MACRONUTRIENTS RELEASE BY GREEN MANURE SPECIES GROWN IN CERRADO/PANTANAL ECOTONE

LIBERAÇÃO DE MACRONUTRIENTES POR ESPÉCIES DE ADUBAÇÃO VERDE CULTIVADAS NO ECÓTONO CERRADO/PANTANAL

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ABSTRACT: Assessing the nutrient release by cover crops species, especially those used in green manure, is important for planning activities aimed at the higher economic return. The use of these species in order to improve the growing conditions in the transition region between the Cerrado and Pantanal biomes, which have particular characteristics, may be a viable alternative. This study aimed to evaluate the amount of biomass produced and macronutrients released in this biomass by different green manure species grown in the Cerrado/Pantanal ecotone. The trial was carried out from April 2013 to June 2014 in the Plant Science sector at State University of Mato Grosso do Sul, Aquidauana-MS (Brazil). Experimental design was completely randomized arranged in time split plot, with four replications. First factor consisted of seven species of green manure, while the second were seven evaluation times (months). The variables evaluated were: dry mass of shoot and nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) contents as a function of time. For all variables evaluated there was significant interaction between the green manure species and the collection months. Vegetable cover showed different rates of decomposition and nutrient release. *Mucuna aterrima* was the species that produced higher amounts of dry mass and nutrient content. After four months of cutting the plants, green manure species do not differentiate between the amounts of released nutrients.

KEYWORDS: Fabaceae. Cover crops. Nutrients. Organic matter. *Mucuna aterrima.*

INTRODUCTION

The main an most important economic activity in the Cerrado/Pantanal ecotone region is the extensive beef cattle, followed by fishing, mining, tourism and agriculture (CALHEIROS; FONSECA JUNIOR, 1996). Extensive beef cattle, whose initial reporting dates from 200 years ago, is characterized by having low performance indexes with disabilities especially in birth and weaning rates as well as poor animal and vegetable sanitary management (ÍTAVO et al., 2016). A common practice in this activity was the regular use of fire, which generated extensive degraded areas resulting in low profitability and socioeconomic return for the region, with vast territorial extensions under high degree of deterioration (CHEFER; DE SOUZA, 2016).

It is necessary to encouraging conservation practices and agroecological systems in order to reverse this situation (GAMA-RODRIGUES et al., 2007). An alternative would be to accelerate the action of the biotic components in the productive environment, mainly in the soil with the use of nutrient recycling techniques. Several researches have demonstrated that the practice of cultivating green manure species as a soil cover is a method that will bring many qualitative and economic benefits to the productive environment besides ecological sustainability (DA COSTA et al., 2016; GAMA-RODRIGUES et al., 2007; PACHECO et al., 2011; TORRES et al., 2005).

One of the benefits of using green manures is the nutrients release from the plant biomass. Among the nutrients, one that has received more attention due to its greater mobility in the soil lately, is the nitrogen (N), which has been one of the most limiting in the productive systems (GIACOMINI et al., 2003). The use of green manure, especially species from the Fabaceae family, it is essential because they are able to N fixation (BNF - Biological Nitrogen Fixation). This characteristic considerably increases the economic return of the main activity considerably, besides reducing the application of the conventional chemical fertilizers. Species from this botanical family also present rapid decomposition compared to other families (PERIN et al., 2003). This happens because these plants present low relation between carbon and nitrogen (C/N ratio) to (GIACOMINI et al., 2003). In this

Received: 15/12/16
Accepted: 03/05/17

family there are many compounds that are easily dissolved, which increases and accelerate the decomposition and mineralization of nutrients and carbon, favoring the microorganisms present in the soil (DE SOUZA et al., 2012). Thus, undoubtedly the use of integrated techniques that seek the rational use of these species is a conservationist practice (MULVANEY et al., 2010).

The use of residues on the soil surface, especially the no-tillage system is a natural reserve of nutrients, which can be released quickly or slowly according to the characteristics of the species used as cover. According to HEAL et al. (1997), the decomposition of biomass is regulated by the interaction of the soil and climatic conditions, the chemical and structural properties of the vegetation cover and the presence of the decomposing community, such as the macro and microorganisms. In general, the climate can have little influence on the variation of its properties in a wide unit of space and ends up controlling the decomposition on a regional scale. The structural and chemical characteristics of the plant tissues from each species affects the process on a local scale (BERG, 2000). Bearing this in mind, the use of green manure species together with the awareness of the factors regulating the nutrient release become of ecological and economic importance for successor crops (GAMA-RODRIGUES et al., 2007).

In order to evaluate the nutrients release by several crops of green manure, some authors verified several results. In this study on *Cajanus cajan* (TORRES et al., 2005), the crop reached 62 kg·ha□1 of nitrogen in its dry mass at 110 days after sowing in the second harvest. This very same crop and the forage peanut (*Arachis pintoi* Krap. & Greg) showed the greatest macronutrients (N, P, K, Ca, Mg and S) release rates over 140 days in the study carried out by (GAMA-RODRIGUES et al., 2007). In this sense, knowing the dynamics of plant residues decomposition of several species in a certain environment such as the Cerrado/Pantanal ecotone will provide information that will support the establishment of more successful cropping systems. This study aimed to evaluate the amount of biomass produced and macronutrients released in this biomass by different green manure species grown in the Cerrado/Pantanal ecotone.

