BOSQUE 43(1): 23-32, 2022 DOI: 10.4067/S0717-92002022000100023

Weed suppression by forage legumes in silvopastoral systems and its effect on soil chemical characteristics

Supresión de malezas por leguminosas forrajeras en sistemas silvopastoriles y su efecto sobre las características químicas del suelo

Sidnei Roberto de Marchi [a], Ricardo Fagundes Marques [b]*, Maria Renata Rocha Pereira [c], Dagoberto Martins [b]

[a] Universidade Federal de Mato Grosso, Campus Universitário do Araguaia, Barra do Garças-Mato Grosso, Brazil, sidneimarchi.ufmt@gmail.com

* Corresponding author: [b] Universidade Estadual Paulista "Júlio de Mesquita Filho", Faculdade de Ciências Agrárias e Veterinárias, Jaboticabal, São Paulo, Brazil, rfmarques94@gmail.com

[c] Faculdade de Tecnologia de Capão Bonito, Capão Bonito, São Paulo, Brazil,

SUMMARY

Even when considered a modern cultivation system, silvopastoral systems can be rapidly degraded if some cares, mainly related to weed control, are not observed at the early stages of establishment of this system. The present work had the objective of evaluating the use of forage legumes on weed suppression and on the initial development of Teak (*Tectona grandis*) when implementing a silvopastoral system. Four legume species were used, namely: pinto peanut (*Arachis pintoi*), Brazilian stylos (*Stylosanthes guianensis*), cowpea (*Vigna unguiculata*) and pigeon pea (*Cajanus cajan*), which were compared with three weeding regimes: (i) mowing, (ii) hand weeding, and (iii) zero weeding (unweeded plot). The experiment was laid out in a randomized complete-block design with four replications. Each experimental plot consisted of the length corresponding to four Teak plants by four meters in width. Weed suppression assessments were carried out at the end of the annual growing period, represented by the high rainfall season in the region. Weed species were identified and quantified. The weed dry matter produced by found species was determined. Teak plants development was assessed by measuring plants height, stem diameter at the plants neck and breast height in a 2-year period. Pinto peanut and Brazilian stylos put little competitive pressure on weeds, although they produced the largest quantities of organic matter and available nitrogen in the soil and did not interfere in the growth variables of the teak component.

Key words: Tectona grandis, floristic diversity, weeds, management.

RESUMEN

Aun siendo considerado un sistema de cultivo moderno, los sistemas silvopastoriles pueden degradarse rápidamente si no se observan algunos cuidados, principalmente, relacionados con el control de malezas, en las primeras etapas de establecimiento de este sistema. El presente trabajo tuvo como objetivo evaluar el efecto del aprovechamiento de leguminosas forrajeras en la supresión de malezas y en el desarrollo inicial de la *Tectona grandis* en la implementación de un sistema silvopastoril. Se utilizaron cuatro especies de leguminosas: *Arachis pintoi*, *Stylosanthes guianensis*, *Vigna unguiculata* y *Cajanus cajan*, que se compararon con tres regímenes de deshierbe: siega, desyerbado a mano y cero deshierbe (parcela sin deshierbe). El experimento se dispuso en un diseño de bloques completos al azar con cuatro repeticiones, y cada parcela experimental consistió en la longitud correspondiente a cuatro plantas teca por cuatro metros de ancho. Las evaluaciones de supresión de malezas se llevaron a cabo al final del período de crecimiento anual, representado por la temporada alta de lluvias en la región. Se identificaron, cuantificaron las especies de malezas y se determinó la materia seca de malezas producidas por las especies encontradas. El desarrollo de las plantas de teca se evaluó midiendo la altura de las plantas, el diámetro del tallo en el cuello de las plantas y en la altura del pecho en un período de dos años. El *A. pintoi* y los *S. guianensis* ejercen poca presión competitiva sobre las malezas, pero no interfieren en las variables de crecimiento de la *T. grandis*.

Palabras clave: Tectona grandis, diversidad florística, malezas, manejo.

INTRODUCTION

Monoculture systems have become a problem for agriculture and livestock worldwide due to its direct relationship with yield losses, increased occurrence of insects, diseases, weeds and degradation of soil and natural resources (Macedo 2009). In this scenario, the integrated Crop-Livestock-Forest (iCLF) strategy emerged, which has been indicated as an alternative to reconcile society's most diverse conflicts of interest because it aims at integrating sustainable production with preservation of agroecosystems (Albuquerque *et al*. 2017).

Silvopastoral systems (SPS) are an example among various models that have been developed, consisting of a set of production activities that include forestry and livestock in the same area, thus being considered a highly sustainable activity. Hence, silvopastoral systems appear as part of the solution to existing problems and are characterized by the integrated production of animal protein, fibers and renewable energy in the same production unit (Balbino *et al*. 2011).

Teak (*Tectona grandis* Linn F.) is an exotic tree species native to Southeast Asian countries and is widely used in SPS areas in Brazil (Madi *et al.* 2020). This species has fast growth and hard wood. The trunk shape and characteristics are associated with local adaptation and its growth rate at the initial development stages (Schuhlim and Paludzyszyn Filho 2010).

Even when considered a modern cultivation system, SPS undergoes rapid degradation if appropriate care is not provided early during the system implementation. Considering the slow growth rate of species like teak, weed control can be pointed out as one of the major difficulties encountered during the early stages of SPS implementation (Pereira *et al*. 2016). These plants can exert strong competition for water, nutrients and space, impairing the initial development of the forest component used (Marques *et al*. 2019).

