

EFFECT OF LOURO-PARDO AND ITS FERTILIZATION ON THE ACCUMULATION OF CARBON IN THE LITTERFALL AND BIOMASS OF ARUANA-GRASS IN A SILVOPASTORAL SYSTEM

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Resumo

Efeito do Louro-pardo e sua fertilização no acúmulo de carbono na serapilheira e biomassa de capim-aruanã em sistema silvipastoril. Avaliou-se o acúmulo de serapilheira/carbono em plantio de louro-pardo em função de diferentes doses de fertilização e a influência do componente arbóreo no acúmulo de biomassa/carbono do capim-aruanã em sistema silvipastoril no Sudoeste do Paraná. Amostras foram coletadas no meio da linha (ML), na projeção de copa (PC) e no ponto médio entre dois renques (PM). Foram também comparados quatro tratamentos de fertilização mineral aplicados à espécie arbórea: T0: sem fertilização, T1: NPK (33-22-9), T2: NPK (66-44-18) e o T3: NPK (99-66-27). O delineamento experimental em blocos ao acaso contou com bifatorial de três posições x quatro doses, totalizando 12 tratamentos com três repetições, alcançando 36 amostras por componente. O acúmulo de serapilheira não apresentou diferenças significativas entre as doses de fertilizante e posições de amostragem, com média geral de 3846,8 kg ha⁻¹. No acúmulo de biomassa do capim-aruanã também não houve diferença significativa entre as diferentes posições e doses, apresentando média geral de 3479,8 kg ha⁻¹. Com relação ao carbono orgânico acumulado, não houve diferença significativa entre as posições de amostragem e doses de fertilização na serapilheira de louro-pardo e biomassa do capim-aruanã, com média de 1791,3 kg ha⁻¹ de carbono para o louro-pardo e 1653,1 kg ha⁻¹ para o capim-aruanã. As doses de fertilização também não influenciaram significativamente nos teores de carbono da serapilheira do louro-pardo, que apresentou média geral de 1797,23 kg ha⁻¹. De maneira geral, a fertilização do louro-pardo não influenciou na quantidade de carbono da serapilheira, nem na quantidade de biomassa do capim-aruanã, não havendo, para este estudo, indicação de fertilização.

Palavras-chave: nutrição florestal, espécie nativa, sistemas integrados de produção agropecuária.

Abstract

Were evaluated the litterfall/carbon accumulation of louro-pardo as a function of different fertilization doses and the influence of the tree component on the biomass/carbon accumulation of aruanã grass in a silvopastoral system in southwestern Paraná, Brazil. Samples were collected in the middle of the row (MR), in the crown projection (CP), and the midpoint between two rows (MR). Four mineral fertilization treatments applied to tree species were also compared: T0: without fertilization, T1: NPK (33-22-9), T2: NPK (66-44-18), and T3: NPK (99-66-27). The experimental design in randomized blocks was bifactorial with three positions x four doses, totaling 12 treatments with three replications, reaching 36 samples per component. Litterfall accumulation did not show significant differences between fertilizer doses and sampling positions, with a general average of 3846.8 kg ha⁻¹. There was also no significant difference in the accumulation of aruanã grass biomass between the different positions and doses, with a general average of 3479.8 kg ha⁻¹. About the accumulated organic carbon, there was no significant difference between the sampling positions and fertilization doses in the louro-pardo litter and the aruanã grass biomass, with an average of 1791.3 kg ha⁻¹ of carbon for the louro-pardo and 1653.1 kg ha⁻¹ for aruanã grass. The fertilization doses also did not significantly influence the carbon content of the litter of louro-pardo, which presented a general average of 1797.2 kg ha⁻¹. In general, the fertilization of louro-pardo did not influence the amount of carbon in the litterfall, nor the amount of biomass of the aruanã grass, and there was no indication for fertilization for this study.

Keywords: forest nutrition, native species, integration crop livestock forest system.

INTRODUCTION

Integrated production systems are effective strategies for optimizing land use by integrating agricultural, livestock, and forestry activities in the same area, which can increase fertility and the content of organic matter in

the soil, favoring an increase in biomass production. From this perspective, the silvopastoral system represents a direct advantage for producers, as it involves the integration of tree species, pastures, or fodder and animals in the same area and at the same time (BUNGENSTAB *et al.*, 2019). These interactions promote social benefits, as there is an economic return obtained by increasing productivity, in addition to the environmental benefits provided by erosion control, soil moisture conservation, nitrogen fixation, and atmospheric carbon sequestration, among others (GIL *et al.*, 2015; BUNGENSTAB *et al.*, 2019).

Based on the environmental benefits of silvopastoral systems, this study evaluated aspects related to the fertilization of the tree component and its influence on litterfall production and carbon accumulation, a positive aspect especially when it comes to production systems that are environmentally more suited to sustainable production, with a positive carbon balance. On the other hand, the tree component can also cause negative situations for the pasture, such as lower biomass production and carbon accumulation, influenced by shading, especially in places closer to the tree lines. These aspects should be taken into account when evaluating integrated systems, such as silvopastoral systems, to provide subsidies for better preparing Brazilian agricultural and forestry production for a context of sustainable intensification and climate change.

