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Productive, morphological and qualitative characteristics of sugarcane in the understory tree species in agroforestry systems

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This study aimed to evaluate productive, morphological and qualitative characteristics of sugarcane in the understory tree species in two agroforestry systems. The study was conducted in the city of Frederico Westphalen, RS, in a randomized complete block design, characterized by a factorial arrangement of 2x5x3, that is, two agroforestry systems (strip and line), five tree species (angico, bracatinga, canafístula, eucalypt and guapuruvu) and three years of sugarcane cultivation (2009, 2010 and 2011), with three replications. The weight, length and stem diameter, number of nodes, Brix degree, juice volume, amount of sucrose, and how these factors are related to the interception of photosynthetically active solar radiation by the tree components in each system were evaluated. The interception of photosynthetically active solar radiation by tree components is smaller in the strip system, but increased over the years of sugarcane cultivation. Among the tree species, eucalypt is responsible for the highest values of interception. When grown in the understory of angico, bracatinga and canafístula, sugarcane presents greater length, diameter and stem weight, juice volume and amount of sucrose, mainly from the second cultivation year than when under the other tree species. The cultivation of sugarcane in the strip system resulted in an increased stem weight and juice volume from the second year of cultivation.

Key words: *Saccharum officinarum* L., solar radiation, shading, stem weight.

INTRODUCTION

One of the biggest challenges of agriculture in Brazil is managing the balance between crop production and

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environmental preservation. In order to achieve this balance, it is necessary to meet the demand for food and energy without compromising existing agro-ecosystems which can be used in order to achieve these objectives. These systems may consist of integrated use of land for (Godfray et al., 2010). Agroforestry systems deserve highlight in this scenario and are a promising strategy, forestry purposes, crops and livestock. This integration has brought numerous socio-economic, environmental and production benefits, such as the recovery of degraded areas, reduced production costs, and an increased input of organic matter, which has been shown to improve chemical, physical and biological properties of soil (Tracy and Zhang, 2008; Neves et al., 2009; Salton et al., 2013).

The insertion of sugarcane (*Saccharum officinarum* L.) in agroforestry systems can be an interesting alternative, due to its socio-economic importance in Brazil; in addition, the monoculture system is predominant for this culture and because of this predominance, it is becoming increasingly important to consider alternative production systems, which aim to preserve natural resources. These systems can provide an alternative to the cultivation of sugarcane in areas unsuited to mechanized harvesting, and considering ecological, agronomic and socioeconomic aspects, such methods may be more ideal for family farmers who may have small area of cultivation as an alternative source of income.

The growth and development of different species in the same area, such as in agroforestry presupposes the existence of dynamic interactions and change over time especially in areas which include trees; given their continued growth in height, crown projection, and the leaf area index, which can modify the distribution of existing resources. These tree interactions can be a source of a constant change in the productivity of both species system (José et al., 2004).Solar radiation, which is to be intercepted by the canopy of the arboreal components of these agroforestry systems can be absorbed, transmitted and reflected in varying proportions depending on the angle of incident sunlight and structural features of plants. The spatial arrangements of plants can include the arrangement of the leaves, leaf insertion angle, leaf area index and various optical properties of vegetation. The radiation transmitted by the canopy is only available to plants beneath the canopy, and can be propagated in a direct or diffuse way. The interactions of the transmitted solar radiation influence the internal microclimate of intersystem vegetation, which can have an effect on the morphological, physiological and nutritional aspects of this species in the understory, thereby affecting growth (Paciullo et al., 2011; Mendes et al., 2013).

The study aimed to evaluate productive, morphological and qualitative characteristics of sugarcane and relate them to the interception of photosynthetically active solar radiation in the understory of five tree species in two arrays of planting in agroforestry systems.