There are several ways to perform weed management, and mechanical and chemical methods are the most common procedures used in SPS. However, both methods have the disadvantage of being palliative, *i.e*. they are effective for a short period of time and may cause environmental contamination, as is the case of use of herbicides in the chemical method (Marchi *et al*. 2018).

Considering the sustainability premise, a potential alternative for use would be the introduction of more than one plant component into the SPS via intercropping, with the purpose of providing soil coverage associated with a long period of suppression of spontaneous vegetation, as long as such association does not interfere adversely with the development of the forest component. Some leguminous species have these characteristics and represent a viable alternative for intercropping when the forest component seedlings are planted (Santos *et al*. 2018).

Therefore, there is a need to generate scientific knowledge to support and examine the use of leguminous plants intercropped with diverse forest species used in SPS implementation, considering the lack of works on this topic in literature. Given the above, this work aimed at determining the possibility of using leguminous forage plants intercropped with teak plants to suppress weeds, when a silvopastoral system is implemented, and their effect on soil chemical characteristics.

METHODS

The experiment was conducted at a Technology Reference Unit (TRU) located at the geographical coordinates 14º 59' 40'' S and 52º 16' 02'' W GR with an approximate altitude of 305 m above sea level.

The climate in the region, according to Köppen classification, is Aw, characterized by average temperatures above 27 ºC during the hottest months (November to February) and above 18 ºC in the coldest months (June to August), and average annual precipitation between 1,000 and 1,500 mm distributed in two typical periods: intense rainfall season (October to March) and drought season (April to September) (Alvares *et al*. 2014).

The tree component species chosen to integrate the silvopastoral system was teak, with a spatial configuration of 8.0 m between rows and 3.0 m between plants. In the moment of the implantation of the experiment the seedlings were 1.2-1.5 m high. The area was planted with soybean before implementation of the tree component. Corrective fertilization before planting the seedlings was performed with 28.7 kg ha^{-1} of P_2O_5 in the form of triple superphosphate and 100 g pit^{-1} of 06-30-06 formulation. Three cover fertilizer applications were carried out with 12-00-24 formulation, containing 1.15 % of boron in its composition. The first one was manually applied onto the top of the tree canopy projection at a rate of 110 g plant^{-1} three months after planting the seedlings. The second cover fertilization was made mechanically in a continuous fillet on the ground along the Teak planting row at a rate of 180 g plant^{-1} 12 months after the previous fertilizer application. The third application occurred 12 months after the second application at a rate of 250 g plant^{-1}, mechanically made in a continuous fillet on the ground along the Teak planting row.

Four legume species were used: pinto peanut (*Arachis pintoi* Krapov. *et* W.C. Gregory), Brazilian stylo (*Stylosanthes guianensis* Sw.), cowpea (*Vigna unguiculate* L. Walp) and pigeon pea (*Cajanus cajan* L. Millsp), which were compared with three weeding regimes: mowing, hand weeding and zero weeding (unweeded plot). The seeds were sown in two rows spaced 2.0 meters away from the base, or neck, of the Teak seedlings, comprising a total cultivated area of 4.0 meters. The sowing was made at the same time of teak seedlings planting. The conditions of the legume species are shown in table 1.

The seven treatments were arranged in a randomized complete-block design with four replications. The area of

Table 1. Sowing conditions of the legume plants used at the time of implementation of the experiment.

Condiciones de siembra de las plantas leguminosas utilizadas al momento de la implementación del experimento.

Forage legume	Sowing method	Seeds arrangement
Pinto peanut (*Arachis pintoi*)	Row	45 x 5 cm
Cowpea (*Vigna unguiculata*)	Row	45 x 5 cm
Pigeon pea (*Cajanus cajan*)	Row	45 x 10 cm
Brazilian stylo (*Stylosanthes guianensis*)	Broadcast	4 kg ha^{-1}

each experimental plot consisted of the length corresponding to four Teak plants by 4.0 meters wide.

Weed suppression was assessed and determined at the end of the annual growth period represented by the rainy period prevailing in the region. The assessments were made in the net area of each experimental plot using a 0.25 m^2 plastic quadrat thrown at random within the plot. The weed species present within the quadrat were identified, counted and taken to a laboratory, where they were washed and dried in a forced air circulation oven at 60 ºC to constant weight. After this procedure, the shoots dry matter of the sampled species was determined using a 0.01 g precision scale.

Based on the data resulting from the counting of the number of plants and accumulated dry matter by different weed species, it was possible to determine the relative importance (RI) of each weed species, as proposed by Monquero *et al*. (2014).

The species diversity indices were calculated by the Shannon-Wiener formula [equation 1] (Ribeiro *et al*. 2017):

$$H' = -\sum_{i=1}^{S} n_i \ln p_i \qquad [1]$$

where H′ = Shannon diversity index, S = number of species, p_i = proportion of the number of individuals (total abundance) represented by ith species, estimated as n_i/N, where ni is the measure of importance of the ith species (number of individuals) and N is the total number of individuals, ln = Napierian logarithm.