MATERIAL AND METHODS

The experiment was carried out between April 2013 and June 2014 in the Plant Science sector at State University of Mato Grosso do Sul (UEMS/UUA), Aquidauana-MS (Brazil), with an average altitude of 170 m. The area soil was identified by (SCHIAVO et al., 2010) as being Red Ultisol distrophic sand texture with the following chemical properties at the depth 0 - 0,20 m: pH (H_2O) = 6.2; Al^{3+} (cmolc dm^{-3}) = 0.0; Ca+Mg (cmolc dm^{-3}) = 4.31; P (mg dm^{-3}) = 41.3; K (cmolc dm^{-3}) = 0.2; organic matter (g dm^{-3}) = 19.74; V (%) = 55; m (%) = 0.0; sum of bases (cmolc dm^{-3}) = 4.51; CEC (cmolc dm^{-3}) = 5.1. Region climate, according to *Köppen*'s classification, is Aw (Savanna Tropical) with hot and humid summer and cold and dry winter and the two periods well determined.

Seven species of green manure were grown: *Canavalia ensiformis* L. DC., *Mucuna aterrima* Piper and Tracy (Merr.), *Dolichos lablab* L., *Cajanus cajan* L. Millsp., *Crotalaria juncea* L., *Crotalaria ochroleuca* (G. Don) and *Crotalaria spectabilis* (Roth). Soil preparation was carried out at the beginning of May 2013. Tillage system was adopted, with plowing and leveling. Green manure species were then seeded manually afterwards using the same spacing of 0.5 m between rows and 14 plants per meter for all species. The experimental plots had 25 m².

Cultural practices consisted of manual control of weeds (weeding) whenever they reached stage 4 to 6 expanded leaves. This practice was extended until the crop caused the suppression of invasive plants. No sowing or cover fertilization was performed. On December 21, 2013, all green manures were harvested close to the soil (cutting) and the biomass left fallow for natural decomposition. In this biomass, at the cutting time, four replicates of 1 m² from each species were collected to evaluate the green mass. This amount was dried in a forced circulation air oven for 72 hours at 60°C and the dry mass was measured, which served as a proportional reference for the calculations of the later collected.

In order to evaluate the nutrients release of the green manures biomass, we used the method proposed by (AITA; GIACOMINI, 2003). Evaluations were made in seven periods: time 0 (at the cutting time), time 1 (one month after cutting), time 2 (two months after cutting), and successively until time 6 (six months after cutting).

For evaluating nutrient amounts, samples of 60 g from green biomass were conditioned inside decomposition bags (*literbag*) at the cutting time and were randomly left fallow on the soil for decomposition next to the biomass corresponding to the species. We used 28 literbags corresponding to four replications per evaluation time for each species, that resulting in 196 literbags. Literbags have dimensions of 25 x 25 cm and 2 mm.

At the collection time, literbags that were left in the experimental area were previously cleaned in running water to remove the soil particles adhered to the mesh and biomass. Subsequently, the samples were placed in paper bags and oven dried with forced air circulation at 60°C for 72 hours. After the drying period, the samples were ground in a Willey mill and sent to a specialized laboratory for the chemical analysis, where were made the determination of macronutrients contents: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) as described by (MALAVOLTA, 1997).

Macronutrients content at each time in the amount of biomass was obtained by the relationship between the nutrient mass contained in a sample and the total biomass produced by species. Thus, it was possible to observe during the evaluation times the quantity accumulated of certain nutrient released.

Experimental design was completely randomized arranged in time split plot, with four replications. First factor consisted of seven species of green manure: Feijão-de-porco (*Canavalia ensiformis* (L.) DC.), Mucuna preta (*Mucuna aterrima* Piper e Tracy (Merr.)), Lab-lab (*Dolichos lablab* L.), Feijão-Guandu (*Cajanus cajan* (L.) Millsp.), *Crotalaria juncea* (L.), *Crotalaria ochroleuca* (G. Don) and *Crotalaria spectabilis* (Roth). Second factor was composed by seven evaluation times (months): time 0 (December), time 1 (January), time 2 (February), time 3 (March), time 4 (April), time 5 (May) and time 6 (June). The following variables were evaluated: dry mass and nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) contents as a function of time.

The analyzed variables were initially submitted to the Shapiro-Wilk test to verify the residue normality, Bartlett test to verify the homogeneity between the variances and Mauchly test to verify if the covariance matrix structures met the sphericity condition. After meeting the above assumptions, data were submitted to analysis of variance applying the F test. Qualitative factor (green manure species) was submitted to the comparison of means by Tukey test at 1% probability level and the quantitative to the polynomial regression analysis. For regression analysis, dispersion diagrams were initially made and from the previous analysis the models tested were linear and exponential. The best adjusted equation was chosen according to the coefficient of determination and the regression coefficients significance, tested by the t-test ($P<0.001$). The mean Euclidian distance was used as a measure of similarity and the Ward cluster method for the determination of species with closer characteristics. All analyzes were performed with R and SAS computational applications. The climatic conditions during the seven collections are expressed in Figure 1.

