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CROP PRODUCTION

Deposition and decomposition of litter in periods of grazing and rest of a tropical pasture under rotational grazing

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ABSTRACT: *The objectives of this study were to determine the rates of plant litter deposition and decomposition in Marandu pastures (Urochloa brizantha cv. Marandu) under a) three forms of nitrogen (N) supply, b) at different stages of rotational grazing and c) to compare the single-exponential decay constant ('k') derived from litterbags with values derived from estimates of deposited and existing litter (DEL technique). The three N supply treatments were: without or with N fertilization (zero or 150 kg N ha^{-1} yr^{-1}) or with the legume Desmodium ovalifolium. There were no significant differences ($p<0.05$) between existing litter and rates of litter deposition and decomposition between the three N supply treatments. The litter decomposition rate was estimated using the DEL technique for the 7-day grazing periods and two subsequent 14-day periods in each 35-day grazing cycle. The litter decomposition rate was ($P<0.05$) higher for the second rest period (days 21 to 35) at 0.089 g g^{-1} day^{-1}, than for the grazing period (0.038 g g^{-1} day^{-1}) and for the first rest period (0.040 g g^{-1} day^{-1}). The mean half-life of the litter was 12 days using the DEL technique while the estimate from the litterbags was 136 days. Results showed that estimates provided by litterbags severely underestimate the decomposition in relation to the DEL technique and predict a long-term accumulation of litter which is not observed.*
Key words: *Urochloa brizantha, decomposition constant, methodological comparison.*

Deposição e decomposição de serapilheira em períodos de pastejo e descanso de uma pastagem tropical sob pastejo rotativo

RESUMO: *Os objetivos deste estudo foram determinar taxas de deposição e decomposição de serapilheira em pastagens de Marandu (Urochloa brizantha cv. Marandu) sob a) três formas de suprimento de nitrogênio (N), b) em diferentes estágios de pastejo rotativo e c) comparar a constante de decomposição ('k') derivada de "litterbags" com os valores derivados das estimativas de serapilheira existente e depositada (técnica SED). Os três tratamentos de suprimento de N foram: sem ou com adubação nitrogenada (zero ou 150 kg N ha^{-1} ano^{-1}) ou com a leguminosa Desmodium ovalifolium. Não houve diferenças significativas ($p<0,05$) entre a serapilheira existente e as taxas de deposição e decomposição da serapilheira entre os três tratamentos de N. A taxa de decomposição da serapilheira foi estimada usando a técnica SED para os 7 dias de pastejo e dois períodos subsequentes de 14 dias em cada ciclo de 35 dias. A taxa de decomposição da serapilheira foi ($p<0,05$) maior no segundo período de descanso (dias 21 a 35) em 0,089 g g^{-1} dia^{-1}, do que no período de pastejo (0,038 g g^{-1} dia^{-1}) e no primeiro período de repouso (0,040 g g^{-1} dia^{-1}). A meia-vida média da serapilheira foi de 12 dias pela técnica SED, enquanto a estimativa dos "litterbags" foi de 136 dias. Os resultados mostram que as estimativas fornecidas pelos "litterbags" subestimam severamente a decomposição em relação à técnica SED, e preveem um acúmulo de serapilheira a longo prazo que não é observado.*
Palavras-chave: *Urochloa brizantha, constante de decomposição, comparação de metodologias.*

INTRODUCTION

It is estimated that 60 to 70% of the 160 million hectares of pasture cultivated in Brazil can be classified as degraded (DIAS-FILHO, 2014). Nutrient deficits - mainly, nitrogen and phosphorus – are considered as the main causes of pasture decline (BODDEY et al., 2004). To maintain sustainable animal production, fertilizers are required, but alternatively nitrogen can be supplied by tree, shrub or forage legumes (MUIR et al., 2014; LIMA et al., 2018).

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Forage plants continuously produce new tissues and, at the same time, older tissues senesce (LONG et al., 1989). The rate of this turnover of plant tissues is dependent on environmental factors and pasture management (ZANINE & VIEIRA, 2006). The tissues not selected and consumed by the animals are deposited on the soil surface. Accumulation of this material established a layer of "existing litter" on the soil surface, the quantity of which depends on the balance between deposition and decomposition.