The effect of the treatments on the growth of the forest component (teak) was also determined at the end of each rainy season where the teak plants height and neck diameter were measured 270, 425 and 790 days after sowing (DAS) of the legume species, and the breast height and diameter (BHD) 790 DAS. The plants height was determined using a portable hypsometer and the neck diameter and breast height with a manual digital caliper.

At 790 DAS, samples composed of ten homogenized subsamples were collected from each plot using a probe-type auger in the depth layer of 0-20 cm from the soil surface. The compound samples were individually packed in plastic bags, identified and kept in a conventional freezer at a temperature of -20 ºC until taken to the laboratory and analyzed to determine total nitrogen content and organic matter content. Total nitrogen was determined by the Kjeldahl method (sulfuric digestion = $H_2SO_4 + H_2O_2$), according to the methodology described by Weng *et al.* (2017); organic matter was analyzed by the colorimetric method (extraction with sodium dichromate) and expressed in quantity, as described by Marchini *et al*. (2015).

The values obtained for the trees height and diameter, total nitrogen and organic matter were subjected to an analysis of variance by the F test using the Assistat 7.6 software program, and the mean values of the treatments were compared by the Tukey test at 5 % probability level.

RESULTS

In the assessments of the infesting community, 12 weed species of six botanic families were observed, as described in table 2.

Table 2. Scientific and common names, international codes of weed species found in the experimental area.

Nombres científicos y comunes, códigos internacionales de especies de malezas que se encuentran en el área experimental.

Scientific name	International code	Family
Eupatorium sp.	-	Asteraceae
Spermacoce latifolia	BOILF	Rubiaceae
Sida santaremensis	SIDSN	Malvaceae
Waltheria indica	WALIN	
Sida carpinifolia	SIDAC	Malvaceae
Glycine wightii	GLYWI	Leguminoseae
Mimosa debilis	MINDE	
Senna obtusifolia	CASOB	
Cyperus difformis	CYPDI	Cyperaceae
Digitaria horizonthalis	DIGHO	Poaceae
Digitaria insularis	DIGIN	
Brachiaria brizantha	BRABR	

The most important floristic diversity at 425 DAS was achieved in the condition where weeds were allowed to coexist with the teak tree (unweeded treatment), followed by the treatment where Brazilian stylos were used as cover plants. Pigeon pea and hand weeding were the treatments that exhibited the highest values of floristic diversity, followed by pinto peanut (figure 1).

There was a decrease of the floristic diversity index at 790 DAS for the treatments with stylo, cowpea, and in the unweeding treatment. However, mowing allowed that the number of weed species increased between the periods assessed, *i.e.* the floristic diversity value increased from 1.17 at 425 DAS to 1.55 at 790 DAS. The floristic diversity values obtained for the treatments with pinto peanut, pigeon pea and in the hand weeding condition remained constant during the experimental period (figure 1).

The highest number of plants at 425 DAS was found in the treatment where no weeds suppression method was employed. In this same period, the treatments with pigeon pea and hand weeding exhibited the largest weed-suppression capacity of the spontaneous population followed by pinto peanut, Brazilian stylo and cowpea (figure 2).

It should be noted that the number of plants changed in the assessment conducted at 790 DAS. The number of plants increased from 30 plants m^{-2} at 425 DAS to 125 plants m^{-2} at 790 DAS in the treatment with cowpea. Where mowing was used, this same number increased from 24 plants m^{-2} at 425 DAS to 57 plants m^{-2} at 790 DAS. However, this variable decreased considerably in the treatment where no method of weed suppression was used, in which the total number of plants dropped from 78 plants m^{-2} at 425 DAS to 19 plants m^{-2} at 790 DAS (figure 2).

The highest weed dry matter production was found in the situation where no weed suppression methods were used. Total dry matter produced by the spontaneous vegetation in the unweeding treatment increased from 1,200 g m^{-2} at 425 DAS to 2,625 g m^{-2} at 790 DAS. A considerable increase in the amount of dry matter accumulated by the spontaneous vegetation was also observed when mowing was used. Accumulated weed dry matter increased from 72 g m^{-2} at 425 DAS to 434 g m^{-2} at 790 DAS (figure 3).

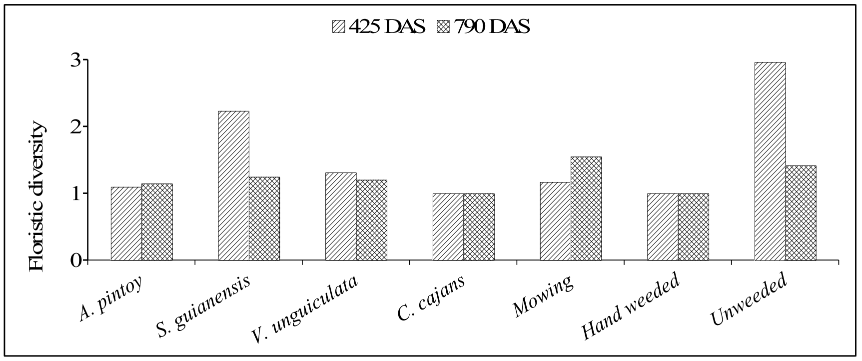

Figure 1. Floristic diversity index obtained at 425 and 790 days after sowing (DAS) of the legume plants.

Índice de diversidad florística obtenido a los 425 y 790 días después de la siembra (DDS) de las plantas leguminosas.