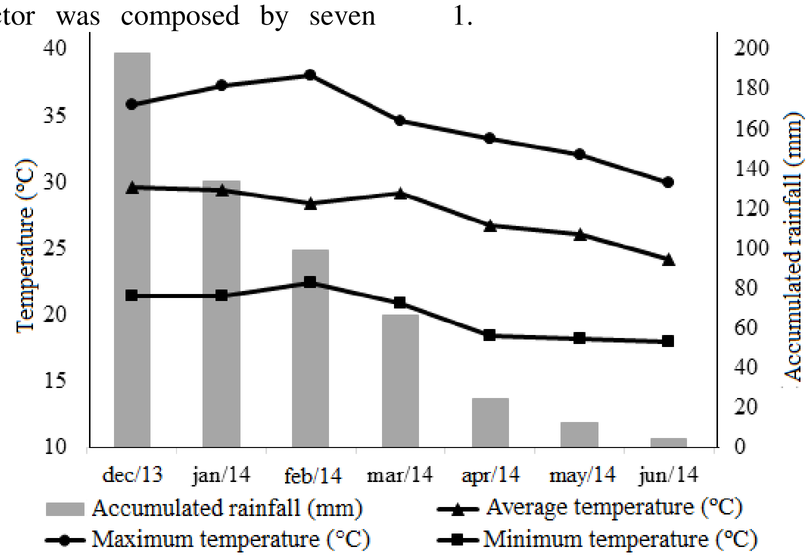

Figure 1. Climatic conditions regarding the period of biomass decomposition of the green manure species grown in Cerrado-Pantanal ecotone.

RESULTS AND DISCUSSION

For all the variables evaluated, the analysis of variance revealed a significant effect ($p>0.01$) species for the factor green manure species (S), month collection (M) and their interaction (Table 1). These results are explained by the different phenologies of the species that have diverse genera (high significance for the factor S) and the set of factors that acts during the period of the straw of these species, such as climatic conditions, action of microorganisms, C/N ratio, among others. Similar results were obtained in other studies that evaluated the nutrients release by species from the Fabaceae family over time (GAMA-RODRIGUES et al., 2007; PACHECO et al., 2011; TORRES et al., 2005).

Table 1. Summary of the analysis of variance (mean squares) for the variables dry mass (DM) and nitrogen, phosphorus, potassium, calcium, magnesium and sulfur contents evaluated in seven green manure species grown in the Cerrado-Pantanal ecotone.

SV	DF	DM	N	P	K	Ca	Mg	S
Species (S)	6	12073255.31*	22760.35*	95.37*	2125.51*	4560.31*	94.03*	56.63*
Error 1	21	95589.48	289.84	2.24	7.49	53.39	1.47	0.87
Month (M)	6	9698625.72*	29095.72*	196.79*	4292.05*	8937.32*	118.14*	76.37*
S x M	36	716089.08*	2814.33*	18.13*	735.16*	764.89*	9.67*	6.13*
Error 2	126	10009.05	29.39	0.70	4.07	8.78	0.17	0.17
CV 1 (%)	---	30.86	44.92	54.06	33.49	40.09	53.13	47.50
CV 2 (%)	---	9.99	14.30	30.13	24.69	16.26	17.95	20.82

*: significant at 1% probability by F test; SV: sources of variation; DF: degrees of variation; CV: coefficient of variation.

M. aterrima produced greater shoot mass (4,336.59 kg ha^{-1}) in the first month of evaluation (December) (Table 2). This position is maintained in all collection times. Results in similar magnitudes were observed by (SUZUKI; ALVES, 2006). However, these authors observed the highest dry mass production for the *C. juncea* species at environments with succession to soybean crops. *M. aterrima*, because it is a species with low growth with very vigor, extending its cycle until obtaining favorable conditions for flowering, it is more stable in producing phytomass independent of the environment (DE CAMARGO; PIZA, 2007).

Table 2. Remaining dry biomass on soil for each green manure species into evaluation time (months) and nitrogen, phosphorus and potassium contents in this biomass grown in the ecotone Cerrado-Pantanal.