MATERIALS AND METHODS

The study was conducted in the experimental area belonging to the Agroclimatology Laboratory, linked to the Federal University of Santa Maria campus in Frederico Westphalen– RS, with geographical location at 27°22’S, 53°25’W at 480 m of altitude. According to the Köppen climate classification, the climate is CFA, that is, humid subtropical with average annual temperature of 19.1°C, varying with maximum of 38°C and minimum of 0°C. The soil of the area is classified as typical Entisol Orthents (Cunha, 2011). The values of soil chemical properties were: pH in water = 5.8; available phosphorus (Mehlich^{-l}) = 2.9 mg dm^{-3}; aluminum = 0.0 cmol$_c$ dm^{-3}; potassium = 82.5 mg dm^{-3}; calcium = 8.7 cmol$_c$ dm^{-3} and magnesium = 2.8 cmol$_c$ dm^{-3}. Fertilization was performed according to the recommendations made by the CQFS (2004).

The experimental design was a randomized complete block design, characterized by a factorial arrangement of 2x5x3, that is, two agroforestry systems, strip and line, five tree species, angico (*Parapiptadenia rigida* (Benth.), bracatinga (*Mimosa scabrella* Benth.), canafístula (*Peltophorum dubium* (Spr.) Taubert), eucalypt (*Eucalyptus urophylla* S.T. Blake x *Eucalyptus grandis* Hill ex Maiden) and guapuruvu (*Schizolobium parahybae* (Vell.) Blake) and three years of sugarcane cultivation. The first evaluation of sugarcane occurred in 2009, the second in 2010, and the one third in 2011, cultivar IAC 87-3396. In each repetition, ten experimental units were randomly assigned to the combination between agroforestry system and tree species.

Forest species were planted in the field in September and the sugarcane in November 2007; the process occurred through the manual planting of seedlings and cuttings, after plowing and harrowing. In the strip system (SS), the forest species were divided into separate strips by 12 m, each was composed of three lines, in which the plants were spaced at 3x3 m. The sugarcane was distributed in six lines (between strips, 12 m in space) and two lines in strips (between lines of trees). In the line system (LS), forestry species were distributed at 6x1.5 m spacing, or 6 m between lines and 1.5 m between plants in the line, and the sugarcane distributed in three lines (among lines of trees).

In both systems, the sugarcane had 1.20 m spacing and a density of 18 buds per meter, with both trees and sugarcane oriented in lines towards the East and West. After planting sugarcane, plots were delineated to have two meters in length, and were distributed at different points in the understory of each experimental unit. These plot areas were chosen with the intention to represent existing microclimate conditions in the areas under the canopy of each tree species and agroforestry system. For subsequent analysis of the data, average values of the lines in each system were calculated in order to comply with objectives of the study, which is the recommendation of the best system and species in different years of assessment. The arrangement of trees, sugarcane and plot of evaluation are shown in Figure 1.

The samples were collected in June 2009 (about one and half years after planting), 2010 and 2011, constituting the three years of sugarcane. In each marked line, two medium stalks were collected which were taken to the laboratory for evaluation. For the existing population in the experimental units, values were extrapolated for one hectare (ha).

The stalk weight (SW, t ha^{-1}) was obtained with the aid of a digital scale and stalk length (SL, m) by means of a measuring tape, the length being considered from the basal portion to the intersection of the youngest leaf sheath. The stalk diameter (SD, mm) was determined by measuring three points in the same basal medium and higher, and then the arithmetic means were obtained. The number of nodes (NN) was obtained by the total count of nodes in each stem of evaluation.

The juice volume (JV, m^3 ha^{-1}), was obtained from milling the stalk, and was measured with the aid of a graduated cylinder with a capacity of 1 L. By JV, samples were taken to determine the Brix