For the best herbage yields of tropical pastures the removal of forage should not be more than 40 to 50% of pasture height (FONSECA et al. 2012). In a study where *Urochloa humidicola* was managed with three stocking rates between 1.4 and 2.5 AU ha^{-1} (1 AU = 450 kg body weight), even at the highest stocking rate only 39% of the estimated net aerial primary productivity was consumed by the cattle (PEREIRA et al., 2009). In consequence, more than half of the shoot dry matter was recycled in the litter along with its content of nutrients. In conditions of low fertilizer input, common in most tropical pastures, nutrients recycled in the litter have a greater impact than in temperate pastures, which are usually reliant almost solely on nutrients supplied in fertilizers.

Most of the studies conducted in the field interpret the decomposition process with the progressive loss of litter mass deposited over time and quantified gravimetrically, as is the case with litterbag methodology (COTRUFO et al., 2010). However, the enclosure of the litter in bags can alter the decomposition environment (BRADFORD et al., 2002). Alternative methods for estimating litter decomposition in pasture without enclosing the material in a nylon bag, such as the deposited litter/ existing litter (DEL) methodology of REZENDE at al. (1999), appear to yield rates of litter decomposition an order of magnitude higher.

In rotational grazing the animals graze and trample the forage species for a short period and the pastures are allowed to regrow for a longer period. No studies have been published to ascertain the rates of litter decomposition during these different phases of rotational grazing. The objectives of this present study were i) to compare the litter deposition and decomposition rates during grazing and during the rest period, in a Marandu pasture, supplied with nitrogen (N) fertilizer, or with an introduced forage legume, in comparison with pasture with no external N supply; and ii) to compare the litterbag methodology with the existing litter/deposited litter methodology in the Marandu pasture.

MATERIALS AND METHODS

The experiment was conducted at the Pasture Experimental Station of the Extreme South of Bahia (CEPLAC - ESSUL), located in the municipality of Itabela, BA (16°39´S e 39°30´W and 918 m asl). The station is located in the Atlantic Forest biome, with an average annual rainfall of 1,300 mm, without a well-defined dry season, and temperatures range from 19 to 29 °C. The soil is classified as Dystrophic Red-Yellow Argissolo (Brazilian Classification, EMBRAPA, 2013) or an Acrisol (WRB/FAO classification). Chemical characteristics of the soil were: pH 6.0, C, 8 g kg^{-1} Al, Ca, Mg, K, 0.0, 1.9, 0.6, 42.9 cmol dm^{-3}, respectively, and available (Mehlich I) P, 2.5 mg kg^{-1}. Data for rainfall, temperature and relative humidity were taken from the Itabela field station meteorological instruments (Figura 1A).

The experiment was installed on pre-existing pastures but rotational grazing started in September 2015. The experimental design was randomized blocks with two replicates. There were three pasture treatments (plots) in each block:

1. FERT-N: A monoculture of *Brachiaria brizantha* (Syn, *Urochloa brizantha*) cv. Marandu fertilized with three annual applications of 50 kg N ha^{-1} as urea.
2. CONTL: A monoculture of the Marandu grass with no N fertilization.
3. GRLEG: A mixed grass/legume pasture of Marandu grass with *Desmodium ovalifolium* cv Itabela.

The area of the plots FERT-N and GRLEG were both 7,800 m^2 and the CONTL of 9,800 m^2. Each plot was subdivided into five paddocks of equal area. Pastures were managed in a rotational stocking system, with seven days of occupation and 28 days of rest.

Forage on offer was sampled by using six frames of 1.0 x 1.0 m (pre-grazing) per paddock, every 14 days. The forage cut was performed at 15 cm height. The animal stocking rate was controlled to maintain forage allowance at 4 % of body weight (BW) day^{-1} of green forage dry matter. In order to adjust the stocking rate according to the green forage on offer, the animals were added or removed from the respective paddocks. For this, the animals were weighed every 28 days and the forage on offer of the pasture (during the grazing period and at the 14 and 28 days of rest) was quantified, thus maintaining the same ratio of animal weight and forage mass available in all treatments. During the eleven months of the experimental period (September 2016 to July 2017) there were nine grazing cycles of 35 days.

The grazing animals were Nellore crossbred heifers, with a mean body weight of 240 kg. Animals were introduced into the experimental area 30 days before the start of data collection to adjust to the experimental conditions.