Species	December	January	February	March	April	May	June	Equation of regression	R²
Dry mass (kg ha^{-1})									
C. juncea	1690.57 c	1332.55 c	1076.45 cd	820.36 c	613.84 c	415.65 cd	192.86 b	-242.4x+ 1604.9	0.990
C. ochroleuca	604.09 e	539.70 e	480.27 e	420.81 d	371.83 d	260.19 de	83.31 c	-79.6x + 633.2	0.942
C. spectabilis	1699.05 c	1509.17 c	1258.70 c	957.16 c	720.74 c	512.64 bc	211.09 ab	-249.8x + 1730.7	0.997
C. cajan	889.14 d	619.60 d	489.46 e	359.32 d	263.27 d	182.03 e	51.89 c	-129.0x + 794.9	0.963
C. ensiformis	2853.49 b	2153.51 b	1716.88 b	1280.26 b	953.01 b	673.33 b	236.71 ab	-413.4x + 2649.7	0.981
D. lablab	1056.95 d	997.94 d	867.85 d	770.47 c	593.13 c	382.70 cd	114.13 c	-154.7x + 1147.0	0.954
M. aterrima	4336.59 a	3489.09 a	2793.67 a	2098.25 a	1569.07 a	1112.17 a	416.75 a	-633.5x + 4159.0	0.992
N (kg ha^{-1})									
C. juncea	100.77 b	56.26 c	38.43 bc	24.72 bc	16.44 bcd	10.22 ab	3.84 a	-14.46x + 79.19	0.858
C. ochroleuca	28.79 e	24.52 e	18.44 de	12.90 de	9.34 cd	5.59 b	1.09 a	-4.65x + 28.32	0.993
C. spectabilis	86.64 c	64.21 bc	49.02 b	34.53 b	23.01 b	13.83 ab	4.27 a	-13.35x + 79.41	0.975
C. cajan	45.04 d	29.62 e	14.21 e	9.39 e	6.20 d	3.85 b	0.60 a	-6.89x + 36.22	0.854
C. ensiformis	108.49 b	71.16 b	47.94 b	30.30 bc	18.48 bc	11.53 ab	4.07 a	-15.50x + 91.21	0.912
D. lablab	40.03 de	34.77 e	27.47 cd	21.41 cd	14.26 bcd	8.59 b	1.99 a	-6.42x + 40.47	0.999
M. aterrima	241.34 a	172.11 a	127.56 a	73.19 a	39.99 a	21.59 a	5.15 a	-39.19x + 214.83	0.992
P (kg ha^{-1})									

C. juncea	7.34 c	5.10 b	3.94 ab	2.16 abc	1.43 ab	0.75 a	0.27 a	-1.16x + 6.47	0.953
C. ochroleuca	2.31 d	1.87 c	0.94 c	0.68 c	0.53 ab	0.32 a	0.07 a	-0.36x + 2.05	0.907
C. spectabilis	6.63 c	5.48 b	3.26 bc	1.89 bc	1.11 ab	0.58 a	0.18 a	-1.12x + 6.09	0.933
C. cajan	3.01 d	1.66 c	1.06 c	0.61 c	0.38 b	0.19 a	0.02 a	-0.45x + 2.34	0.853
C. ensiformis	9.79 b	5.91 b	3.95 ab	2.47 ab	1.21 ab	0.70 a	0.20 a	-1.50x + 7.95	0.889
D. lablab	4.00 d	3.28 c	2.37 c	1.91 bc	1.15 ab	0.61 a	0.09 a	-0.65x + 3.87	0.993
M. aterrima	19.64 a	11.44 a	5.59 a	3.82 a	2.16 a	1.31 a	0.41 ab	-2.91x + 15.05	0.992
K (kg ha^{-1})									
C. juncea	31.48 b	22.39 b	1.77 b	1.23 a	0.92 a	0.62 a	0.22 a	-4.93x + 23.18	0.777
C. ochroleuca	8.03 e	3.09 d	0.72 b	0.64 a	0.52 a	0.26 a	0.08 a	-1.06x + 5.09	0.632
C. spectabilis	26.13 c	14.02 c	4.99 ab	2.06 a	1.37 a	0.77 a	0.30 a	-3.84x + 16.62	0.740
C. cajan	15.88 d	1.49 d	0.79 b	0.54 a	0.40 a	0.16 a	0.02 a	-1.08x + 8.18	0.753
C. ensiformis	35.45 b	5.47 d	3.44 ab	2.06 a	1.43 a	1.01 a	0.21 a	-4.17x + 19.50	0.789
D. lablab	12.56 d	3.13 d	1.96 b	1.54 a	1.03 a	0.53 a	0.11 a	-1.55x +7.64	0.797
M. aterrima	98.09 a	74.76 a	7.40 a	4.20 a	2.80 a	1.67 a	0.63 a	$-26.05^{(0.19x)} + 15.05$	0.841

Means followed by lower case letters in the same column do not differ by Tukey test at 1% probability; R^2: coefficient of determination.

This species also has a more distributed root system over the profile (ALVARENGA et al., 1995) allowing it to explore a greater volume of soil. However, C. juncea showed to be more responsive to soils with frequent fertilization and the presence of high concentration of nitrogen fixing bacteria strains (soybean cultivation). This fact explains the intermediate performance of this species together with *C. spectabilis* (1690.57 and 1699.05 kg ha^{-1}, respectively), in the collection of December.

C. cajan, *D. lablab* and *C. ochroleuca* presented the lowest means of dry mass in all evaluation periods. (TORRES et al., 2008) evaluating green manure species also found low dry mass yield for these species. These authors concluded that due to low leaf area index and low C/N ratio, they produce less dry mass and decomposing at higher rates. However, these species have roots with excellent beneficial characteristics for the soil.