To achieve greater pasture production in silvopastoral systems, competition for natural resources must be minimal, and it is of fundamental importance to consider the spatial arrangement, the behavior of the species used, and the density of the trees since the presence of the tree component alters the amount of light that reaches the forage; promoting different microclimatic conditions that consequently affect the production and productivity of the animals (OLIVEIRA *et al.*, 2016). In addition, the biomass productivity and carbon accumulation of this system are also related to the amount of nutrients stored in the vegetation, soil, and litterfall.

In this context, it is worth highlighting the importance of tree species that deposit considerable amounts of litterfall on the soil surface and also contribute to the stock of organic carbon, generating an increase in the efficiency of nutrient cycling, improving the chemical, physical, and biological properties of the soil (GIL *et al.*, 2015). In integrated systems, grasses are also the plants responsible for maintaining the quality of the soil cover. In these areas, animals release nutrients into the soil through their excretions, as part of the biomass consumed by them returns to the soil through feces and urine, which are then processed by the soil fauna, and the nutrients released in this process are reabsorbed by the plant roots. Understanding the dynamics of these systems is important for devising strategies that help improve the performance of these species and maintain soil quality.

Cordia trichotoma (Vell.) Arrab. ex Steud. (Boraginaceae) species, popularly known as louro-pardo, has been considered for use in silvopastoral systems, as it has high volumetric growth, wood quality, and multi-functionality, in addition to its economic viability and potential in environmental recovery alternatives (FLECK *et al.*, 2019). In silvopastoral systems, the introduction of grasses is a viable option to increase the availability of food for animals. Among the different grass species, Aruana grass (*Panicum maximum* cv. Aruana) is well accepted by animals, especially sheep, due to its high capacity to produce leaves and tillers with rapid regrowth after cutting, as well as its tolerance to grazing and considerable annual dry matter production (BARBOSA *et al.*, 2003).

Bearing in mind that mineral fertilization can influence the growth of the louro-pardo in terms of diameter, height, and canopy area, it is hypothesized that increasing the dose of fertilization for the louro-pardo will lead to a greater accumulation of litterfall and organic carbon stored in it, a condition that is favored in places closer to the tree lines. In addition, it is known that the tree canopy reduces the amount of sunlight available to the herbaceous stratum, and this can influence the biomass production of the forage, generating variation in its accumulation, and consequently of organic carbon, in the Aruana grass in different parts of the system. In this context, the work had two main objectives: to evaluate the accumulation of litterfall/carbon of the louro-pardo on the soil as a function of different doses of fertilization and to evaluate the influence of competition from the tree component on the biomass/carbon of the Aruana grass.

MATERIAL AND METHODS

Characterization of the study area

The study was carried out at the Experimental Farm of the Federal University of Technology - Paraná (UTFPR) in Dois Vizinhos (25°41'37" S and 53°06'07" W, altitude between 495 and 504 m). The region's climate is classified as humid subtropical (Cfa), with an average annual temperature of 19°C and annual rainfall of 2,025 mm (ALVARES *et al.*, 2013). In this region, the Mixed Ombrophilous Forest naturally occurs in transition with the Semideciduous Seasonal Forest. The soil in the experimental area is classified as typical dystrophic Red Latosol (SANTOS *et al.*, 2018).

The study area was planted in September 2013 with louro-pardo seedlings produced from seeds collected from selected matrices in a seed collection area in the southwest and west of Paraná, at the Instituto Água e Terra (IAT) Forest Nursery in Cascavel/PR. The area had been grazed since 2011 with Aruana grass (*Panicum maximum* cv. Aruana), measuring 48 m x 45 m with 4 double rows of trees, called clumps, spaced 2 m apart within each clump and 1.5 m apart, with a 10 m interval between the clumps.

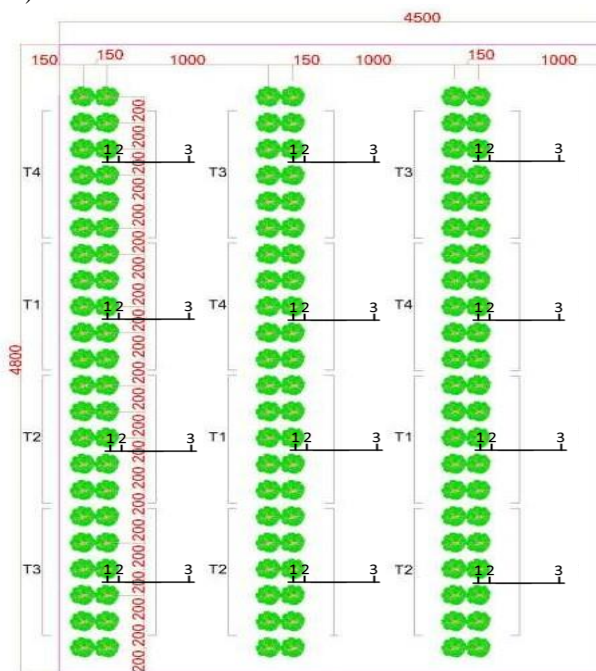
To prepare the soil in the tree planting line, a tractor-driven scarifier with five rods was used to a depth of 30 cm. Twenty-two seedlings were planted per row, corresponding to 44 seedlings per row, for a total of 176 seedlings. To ensure that the roots were hydrated and the seedlings set, 250 ml plant⁻¹ of hydrogel solution (0.2%) was added to the planting hole. The control of leaf-cutting was carried out during the preparation of the area and in the first year after planting, using granulated baits (0.03 g/kg) based on Fipronil, at a dosage of 10 g/m² next to the paths and scouts. Fipronil-based liquid formicide at a dosage of 80 mL/ha was also sprayed on the seedlings in drastic attack situations. Regarding plant maintenance, in the first few months after planting, manual crowning was carried out around the seedlings within a radius of one meter, and tractor mowing was carried out between the planting lines (ANTONELLI *et al.*, 2015).

