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Article

Forage behavior of the herbaceous stratum in different tree densities of low deciduous forest

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Abstract

The shade of the trees projected on the herbaceous stratum that grows under the canopy represents an undesired effect for livestock farmers for forage production in the silvopastoral system. In order to determine the dry matter production and the floristic composition of the herbaceous stratum with different amounts of photosynthetically active radiation, three plots with low tree density (BDA; 50 to 200), moderate tree density (MDA; 201 to 350) and high tree density (ADA; 350 to 500) trees ha^{-1} were selected. In each plot, photosynthetically active radiation (RFA) that affects the herbaceous stratum was estimated and the dry matter production (DM) of the forage herbaceous plants present during 15 weeks of the rainy season was determined. The intensity of light under the canopy and the production of herbaceous forage biomass in BDA, MDA and ADA were 8 594, 6 437 and 3 801 MJ m^2 year^{-1} and 2 859, 1 988 and 1 679 kg of DM ha^{-1}, respectively. The number of herbaceous species in BDA, MDA and ADA was 38, 48 and 27, respectively, although the dominant species, with more than 80% of the botanical composition, were only six. It is concluded that the tree density modifies the amount of light that falls on the herbaceous stratum, affecting the biomass production and the floristic composition of forage herbaceous plants that grow under the tree canopy in a traditional silvopastoral system in the Low Deciduous Forest.

Keywords: forage biomass, herbaceous stratum, light intensity, Sierra de Huautla, silvopastoralism.

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Introduction

The need to reduce agricultural inputs without significant loss of productivity requires the redesign of production systems (Jamar *et al*., 2015). Agroforestry systems can contribute to feeding the growing population in a sustainable way Groeneweg (2018). The benefits of mixing herbaceous and woody species in agroforestry systems will depend on the specific interactions between the components of the system (Lovell *et al*., 2018).

Tree and herbaceous plant species frequently compete in time and space for natural production inputs: light, water and nutrients (Yu *et al*., 2015; Hong *et al*., 2017). Solar radiation is the main factor that affects photosynthesis and the performance of agroforestry systems (Jose *et al*., 2008). The quantity and quality of the solar radiation that affects the herbaceous layer are affected by numerous factors: tree species, tree height, canopy architecture, leaf area index, time of day and day of the year, location (latitude, longitude) and sun exposure of the surface according to the slope (Burner *et al*., 2018).

By optimizing the pasture-tree interaction, the productivity of the land can be improved, although the management of the system can be more complex because the interactions between the components of a silvopastoral system include changes in the microclimate associated with the pasture, of which the most notorious are the light intensity and the quality of the solar radiation that reaches the herbaceous component through the tree canopy. Sunlight that intercepts tree foliage affects the quantity and forage quality of herbaceous species that grow under the influence of the tree canopy and modify the botanical composition of paddocks (Cruz *et al*., 1999; Burner *et al*., 2018).

Tropical pastures, with a predominance of C4 plants, reach their maximum production with high levels of light intensity (Jose *et al*., 2008). However, comparable or even higher dry matter values have been reported when grasses are associated with trees, compared to pure grass grasses (Cruz *et al*., 1999).

These increases have been obtained in conditions of moderate shade in the range of 30 to 40%. Although, the availability of the total DM and the nutritional value of the forage herbaceous are often lower under the tree canopy (Ribaski, 2000). In other cases, dry matter production is affected by shade, but not the nutritional value of forage (Pentón *et al*., 1998). Trees in paddocks fulfill important functions within livestock systems and provide eco-systemic products and services (Ribaski and Menezes, 2002).

The most important thing for the ranchers is the shade that the trees provide to the animals, as well as, to obtain firewood and economic resources by selling wood or fruits. However, the shading of the trees can affect the productivity of the grasses, mainly, under ADA conditions, when the woody ones are dense crowns because they have a greater capacity of interception of the solar radiation necessary for the optimal growth and development of the plants that make up the herbaceous layer (Jose *et al*., 2008).