It is possible to observe that with material at the field for longer periods, there is a uniformization trend among species in the release of N, P and K from the 6th, 5th and 3rd month, respectively. Given these results, we can infer that the use of these species for soil cover over the off-season should be carried out a few months before the crop-target be sown. This technique will benefit the subsequent crop for providing better utilization of higher contents of available nutrients and the non-fructification of the green manures will prevent them from becoming invasive plants later.

High temperatures and rainfall accelerate the process of plant tissues decomposition, since these factors increase the biological activities of the soil (HEINZ et al., 2011). The conditions found in this trial (Figure 1) reinforce the rapid decrease in Ca, Mg and S contents (Table 3) in the first months (December 2013 to March 2014), and the low dry mass availability of green manures in the last collection times and, consequently, these are not different between species in these periods.

In general, in relation to the secondary macronutrients, the species that provided the highest Ca content were *M. aterrima* (107.4 kg·ha^{-1}) and *D. lablab* (95.98 kg·ha^{-1}). The other species presented smaller results, but with differences between them. Regarding Mg, there is the same trend, with the emphasis to *C. juncea* and *C. spectabilis*. For the S, *M. aterrima* also was superior until the fourth month (11.17; 5.46; 5.61 and 5.36 kg ha^{-1}). *M. aterrima* Immobilized twice as much (sometimes more) nutrients than the other species evaluated at all collection times.

Table 3. Unfolding the significant interaction for each green manure species into evaluation time (months) for calcium, magnesium and sulfur contents (Ca, Mg, S, respectively) evaluated in seven green manure species grown in the ecotone Cerrado-Pantanal.

Species	December	January	February	March	April	May	June	Equation of regression	R²
Ca (kg ha^{-1})									
C. juncea	42.21 c	27.00 c	16.40 cd	12.29 b	8.56 abc	5.20 ab	1.27 a	-6.22x + 34.80	0.777
C. ochroleuca	13.47 e	11.13 e	5.66 e	4.16 c	2.48 cd	1.16 ab	0.35 a	-2.23x + 12.18	0.632
C. spectabilis	43.57 c	30.74 c	21.61 c	12.88 b	9.42 ab	4.26 ab	1.27 a	-6.86x + 38.25	0.943
C. cajan	17.35 e	10.96 e	8.02 e	4.21 c	2.14 d	0.60 b	0.06 a	-2.80x + 14.60	0.917
C. ensiformis	95.98 b	51.27 b	29.29 b	12.84 b	8.21 bcd	4.08 ab	0.81 a	$-21.45^{(0.13x)} + 80.51$	0.789
D. lablab	30.43 d	21.46 d	15.15 d	10.56 b	5.65 bcd	2.47 ab	0.12 a	-4.94x + 27.09	0.960
M. aterrima	107.40 a	76.87 a	53.60 a	25.01 a	14.28 a	7.96 a	1.37 a	-17.69x + 93.99	0.925
Mg (kg ha^{-1})									
C. juncea	6.32 b	3.82 b	2.61 b	1.81 b	1.01 b	0.46 b	0.11 a	-0.96x + 5.19	0.905
C. ochroleuca	2.04 d	1.34 c	0.98 c	0.80 cd	0.56 b	0.25 b	0.04 a	-0.31x + 1.78	0.950
C. spectabilis	6.10 b	4.07 b	2.95 b	1.62 bc	1.00 b	0.50 b	0.04 a	-0.97x + 5.25	0.934
C. cajan	2.58 cd	1.52 c	0.93 c	0.61 d	0.35 b	0.11 b	0.05 a	-0.39x + 2.05	0.874
C. ensiformis	6.26 b	3.76 b	2.71 b	1.70 b	1.05 b	0.12 b	0.00 a	-0.99x + 5.19	0.917
D. lablab	3.03 c	1.88 c	1.43 c	1.18 bcd	0.70 b	0.30 b	0.02 a	-0.46x + 2.61	0.944
M. aterrima	14.65 a	10.59 a	7.91 a	5.33 a	2.97 a	1.42 a	0.24 a	-2.38x + 13.28	0.968
S (kg ha^{-1})									
C. juncea	5.61 b	3.68 bc	2.69 bc	1.78 b	1.20 bc	0.77 ab	0.20 a	-0.84x + 4.40	0.932
C. ochroleuca	1.92 c	1.36 d	1.05 d	0.81 cd	0.60 cd	0.35 ab	0.07 a	-0.29x + 1.74	0.973
C. spectabilis	5.36 b	4.05 b	3.13 b	2.28 b	1.51 ab	0.80 ab	0.19 a	-0.84x + 5.00	0.986
C. cajan	1.81 c	1.01 d	0.75 d	0.46 d	0.25 d	0.07 b	0.00 a	-0.28x + 1.46	0.893
C. ensiformis	5.46 b	3.12 c	2.14 c	1.48 bc	0.78 bcd	0.34 ab	0.00 a	-0.83x + 4.40	0.894
D. lablab	1.83 c	1.47 d	1.09 d	0.87 cd	0.53 cd	0.18 ab	0.00 a	-0.51x + 1.78	0.993
M. aterrima	11.17 a	8.40 a	6.11 a	4.01 a	2.25 a	0.96 a	0.10 a	-1.86 + 10.28	0.972

Means followed by lower case letters in the same column do not differ by Tukey test at 1% probability; R²: coefficient of determination.