According to the soil analysis of the area studied, the base fertilization recommendation was 30 kg ha⁻¹ of P₂O₅, 20 kg ha⁻¹ of K₂O, and 50 kg ha⁻¹ of N. The sources used were triple superphosphate (40% P₂O₅), potassium chloride (60% K₂O) and urea (45% N), respectively. Fertilization was carried out in the second month after planting, where NPK was applied in the following formulations: T1: no fertilization (SF); T2: NPK (33-22-9) (recommended by analysis - RA); T3: NPK (66-44-18) (double the recommended - DR) and T4: NPK (99-66-27) (three times the recommended amount - TR) using the method of lateral pits around the seedlings, considered as basic fertilization, concerning the previous soil analysis carried out with composite samples from the area, using the official recommendation for eucalyptus in SBCS (2004) as a basis, since the louro-pardo does not yet have specific fertilization recommendations in the literature. Cover fertilization was also carried out 18 months after planting with NPK (6-30-6) according to the soil analysis carried out before planting; 168g/plant of the fertilizer was applied and the doses were distributed according to the pre-established treatments.

Evaluation of louro-pardo leaf litterfall and Aruana grass biomass

The accumulated leaf litterfall of louro-pardo and biomass of aruana grass was sampled using a square-shaped metal template measuring 50 x 50 cm, covering an area of 0.25 m². To ascertain the influence of distance from the trees on litterfall deposition and grass biomass production in the silvopastoral system, the template was installed on the soil surface and, within this sampling position, the biomass of the Aruana grass was collected with the help of pruning shears and, immediately after, the litterfall of the louro-pardo was collected. Collections were made in three places: in the middle of the double row (row) (ML), at the edge of the canopy projection (PC), and, at the midpoint between two rows (PM), where one row is made up of a double row of louro-pardo trees.

The fertilization treatments installed at the beginning of the experiment in September 2013 were used as a basis to verify the probable existence and magnitude of the influence of mineral fertilization in the three collection positions on the variables of louro-pardo litterfall, aruana grass biomass, and the contents and quantities of carbon accumulated in both (Figure 1).



CROQUI - NO SCALE (measurements in cm)

Figure 1. Schematic sketch of the sampling points of the Silvopastoral System in relation to the position of the tree species. The sequence of numbers indicates the collection positions: 1. In the middle of the line; 2. In

the tree canopy projection; 3. At the midpoint between two rows. Obs.: numbers followed by the letter “T” mean the fertilization treatments applied, in different doses, each ten trees of the same block.

Figura 1. Croqui esquemático dos pontos de amostragem do Sistema Silvopastoril em relação a posição da espécie arbórea. A sequência de números indica as posições de coleta: 1. No meio da linha; 2. Na projeção da copa das árvores; 3. No ponto médio entre dois renques. Obs.: números seguidos da letra “T” designam os tratamentos de fertilização aplicados, em diferentes doses, a cada 10 árvores no mesmo bloco.

The samples were collected in September 2019, when the trees were six years old, at the end of the pasture's fallow period. The samples were packed in plastic bags, duly identified, and then taken to the UTFPR Forestry Laboratory. At the laboratory, the samples were placed in paper bags and taken to a forced ventilation oven at a temperature of 65°C until they reached a constant weight. They were then weighed on a digital scale (0.01g) to obtain their dry mass. The accumulated tree litterfall was then calculated in kg ha⁻¹ for each dose of fertilizer applied and according to the sampling position, as well as the total dry biomass of the grass at each sampling position.

Determining accumulated organic carbon

To determine the organic carbon content of the louro-pardo litterfall and the aruana grass biomass, part of the samples obtained in the previous step were ground in a Willey-type knife mill and passed through a 20 mesh sieve, retaining approximately 20 g of plant tissue per sample, which was duly identified. Afterward, 0.1 g of the plant tissue was weighed, placed in a digestion tube, and subjected to sulphochromic digestion, according to the methodology adapted from Carmo (2000), determining the organic carbon content of each sample.

Statistical Analysis

The experimental design used was a randomized block design, as the experiment had been installed in 2013, due to the potential heterogeneity of the area, in a bifactorial arrangement, with three treatments (positions) and four doses, with three repetitions per dose, totaling 36 samples for the louro-pardo and 36 samples for the aruana grass. The samples of louro-pardo litterfall and aruana grass biomass were also analyzed in a bifactorial manner, assessing the effect of proximity to the fertilization treatment, in the samples that are in the middle of the line, in the canopy projection and at the midpoint between two fields, as shown in the sketch. The data was subjected to the homogeneity of variance and normality tests, and the averages of louro-pardo litterfall referring to the doses and sampling positions were compared in factorial mode (AxB) and then by the Tukey test at 5% significance. The average biomass of aruana grass in the different sampling positions was compared using the Tukey test at 5% significance in the Rbio 119:06.06.2019 program. Similarly, regarding organic carbon content, the data was subjected to analysis of variance (ANOVA), and the means were compared using the Tukey test, both at a 5% probability of error using the R software (R CORE TEAM, 2018).