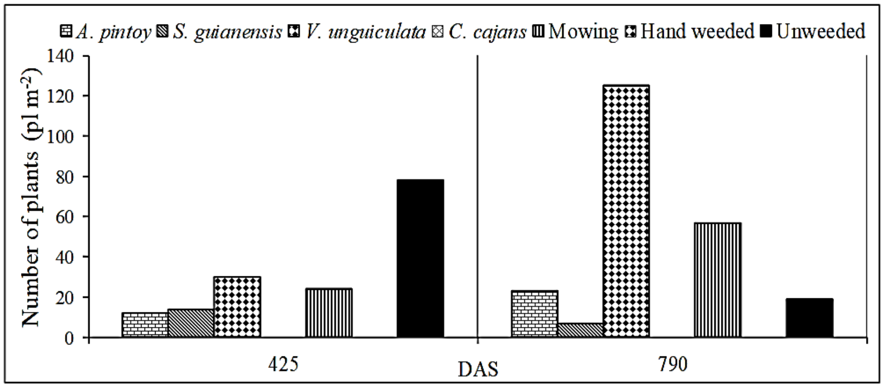

Figure 2. Total number of plants found among the spontaneous vegetation at 425 and 790 days after sowing (DAS) with legume species.

Número total de plantas encontradas entre la vegetación espontánea a los 425 y 790 días después de la siembra (DDS) con especies de leguminosas.

It is worth noting that the Brazilian stylo species exhibited the highest reduction of weed dry matter production (figure 3), although the number of plants increased during the period of the experiment, as shown in figure 2. The total amount of weed dry matter decreased from 786 m^{-2} at 425 DAS to 241 g m^{-2} at 790 DAS, representing a 68.7 % reduction in biomass accumulation over the study period (figure 3).

On the other hand, the accumulated dry matter by the infesting community remained constant and below 150 g m^{-2} in the treatments where pinto peanut and cowpea legumes were used; yet for pigeon pea and hand weeding, there was no dry matter production by the spontaneous plants in the assessments conducted at 425 and 790 DAS (figure 3). Change in the infesting community can also be demonstrated by the different values of relative importance (RI) found in this study; these values varied according to the time of assessment and treatment.

The assessment conducted at 425 DAS revealed that CASOB weeds had a higher RI in the treatment where pinto peanut was used as cover crop, and WALIM was the second species with higher RI among those found (figure 4). Comparatively, GLYWI, CYPDI, SIDAC and BRABR were the weed species that achieved the highest RI in the treatments that respectively used stylo, cowpea and mowing and where weeds coexisted with the legume plants (unweeded plot) (figure 4).

The assessment conducted at 790 DAS showed that the RI of DIGIN surpassed other species in the treatments where pinto peanut, cowpea and mowing were used (figure 5). Nevertheless, in the absence of control and in the treatment containing Brazilian stylo, it was possible to observe an increase in RI for GLYWI and BRABR species, respectively, indicating a possible advantage of these species *in situ* (figure 5).

It should be noted that no epigeal germination of weed plants was found at 425 and 790 DAS, when pigeon pea was used as green legume forage and when hand weeding was used as a control method (figures 4 and 5).

It can be seen that the treatment where weeds were manually suppressed exhibited the lowest values of orga-

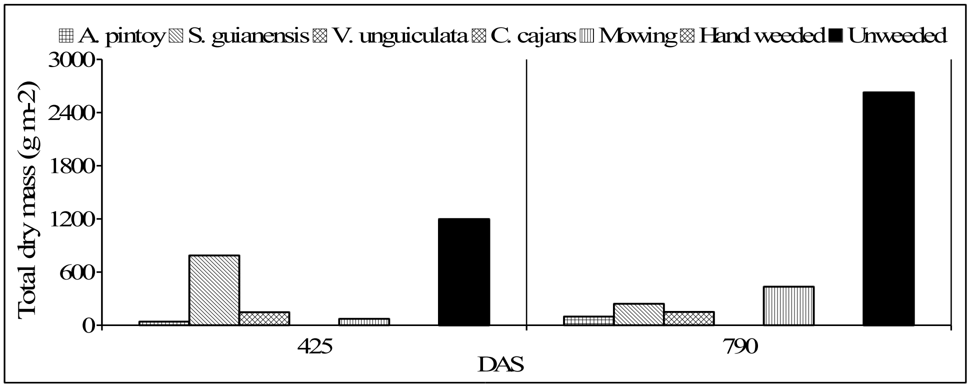

Figure 3. Total weed dry matter obtained at 425 and 790 days after sowing the legumes.

Materia seca total de malezas obtenida a los 425 y 790 días después de la siembra de las leguminosas.

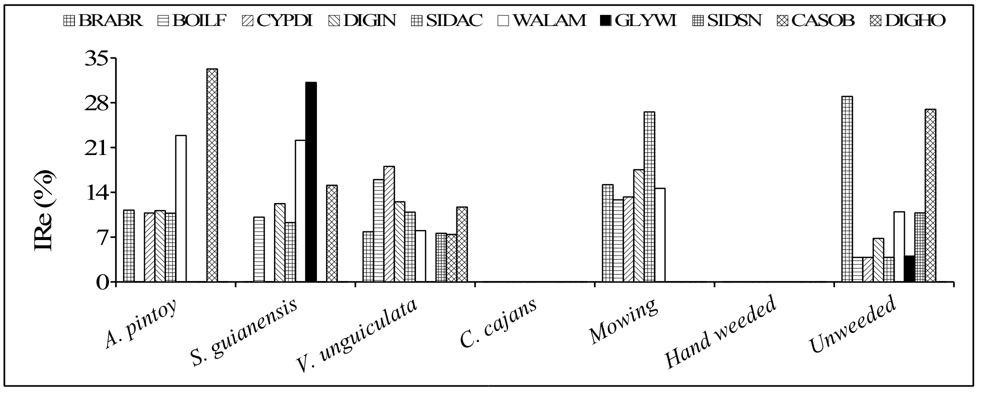

Figure 4. Relative importance index of the weed species found at 425 days after sowing the legumes.