All species presented a linear fit in the model adjustment as a function of time for the dry mass production (Table 2). *M. aterrima* presented the greatest amount of masses over the months. According to the regression coefficient, the phytomass decomposition rate of this species was 633.5 g per hectare. It was the fastest rate of decomposition, and consequently, the species that releases higher nutrients contents in a smaller time unit. In contrast, *C. acholeuca* showed the slowest rate of biomass decomposition (79.63 grams per day) and yielded the lowest average dry mass with 604.09 kg ha^{-1} (Table 2).

C. cajan, with rate of decomposition of 129 g per day, at the end of collection times, it presented little or no remaining material for decomposition (Table 2). With the exception of *M. aterrima* and *C. cajan*, the other species presented slow macronutrients release (decomposition of little phytomass in time unit). This fact can be explained by the high carbon/nitrogen ratio in the vegetal tissues from these species, which causes slowness of soil organisms to decompose this matter (SODRÉ FILHO et al., 2004). According to (LIMA et al., 2012), a comparison of the carbon ratio among *M. aterrima* (14/1) and *Crotalaria spp.* (30/1) it explains the faster biomass decomposition by *M. aterrima*.

All species presented a linear adjustment in the model adjustment as a function of time for the amount of N released (Table 2). *M. aterrima* species had the highest amount of N released every month. According to the regression coefficient for *M. aterrima*, rate of release of this nutrient from the remaining phytomass was 39.19 kg ha^{-1} per day. The other species ranged from 4.65 to 15.5 kg ha^{-1} per day (*C. ochroleuca* and *C. ensiformis*, respectively).

For the amount of released P, there was a linear adjustment of the regression equation model in all species (Table 2). *M. aterrima* Released the highest amounts of the nutrient in the experimental period, with an average of 2.91 kg ha^{-1} per day. At fifth month, there were practically no remaining P content to be released.

Only *M. aterrima* presented an exponential adjustment for the amounts of K released as a function of the months elapsed (Figure 5), being the one that released larger amounts of this nutrient. The other species presented linear adjustment and released smaller amounts of this nutrient. These results are similar to those observed by (TORRES; PEREIRA, 2008).

Canavalia ensiformis presented an exponential adjustment for the amounts of Ca released (Table 2) in function of the months elapsed. This species provided the highest amount of Ca in the initial month, presenting a sudden drop in the amount of this nutrient released over the trial. The other species presented linear adjustment, where *M. aterrima* released the highest amounts of Ca from the second month, and on a regular way (17.69 kg ha^{-1}).

All green manure species presented linear adjustment of the regression equation for both the released of Mg and S (Table 3). Again *M. aterrima* stood out over the other species (which presented similar results among themselves) with larger amounts for both nutrients (2.38 and 1.86 kg ha^{-1}, respectively). The fact that *M. aterrima* has released the highest amounts of nutrients in all nutrients is strictly related to the production of dry mass. *M. aterrima* produced more phytomass and the greater amount available for decomposition releases larger amounts of nutrientes. The product of the nutrient contents in the samples of each collection time versus the relation of the loss of mass of these samples and the total dry biomass produced by each species helps to understand the results observed in this study.

It is necessary to observe some factors in order to choose a green manure species. For example, the succession of *C. cajan* with another summer crop in the same agricultural year is not possible due to its long cycle. However, its cultivation in fallow areas would be interesting because of its great capacity to promote physical improvements in the soil and can be used as an alternative source of animal protein supplementation (ALVARENGA et al., 1995). In addition to this, there are allelopathic effects on weeds, which also deserve attention. Several authors describe the use of green manure species for this purpose; (CAAMAL-MALDONADO et al., 2001) (SEVERINO; CHRISTOFFOLETI, 2004; ZANUNCIO et al., 2013) and (SEVERINO; CHRISTOFFOLETI, 2001) as an integrated management for controlling weeds, however, the allelopathic effect caused on the main crop also should also be observed. For example, *M. aterrima*, a species that best exceled in this trial due to the great amount released from all macronutrients, it exerts a strong allelopathic effect (reduction of significant yield) when grown before common bean (MENEZES et al., 2009).

CONCLUSIONS

Green manures showed different rates of decomposition and macronutrients release.

Mucuna aterrima was the species that produced higher amounts of dry mass and nutrient content.

After four months of cutting the plants, green manure species do not differentiate between the amounts of released nutrients.