Silvopastoral systems have been developed to improve the quality and performance of grasslands through the interaction between herbaceous and forage tree species (Bellow and Nair, 2003). In this way, the association of grasses with woody plants contributes to improving the productivity of the land in both meat and milk production (Clavero, 2011). However, in silvopastoral systems the productivity of the herbaceous stratum may be conditioned by the canopy cover of the trees, which, by interference, limits the amount of light that reaches the herbaceous stratum (Gargaglione *et al*., 2014).

In this sense, as an alternative to improve the DM production of the herbaceous stratum, it is convenient to establish grass species tolerant to a certain level of shading (Gargaglione *et al*., 2015). The partial interception of sunlight by the tree foliage modulates the photosynthetically active radiation and the intensity of light that reaches the herbaceous stratum, affecting the morphology and growth of the plants that grow under the canopy, Fassola *et al*. (2006) they reported that the interception of the RFA in the canopy, promotes an increase in the maximum forage accumulation of the pastures when there is 40% shade and then descends until reaching critical levels from 70% shade. Ovispo *et al*. (2008) demonstrated that both production and forage quality are affected by the amount of shade that the tree canopy casts on the herbaceous layer, so that too much shade cast by the tree negatively affects pasture yield.

Thus, the shadow cast by the tree canopy on the herbaceous layer constitutes one of the most important negative effects of the presence of trees in silvopastoral systems (Pentón, 1998). However, the botanical composition of herbaceous plants can be similar in both production systems of grasses with and without trees; likewise, the percentage of C4 plants increases and that of C3 decreases when they grow at a greater distance from the base of the tree (Ruiz *et al*., 2001).

Several studies have addressed the interaction of trees on pastures that have reported higher growth, productivity and nutritional quality of herbaceous plants that grow in the shade (Cruz *et al*., 1999; Fassola *et al*., 2006; Jose *et al*., 2008; Piñeros *et al*., 2011; Burner *et al*., 2018). However, there are differences in the information regarding the benefits and limitations of the shade of trees on the herbaceous layer. This heterogeneity of results is determined by the diversity of conditions in which the investigations have been carried out, as well as by the different experimental methodologies used.

The herbaceous layer that grows during the rainy season under the canopy of the trees of the traditional silvopastoral system of the Sierra de Huautla, Morelos, is of great importance for the economy of the peasant communities that inhabit that region, however, little information is available to improve the management of the components of the ecosystem.

The objective of this study is to analyze the productive behavior and the floristic composition of the herbaceous layer that grows below the canopy as a function of the tree density and the photosynthetically active light intensity in the traditional silvopastoral system of the Low Deciduous Forest of the Sierra de Huautla, Morelos, Mexico.

Materials and methods

The study was carried out during the rainy season in the communities of Los Sauces and El Limón, in the municipality of Tepalcingo, Morelos, Mexico, in the region called Sierra de Huautla, located to the south of the entity. The coordinates of the study area are 18° 20’ north latitude and 98° 51’ west longitude (Dorado *et al*., 2005).

The dominant climate, reported by Koppen and modified by García (2004), is Aw0(w)(i')g, the driest of sub-humid climates, with a rainfall regime in summer and winter precipitation of less than 5%; mean annual precipitation of 900 mm, and mean annual temperature of 25 °C, with annual fluctuation of monthly mean temperatures between 5 and 7 °C. With two climatic seasons during the year: the rainy season from July to October and the dry season that includes the other eight months of the year.

The predominant soils are the Haplic Feozems and the Luvic Feozems; where chromic Luvisols and Lithosols are more abundant presenting a lithic phase, with a rocky bed between 10 and 20 cm deep (INIFAP, 1995). Land use is given by semi-extensive cattle farming and seasonal agriculture with annual crops linked to livestock feeding (Uribe *et al*., 2015).

The dominant vegetation is the Low Deciduous Forest (Miranda and Hernández, 1963) characterized by species, arborescent and arboreal with 4 to 10 m in height. The dominant plant families are: Fabaceae, Euphorbiaceae, Burseraceae and Bombonaceae (Rzedowski, 2006). For the selection of experimental plots, visits were made to the study area in the common territory 'Los Sauces' and 'El Limon'. Using the photointerpretation technique, areas of high, moderate and low tree density were identified with the help of Google Earth Pro software (Guerra, 2003).