Índice de importancia relativa de las especies de malezas encontrado a los 425 días después de la siembra de leguminosas.

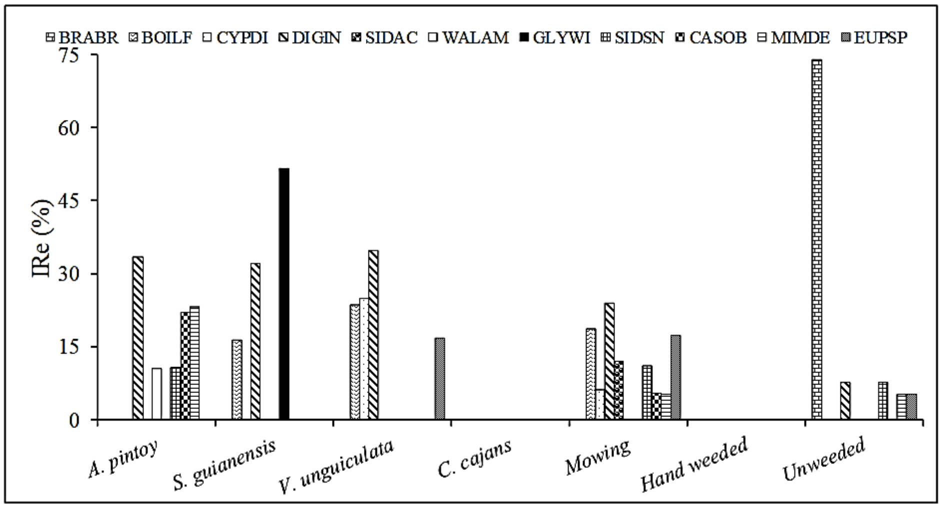

Figure 5. Relative importance index of the spontaneous species found 790 days after sowing the legume plants.

Índice de importancia relativa (IR) de las especies espontáneas encontrado 790 días después de la siembra de las leguminosas.

nic matter and total nitrogen in soil, also being statistically lower when compared to the treatment where no weed suppression method was used (table 3).

The highest amounts of organic matter and total nitrogen in soil were achieved in the treatments sown with legumes, which ranged b 11.5 to 11.8 g dm^{-3}; and 1,035.7 to 1,118.3 mg kg^{1}, respectively. It should be noted that no significant differences were observed between the organic matter in soil in the unweeded plot and that found for all forage legumes. Still for the unweeded condition, the total nitrogen value in soil was not statistically different from that found in the treatments with cowpea and pigeon pea (table 3).

Table 3. Mean values of the amount of organic matter and total nitrogen found 790 days after sowing the legume plants.

Valores medios de la cantidad de materia orgánica y nitrógeno total encontrados 790 días después de la siembra de las leguminosas.

Treatments	Organic matter (g dm^{-3})		Total nitrogen (mg kg^{-1})	
Arachis pintoi	11.7	a	1,106.5	a
Stylosanthes guianensis	11.5	a	1,118.3	a
Vigna unguiculata	11.5	a	1,035.7	ab
Cajanus cajan	11.8	a	1,057.5	ab
Mowing	9.5	b	949.5	bc
Hand weeding	9.0	b	843.5	c
Unweeding	11.8	a	975.8	b
F Treatment	9.322**		17.02**	
F Block	0.22^{NS}		0.59^{NS}	
LSD	1.8		109.8	
C.V. (%)	7.1		4.6	

NS – Not significant; ** - Significant at the 1 % level of probability. Means followed by the same letter in column do not differ statistically from one another by the Tukey test at 5 % level of probability.

The height and diameter of the teak plants neck determined prior to the experiment installation showed that this condition was the same in all plants, since no statistical differences were found for these two variables. This same condition extended up to 270 DAS when no statistical difference was observed for the plants neck height and diameter (table 4).

The coexistence of the tree species with the weeds present in the treatment without usage of suppression methods (unweeded plot) affected adversely the teak development at 425 DAS, both for the plants height and neck diameter (table 4), which can be justified by the steady increase of dry matter accumulation by *B. brizantha* in the area with higher RI than that presented by other weed species found, indicating that *B. brizantha* possibly was the main species responsible for the interference inflicted on the tree component (table 4).

Similarly, it can be seen that in the treatment with pigeon pea, an adverse interference with the development of the tree component also occurred, despite the absence of weeds in the area, and a higher level of total nitrogen fixation in soil. The plants height and neck diameters determined at 425 DAS for this treatment were statistically similar to those observed in the unweeded condition, though lower than those found in the treatment containing pinto peanut (table 4).