RESULTS

Louro-pardo litterfall

The interaction between the factors tested (sampling position x fertilizer dose) was not significant at a 5.0% probability of error ($p < 0.05$), so the results were presented separately for the effect of dose and collection position in the silvopastoral system. Similarly, the Shapiro-Wilk normality test showed that the data had a normal distribution ($W > W_n; \alpha$).

Table 1 shows the amount of litterfall by the louro-pardo in the different soil fertilization treatments and sampling positions. Theoretically, trees that grow in soils with greater fertilization are expected to have greater growth, with a larger trunk and crown, and develop a greater number of leaves (greater leaf area), which would consequently lead to greater deposition and accumulation of litter near them. Although no statistically significant differences were diagnosed in terms of absolute numbers, this premise can be partially supported by the results of this work, given that the sites that received triple the recommended fertilization had an average of 4,264.62 kg ha⁻¹ of litter, 10.9% more than the overall average.

Similarly, in the middle of the line, there was an increase of 18.4% in the accumulation of litter compared to the general average; a fact that could be explained by the shorter distance between the tree component and the collection area. Even without statistical significance, the results related to the collection position show that the greater the distance from the trees, the lower the accumulation of litter above the ground.

Table 1. Average amount (kg ha⁻¹) of louro-pardo litterfall accumulated above ground according to different fertilization rates and sampling positions.

Tabela 1. Quantidade média (kg ha⁻¹) de serapilheira do louro-pardo acumulada acima do solo de acordo com as diferentes doses de fertilização e posições de amostragem.

DOSES	SF*	RA	DA	TA	Overall average
Litter (kg ha ⁻¹)	4065.11**	3587.38	3470.27	4264.62	3846.84
CV %	70.6	16.9	27.4	38.0	9.9
%**	+ 5.7	- 6.7	- 9.8	+ 10.9	100.0
POSITION	ML	PC	PM	Overall average	
Litter (kg ha ⁻¹)	4554.60***	3694.83	3291.10	3846.84	
CV %	17.7	35.9	48.3	16.8	
%	+ 18.4	- 4.0	- 14.4	-	

* No fertilization (SF), recommended by soil analysis (RA), double the analysis (DA), triple the analysis (TA), middle of the line (ML), canopy projection (PC), the midpoint between two plots (PM); ** relative variation of louro-pardo litterfall evaluated according to doses and positions about the general average (%); *** There were no statistically significant differences between the averages of accumulated louro-pardo litterfall the different doses of soil fertilization or in the different collection positions, verified by Tukey's test at a 5% probability of error.

The SF had an average of 4065.11 kg ha⁻¹ of accumulated litterfall, while in the RA and DA treatments, this amount was lower, at 3587.38 and 3470.27 kg ha⁻¹, respectively. This suggests that greater soil fertilization does not necessarily translate into greater production and accumulation of litterfall. This trend seen in Table 1, although not diagnosed statistically, may show that only in the TA treatment was the amount of nutrients applied sufficient for plant growth at a level that also affected the canopy and leaf area, unlike the others.

Aruana grass biomass

In terms of the biomass production of Aruana grass (Table 2), the position in the middle of the row had the lowest amount of biomass (2,804.67 kg ha⁻¹), as opposed to the position at the mid-point between two plots, where an average of 4031.17 kg ha⁻¹ was observed, which shows a lower production of forage in the more shaded areas, with an intermediate production in the projection of the tree canopy.

Table 2. Average biomass (kg ha⁻¹) of aruana grass according to different sampling positions.

Tabela 2. Biomassa média (kg ha⁻¹) de Capim-aruaana de acordo com as diferentes posições de amostragem.

POSITION	ML*	PC	PM	Overall average
Biomass (kg ha ⁻¹)	2804.67**	3603.60	4031.17	3479.81
CV %	40.2	42.1	48.3	17.9
%	- 19.4	+ 3.5	+ 15.8	-

* Mid-row (ML), canopy projection (PC), mid-point between two plots (PM), CV%: coefficient of variation; %: relative variation of Aruana grass biomass about the general average (%). ** There were no significant differences between the averages of accumulated Aruana grass biomass in the different sampling positions, as verified by the Tukey test at a 5% probability of error.

No statistically significant differences were found in the accumulated litter of the louro-pardo or the biomass of the aruana grass about the sampling position and soil fertilization, as shown in Tables 1 and 2. Although there seemed to be a slight trend towards greater accumulation of litterfall and lower grass biomass near the trees and, conversely, the greater the distance from the trees, the lower the accumulation of litterfall and the higher the grass biomass, this trend was not confirmed in the data analysis.

Carbon from louro-pardo and aruana grass

Table 3 shows the capacity of the silvopastoral system under study to sequester atmospheric carbon and store it in the litterfall, as well as verifying whether the higher doses of soil fertilization promote greater leaf area growth and whether this consequently leads to a greater stock of organic carbon. However, the average carbon contents showed no statistically significant difference between the collection positions for the louro-pardo litterfall or the grassland biomass in the different collection positions.