With field information, wooded areas were delimited with (ADA; 351 to 500), (MDA; 201 to 350) and (BDA; 50 to 200) trees ha^{-1}. To determine the tree density, the sampling sites were divided into quadrants of 50 x 60 m using the diameter of the stem at the height of the first fork (> 5 cm) and height at the crown (> 2.5 m) of the arboreal ones, identifying the dominant species and botanical family. The experimental area considered nine 1000 m^2 sampling plots (three plots for each tree density).

Herbaceous plant material was collected every 14 days using a 1 m^2 quadrant. Four 50 x 50 cm sampling sites were located in each experimental plot, where herbaceous plant material was collected to determine floristic diversity. To determine the floristic composition of the herbaceous species present in the forage, the collected herbaceous material was separated and identified by visual comparison with the species described by (Dorado *et al*., 2005).

The collected plant material was weighed with a digital scale separating the botanical species present. Subsequently, a sub-sample of 20% of the collected material was taken, which was placed in brown paper bags and dried at a constant weight in a forced air stove at 60 °C, to determine the dry weight of each sample. Thus, the daily biomass production of the herbaceous stratum was calculated for each tree density in each sampling period, dividing the total weight of the biomass of each sample between the days of the sampling period.

To measure the photosynthetically active radiation entering the herbaceous stratum through the tree canopy, photographs were taken using a digital camera with a hemispherical lens. Randomly, three photographs were taken at each sampling site, placing the camera 50 cm from the ground, obtaining nine photographic images for each of the evaluated tree densities. The images were obtained by aiming the camera lens up from a point under the tree canopy.

Using a 180° 'fish eye' lens with a high resolution digital camera following the protocol of use established by Ramírez-Contreras y Rodríguez-Trejo (2006). For this, uniform clear sky conditions were considered, just before sunrise or sunset or when the sky was cloudy but uniform. To estimate RFA, each digitized photographic image was analyzed with the HemiView V.2.1 program, using the simple molar model to obtain RFA in Mj m^2 $year^{-1}$ (Ramírez-Contreras y Rodríguez-Trejo, 2006).

The experimental design was completely randomized, taking tree density as treatment, with three replications and nine sampling sites per treatment, with each sampling site as the experimental unit. Forage yield data was analyzed by analysis of variance using the SAS GLM procedure (Park, 2009).

Results and discussion

The richness, abundance and density of trees scattered in paddocks in the traditional silvopastoral system in the study region is a product of the decisions taken by producers to conserve those multi-purpose tree species in the pastures. Generally, producers leave trees in the pastures that provide services and benefits to their paddocks and their families. In the experimental area, 37 multipurpose tree species corresponding to 18 botanical families were identified, with the Fabaceae family standing out (Table 1).

Table 1. Trees present in the study area of the traditional silvopastoral system of the Sierra de Huautla, Morelos.

Common name	Scientific name	Family
Palo dulce	*Eysenhardtia polystachia*	Fabaceae
Tecolohuixtle	*Mimosa benthamii*	Fabaceae
Palo Brasil	*Haematoxylum brasiletto*	Fabaceae
Cuachalalate	*Amphipterygium adstringens*	Anacardiaceae
Cuatecomate	*Crescentia alata*	Bignoniaceae
Cubata	*Acacia cochliacantha*	Fabaceae
Ciruelo	*Spondia purpurea*	Anacardiaceae
Tepemezquite	*Lysiloma divaricata*	Fabaceae
Guayacan	*Miroxylom balsamum*	Fabaceae
Pochote	*Ceiba aesculifolia*	Malvaceae
Cuahulote	*Guazuma ulmifolia*	Malvaceae.
Mata rata	*Gliricidia sepium*	Fabaceae
Panicua	*Cochlospermum vitifolium*	Bixaceae
Tepehuaje	*Lysiloma acapulcense*	Fabaceae
Copal chino	*Bursera bipinnata*	Burseraceae
Amate	*Ficus* spp.	Moraceae
Guachocote	*Malpighia mexicana*	Malpighiacea

