○) = $0{,}7857x^2 - 7{,}2143x + 101{,}2$ $R^2 = 0{,}90$**

ŷ (triangle, Δ) = $1{,}0714x^2 - 13{,}729x + 94{,}4$ $R^2 = 0{,}95$**

ŷ (square, □) = $1{,}8571x^2 - 17{,}343x + 90{,}2$ $R^2 = 0{,}99$**

ŷ (solid triangle, ▲) = $8{,}6429x^2 - 67{,}357x + 139{,}4$ $R^2 = 0{,}95$**

** Significant at 1% by the F test

Nutrient contents varied among species (Table 2). Jack bean showed higher N and Ca contents while pearl millet had higher P content. The higher K contents were observed in dense crowngrass and signalgrass, but this one did not differ from sunn hemp; the highest Mg contents were observed for signalgrass (Table 2).

Potential accumulation of nutrients into soil varied among species. Jack bean and signalgrass had the highest C and P accumulation capacity (Table 3). Furthermore, jack bean stood out for accumulating the highest amount of N and Ca, while signalgrass was the species with greatest accumulation capacity of K and Mg.

The dry matter decomposition constant (k) and half-life time showed longer persistence for grasses when compared with legumes; dense crowngrass obtained the highest half-life time (334 days) and sunn hemp, the lowest (30.7 days) (Table 4).

DISCUSSION

Signalgrass had high dry matter yield (9,696 kg ha^{-1}) (Figure 1), higher than the means found in a Cerrado area (Torres *et al.* 2005). The jack bean also showed high dry matter yield (8,696 kg ha^{-1}), due to its good adaptation in low fertility soils (Fernandes *et al.* 2007), like those found in Northeastern Pará. As a yield of 6 t ha^{-1} has been considered the minimum amount of plant residues for appropriate soil

Table 4. Dry matter decomposition constant (k) and half-life time.

Species	k (g g^{-1})	Half-life time (days)
Signalgrass	0.00713	86.5b
Dense crowngrass	0.00208	334.0a
Pearl millet	0.00756	91.7b
Sunn hemp	0.02258	30.7c
Jack bean	0.00779	39.0b

Means followed by the same letters in the columns do not differ from each other by the Duncan test ($p < 0.05$).

coverage in NT (Darolt 1998), the signalgrass and jack bean may be recommended as cover crops for that region.

Cultivated plants under weather conditions of Amazon have often different yields than those cultivated in the Cerrado. Jack bean showed a superior yield than that cultivated in the Cerrado (3.43 t ha^{-1}). Moreover, pearl millet had better development under Cerrado conditions, producing 14.18 t ha^{-1} (Oliveira *et al*. 2002). The low dry matter production of legumes, including jack bean, may be related to the lack of fertilization and inoculation (Oliveira *et al*. 2002). For the same species, different yields between regions can reflect variation in soil properties and weather conditions, emphasizing the importance of regional studies for NT.

The lowest biomass decomposition of grasses, in comparison with legumes, may be explained by higher C/N ratio (Table 2). Residue quality, especially C/N ratio, is one of the factors that regulate decomposition and, therefore, persistence time of plant biomass in the soil (Borkert *et al*. 2003). Other factors that affect persistence of residues in the soil are the presence of (micro) organisms, soil chemical and physical characteristics, and environmental conditions (Swift *et al*. 1979).

The species produced plant biomass with low decomposition rate, mainly due to the overlap of cutting periods and periods of low rainfall, which was associated with high temperatures, when evapotranspiration is greater than precipitation; soil moisture was reduced during this period. According to Calegari *et al.* (1993), plant biomass persistence in the soil depends on soil moisture and temperature conditions. Higher signalgrass decomposition rates were found by Bernardes *et al*. (2010) in the Brazilian Cerrado, who described that, at 75 days, 33% of the dry mass had already been decomposed.

The lowest decomposition rate of signalgrass, dense crowngrass and pearl millet, in comparison with sunn hemp and jack bean may be related to their higher content of recalcitrant substances, such as cellulose and lignin that are present in tissue structures, once residue with higher C/N ratios and less soluble molecules are more persistent in the soil (Barbosa *et al*. 2012). On the contrary, tissues with low C/N ratio, more soluble C forms and high N contents have higher decomposition rate (Aita *et al*. 2003), as it occurs in legumes. Therefore, soil coverage species may be classified as of fast decomposition (legumes) and low decomposition (grasses).

Apart from legume characteristics (e.g. high N content, compared with grasses) that contribute to accelerate decomposition (Aita *et al*. 2003), the lower plant biomass quality produced by sunn hemp may have contributed to the increased decomposition rate (Kliemann *et al*. 2006), causing only 15% of soil coverage. Smaller fragments of dry matter promote more contact with the soil (Alvarenga *et al.* 2001), exposing larger contact surface to microbial attacks.

Dry mass carbon contents in the shoot part did not vary among cover crops, with the exception of dense crowngrass, which had the lowest value (Table 2). The highest accumulation, obtained by signalgrass and jack bean derived from their higher dry mass production (Table 2). Therefore, the carbon content does not determine the decomposition rate, although N content can influence C/N ratio. This was the case of dense crowngrass that showed the lowest N content and highest C/N ratio, thus leading to longer persistence in the soil. Torres *et al.* (2005) report lower C contents in sunn hemp, pearl millet, and signalgrass than those obtained in this study, due to higher soil fertility. High C accumulation in signalgrass and jack bean enabled greater input and, thereby, increased C stock in the soil.