It can be seen that the highest values of the Teak plants height and neck diameters determined at 425 DAS were achieved by the treatment where pinto peanut was intercropped with the tree plants, variables that were not statistically different from those of the treatment where stylos and cowpea were intercropped with teak plants or those achieved with mowing and hand weeding (table 4).

The effects of the treatments on the plants height were even more evident in the evaluation performed at 790 DAS, where the treatments with pinto peanut, Brazilian stylos, mowing and absence of weeds as a result of hand weeding, determined the highest mean values of teak height, indicating a significant difference when compared to the other treatments. Cowpea and pigeon pea reduced the Teak plants height and did not differ statistically from the unweeding treatment. There was a significant BHD reduction in the treatment with pigeon pea and in the unweeded condition compared to the other treatments. It should be pointed out the largest diameter at the teak plants breast height was found in the treatment where the tree plants were intercropped with pinto peanut (table 4).

Table 4. Mean values of height (cm), neck diameter (cm) and diameter (cm) at the breast height of teak plants.

Valores medios de altura (cm), diámetro del cuello (cm) y diámetro (cm) a la altura del pecho de las plantas de teca.

Treatments	Previous		270 DAS\1	
	Height (cm)	ND\2 (cm)	Height (cm)	ND (cm)
Arachis pintoi	153.5	4.19	300.4	6.41
Stylosanthes guianensis	137.8	3.78	256.2	5.68
Vigna unguiculata	135.2	4.04	241.9	5.47
Cajanus cajan	127.4	3.68	224.9	5.33
Mowing	103.2	3.47	234.7	5.73
Hand weeding	136.2	4.00	261.4	5.96
Unweeding	123.8	3.21	230.5	5.54
F Treatment	1.79^{NS}	0.96^{NS}	1.14^{NS}	0.77^{NS}
F Block	6.68**	4.26*	4.89*	2.34^{NS}
LSD	58.2	1.40	113.4	1.75
C.V. (%)	19.24	15.83	19.43	13.15

Treatments	425 DAS				790 DAS			
	Height (cm)		ND (cm)		Height (cm)		DBH/3 (cm)	
Arachis pintoi	587.9	a	11.8	a	839.2	a	9.4	a
Stylosanthes guianensis	530.3	ab	10.9	ab	769.1	ab	8.5	abc
Vigna unguiculata	532.3	abc	10.4	ab	722.4	bc	8.2	abc
Cajanus cajan	487.4	bc	9.3	b	627.0	c	6.7	c
Mowing	519.2	abc	10.6	ab	804.0	ab	8.3	abc
Hand weeding	536.6	abc	10.5	ab	837.4	a	8.6	ab
Unweeding	451.8	c	9.2	b	712.3	bc	7.5	bc
F Treatment	4.91**		4.31**		12.32**		4.55**	
F Block	7.47**		2.26^{NS}		0.22^{NS}		2.10^{NS}	
LSD	92.5		2.01		102.5		1.9	
C.V. (%)	7.57		8.29		5.79		9.87	

NS – Not significant; ** - Significant at 1 % level of probability; * - Significant at 5 % level of probability. Means followed by same letter in column did not differ statistically from one another by the Tukey test at 5 % level of probability. \1 DAS – Days after sowing the forage legume. \2 ND – Diameter of the plant neck \DBH – diameter at breast height.

DISCUSSION

Based on evaluations of the weed community carried out in this research, it could be seen that there was an intense competition between weed plants and the teak forest component for environmental resources, due to the large number of weed species and, mainly, the high level of infestation of these plants (table 2 and figures 1, 2, 3, 4 and 5).

Such excessive number and diversification of weed species in silvopastoral areas are mainly due to the slow initial growth of tree component and an abundance of propagules in the soil seed bank. Therefore, weed control in these areas, which often have species with rapid initial development, becomes ineffective (Caron *et al*. 2012).

The 12 weed species found (table 2) had distinct distributions detected by the Shannon – Wiener floristic diversity. High indices of floristic diversity indicated more evenness in the number of weed communities where the dominance of species groups is lower. Shannon floristic diversity is considered high when the scores are above three, medium between two and three, low between one and two and very low below one (Schlickmann *et al.* 2019). Therefore, in this study, the treatments with pinto peanut, cowpea and mowing exhibited low floristic diversity throughout the experimental period.

The treatments with stylos and in the unweeding condition indicated at 425 DAS Shannon diversity indices considered medium, which tended to decrease at 790 DAS. Such decrease in the floristic diversity may be associated both with the competition exerted by the forage legumes and the competition between the weed species present in the infesting community, since perennial weeds tend to have a higher competitive potential in the long term while annual weeds exhibit more competitive strength for a short period of time (Bellé *et al.* 2018).

Treatments with pigeon pea and hand weeding exhibited a floristic diversity index below one in both periods of assessment, and thus diversity is ranked as very low. It should be noted that epigeal germination and consequent accumulation of weed dry matter were not found in both these treatments (figure 2 and 3). The main desirable characteristics of pigeon pea are its rapid initial growth, high stature and high capacity to allocate resources from the environment and transform them into accumulated dry matter in just 142 DAS, which makes it important in weed management (Dantas *et al*. 2015).