Common name	Scientific name	Family
Tepame	*Acacia pennatula*	Fabaceae
Tzompantle	*Erythrina americana*	Fabaceae
Guayaba	*Psidium guajava*	Myrtaceae
Bonete	*Jacaratia mexicana*	Caricaceae
Huevo de gato	*Stemmadenia pubescens*	Apocynaceae
Nopal	*Opuntia* spp.	Cactaceae
Mata piojo	*Hippocratea acapulcensis*	Celastraceae
Mezquite	*Prosopis laevigata*	Fabaceae.
Carpinceran	*Dalbergia congestiflora*	Fabaceae
Ayoyote	*Thevetia thevetioides*	Apocynaceae
Quiebracho	*Lonchocarpus rugosus*	Fabaceae
Guamuchil	*Pithecellobium dulce*	Fabaceae
Encino	*Quercus castanea*	Fagaceae
Zopilote	*Swietenia humilis*	Meliaceae
Cazahuate	*Ipomea arborescens*	Convolvulacea
Chupandilla	*Cyrtocarpa procera*	Anacardiaceae
Quina	*Chinchona* spp.	Rubiaceae.
Cuajiote	*Bursera fagaraoides*	Burseraceae
Linaloe	*Bursera aloexylon*	Burseraceae
Pegahueso	*Euphorbia fulva*	Euphorbiaceae

The behavior of solar radiation in the canopy varied with the density of trees present. The highest RFA in the herbaceous stratum was found at the BDA sites, with this radiation being 25.1 and 55.8% higher than those registered at the sites with MDA and ADA, respectively ($p < 0.05$; Table 2). The production of forage biomass from the herbaceous stratum was directly proportional to RFA and inversely proportional to the tree density, the higher the radiation and the lower tree density, the greater the production of forage biomass from the herbaceous stratum.

Table 2. Photosynthetically active radiation (RFA), forage biomass production (PBF) and forage production rate (TPF) of the herbaceous layer in the traditional silvopastoral system of the Sierra de Huautla, Morelos.

Variables	BDA	MDA	ADA	EEM	*p* value
RFA (MJ m^2 $year^{-1}$)	8 594 ^{c}	6 437 ^{b}	3 801 ^{a}	364	<0.001
PBF (kg DM ha^{-1})	2 859 ^{b}	1 988 ^{ab}	1 679 ^{a}	330	<0.037
TPF (kg DM ha^{-1} d^{-1})	37.18 ^{b}	25.15 ^{a}	23.06 ^{a}	2.82	<0.001
DM (%)	27.7 ^{b}	23.6 ^{ab}	20.3 ^{a}	1.66	<0.006

^{abc}= means with different literal in the same row show significant differences ($p > 0.05$); ADA= high tree density (sites with 351 to 500 trees ha^{-1}); MDA= moderate tree density (sites with 201 to 350 trees ha^{-1}); BDA= low tree density (sites with 50 to 200 trees ha^{-1}).

The BDA sites, but with higher RFA in the herbaceous stratum, produced 30.5 and 41.3% more forage biomass than the sites located in MDA and ADA, respectively ($p < 0.05$; Table 2). The behavior of solar radiation in the canopy varied with the density of trees present. The highest RFA in the herbaceous stratum was found at the BDA sites, with this radiation being 25.1 and 55.8% higher than those registered at the sites with MDA and ADA, respectively ($p < 0.05$; Table 2).

The production of forage biomass from the herbaceous stratum was directly proportional to RFA and inversely proportional to the tree density, the higher the radiation and the lower tree density, the greater the production of forage biomass from the herbaceous stratum. Thus, the BDA sites, but with the highest RFA in the herbaceous stratum, produced 30.5 and 41.3% more forage biomass than the sites located in MDA and ADA respectively ($p < 0.05$; Table 2).