Table 3. Content (g kg^{-1}) and amount (kg ha^{-1}) of organic carbon in louro-pardo litterfall and in aruana grass biomass according to sampling position and soil fertilization.

Tabela 3. Teor (g kg^{-1}) e quantidade (kg ha^{-1}) de carbono orgânico na serapilheira do louro-pardo e na biomassa do capim-aruaana de acordo com a posição de amostragem e fertilização do solo.

Species/position	ML*	PC	PM	Overall average
	Carbon content (g kg^{-1})			
Louro-pardo (litterfall)	454.3**	471.3	475.0	466.9
Aruana grass (biomass)	474.6	472.7	477.5	474.9
Species/doses	SF	RA	DA	TA
	Carbon content (g kg^{-1})			
Louro-pardo (litterfall)	483.3	470.5	453.4	460.3
Species/position	ML	PC	PM	Overall average
	Quantity of Carbon (kg ha^{-1})			
Louro-pardo (litterfall)	2069.15	1741.37	1563.27	1791.3
Aruana grass (biomass)	1331.09	1703.42	1924.88	1653.1
Species/doses	SF	RA	DA	TA
	Quantity of Carbon (kg ha^{-1})			
Louro-pardo (litterfall)	1964.66	1687.86	1573.42	1963.00
General Average	1797.23	-	-	-

Where: * Middle of the row (ML), canopy projection (PC), the midpoint between two plots (PM), without fertilization (SF), recommended by soil analysis (RA), double the analysis (DA), triple the analysis (TA); ** There were no significant differences between the averages of organic carbon content and quantity in louro-pardo and aruana grass in the different doses and sampling positions, according to Tukey's test at a 5% probability of error.

The same behavior in terms of carbon content was seen for fertilizer doses, where only small numerical variations could be seen, less than 5% about the overall average content, for all treatments.

In terms of the amount of carbon accumulated in the litterfall, the average in the fertilization treatments was $1963.0 \text{ kg ha}^{-1}$ and the average between the positions was $1791.3 \text{ kg ha}^{-1}$. Aruana grass biomass had an average carbon accumulation of $1653.1 \text{ kg ha}^{-1}$.

Even though there was no significant difference between the litter collection positions, it was found that the highest organic carbon value of the brown laurel was in the middle of the row, unlike the biomass of the aruana grass, whose highest value was at the midpoint between the two plots. These values are related to the greater stock of litter deposited closer to the trees in the middle of the row and, as for the biomass of aruana grass, due to the greater incidence of solar radiation at the midpoint of collection between the clumps of trees (Table 3).

DISCUSSION

Louro-pardo litterfall

The amount of litterfall was not influenced by the fertilization of the louro-pardo and there was also no difference in the amount of litterfall accumulated in the different sampling positions, but there was a slight tendency for a gradual increase in the amount of litterfall, associated with the positions closest to the louro-pardo.

In studies carried out with native forest species from the same physiognomy, Brun *et al.* (2013) evaluated the accumulation of litter from *Luehea divaricata* Mart. and *Parapiptadenia rigida* (Benth.) Brenan in pure plantations, both six years old, in Dois Vizinhos-Paraná, obtaining relatively high litter accumulation values of 19.0 and 20.4 Mg ha^{-1} , respectively, with greater accumulation in the leaf fraction (46% and 51.4%, a predominance related to the time of sampling, just after the period of greatest deposition (September) but which, even so, this did not prevent a large accumulation of branches where the same authors mention that the angico-vermelho has low natural pruning, accumulating 4551 kg ha^{-1} of branches, and that the amount of branches of the açoita-cavalo was more representative with 5725 kg ha^{-1} , which may mean a greater propensity to natural pruning.

The variation in the amount of litterfall accumulated in silvopastoral systems and pure forest plantations, regardless of the species, is directly related to the management applied to the area, which is more intensive in the

former, resulting in a higher rate of litter decomposition and, consequently, less accumulation, even in places close to the trees. In pure or mixed plantations of forest species, without pasture, crops, or livestock, the amount of accumulated litter tends to be greater, since fewer factors detract from this amount are present.

Regarding plant growth versus mineral fertilization, Antonelli *et al.* (2015), evaluating the influence of fertilization on the growth of brown laurel in this same experiment, observed a difference in growth in the diameter of the neck of the plants, from 180 days after planting, where the TA treatment obtained an average neck diameter (Dc) of 26 mm, while the SA treatment was 15.7 mm. The same authors also found greater results in terms of height and crown area in the TA treatment. These data show that mineral fertilization influenced the initial growth of this species.

In the work carried out by Silva *et al.* (2022), when comparing the use of simple superphosphate at dosages of 0, 150, 300, and 450 grams/well on seven native species, assessed at 300 days after planting, they observed significant differences in the growth of *Schinus terebinthifolius* Raddi and *Guazuma ulmifolia* Lam. which showed the most growth, with average height values of 197.1 and 160.1 cm, respectively. The same authors found that the estimated dose of 239.58 g of simple superphosphate was considered ideal for the growth in diameter of the species *Citharexylum myrianthum* Cham. corroborating the data from this study.

The use of fertilizers provides numerous advantages for plants, which can vary according to the amount and sources used, where it is generally possible to notice an increase in plant growth, which promotes a greater competitive advantage over the competing plants present (CUNHA *et al.*, 2021). Silva *et al.* (2022), evaluating phosphate fertilization on the initial growth of seven native forest species, observed higher growth rates in plants that received fertilization when compared to plants that were not fertilized, showing the positive influence of doses of simple superphosphate on the growth of the species evaluated.