RESUMO: Avaliar a liberação de nutrientes por espécies de plantas de cobertura, especialmente aquelas utilizadas na adubação verde é importante para o planejamento das atividades objetivando o maior retorno econômico. O uso dessas espécies afim de se melhorar as condições de cultivo na região de transição entre os biomas do Cerrado e Pantanal que possuem características particulares, pode ser uma alternativa viável. O objetivo deste trabalho foi avaliar as taxas de liberação de macronutrientes de diferentes espécies de adubação verde cultivadas no ecótono Cerrado/Pantanal. O experimento foi realizado entre os meses de abril de 2013 a junho de 2014 no setor de Fitotecnia da Universidade Estadual de Mato Grosso do Sul, Aquidauana-MS. O delineamento experimental adotado foi o inteiramente casualizado disposto em esquema de parcelas subdivididas no tempo, com quatro repetições. O primeiro fator consistiu em sete espécies de adubação verde, enquanto o segundo em sete épocas (meses) de avaliação. As variáveis avaliadas foram: massa seca da parte aérea e quantidades de nitrogênio (N), fósforo (P), potássio (K), cálcio (Ca), magnésio (Mg) e enxofre (S) liberados em função do tempo. Para todas as variáveis avaliadas houve interação significativa entre as espécies de adubação verde vezes os meses de coleta. As coberturas vegetais apresentaram distintas taxas de decomposição e de liberação de nutrientes. *Mucuna aterrima* foi à espécie que produziu maiores quantidades de massa seca e disponibilizou as maiores quantidades de nutrientes. Após quatro meses de corte das plantas, as espécies de adubação verde não diferiram entre si quanto as quantidades liberadas de nutrientes.

PALAVRAS-CHAVE: *Fabáceas*. cultivos de cobertura. nutrientes. matéria orgânica. *Mucuna aterrima*

REFERENCES

AITA, C., GIACOMINI, S. J., Decomposição e liberação de nitrogênio de resíduos culturais de plantas de cobertura de solo solteiras e consorciadas. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 27, p. 601-612, 2003.

ALVARENGA, R., COSTA, L. D., MOURA FILHO, W., REGAZZI, A., Características de alguns adubos verdes de interesse para a conservação e recuperação de solos. **Pesquisa Agropecuária Brasileira**, Brasília, v. 30, p., 1995.

BERG, B., Litter decomposition and organic matter turnover in northern forest soils. **Forest ecology and Management**, Amsterdã, v. 133, p. 13-22, 2000.

CAAMAL-MALDONADO, J. A., JIMÉNEZ-OSORNIO, J. J., TORRES-BARRAGÁN, A., ANAYA, A. L., The use of allelopathic legume cover and mulch species for weed control in cropping systems. **Agronomy Journal**, Madison, v. 93, p. 27-36, 2001. https://doi.org/10.2134/agronj2001.93127x

CALHEIROS, D. F., FONSECA JUNIOR, W. D., Perspectivas de estudos ecológicos sobre o Pantanal. **Embrapa-CPAP, Corumbá. Documento**, v., p., 1996.

CHEFER, D. M., DE SOUZA, D. M., BOVINOCULTURA DE CORTE: PRINCIPAIS MANEJOS DURANTE A FASE DE CRIA. **Revista Iniciare**, Recife, v. 1, p., 2016.

DA COSTA, D. M., CAMPOS, M. S., MARGARIDO, L. A. C., COELHO, C. R., Levantamento da entomofauna de solo associada à adubos verdes. **Cadernos de Agroecologia**, Recife, v. 10, p., 2016.

DE CAMARGO, R., PIZA, R. J., Produção de biomassa de plantas de cobertura e efeitos na cultura do milho sob sistema plantio direto no município de Passos, MG. **Bioscience Journal**, Uberlândia, v. 23, p., 2007.

DE SOUZA, L. C. D., DE SÁ, M. E., DA SILVA, M. P., ABRANTES, F. L., SIMIDU, H. M., ARRUDA, N., VALÉRIO FILHO, W. V., Efeito da adubação verde e época de semeadura de cultivares de feijão, sob sistema plantio direto, em região de cerrado= Effect of green manure and time of sowing of bean cultivars under direct planting system in the region of savannah. **Bioscience Journal**, Uberlândia, v. 28, p., 2012.

GAMA-RODRIGUES, A. D., GAMA-RODRIGUES, E. D., BRITO, E. D., Decomposição e liberação de nutrientes de resíduos culturais de plantas de cobertura em Argissolo Vermelho-Amarelo na região Noroeste Fluminense (RJ). **Revista Brasileira de Ciência do Solo**, Viçosa, v. 31, p. 1421-1428, 2007.

GIACOMINI, S. J., AITA, C., VENDRUSCOLO, E. R. O., CUBILLA, M., NICOLOSO, R. S., FRIES, M. R., Matéria seca, relação C/N e acúmulo de nitrogênio, fósforo e potássio em misturas de plantas de cobertura de solo. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 27, p. 325-334, 2003.

HEAL, O., ANDERSON, J., SWIFT, M., Plant litter quality and decomposition: an historical overview. **Driven by nature: plant litter quality and decomposition**, v., p., 1997.

HEINZ, R., GARBIATE, M. V., NETO, A. L. V., MOTA, L. D. S., CORREIA, A. M. P., VITORINO, A. C. T., Decomposição e liberação de nutrientes de resíduos culturais de crambe e nabo forrageiro. **Ciência Rural**, Santa Maria, v. 41, p. 1549-1555, 2011. https://doi.org/10.1590/S0103-84782011000900010

ÍTAVO, C. C. B. F., ÍTAVO, L. C. V., DIAS, A. M., DA SILVA, J. P. B., EUCLIDES FILHO, K., DA GRAÇA MORAIS, M., Fatores inerentes à economicidade de sistemas de produção de bovinos de corte, no município de Campo Grande, Mato Grosso do Sul. **Interações,** Campo Grande, v. 6, p., 2016.