The quantification of the decomposition rate was determined using the deposited and existing litter (DEL) technique as described REZENDE et al. (1999) but modified for application in rotational grazing. The litter was collected using 1.0 x 0.5 m frames and three frames were sampled from each paddock. When animals entered the picket for the grazing period, the existing litter (LE0) was collected from each frame. After a grazing period of seven days, the deposited litter (LD7) was collected from the frame that had been cleared of litter on day zero (LE0). On the same day, a new existing litter frame (LE7) was also collected. After a further 14 days the litter deposited in this frame was collected (LD21) and a new frame (LE21) was used to collect existing litter. The same procedure with the 14-day collection period was repeated for day 35. Then on the same day that the frame (LD35) was used to collect deposited litter on day 35, a new cycle began with the positioning of a new LE0. In this way, for each grazing cycle the existing litter was quantified on days 0, 7, 21 and 35 and the litter deposited on bare soil was evaluate for the first 7 days and the subsequent two consecutive periods of 14 days.

The litter samples were placed in paper bags, taken to the laboratory, dried in a forced air oven at 65 °C for 72 hours. After drying, the litter was separated from soil aggregates and coprolites in a tray. The litter was then weighed to determine the dry matter (DM).

Rates of litter disappearance in the 7-day period of grazing and the two 14-day rest periods between samplings of existing litter were calculated from the equations of WIEGERT & EVANS (1964):

DM of the litter which disappeared

$(L_{dis}) = LE_i + LD_f - LE_f$ Eqn. (1)

where LE_i is the DM of existing litter at the start of the period of grazing or rest, LD_f is the litter DM deposited until the end of the period of grazing or rest and LE_f is the DM of existing litter at the end of the period of grazing or rest.

The decomposition constant `k´ for the litter was calculated based on a single exponential decay function derived from the equation used by THOMAS & ASAKAWA (1993):

$LE_f = (LE_i + LD_f)\, e^{-kt}$ Eqn. (2)

which resolving for `k` becomes:

$k = \{\ln(LE_i + LD_f) - \ln(LE_f)\}/t$ Eqn. (3)

The units of 'k' become g g^{-1} day^{-1}.

The half-life of the litter was calculated from the expression:

$t^{½} = \ln(2)/k$ Eqn. (4)

The methodology for the litterbags was performed according to DUBEUX et al. (2006). This methodology was conducted only in the N-FERT treatment. The senescent plant material of each plot of Marandu grass was collected in the field consisting of senescent leaves and stems still attached to the plant. Samples were oven-dried at 65 °C for at least 72 hours. Subsamples of 5 g each were collected and placed in 15 x 20 cm nylon mesh bags and 1 mm mesh.

Bags were deposited on the soil and incubated under the surface layer of litter in the pastures. Collections occurred after 2, 4, 8, 16, 32, 64, and 128 days with 12 litterbags being collected at each time. After 64 days incubation, it was reported that a few of the bags were being disturbed by the cattle and small steel cages were placed over the areas where the bags were buried. For the collection of the bags, the external parts were cleaned with a brush, to remove contaminations. Subsequently, the material was oven dried at 65 °C for 72 hours and weighed.

The decomposition constant 'k' was estimated using the equation of THOMAS & ASAKAWA (1993), according to the equation [4] of simple exponential decay. The remaining mass in litterbags in time was adjusted to a simple exponential curve with the aid of Sigmaplot software.

$X_t = X_0 \,.\, e^{-kt}$ Eqn. (5)

Where X_t is the dry weight of the litter remaining in the soil after t days and X_0 is the original dry mass put into the bag when t = 0. Determination of half-life was performed as before (Eqn. 4.).

The experimental design for the existing litter/deposited litter methodology was in randomized blocks with split plots. The main plots corresponded to the pasture management (N-FERT, GRLEG and CONTL), the sub-plot to the litter collection period and the nine grazing cycles were sub-plots. R software was used for the normality test (Shapiro-Wilk) and homogeneity of variances (Levene's). The variable k was transformed by applying natural logarithm to meet the criterion of homogeneity of variances. Analysis of variance was performed using the SISVAR software. The means were separated based on the Student least significant difference test at $p<0.05$.