The maximum accumulation of forage biomass in the herbaceous stratum for the different tree densities was around the sixth sampling period, approximately 84 days after the start of the rainy season. Likewise, the forage production rate of the herbaceous stratum was 32.4 and 38.0% higher in the BDA sites, compared to the MDA and ADA sites, respectively ($p < 0.05$; Table 2).

Similar behavior was observed in the dry matter content of the forage biomass of the herbaceous stratum. Forage samples harvested at BDA sites had 14.8 and 26.7% more DM content compared to forage harvested at MDA and ADA sites, respectively ($p < 0.05$; Table 2).

Similar results to those obtained in the present study were reported by Acciaresi *et al*. (1994); Cruz *et al*. (1999); Fassola *et al*. (2006); Jose *et al*. (2008); Piñeros *et al*. (2011); Burner *et al*. (2018), who found higher forage yields in places without shade and in places with low levels of shade. Under ADA conditions, forage biomass production was affected due to less solar radiation reaching the herbaceous layer.

In contrast, in sites with BDA, where the incidence of solar radiation is higher, grasses and other forage that grow under the tree canopy show higher yield due to the higher rate of photosynthesis, since the flow of solar energy has direct relationship with forage production (Hernández and Guenni, 2008). Likewise, the RFA increased in the sites with the highest solar radiation, similar to that reported by Bernal *et al*. (2006) with the growth rate of native grasses in the oak forest of the state of Mexico.

Ribaski *et al*. (2002) report similar results when studying the availability and quality of buffel grass (*Cenchrus ciliaris*) in a silvopastoral system with carob (*Prosopis juliflora*) in the Brazilian semi-arid region. The forage produced under the carob tree presented higher nutritional value, characterized mainly by higher levels of crude protein. However, forage yield was lower. Ovispo *et al*. (2008) studied the effect of shading on the production and quality of guinea grass (*Panicum maximun*) in a silvopastoral system and found that the production and quality of the biomass of *Panicum maximum* was negatively affected by the level of shading. Different results were found by Piñeros *et al*. (2011) when studying the response of vidal grass (*Bothriochloa saccharoides*) to different simulated shade intensities in the Magdalena warm Valley in Tolima, Colombia.

The objective of these Colombian researchers was to analyze the biomass production and nutritional quality of vidal grass under shadow simulators, with percentages of 0% 30% and 50% shade, however, they did not find significant differences with respect to the percentages of shade in the yield and quality of the forage. This reflects that the productive behavior and nutritional quality of vidal grass are not affected by shading and confirm the tolerance to shade of some grasses described by other researchers (Bernal *et al*., 2006; Piñeros *et al*., 2011; Gargaglione *et al*., 2015).

The results of the identification of herbaceous plants that make up the forage mass that grows under the canopy in the different tree densities are presented in Table 3. For the BDA condition, 38 herbaceous species were recorded, although only 12 of them occupied 90.2% of the botanical composition of the study area, highlighting *Rhynchelytrum repens*, *Atheropogon radicosa*, *Brachiaria brizantha*, *Oplismenus burmanni* and *Andropogon citratus* corresponding to the Poaceae family, all of which are C4-type grasses that require higher light intensity.

Table 3. Floristic composition of the herbaceous layer in sites of low tree density BDA in the traditional silvopastoral system of the Sierra de Huautla, Morelos.