Additionally, when compared with other legumes, pigeon pea grows well in dry regions and can fix atmospheric nitrogen in the soil and therefore has the ability to adapt to adverse soil conditions (Mahajan *et al*. 2019), characteristics that can be observed in table 3. However, supposedly due to said particularities, pigeon pea also suppressed the teak plants growth and development at 425 and 790 DAS (table 4). This result is likely to be related to the higher growth rate of pigeon pea when compared with that of teak and, consequently, to the higher competition between this legume and weeds for the allocation of environmental resources.

In the treatment containing cowpea, the number of weed plants was considered high and increased significantly in the period between 425 and 790 DAS (figure 2). However, the accumulated weed dry matter remained constant and was considered low at the DAS cited above (figure 3). For this reason, it can be seen that the treatment with cowpea did not interfere in the weeds germination and emergence processes, although it was capable of suppressing weeds growth, thus being an important alternative for weed management in forest-livestock integrated systems. It is also important to emphasize that this treatment produced large quantities of organic matter and total nitrogen in the soil (table 3), however interfered significantly in the teak plants height at 790 DAS (table 4).

Some of the main characteristics that make cowpea one of the preferred grazing crops for intercropping cultivation is the fact that this legume is resistant to temporary lack of water in soil and provides large amounts of nitrogen through the symbiosis with specific bacteria (Dutra *et al*. 2015). Probably, due to the morphological and physiological characteristics of this crop, such as high production of shoots dry matter, indeterminate growth habit and nutrient accumulation even in unfertile soils, cowpea growth and development are not affected by the competition with weeds (Oliveira *et al.* 2018). It is assumed that these particularities also affected the growth of the teak tree component at 790 DAS.

Although the treatments with pinto peanut and stylos have placed little competitive pressure on weeds (figures 2 and 3), it should be emphasized that both legume species produced the largest quantities of organic matter and total nitrogen in the soil (table 3) and did not interfere in the growth variables of the Teak tree component in any of the evaluation periods of this research. Because of this, from the agronomic viewpoint, both legumes are the most recommended species for integrated crop-livestock-forest systems.

Biological nitrogen fixation is crucial for sustainable agriculture (Udvardi and Poole 2013) because it represents the main entryway of nitrogen into various terrestrial ecosystems. The supply of nitrogen by forage legumes is accomplished by biological fixation, where the symbiosis between bacteria such as *Rhizobium* spp. and legumes is necessary in order that this atmospheric nitrogen fixation can occur in the soil (Carvalho *et al*. 2019).

In general, the use of cover crops with legumes has been an important tool in the most diverse farming systems to help eliminate weeds by means of allelopathic effects, diminishing the space for growth and competition for water, sunlight, oxygen and nutrients and suppressing re-infestations (Lima *et al*. 2014).

CONCLUSIONS

The coexistence with weeds during the period of implementation is detrimental to teak development, especially when *Brachiaria brizantha* is present in the infesting community. Intercropping with forage legumes increases the levels of organic matter and total nitrogen in soil in forest-livestock integrated systems. Pinto peanut and Brazilian stylos exert little competitive pressure on weeds, produce larger quantities of organic matter and available nitrogen in the soil and do not interfere with the growth variables of the teak tree component. The treatments with cowpea and pigeon pea were capable of suppressing weeds growth. Nonetheless, intercropped cultivation with these species jeopardizes teak plants growth during the period of implementation of the silvopastoral system.

REFERENCES

Albuquerque CJB, SM Silva, JMQ Lu, CH Zandonadi. 2017. Consortium of eucalyptus with foragesorghum in semiarid of Minas Gerais State. *Ciência Rural* 47(11):1-6. DOI: 10.1590/0103-8478cr20160939

Alvares CA, JL Stape, PC Sentelhas, JLM Gonçalves, G Sparovek. 2014. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift* 22(6):711–728. DOI: 10.1127/0941-2948/2013/0507

Balbino LC, LAM Cordeiro, V Porfírio-da-Silva, AD Moraes, GB Martínez, RC Alvarenga. 2011. Evolução tecnológica e arranjos produtivos de sistemas de integração lavoura-pecuária-floresta no Brasil. *Pesquisa Agropecuária Brasileira* 46(10):1-11. DOI: https://doi.org/10.1590/S0100-204X2011001000001

Bellé JR, SR Marchi, D Martins, AC Sousa, GHR Pinheiro. 2018. Nutritional value of Marandú palisade grass according to increasing coexistence periods with weeds. *Planta Daninha* 36:1-11. DOI: https://doi.org/10.1590/S0100-83582018360100070

Caron BO, FP Lamego, VQD Souza, EC Costa, E Eloy, A Behling, R Trevisan. 2012. Interceptação da radiação luminosa pelo dossel de espécies florestais e sua relação com o manejo das plantas daninhas. *Ciência Rural* 42(1):75-82. DOI: https://doi.org/10.1590/S0103-84782012000100013

Carvalho LR, LET Pereira, M Hungria, PBD Camargo, SC Silva. 2019. Nodulation and biological nitrogen fixation (BNF) in forage peanut (*Arachis pintoi*) cv. Belmonte subjected to grazing regimes. *Agriculture, Ecosystems & Environment* 278:96-106. DOI: https://doi.org/10.1016/j.agee.2019.02.016

Dantas RDA, R Carmona, AMD Carvalho, TA Rein, JV Malaquias, JDDGD Santos Júnior. 2015. Produção de matéria seca e controle de plantas daninhas por leguminosas consorciadas com cana-de-açúcar em cultivo orgânico. *Pesquisa Agropecuária Brasileira* 50(8):681-689. DOI: https://doi.org/10.1590/S0100-204X2015000800006

Dutra AF, AS Melo, LMB Filgueiras, ARF Silva, IM Oliveira, MEB Brito. 2015. Parâmetros fsiológicos e componentes de produção de feijão-caupi cultvado sob defciência hídrica. *Revista Brasileira de Ciências Agrárias* 10(2):189-197. DOI: https://doi.org/10.5039/agraria.v10i2a3912

Lima SF, PC Timossi, DP Almeida, UR Silva. 2014. Fitossociologia de plantas daninhas em convivência com plantas de cobertura. *Revista Caatinga* 27(2):37-47.