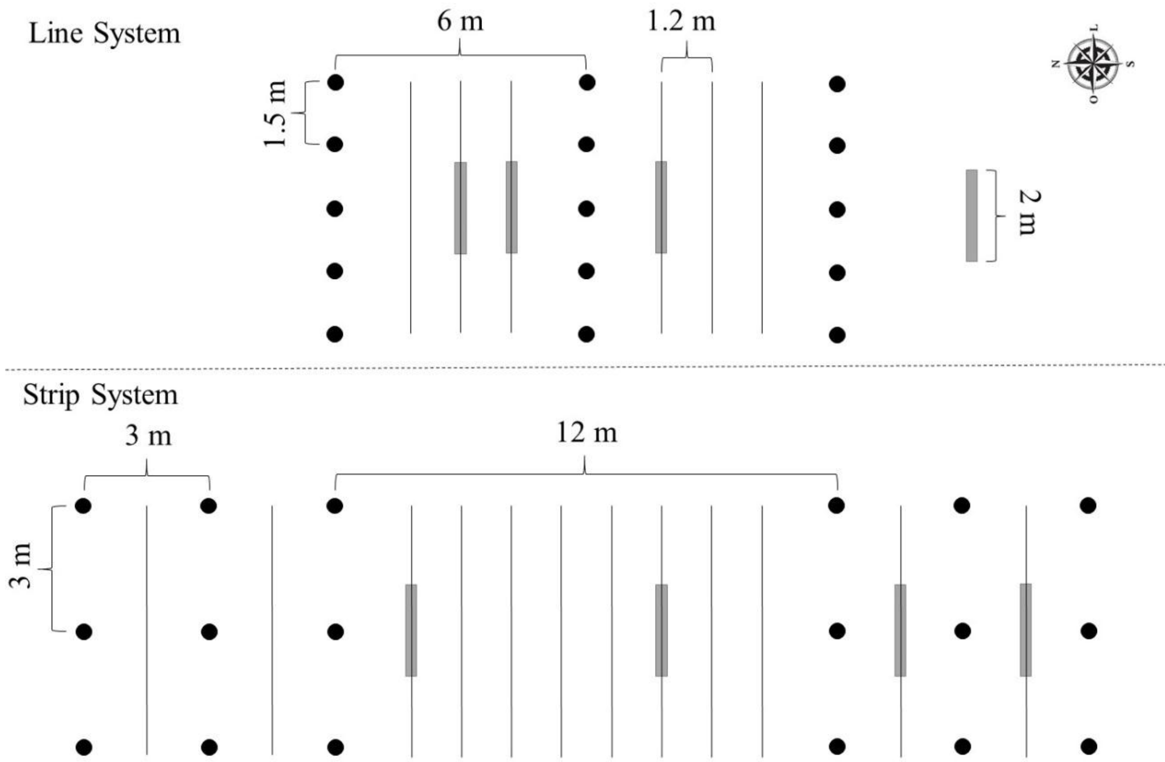

Figure 1. A sketch of an experimental unit of line and strip systems. Black circles represent the trees; continuous lines indicate where the sugarcane was planted, and the rectangles in gray represent the annual evaluation plots of sugarcane.

degree by means of an automatic digital refractometer Acetec RDA 8600. The sucrose concentration (SC, g L^{-1}) was determined using the equation proposed by Torres et al. (2006):

$$SC = \text{Brix degree} \times 10.13 + 1.445 \quad (1)$$

Where, SC = sucrose concentration (g L^{-1}).
The sucrose quantity (S, t ha^{-1}) was determined from the values of SC and JV, by the following expression:

$$S = SC \times JV / 1000 \quad (2)$$

Where, S = sucrose quantity (t ha^{-1}); SC = sucrose concentration (g L^{-1}); JV = juice volume (m^3 ha^{-1}).
Photosynthetically active radiation (PAR) was obtained at harvest over the three years of evaluation, with the aid of a quantum sensor LI-190-1, with spectral strip of 400-700 nm, coupled to a porometer dynamic balance LICOR-LI1600 model. From this, the interception of photosynthetically active radiation was determined (IPAR) by canopy tree species, according to the equation proposed:

$$IPAR (\%) = [100 - (Rn \times 100/Rt)] \quad (3)$$

Where, Rn = photosynthetically active radiation inside the canopy of the tree species; R_t = photosynthetically active radiation inside the canopy of the tree species.