Species	Family	(%)		
		BDA	MDA	ADA
Oplismenus burmanni (Retz.) P. Beauv.	Poaceae	9.69	10.06	58.36
Tithonia tubaeformis (Jacq.) Cass.	Compositae	0.39	11.52	23.74
Setaria geniculata P. Beauv.	Poaceae	2.36	0.42	8.51
Simsia sanguinea A. Gray	Compositae	-	2.32	1.7
Bouchea prismatica (L.) Kuntze	Verbenaceae	0.53	0.47	1.05
Elytraria imbricata (Vahl) Pers.	Acanthaceae	-	0.16	0.83
Brachiaria brizantha (A.Rich.) Stapf	Poaceae	10.08	21.93	0.83
Acalypha sp.	Euphorbiaceae	-	0.67	0.6
Porophyllum ruderale (Jacq.) Cass.	Compositae	-	0.02	0.53
Desmodium procumbens (Mill.) Hitchc.	Leguminosae	-	0.37	0.36
Amaranthus sp.	Amaranthaceae	0.3	1.44	0.35
Commelina dianthifolia Delile	Commelinaceae	-	4.3	0.28
Jaltomata procumbens (Cav.) J.L. Gentry	Solanaceae	0.1	2.4	0.27
Justicia salviifolia Kunth	Acanthaceae	-	-	0.22
Heliocarpus pallidus Rose	Malvaceae	-	0.11	0.19
Clematis grossa Benth.	Ranunculaceae	-	-	0.15
Gaudichaudia albida Schltdl. & Cham.	Malpighiaceae	0.14	0.3	0.12
Dioscorea convolvulacea Cham. & Schltdl.	Dioscoreaceae	-	0.2	0.11
Cyperus iria L.	Cyperaceae	0.94	0.64	0.07
Euphorbia subreniformis S. Watson	Euphorbiaceae	0.54	1.07	0.04
Rhynchelytrum repens (Willd.) C. E. Hubb.	Poaceae	38.09	19.32	-

Species	Family	(%)		
		BDA	MDA	ADA
Bouteloua radicosa (E.Fourn.) Griffiths	Poaceae	16.3	5.65	-
Setariopsis auriculata (E.Fourn.) Scribn.	Poaceae	-	1.78	-
Florestina pedata (Cav.) Cass.	Compositae	2.23	1.42	-
Bidens riparia Kunth	Compositae	1.63	1.3	-
Nama origanifolium Kunth	Hydrophyllaceae	0.54	0.74	-
Crusea palmeri A. Gray	Rubiaceae	0.06	0.49	-
Lantana achyranthifolia Desf.	Verbenaceae	0.73	0.49	-
Sida glabra Mill.	Malvaceae	0.56	0.39	-
Ageratum corymbosum Zuccagni ex Pers.	Compositae	0.38	0.25	-
Ipomoea arborescens (Humb. & Bonpl. ex Willd.) G. Don	Convolvulaceae	-	0.25	-
Zornia diphylla (L.) Pers.	Leguminosae	0.41	0.25	-
Physalis sp.	Solanaceae	0.07	0.23	-
Dyssodia tagetiflora Lag	Compositae	-	0.12	-
Dalea sp.	Leguminosae	-	0.1	-
Crusea setosa (M.Martens & Galeotti) Standl. & Steyerm	Rubiaceae	0.21	0.07	-
Lepidium virginicum L.	Brassicaceae	-	0.07	-
Andropogon pertusus (L.) Willd.	Poaceae	-	0.07	-
Guazuma ulmifolia Lam.	Malvaceae	0.09	0.05	-
Melampodium sp.	Compositae	1.11	0.02	-
Oxalis sp.	Oxalidaceae	-	0.02	-
Andropogon citratus DC.	Poaceae	6.54	-	-
Bessera elegans Schult. f.	Asparagaceae	0.34	-	-
Bidens bigelovii A. Gray	Compositae	0.33	-	-
Tragoceros schiedeanus Less.	Compositae	0.33	-	-
Bidens odorata Cav.	Compositae	0.15	-	-
Heliotropium sp.	Boraginaceae	0.13	-	-
Mimosa albida Willd.	Leguminosae	0.07	-	-
Solanum deflexum Greenm.	Solanaceae	0.02	-	-
Heimia salicifolia (Kunth) Link	Lythraceae	0.07	-	-
Otras		4.70	8.6	1.7

It is evident that the intensity of solar radiation directly influences the composition and richness of herbaceous species in paddocks, herbaceous plants tolerant to a certain shade condition and those that require a higher incidence of light developing more easily. The first three herbaceous species *Rhynchelytrum repens* (38.1%), *Atheropogon radicosa* (16.3%) and *Brachiaria brizantha* (10.08%), are important foragers in the SBC of the study region, since they are used for livestock feeding.