Bearing in mind that forest fertilization, despite involving costs, promotes better conditions for seedling development, Antonelli *et al.* (2015) recommended 192 g plant⁻¹ (N; P₂O₅; K₂O) represented by three times the recommended dose for eucalyptus, as it was the dose that generated the best results for growth in height, neck diameter and crown area for the louro-pardo species.

Aruana grass biomass

In a silvopastoral system, the results suggest that the animals would have greater access to forage when grazing at points away from the groves, even though the values showed little difference. Even so, the shade of the laurel tree did not significantly influence the biomass production of the Aruana grass, regardless of the sampling positions. This behavior can be explained by the fact that the species is semi-deciduous to deciduous, which favors the entry of light radiation into the understory, and consequently the production of the grass. It was also possible to observe a slight upward trend in biomass production at the mid-point between the two plots, as it is farther away from the shading trees and is the place with the highest solar incidence rates.

As louro-pardo litterfall is not fodder material, its main function is to improve soil fertility in the system, via nutrient cycling, a fact that will occur to a greater extent in the line and projection of the tree canopy, where the amount of litterfall returned and accumulated is greater, consequently contributing a greater amount of carbon and nutrients to the soil. The places closest to the trees, in integrated production systems, are also the places where animals tend to stay for longer during the hottest hours of the day, also contributing a greater volume of excreta to these places.

The effects of trees on the biomass production of forage species in a silvopastoral system depend on the interaction between the species involved, climatic conditions, and the degree of shading, and can be favorable when the system is well managed. Silva *et al.* (2015), in a study evaluating the effect of defoliation frequency and intensity on the biomass components of Aruana grass in a rotational grazing system, obtained average total forage biomass of 2560 and 3521 kg ha⁻¹, values close to those of the present study, in the pre-grazing condition. According to the same authors, Aruana grass under the influence of 85% active photosynthetic radiation showed greater biomass related to leaf lamina/stem and less dead forage.

There are studies on silvopastoral systems, such as the one by Freitas *et al.* (2013), which show that forage quality tends to improve in areas closer to the tree canopy, highlighting the importance of the tree arrangement in the system. Paciullo *et al.* (2011), when assessing the nutritional and productive characteristics of the pasture in an agrosilvopastoral system, found that between 7 and 10 m from the branch was where the highest protein content of the pasture occurred, being highest near the treetops and lowest at a distance of 13.5m.

Salles *et al.* (2020), studied the quality of *Urochloa brizantha* cv. Xaraés fodder in a silvopastoral system, with eucalyptus clones as the tree component, found that grass production was influenced by clone spacing, with a greater increase in dry mass as spacing increased, showing that close to the tree lines, the fodder was significantly influenced by shading or root competition from the tree species for water or nutrients. These results are different from those of the present study, which did not differ statistically in terms of biomass production of aruana grass, finding similarity in the three sampling positions (Table 2).

Carbon in louro-pardo and aruana grass

About the amount of carbon in the louro-pardo as a function of the fertilization doses, there was a slight increase in the treatment with three times the amount recommended by the analysis, which was similar to the value of the treatment without fertilization when compared to the others. This shows that the species has good growth and leaf production and that fertilization had little or no influence on the amount of carbon in the litterfall.

Regarding the amount of carbon in the brown laurel, even though there was no significant difference about the sampling positions, it was possible to observe a slight tendency for the amount of carbon to increase in the positions closest to the trees, the highest being in the middle of the row and the lowest at the mid-point between two plots, which can be explained by the greater deposition of tree residues on the surface just below the trees.

The amount of carbon in the Aruana grass biomass did not differ statistically about the different positions, however, there was a slight upward trend in the positions furthest from the trees, with the highest value at the midpoint between the two plots and the lowest value in the middle of the row, which can be explained by the higher rate of light incidence at the midpoint, with greater biomass production. In physiological terms, Aruana grass is well adapted to systems with shading of up to 50% of solar interception, such as silvopastoral systems, showing greater biomass production in lighter shading and in full sun (RENNÓ *et al.*, 2013).

According to Saidelles *et al.* (2009), in a study carried out to determine the carbon content of *Acacia mearnsii* De Wild. at 4 years of age, in the municipality of Arroio dos Ratos/RS, analyzing different components of the plant (leaf, live branch, dead branch, bark, wood, root), they obtained organic carbon content with a total average of 420.98 g kg⁻¹, and the highest value found was in the leaf component with 455.80 g kg⁻¹. Sanquetta *et al.* (2013), for *Cryptomeria japonica* (Thunb. ex L. f.) D. also found a higher organic carbon content in the foliage fraction.

A silvopastoral system promotes greater yields in the production of biomass and the amount of organic carbon in crops and pastures and thus generates more efficient nutrient cycling, increases soil microbial diversity, improves soil quality and fertility, and acts to conserve biological diversity (MORAES *et al.*, 2014; LEMAIRES *et al.*, 2014).