RESULTS AND DISCUSSION

The existing litter, ranged from approximately 300 to 1000 kg DM ha^{-1} (Figure 1B). There was no significant difference between the N-FERT, GRLEG and CONTL treatments, nor between the grazing and rest periods or significant

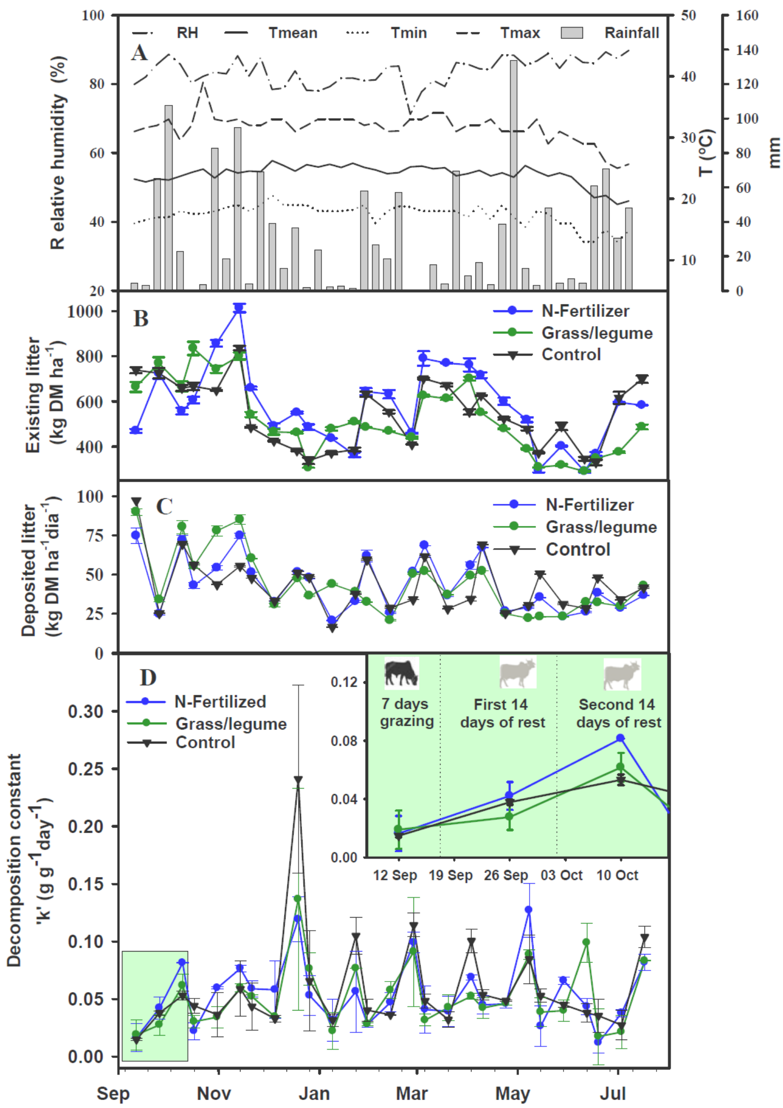

Figure 1 - Variation of A. Rainfall, mean, maximum and minimum temperature and relative humidity, B. Existing litter, C. Deposited litter and D. the decomposition constant 'k' during the nine 35-day gazing cycles from September 2016 to June 2017.

effects of the interactions, with means of 0.58, 0.52, 0.54 Mg MS ha^{-1} of existing litter for the three treatments, respectively.

Litter deposition ranged from just under 20 kg DM ha^{-1} day^{-1} to almost 100 kg DM ha^{-1} day^{-1} (Figure 1C). There was no effect of the pasture N supply management on the deposited litter, nor was the interaction with the grazing cycle periods significant. Conversely, there was a significant difference between the periods of the grazing cycle ($p<0.001$) (Figure 2). The deposited litter in the 7-day grazing period had the highest mean deposition with 54 kg MS ha^{-1} day^{-1}, followed by the first 14-day rest period with 46 kg MS ha^{-1} day^{-1}, followed by the final 14-day rest period with 32 kg MS ha^{-1} day^{-1}.