The height values (H), diameter at breast height (DBH) and average crown diameter (MDC) of forest species at harvest of each year of sugarcane cultivation were collected for characterization purposes of the conditions existing in the experimental area (Table 1). They were obtained with the aid of a Hypsometer Vertex III, tape measure and graduated tape, respectively.

The values of meteorological elements during the experiment were obtained from the Climatological Station INMET (National Institute of Meteorology) linked to Agroclimatology Laboratory (UFSM), which is located about 1500 m from the study site at coordinates 27° 39'S and 53° 43'W. The data was statistically analyzed with the software “Statistical Analysis System” (SAS, 2003), and the results were obtained through the analysis of variance, F test and Tukey test ($p > 0.05$). The Bartlett test was used to verify the homogeneity of variances.

RESULTS AND DISCUSSION

Average monthly maximum, minimum temperature, monthly accumulation of precipitation and solar radiation during the study are shown in Figure 2. The annual average minimum and maximum temperatures were 18.5 and 19.9°C in 2008; 18.7 and 20.1°C in 2009; 18.4 and 19.8°C in 2010; 18.4 and 19.8 °C in 2011. The cumulative annual rainfall for these respective years was 1606.20, 2246.60, 1978.40 and 2229.40 mm. The accumulated global radiation flux averaged 513.4, 501.1, 504.9 and 516.2 MJ m^{-2} $month^{-1}$ in 2008, 2009, 2010 and2011, respectively. These values varied in the same order, from 265.6 to 806.6; 302.7 to 722.1; 275.92 to 717.9 and 258.9 to 808.5 MJ m^{-2} $month^{-1}$.