LIMA, J. D., SAKAI, R. K., ALDRIGHI, M., Produção de biomassa e composição química de adubos verdes cultivados no vale do ribeira= Biomass production e chemical composition of green manure cultivated in vale do ribeira. **Bioscience Journal**, Uberlândia, v. 28, p., 2012.

MALAVOLTA, E., Avaliação do estado nutricional das plantas: princípios e aplicações/Eurípedes Malavolta, Godofredo Cesar Vitti, Sebastião Alberto de Oliveira.—2. ed., ver. e atual. **Piracicaba: Potafos**, v., p., 1997.

MENEZES, L. A. S., LEANDRO, W. M., DE OLIVEIRA JÚNIOR, J. P., DE BARCELLOS FERREIRA, A. C., DAS GRAÇAS SANTANA, J., BARROS, R. G., Produção de fitomassa de diferentes espécies, isoladas e consorciadas, com potencial de utilização para cobertura do solo. **Bioscience Journal**, Uberlândia, v. 25, p., 2009.

MULVANEY, M. J., WOOD, C., BALKCOM, K., SHANNON, D., KEMBLE, J., Carbon and nitrogen mineralization and persistence of organic residues under conservation and conventional tillage. **Agronomy journal**, Madson, v. 102, p. 1425-1433, 2010.

PACHECO, L. P., LEANDRO, W. M., MACHADO, P., ASSIS, R. D., COBUCCI, T., MADARI, B. E., PETTER, F. A., Produção de fitomassa e acúmulo e liberação de nutrientes por plantas de cobertura na safrinha. **Pesquisa Agropecuária Brasileira**, Brasília,v. 46, p. 17-25, 2011. https://doi.org/10.1590/S0100-204X2011000100003

PERIN, A., GUERRA, J. G. M., TEIXEIRA, M. G., Cobertura do solo e acumulação de nutrientes pelo amendoim forrageiro. **Pesquisa Agropecuária Brasileira**, Brasília,v. 38, p. 791-796, 2003. https://doi.org/10.1590/S0100-204X2003000700002

SCHIAVO, J. A., PEREIRA, M. G., MIRANDA, L. P. M. D., NETO, D., HYPÓLITO, A., FONTANA, A., Caracterização e classificação de solos desenvolvidos de arenitos da formação Aquidauana-MS. **Revista Brasileira de Ciência do Solo**, Viçosa, v., p. 881-889, 2010.

SEVERINO, F. J., CHRISTOFFOLETI, P. J., Banco de sementes de plantas daninhas em solo cultivado com adubos verdes. **Bragantia**, Campinas, v. 60, p. 201-204, 2001. https://doi.org/10.1590/S0006-87052001000300007

SEVERINO, F. J., CHRISTOFFOLETI, P. J., Weed supression by smother crops and selective herbicides. **Scientia Agricola**, Piracicaba, v. 61, p. 21-26, 2004. https://doi.org/10.1590/S0103-90162004000100004

SODRÉ FILHO, J., CARDOSO, A. N., CARMONA, R., CARVALHO, A. M. D., Fitomassa e cobertura do solo de culturas de sucessão ao milho na Região do Cerrado. **Pesquisa Agropecuária Brasileira**, Brasília, v. 39, p. 327-334, 2004. https://doi.org/10.1590/S0100-204X2004000400005

SUZUKI, L., ALVES, M. C., Fitomassa de plantas de cobertura em diferentes sucessões de culturas e sistemas de cultivo. **Bragantia**, Campinas, v. 65, p. 121-127, 2006. https://doi.org/10.1590/S0006-87052006000100016

TORRES, J. L. R., PEREIRA, M. G., Dinâmica do potássio nos resíduos vegetais de plantas de cobertura no Cerrado. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 32, p. 1609-1618, 2008.

TORRES, J. L. R., PEREIRA, M. G., ANDRIOLI, I., POLIDORO, J. C., FABIAN, A. J., Decomposição e liberação de nitrogênio de resíduos culturais de plantas de cobertura em um solo de cerrado. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 29, p. 609-618, 2005.

TORRES, J. L. R., PEREIRA, M. G., FABIAN, A. J., Produção de fitomassa por plantas de cobertura e mineralização de seus resíduos em plantio direto. **Pesquisa Agropecuária Brasileira**, Brasília, v. 43, p. 421-428, 2008. https://doi.org/10.1590/S0100-204X2008000300018

ZANUNCIO, A., TEODORO, P. E., RIBEIRO, L. P., CORREA, C. C., OLIVEIRA, M., TORRES, F. E., Alelopatia de adubos verdes sobre Cyperus rotundus. **Revista de Ciências Agrárias**, Lisboa v. 36, p. 441-446, 2013.