Macedo MCM. 2009. Integração lavoura e pecuária: o estado da arte e inovações tecnológicas. *Revista Brasileira de Zootecnia* 38:133-146. DOI: https://doi.org/10.1590/S1516-35982009001300015

Madi JPS, N Calegario, R Môra, MPLC Carvalho, SPC Carvalho. 2020. Density management in clonal *Tectona grandis* Linn. f. plantations. *Scientia Forestalis*, 48(125):e3296. DOI: https://doi.org/10.18671/scifor.v48n125.25

Mahajan G, RC Rachaputi, BS Chauhan. 2019. Integrated weed management using row arrangements and herbicides in pigeonpea (*Cajanus cajan*) in Australia. *Crop and Pasture Science* 70(8):676-683. DOI: https://doi.org/10.1071/CP19186

Marchi SR, RF Marques, PPS Araújo, AS Marques, RM Souza. 2018. Ação de herbicidas pré-emergentes no estabelecimento inicial de plântulas de espécies nativas do Cerrado. *Revista Brasileira de Herbicidas* 17(4):612-619. DOI: https://doi.org/10.7824/rbh.v17i4.612

Marchini DC, TC Ling, MC Alves, S Crestana, SN Souto Filho, OGD Arruda. 2015. Matéria orgânica, infiltração e imagens tomográficas de Latossolo em recuperação sob diferentes tipos de manejo. *Revista Brasileira de Engenharia Agrícola e Ambiental* 19(6):574-580. DOI: https://doi.org/10.1590/1807-1929/agriambi.v19n6p574-580

Marques RF, GHR Pinheiro, AS Marques, RM Souza, SR Marchi. 2019. Effect of pre-emergent graminicide herbicides on germination and early development of native species. *Científica* 47(1):28-35. DOI: https://doi.org/10.15361/1984-5529.2019v47n1p28-35

Monquero PA, ACS Hirata, RA Pitelli. 2014. Métodos de levantamento da colonização de plantas daninhas. *In* Monquero PA. ed. Aspectos da biologia e manejo de plantas daninhas. São Carlos, Brasil. RiMa Editora. p. 103-127.

Oliveira FS, DRS Gama, JLD Dombroski, DV Silva, FS Oliveira Filho, T Ramalho Neta. 2018. Competition between cowpea and weeds for water: Effect on plants growth. *Revista Brasileira de Ciências Agrárias* 13(1):1-7. DOI: https://doi.org/10.5039/agraria.v13i1a5507

Pereira MRR, GSF Souza, AC Silva Junior, D Martins. 2016. Desenvolvimento de plantas de *Pinus* em convivência com espécies de plantas daninhas. *Revista de Ciências Agrárias* 59(2):138-143. DOI: https://doi.org/10.4322/rca.1982

Ribeiro TDO, IA Bakke, PC Souto, OA Bakke, DDS Lucena. 2017. Diversidade do banco de sementes em diferentes áreas de Caatinga manejadas no semiárido da Paraíba, Brasil. *Ciência Florestal* 27(1):203-213. DOI: https://doi.org/10.5902/1980509826459

Santos MM, KP Vieira, ER Moreira, RG Prates, TC Oliveira, RR Fidelis. 2018. Crescimento inicial de eucalipto consorciado com feijão-caupi. *Cultura Agronômica* 27(1):57-66. DOI: https://doi.org/10.32929/2446-8355.2018v27n1p57-66

Schlickmann MB, MEA Ferreira, EP Varela, JL Pereira, E Duarte, APCD Luz. 2019. Fitossociologia de um fragmento de restinga herbáceo-subarbustiva no sul do Estado de Santa Catarina, Brasil. *Hoehnea* 46(2):1-7. DOI: https://doi.org/10.1590/2236-8906-29/2018

Schuhli GS, E Paludzyszyn Filho. 2010. O cenário da silvicultura de teca e perspectivas para o melhoramento genético. *Pes-*

quisa Florestal Brasileira 30(63):217-230. DOI: https://doi.org/10.4336/2010.pfb.30.63.217
Udvardi M, PS Poole. 2013. Transport and metabolism in legume-rhizobia symbioses. *Annual review of plant biology* 64:781-805. DOI: https://doi.org/10.1146/annurev-arplant-050312-120235
Weng Y, A Shi, WS Ravelombola, W Yang, J Qin, D Motes. 2017. A rapid method for measuring seed protein content in cowpea (*Vigna unguiculata* (L.) Walp). *American Journal of Plant Sciences* 8(10):2387-2396 DOI: https://doi.org/10.4236/ajps.2017.810161

Received: 17.09.20
Accepted: 01.02.22