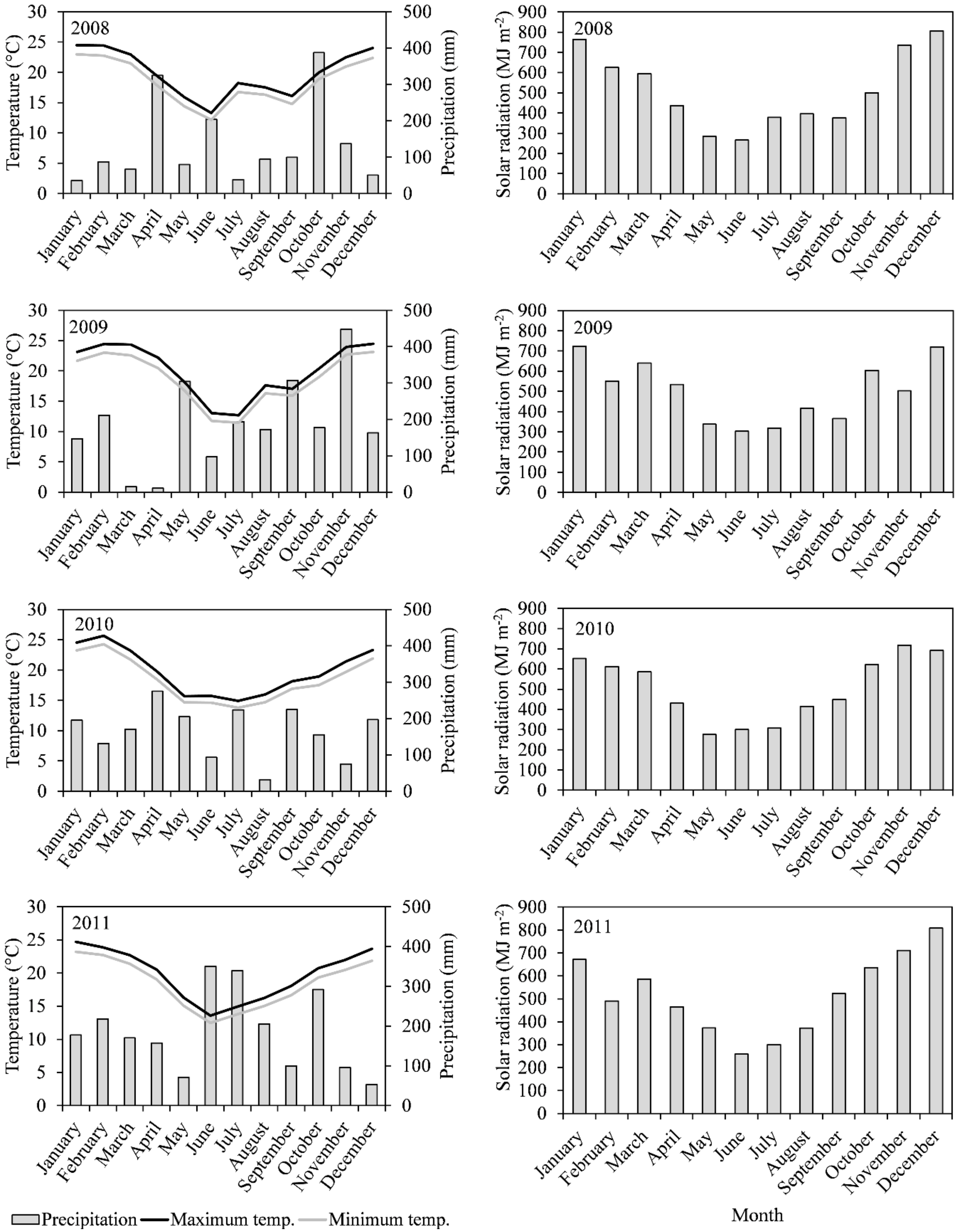

Figure 2. Average monthly maximum and minimum temperature; precipitation and cumulative monthly global solar radiation during the years, 2008, 2009, 2010 and 2011 in the city of Frederico Westphalen for the whole study period.

Table 1. Height (H), diameter at breast height (DBH) and mean diameter of crown (MDC) of forest species at harvest of each year of sugarcane cultivation, in agroforestry systems strip and line.

Variable	Species	Years					
		2009		2010		2011	
		Strip	Line	Strip	Line	Strip	Line
H	Angico	2.42	2.19	3.56	4.01	3.58	3.56
	Bracatinga	3.24	3.00	4.04	4.06	3.78	5.60
	Canafístula	2.40	2.27	3.60	3.14	4.29	4.82
	Eucalypt	6.82	6.24	10.90	10.14	15.34	14.06
	Guapuruvu	1.75	1.96	2.62	4.03	3.18	4.58
DBH	Angico	1.61	1.54	2.80	3.21	3.71	4.58
	Bracatinga	2.53	2.41	4.14	3.30	3.43	4.57
	Canafístula	2.05	1.94	4.35	3.82	4.71	4.88
	Eucalypt	6.83	5.20	12.35	9.31	16.64	12.16
	Guapuruvu	3.00	3.94	6.37	8.91	6.15	8.42
MDC	Angico	0.99	0.65	1.5	1.25	2.34	1.74
	Bracatinga	1.56	1.36	1.58	1.95	1.62	1.98
	Canafístula	1.10	1.00	1.35	1.22	1.86	1.75
	Eucalypt	2.79	2.11	3.08	2.74	4.67	4.16
	Guapuruvu	1.98	1.90	2.48	1.64	2.74	2.95

The analysis of variance revealed differences in the IPAR, SL, SD, SW, JV and S for interactions between tree species x year of sugarcane cultivation and IPAR, SW and JV for agroforestry system x year of sugarcane cultivation. All the tree species showed an increase of IPAR over the growing year of sugarcane (Table 2), except bracatinga, where values between 2010 and 2011 (first and second year, respectively) showed no difference.