The results of this study showed small variations, not statistically significant, in the accumulation of litterfall from the louro-pardo and the biomass production of the aruana grass as a function of fertilization and position within the system, a behavior that also occurred in the content and quantity of organic carbon of both, providing a basis for scientific understanding of the functioning of this system with a native forest species that produces noble wood associated with a pasture that has the potential for wide use by cattle and sheep, mainly

By scientifically demonstrating the potential for using native forest species in integration systems, the biodiversity of the Atlantic Forest Biome is valued and native species are integrated into agricultural production systems, a fundamental aspect of biodiversity conservation. Furthermore, it seems that with proper management of the native forest species within the system, negative interference with the pasture is minimized, generating indirect benefits for the pasture (and consequently for the animals), in addition to nutrient cycling and carbon sequestration, which are of fundamental importance to the soil, as well as the increased economic value of the system, with the accumulation of hardwood for future sale. This makes silvopastoral systems with native forest species promising for forestry, animal, and agricultural production, as well as their importance in promoting soil quality and carbon sequestration.

CONCLUSIONS

The analyses carried out show that:

- Fertilization and sampling position does not influence the accumulation of louro-pardo litterfall or the production of aruana grass biomass;
- The average carbon content showed great similarity between the louro-pardo litterfall and the aruana grass biomass, regardless of the treatment;
- There is a tendency for more litterfall and carbon to accumulate in the positions closest to the trees, while the opposite is true for grassland biomass and its carbon content;
- The capacity to store carbon corresponded to the accumulated litterfall and the biomass of aruana grass, which was not influenced by the different collection positions or fertilization doses, being important in sequestering carbon from the air and inclusion in the silvopastoral system.

REFERÊNCIAS

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. de M.; SPAROVEK, G. Mapa de classificação climática do Brasil. *Meteorologische Zeitschrift*, Stuttgart, v. 22, n. 6, p. 711 - 728, 2013.

- ANTONELLI, P. V.; BRUN, E. J.; SANTOS, M. A. B.; SARTOR, L. R.; BRUN, F. G. K. Desenvolvimento de *Cordia trichotoma* em função da adubação, em sistema silvipastoril no Sudoeste do Paraná-Brasil. **Ecologia e Nutrição Florestal**, Santa Maria, v. 3, n. 3, p. 57 - 70, 2015.
- BARBOSA, C. M. P.; BUENO, M. S.; CUNHA, E. A. da.; SANTOS, L. E. dos.; ESTRADA, L. H. C.; QUIRINO, C. R.; SILVA, J. F. C. Consumo voluntário e ganho de peso de borregas das raças Santa Inês, Suffolk e Ile de France, em pastejo rotacionado sobre *Panicum maximum* Jacq. CVS aruana ou tanzânia. **Boletim de Indústria Animal**, Odessa, v. 60, n. 1, p.55-62, 2003.
- BUNGENSTAB, D. J.; ALMEIDA, R. G. de.; LAURA, V. A.; BALBINO, L. C.; FERREIRA, A. D. **ILPF inovação com integração de lavoura, pecuária e floresta**. Brasília: Embrapa, 23 ed. 2019, 835 p.
- BRUN, E. J.; BRUN, F. G. K.; FRIGOTTO, T.; RIBEIRO, R. R.; MEZZALIRA, C. C. Crescimento e acúmulo de serapilheira em plantios homogêneos de *Luehea divaricata* Marc. e *Parapiptadenia rígida* (Benth.) Brenan no Sudoeste do Paraná. **Ecologia e Nutrição Florestal**, Santa Maria, v.1, n.3, p.125-132, 2013.
- CARMO, C. A. F. de S.; ARAUJO, W. S. de.; BERNARDI, A. C. de C.; SALDANHA, M. F. C. **Métodos de análise de tecidos vegetais utilizados na Embrapa Solos**. Rio de Janeiro: Embrapa, 21 ed. 2000, 41 p.
- CUNHA, F. L.; NIERI, E. M.; SANTOS, J. A. dos.; ALMEIDA, R. S. de.; MELO, L. A. de.; VENTURIN, N. Uso dos adubos de liberação lenta no setor florestal. **Pesquisa Florestal Brasileira**, Colombo, v. 41, p. 1 - 11, 2021.
- FERREIRA, D. F. Sisvar: A Computer Statistical Analysis System. **Ciência e Agrotecnologia**, Lavras, v. 35, n. 6, p. 1039 - 1042, 2011.
- FLECK, M. D.; COSTA, E. C.; ARAUJO, M. M.; SCHOENINGER, K.; MACHADO, L. M.; SILVA, J. A. da.; PEDRON, L.; MACHADO, D. do. N.; BOSCARDIN, J. Occurrence of *Amblycerus* species in *Cordia trichotoma* seeds and their influence on germination. **Revista Brasileira de Entomologia**, Santa Maria, v. 63, n. 3, p. 212 – 216, 2019.
- FREITAS, E. C. S. DE.; OLIVEIRA N, S. N. de.; FONSECA, D. M. da.; SANTOS, M. V.; LEITE, H. G.; MACHADO, V. D. Deposição de serapilheira e de nutrientes no solo em sistema agrossilvipastoril com eucalipto e acácia. **Árvore**, Viçosa, v. 37, n. 3, p. 409 - 417, 2013.
- GIL, J.; SIEBOLD, M.; BERGER, T. Adoption and development of integrated crop-livestock-forestry systems in Mato Grosso, Brazil. **Agriculture, Ecosystems and Environment**, Amsterdã, v. 199, p. 394 – 406, 2015.
- LEMAIRE, G.; FRANLUEBBERS, A.; CARVALHO, P. C. de. F.; DEDIEUD, B. Integrated crop-livestock systems: strategies to achieve synergy between agricultural production and environmental quality. **Agriculture, Ecosystems and Environment**, Amsterdã, v. 190, p. 4 – 8, 2014.
- OLIVEIRA, C. H. R.; REIS, G. G.; REIS, M. G. F.; LEITE, H. G.; SOUZA, F. C.; FARIA, R. S.; OLIVEIRA, F. B. Dynamics of eucalypt clones canopy and *Brachiaria brizantha* production in silvopastoral systems with different spatial arrangements. **Agroforestry Systems**, Viçosa, v. 90, n. 6, p. 1077 – 1088, 2016.
- MORAES, A. de.; CARVALHO, P. C. F. de; ANGHINONI, I.; LUSTOSA, S. B. C.; COSTA, S. E. V. G. de. A.; KUNRATHB, T. R. Integrated crop–livestock systems in the Brazilian subtropics. **European Journal of Agronomy**, Conthey, v. 57, p. 4 – 9, 2014.
- PACIULLO, D. S. C.; GOMIDE, C. A. M.; CASTRO, C. R. T. DE.; FERNANDES, P. B.; MÜLLER, M. D.; PIRES, M. DE. F. A.; FERNANDES, E. N.; XAVIER, D. F. Características produtivas e nutricionais do pasto em sistema agrossilvipastoril, conforme a distância das árvores. **Pesquisa Agropecuária Brasileira**, Brasília, v. 46, n. 10, p. 1176 – 1183, 2011.
- R CORE TEAM. **R: A language and environment for statistical computing**. Disponível em: < <https://www.R-project.org/> > Acesso em: 01 ago. 2022.
- RENNÓ, A. P. A.; LAVORATO JUNIOR, F. J. V.; PORTO, P. P.; PORTO, E. P.; FLORES, A. O. Efeito da desrama de *Eucalyptus* spp. sobre a taxa de acúmulo e altura do capim aruanã (*Panicum maximum*) em sistema silvipastoril com ovinos. **Synergismus Scientifica**, Pato Branco, v, 8, n. 2, 2013.
- SAIDELLES, F. L. F.; CALDEIRA, M. V. W.; SCHUMACHER, M. V.; BALBINOT, R. Uso de equações para estimar carbono orgânico em plantações de *Acacia mearnsii* de Wild. No rio grande do Sul - Brasil. **Árvore**, Viçosa, v. 33, n. 5, p. 907 - 915, 2009.