Higher N content was associated with higher dry mass accumulation on aerial part of jack bean plants in comparison with other species (Tables 2 and 3), due, probably, to legume differentiated capacity to fix atmospheric nitrogen. Gama Rodrigues *et al.* (2007), when studying cover crops (grasses and legumes), observed that jack bean had the highest N contents and, consequently, lower C/N ratio, resulting in better quality of residues. Nitrogen contents and accumulation observed in sunn hemp were similar to those obtained by Amabile *et al.* (1999). For jack bean, similar values were found by Fernandes *et al.* (2007). For sunn hemp, pearl millet and signalgrass Torres *et al*. (2005) related greater N contents to those noted in this study, mainly because of higher soil fertility, higher pH and organic matter contents.

Thus, low N contents and high C/N ratio of studied grasses (Table 2) indicate lasting nutrient immobilization due to longer persistence of plant biomass in the soil. In these conditions, low release of N reduces its availability in the soil and thereby it inhibits microbial activity, reducing plant biomass decomposition (Gama-Rodrigues *et al*. 2007). Therefore, N availability to plants decreased, forcing nutrient application in soil in order to favor the following crop yield.

The lower C/N ratio of legumes is due to high N contents (Table 2). Lower C/N ratios than those obtained in the current study for sunn hemp, pearl millet, and signalgrass were observed by Torres *et al*. (2005) under Cerrado conditions. The superior values may be related to weather conditions, i.e., temperature, humidity and luminosity, which are higher in the North region of Brazil, promoting greater efficiency of CO_2 fixation and resulting in synthesis of compounds with higher C/N ratio.

The P content in jack bean tissues was superior to those obtained in other studies (Fernandes *et al*. 2007; Oliveira *et al*. 2002). Apart from soil factors, weather and climatic variation during the year may influence nutrient uptake by plants. This was obvious for Amabile *et al*. (1999), who found different P contents in sunn hemp according to its cultivation in different times of the year.

Accumulation of P was also higher in jack bean because of high organic matter content and production (Table 3). Oliveira *et al*. (2002), working with same species, observed less amounts of P than those found in the current study due to minor dry matter content and production. Conversely, Fernandes *et al*. (2005) obtained higher amounts of P. Regarding sunn hemp, Silva *et al*. (2006) found larger P quantities than this study, as a result of higher dry matter production.

The highest K contents in shoot dry mass of signalgrass and dense crowngrass (Table 2) are related to the minor CEC found in the roots of those plants, in comparison with legumes (Marschner 2012). This confirms the high K recycling capacity of grasses and their potential use as cover crops (Raij *et al*. 1997). Lower K contents and accumulation in signalgrass were obtained by Primavesi *et al*. (2006).

Jack bean and pearl millet showed the lowest K contents (Table 2); however, due to great dry matter production, jack bean had higher accumulated values of K than sunn hemp and pearl millet, differing from values described in the literature. Contents found in this study are higher than those observed by Oliveira *et al*. (2002) and Ceretta *et al*. (1994).

Sunn hemp K contents were higher than those described by Amabile *et al.* (1999) and Silva *et al.* (2006); however, due to its low dry matter production, K accumulation was lower than what was found by those same authors.

Jack bean was the cover crop species that showed highest Ca content and accumulation in aerial part dry mass (shoot), followed by sunn hemp (Tables 2 and 3). This suggests that legumes, when compared with grasses, absorb and incorporate in their tissues, a greater Ca amount from soil. This occurs because legumes have a higher root capacity for cation exchange, promoting greater affinity with divalent cations (Marschner 2012).

High half-life time (Table 4) may be explained by low rainfall during the time plant biomass remained on the soil surface, from October to December (Table 1), directly affecting its decomposition. Costa *et al*. (2005) studied nutrient decomposition and nutrient release by tree litter in a *Eucalyptus grandis* stand and concluded that there was higher decomposition rate during the wettest rainfall period. Appropriate conditions of soil moisture and temperature increase microbial activity and enhance decomposition rate (Alves *et al*. 2006).

Cover crops with different chemical composition have been cultivated in order to adjust nutrient kinetics release for crop uptake (Aita and Giacomini 2003). Such process has resulted in faster decomposition of more recalcitrant materials and slower decomposition of better quality materials (Gama-Rodrigues *et al*. 2003). Therefore, signalgrass-jack bean intercropped as cover crops, may be a viable alternative for no-tillage system in Northeastern Pará, once signalgrass have high dry matter production and low decomposition rate, and jack bean high dry matter production and high decomposition rate.

High accumulation of N, P, and Ca, and low C/N ratio, as found in jack bean are desirable characteristics of plants that produce good quality residue (Gama Rodrigues *et al*. 2007). Thus, this species may be a cover crop alternative in regions with high rainfall and temperatures, and soils of low fertility. On the other hand, signalgrass showed high accumulation of C, K, and Mg, and was the greatest dry matter producer, also becoming an alternative for NT.

CONCLUSIONS

Signalgrass had greater dry mass production and was the species that incorporated the highest amount of C, K, and Mg. Jack bean also showed high biomass production and was the species that most incorporated N, P, and Ca. Signalgrass and jack bean are species that show potential to be used as cover crops due to their biomass production, above 6 t ha^{-1}. Their residues provide appropriate soil coverage and contribute for recycling large amounts of nutrients.

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