Comparing all the species, eucalypt was responsible for the higher values in 2009 and 2011, and did not differ from canafístula in 2010. Angico had the lowest percentage of IPAR in the first two years (2008 and 2009). Bracatinga had the lowest percentages of IPAR in the third year. These variations are related to an increase of the MDC of tree species (Table 1) which increased leaf area and intercept a larger quantity of solar radiation. Similarly, for bracatinga, this small variation in IPAR was influenced by reduced growth in MDC from 2010 to 2011.

The IPAR values are similar to those found by Caron et al. (2012) in between planting lines of from 42.3% in black wattle, 83.2% in bracatinga and 89.1% in eucalypt trees with one year old. In the case of agroforestry systems, the amount of radiation intercepted by the tree component can be considered a determining factor of their deployment in the understory since the radiation transmitted inside the canopy of tree plants should be sufficient for growth and development. The evaluation of dynamic radiation of forestry species and systems is not a widespread practice in scientific circles yet. Another study was carried out by Pezzopane et al. (2015) and Bosi et al. (2014) who reported on high relation between levels of incident solar radiation, and its effect on microclimate, growth characteristics of plants and soil moisture in areas with high rations

During crop cycles, there is an increase in the overall radiation interception, followed by an increase in leaf area index (LAI), but only up to a certain value when full canopy closure is reached, due to leaf self-shadowing (Posada et al., 2012). At this point, the issue of new leaves does not result in an increased amount of light interception. In the case of this study, it can be noted that, maximum IPAR may not be present for up to four years after planting since there was an increase of this variable every year, without stabilization trend (Table 2). The response of plants to shade varies depending on the species, and the degree of shading. According to Varella et al. (2010), percentages of transmission below 50% can harm the growth and development of fodder of temperate climate. Bosi et al. (2014) found that silvopastoral systems with native trees, indicated shading greater than 39% which affected the productivity of the species, *Urochloa decumbens*. Baruch and Guenni (2007) stated that shading levels above 35 to 40% can affect the growth of most tropical grasses.

The SL of sugarcane when grown in the understory of angico, canafístula and eucalypt remained stable over the cultivation years (Table 2). Under bracatinga, higher means were found in the past two years. The angico understory showed higher SL values in the first year,

Table 2. Interception of photosynthetically active radiation (IPAR), stem length (SL), stem diameter (SD), stem weight (SW), juice volume (JV) and amount of sucrose (S) of sugarcane grown in the understory of various tree species from 2009 to 2011, in the city of Frederico Westphalen - RS.

Variable	Species	Years of sugarcane cultivation		
		2009	**2010**	**2011**
	Angico	27.02^{dC}	40.46^{cB}	46.43^{eA}
	Bracatinga	46.67^{cB}	56.41^{bA}	58.74^{dA}
IPAR (%)	Canafístula	50.98^{bC}	68.81^{aB}	73.3^{bA}
	Eucalypt	56.41^{aC}	65.06^{aB}	89.74^{aA}
	Guapuruvú	47.78^{bcC}	55.23^{bB}	67.66^{cA}
	Angico	1.51^{aA}	1.74^{aA}	1.52^{bA}
	Bracatinga	1.22^{bB}	1.78^{aA}	1.81^{aA}
SL (m)	Canafístula	1.19^{bB}	1.63^{aA}	1.56^{abA}
	Eucalypt	1.24^{bA}	1.25^{bA}	1.20^{cA}
	Guapuruvú	1.27^{bB}	1.64^{aA}	1.30^{bcB}
	Angico	21.97^{aA}	20.95^{abA}	20.68^{bA}
	Bracatinga	19.37^{bB}	23.35^{aA}	23.31^{aA}
SD (mm)	Canafístula	19.44^{bA}	20.34^{bA}	21.14^{abA}
	Eucalypt	19.80^{bA}	17.09^{cB}	18.55^{cAB}
	Guapuruvú	20.53^{abA}	19.41^{bcAB}	18.19^{cB}
	Angico	61.89^{aA}	53.08^{aA}	41.56^{abB}
	Bracatinga	26.56^{cB}	50.44^{aA}	50.52^{aA}
SW (t ha^{-1})	Canafístula	30.44^{bcA}	36.19^{bA}	35.26^{bA}
	Eucalypt	30.48^{bcA}	14.81	15.20
	Guapuruvú	36.42^{bA}	36.25	18.04
	Angico	30.11^{aA}	25.77	19.68
	Bracatinga	15.34^{bB}	24.97	25.10
JV (m^3 ha^{-1})	Canafístula	16.59^{bA}	16.60	17.06
	Eucalypt	17.45^{bA}	5.94	6.80
	Guapuruvú	18.74^{bA}	17.11	7.37
	Angico	5.05^{aA}	4.88	3.79
	Bracatinga	2.32^{bB}	4.75	4.94
S (t ha^{-1})	Canafístula	2.76^{bA}	3.28	3.24
	Eucalypt	2.39^{bA}	1.09	1.27
	Guapuruvú	2.86^{bAB}	3.46	1.26