Production of litter in pastures depends on the production of pasture biomass and the rates of senescence and loss of standing biomass by trampling (REZENDE et al., 1999). When the animals enter the paddock, the accumulated material of biomass was maximum after 28 days of rest. Therefore, the largest deposition of litter due to senescence was expected

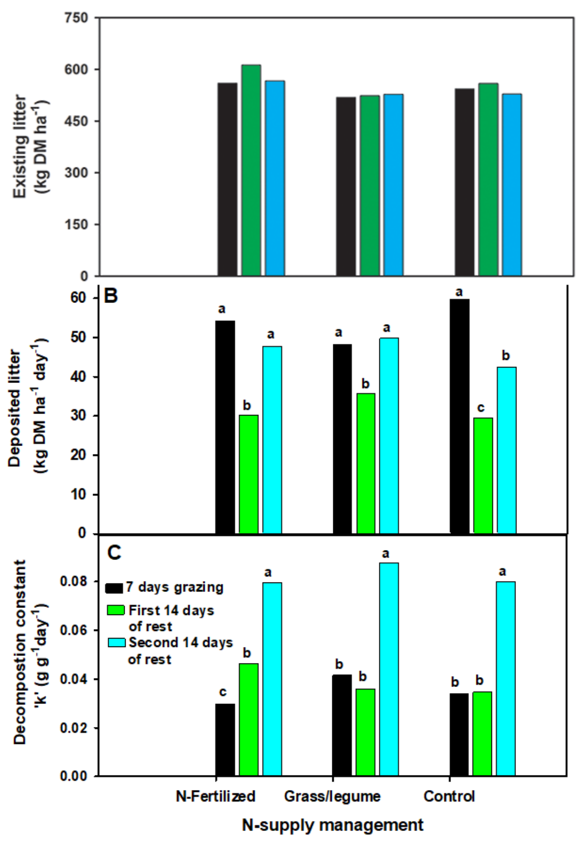

Figure 2 - Mean values of A. rates of litter deposition and B. decomposition constant ‘k’ for Marandu pastures under the three N supply treatments (N fertilized, grass/legume and control [zero N] and during three stages of the grazing cycle of 7 days grazing and the two subsequent period of 14 days of rest. The same lowercase letters above the bars within the same N supply treatment indicated that the difference between the means were not significantly different at $p<0.05$ (Student LSD test).

in this first period of the cycle, especially as litter is also produced by trampling of the sward (Figure 2). After the grazing period, during the first 14 days of rest, the amount of litter deposited is lower as there is no grazing and plant growth resumes. In the final 14 days of the cycle, leaf production and senescence approach equilibrium, when more litter deposition is to be expected compared to the previous 14 days.

The estimates of the decomposition constant ‘k’ (Figure 2) did not show differences regarding N supply management and did not show significant interaction with the grazing cycle periods. The constant ‘k’ was higher for the second 14-day rest period of 0.089 g g $^{-1}$ day $^{-1}$, followed by 0.038 and 0.040 g g $^{-1}$ day $^{-1}$ for the 7 days grazing and first 14 days rest, respectively. The variation of ‘k’ with time in each pasture is shown in Figure 1D.

The constant ‘k’ reported for the rate of litter decomposition using the deposited litter/existing litter methodology implies half-lives from 9 to 17 days. This indicated that in one year there is time for 21 to 41 half-lives, which would mean less than 0.001% of the litter would be carried over to the next year, such that there would be no observable increase in existing litter in the long term. This was observed in these pastures (Figure 1) and has been reported previously for pastures of *Urochloa humidicola* (REZENDE et al., 1999) and other pastures of *Urochloa* spp. in Santo Antônio de Goiás, GO (SANTOS et al., 2006).

There is a high sensitivity of the decomposition process to the inputs and outputs of biomass of the system. A larger range of variation is observed in a shorter time period for deposited litter and ‘k’ compared to existing litter. The existing litter did not increase during the rest period, whereas this occurs with the deposited litter. Therefore, when senescent material inputs increase, the decomposition rates increase, which gives stability to the existing litter over time.

The litter bag test presented a good fit for the values of the remaining litter mass (r^2 = 0.98 – Figure 3). The decomposition constant was 0.0051g g^{-1} d^{-1} for the Marandu litter, close to that registered using the same litterbag technique (0.0042 g g^{-1} d^{-1}) with *B. humidicola* at the same field station (REZENDE et al., 1999). These values were similar to those reported by DUBEUX et al. (2006) and LIU et al. (2011) working on Pensacola Bahia grass (*Paspalum notatum*) and Bermuda grass (*Cynodon dactylon*) in Florida (USA), respectively.