For the MDA range, 48 herbaceous species were recorded that grow under the tree canopy (Table 3). Of these, only 25 species represent 90.2%, among which stand out: *Brachiaria brizantha*, *Rhynchelytrum repens*, *Tithonia tubaeformis*, *Oplismenus burmanni*, *Atheropogon radicosa* and *Commelina dianthyfolia*, belonging to the Poaceae, Asteraceae and Commelinaceae families; however, the percentages of grasses are lower than those observed in the BDA condition, which is explained by the lower incidence of sunlight reaching the herbaceous layer and allowing the growth of other herbaceous species other than grasses that are tolerant to certain levels of shade.

In the condition of (ADA; Table 3) 27 herbaceous species were registered under the tree canopy, of these, 90.7% correspond to *Oplismenus burmanni*, *Tithonia tubaeformis* and *Setaria geniculata*, belonging to the Poaceae and Asteraceae families. These results indicate that the different tree densities generate conditions for the development of species such as *Tithonia tubaeformis* (family Asteraceae), which changes the composition of herbaceous vegetation in the SBC (Larenas *et al*., 2004). Larenas and De Viana (2005) suggest that *Tithonia tubaeformis* is an important herbaceous as a remediator of contaminated soils, although its forage value is low.

The results indicate that the tree density, through modifying the light intensity that affects the herbaceous layer, imposes conditions for the development of the dominant herbaceous species that grow under the canopy of the trees present in the SBC (Larenas *et al*., 2004; Larenas and De Viana, 2005). Results similar to those of the present study in the Tuxtla region in the state of Veracruz, Mexico were reported by Lira *et al*. (2007); also, research carried out by Ruiz *et al*. (2001), determined the botanical composition of herbaceous species in a livestock production system with and without trees. These researchers found that the botanical composition of herbaceous plants under the canopy did not vary in paddocks with and without trees, however, they found that the greater the distance from the base of the tree, the percentage of type C4 grasses was higher, while the percentage of herbaceous broadleaf type C3 was greater at a shorter distance from the base of the trees.

In this way, the solar radiation that affects the herbaceous stratum influences the composition and floristic richness of the herbaceous plants in the pastures of the traditional silvopastoral system of the SBC of the Sierra de Huautla, Morelos, promoting greater abundance of herbaceous species tolerant to the shade cast by the trees present. These herbaceous species are of importance in livestock feeding, forming the mixture of forage plants with high nutritional value that satisfy the requirements in the daily diet of animals during the rainy season (Rosales, 1999).

Although the shading of the trees offers conditions for the greater diversity of species in the herbaceous stratum, it is also true that the forage yield decreases with increasing tree density in the traditional silvopastoral system of the Sierra de Huautla. This encourages producers to clear existing vegetation for the establishment of pure pastures, with serious consequences for the stability of the SBC, due to decreased biodiversity, soil erosion, deterioration of hydrological basins and degradation of pastures.

Conclusions

There was a marked difference in the amount of RFA reaching the herbaceous stratum in the different tree densities of the traditional silvopastoral system of the Low Deciduous Forest of the Sierra de Huautla, Morelos, which affected the floristic composition and growth of the herbaceous species that grow under the canopy of trees. Forage biomass production of herbaceous species growing under the tree canopy was higher in the BDA condition compared to dry matter production.

Obtained under MDA conditions, due to the greater amount of RFA available for the growth of herbaceous plants. The maximum yield of forage herbaceous plants that grow under the tree canopy is around 84 days after the start of the rains, which can contribute to establishing rational grazing systems with two or three periods of occupation during the rainy season in the cattle ranches of the traditional silvopastoral system of the Sierra de Huautla, Morelos.

The study of the shade produced by the trees presents questions that do not allow us to reach definitive conclusions about the phenomenon. It is suggested to delve into the subject studied to develop a higher quality herbaceous plant layer for livestock feeding in the traditional silvopastoral system of the Sierra de Huautla, Morelos.

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