Means followed by the same letter, lowercase in the column compare the species in each year and uppercase letters in each line compare the years for each species, the means do not differ among themselves by Tukey test of probability at 5% of error.

probably due to reduced IPAR (27.0%) as compared to other species. In the second year, this difference was not observed; instead, in the third year, only lower averages were observed in the cultivations located in the understory of eucalypt and guapuruvu. According to Abreu et al. (2007) values of 1.80; 1,.70; 1.88; 1.92; 1.87 e 1.85 m were found for the cultivars IAC 86-2210, IAC 86-2480, IAC 93-6006, SP 81-3250, IAC 87-3396, RB 72-454, respectively, in the city of Barbacena/Minas Gerais, 15 months after planting.

Similarly, one can observe a reduction in SD from 2010 for the understory of Eucalypt and guapuruvu, and similar medians for angico and canafístula, respectively between the years (Table 2). In this context, Guiselini et al. (2013) analyzed the acclimation of sugarcane seedlings in greenhouse under two types of shading screens, found a limitation of SL and SD of the sugarcane when grown in an environment with less availability of solar radiation. This feature was not observed in bracatinga understory, where levels were higher in the last two years.

Cultivars grown under eucalypt negatively affected SW in the second year of cultivation, as compared with the first, where SW was not strongly effected (Table 2). In addition, for in bracatinga understory, even with increasing solar radiation over the years and an increase in tree components' crown diameter, SW increased in the second and third cultivation year (Table 1). Abreu et al. (2013), working with five varieties of sugarcane, found the following SW averages: 89 t ha^{-1} in first year, 75 t ha^{-1} in second year and 88 t ha^{-1} in the third year in Tabuleiros Costeiros/Alagoas. Torres et al. (2006) found mean values of 64.5 t ha^{-1} for cultivation of SP79-1011 in the first year in the city of Capim/Paraíba. The values recorded in the aforementioned article are higher than those found in this study; however, this may be due to the variety used, the site of cultivation, weather conditions occurring in each cultivation cycle and, in this case, the amount of radiation available for the sugarcane cultures.

This last factor can be observed in this study, where the SW of sugarcane when cultivated under the eucalypt in the third cultivation year (152 t ha^{-1}) was decreased by 63.4% when compared with the angico (41.6t ha^{-1}) and 69.9% as bracatinga (50.5t ha^{-1}); whereas IPAR values in this cultivation year were 89.7% for eucalypt, 46.4 and 58.7% for the angico and bracatinga, respectively. This reduction in the SW of sugarcane may due to the fact that morphophysiological adjustments, as to shade tolerance strategy, were not able to compensate the radiation reduction in Eucalypt understory conditions (Paciullo et al., 2011). By comparing the species, it can be seen that SW values were higher in the cultures under angico in the first cultivation year. In the second and third years, this characteristic was observed to be greater for both angico and bracatinga (Table 2).