The single exponential model used has a unique decomposition constant “k” where the condition of no change in the degree of lability of the deposited litter with time is assumed. A half-life time of 136 days was calculated from the model ($T^{1/2}$= 0.693/k) (THOMAS & ASAKAWA, 1993). Considering that litter deposition is a continuous process, the residual mass of litter after 1 day of decomposition is summed to the newly deposited mass of litter to undergo decomposition, which follows day after day. Hence, using the model Ri = [D + R(i-1)]e^{-kt}, being Ri the residual litter after day “i”, D the litter deposition rate (daily basis) and “t” a 1 day constant time interval, it can be estimated that after a year 45 % of the total litter deposited on the pasture would be still visible in place. Nature of the model indicated that a steady-state between deposition and decomposition will occur in the future. After 10 years, only 5% of the total litter deposited would be present, but it means a ratio of existing litter to daily litter deposition of 195:1, approximately. Considering a mean daily deposition of litter between 50 to 60 kg DM ha^{-1} day^{-1} (Figure 1) a total existing litter of about 10 Mg DM ha^{-1} would be expected at the equilibrium assuming the calculated “k” from the litterbag study is correct. However, our field data showed a mean

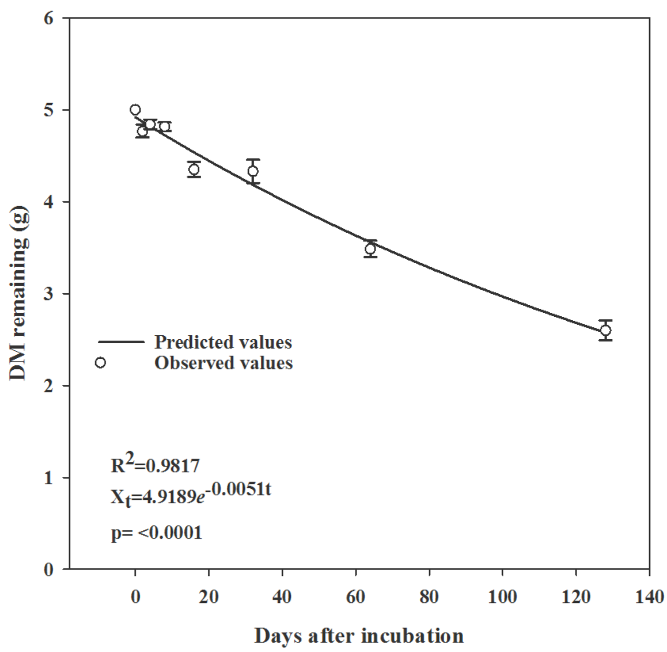

Figure 3 - Values of remaining litter dry matter in litterbags originally containing 5 g of senescent leaves of N Marandu grass over a period of 128 days. Values are means of 12 replicate litterbags. The date were fitted to the single exponential decay model after THOMAS & ASAKAWA (1993).

existing litter of about 500 to 600 kg DM ha^{-1} (Figure 1) much less than expected from "k", suggesting that the litterbag technique severely underestimated litter decomposition.

REZENDE et al. (1999) discussed the hypothesis that as the litterbag mesh is a physical barrier to the entrance of a new material, the new, more easily decomposable, deposited litter fails to interact with the existing litter to maintain an active microbial biomass. That is, the new litter "primes" the decomposition of the existing litter by the addition of easily decomposed substrate in the catabolic process (KUZYAKOV, 2010).

CONCLUSION

The existing litter/deposited litter methodology showed that in rotational grazing of Marandu grass, the rate of deposition of litter was significantly higher during the grazing period and the second period of rest than in the first period of rest. The rate of decomposition was significantly higher during second period of rest than the first period of rest and period of grazing. The estimates of litter decomposition rate using litterbags were approximately an order of magnitude lower than the estimates derived from the existing litter/deposited litter technique. These lower rates are not in agreement with the quantities of existing litter over the long term.

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BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

We authors of the article entitled "Dynamics of litter in Brachiaria pastures in monoculture or in a mixed sward with a forage legume" declare, for all due purposes, the project that gave rise to the present data of the same has not been submitted for evaluation to the Ethics Committee of the Executive Comission for Cocoa Cultivation Planning (CEPLAC) but we are aware of the content of the Brazilian resolutions of the National Council for Control of Animal Experimentation - CONCEA "http://www.mct.gov.br/index.php/content/view/310553.html" if it involves animals.

Thus, the authors assume full responsibility for the presented data and are available for possible questions, should they be required by the competent authorities.

DECLARATION OF CONFLICT OF INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved the final version.

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