SALLES, N. A.; SANTOS, S. C.; SANTOS, V. C.; SANTOS, C. C.; LOURENTE, E. R. P.; ALOVISI, A. M. T.; SOUZ, G. G. de. **Sistema silvipastoril com clones de eucalipto e a qualidade da *Urochloa brizantha* (hochst. Ex a. Rich.) Stapf cv. Xaraés**. Dourados: Padrões Ambientais Emergentes e Sustentabilidade dos Sistemas, 2020, p. 216.

SANQUETTA, M. N. I.; SANQUETTA, C. R.; CORTE, A. P. D.; MOGNON, F.; MENDONÇA, V. C. Teores de carbono e densidade básica da madeira de *Cryptomeria japonica* (Thunb. ex L. f.) D. Don em povoamentos no município de Rio Negro – PR. **Enciclopédia biosfera**, Goiânia, v. 9, n. 17, p. 2451, 2013.

SANTOS, D. de C.; GUIMARAES JUNIOR, R.; VILELA, L.; PULROLNIK, K.; BUFON, V. B.; FRANÇA, A. F. de S. Forage dry mass accumulation and structural characteristics of Piatã grass in silvopastoral systems in the Brazilian savannah. **Agriculture, Ecosystems and Environment**, Amsterdã, v. 233, p. 16 – 24, 2016.

SANTOS, H. G. dos.; JACOMINE, P. K. T.; ANJOS, L. H. C. dos.; OLIVEIRA, V. A. de.; LUMBRERAS, J. F.; COELHO, M. R.; ALMEIDA, J. A. de.; ARAUJO FILHO, J. C. de.; OLIVEIRA, J. B. de.; CUNHA, T. J. F. SANTOS, H. G. **Sistema Brasileiro de Classificação de Solo**. Brasília: EMBRAPA, 5 ed. 2018, 356 p.

SILVA, L. V. da.; CÂNDIDO, M. J. D.; PESSOA, J. P. M.; CAVALCANTE, A. C. R.; CARNEIRO, M. S. de. S.; SILVA, A. do. N. Componentes da biomassa e características estruturais em capim-aruana sob diferentes frequências e intensidades de desfolhação. **Pesquisa Agropecuária Brasileira**, Brasília, v. 50, n. 12, p. 1192-1200, 2015.

SILVA, O. M. das C.; NIERI, E. M.; SANTANA, L. S.; ALMEIDA, R. S.; ARAÚJO, G. do C. R.; BOTELHO, S. A.; MELO, L. A. de. Adubação fosfatada no crescimento inicial de sete espécies florestais destinadas à recuperação de uma área degradada. **Ciência Florestal**, Santa Maria, v. 31, n. 1, p. 371 - 394, 2022.