The JV of sugarcane grown under the angico and guapuruvu remained stable until the second cultivation year (2010), and were subsequently reduced (Table 2). This decrease was also observed in the second year for eucalypt; however, an opposite behavior was seen in the understory of bracatinga whose JV values increased from the second year and remained similar in the third year. In the analysis between species, higher means was found in cultivation under angico in the first year and, under angico and bracatinga in the second and third year. In third year, intermediate values were observed under canafístula and lower under the eucalypt and guapuruvu.

The average S showed no difference over the cultivation years in the understory of tree species angico, eucalypt and canafístula (Table 2). This result indicates greater stability in the metabolic activity of sugarcane when subjected to shading. In this regard, Caron et al. (2014) found that the production of *Ilex paraguariensis* (leaves + branches) is higher in unshaded cultivations when compared with shaded cultivations. Taking into account the content of some nutrients (calcium, magnesium and phosphorus) in these plant, minor variations were observed in low light conditions (85% shading) for different times of the year which may indicate a more constant level of metabolic activity of the studied plants, and be considered an important factor in the final product quality.

The S of sugarcane in the understory of bracatinga was higher in the last two years, since when grown under guapuruvu, the highest averages were found in the second year, even with the IPAR of 55.2%. In the third year, the S values declined, since the IPAR increased to almost 70%. It can be seen that both the highest values of treatment with guapuruvu were seen in the second year, and for bracatinga in the last two years, the radiation interception remained in the range of 55-60%. In this respect, Paciullo et al. (2011) found that the shading caused a positive effect on crude protein species, *Urochloa decumbens* grown in the understory of *Acacia mangium*, *Acacia angustissima*, *Mimosa artemisiana* and *Eucalyptus grandis.*

Another important aspect to be emphasized is that the lower amounts of solar radiation inside the canopy, due to the interception of it through the canopy, may have been offset by the increase of diffuse radiation in this environment. This fraction of the radiation has the characteristic of being multidirectional and better penetrate inside the canopy (Buriol et al., 1995), promoting more efficient use of solar radiation. However, this increase in efficiency can often not compensate for the reduction in photosynthetic rate, since there is a smaller amount of solar radiation available under the tree species.

IPAR between systems demonstrated the difference of this the first year (Table 3), but this difference did not affect the SW and JV. This variation was observed in the last two years (2010 and 2011), where the strip system was responsible for the greatest values of both productive variables of sugarcane. This system provided higher SW in the second year of cultivation, where the IPAR was 48.9%. Except in this case, the SW and JV did not show difference between the first two years, while the third was reduced.

In the strip system, likely due to the spacing of 3 m between lines and between plants, and 12 m between trees strips, there was lower IPAR as compared to the line system in which the plants were spaced every 1.5 m and the spacing between lines of trees was 6 m. Consequently, the smaller IPAR in strip system led to greater transmissivity of solar radiation into the canopy, which was crucial to the larger SW and MS values.

In addition, the greater proximity to the root systems of trees in the line system may have intensified the competition in the system. Whereas, IRFA values were already higher in the first year, it is assumed that this system demonstrated a closing between lines faster than

Table 3. Photosynthetically active radiation interception (IPAR), stem weight (SW) and juice volume (JV) of sugarcane in agroforestry systems of strip and line for three years of sugarcane cultivation (2009, 2010 and 2011) in the city of Frederico Westphalen - RS.

Variable	System	Years of sugarcane cultivation		
		2009	2010	2011
IPAR (%)	Strip	40.78^{bC}	48.86^{bB}	59.980^{bA}
	Line	50.78^{aC}	65.53^{aB}	74.37^{aA}
SW (t ha^{-1})	Strip	39.304^{aB}	48.891^{aA}	40.180^{aB}
	Line	35.014^{aA}	27.414^{bAB}	24.054^{bB}
JV (m³ ha^{-1})	Strip	20.888^{aAB}	24.071^{aA}	19.439^{aB}
	Line	18.340^{aA}	12.082^{bAB}	10.969^{bB}

Means followed by the same letter, lowercase in a column compare the system in each year and uppercase in each line compare the years in each system, the means do not differ among themselves by Tukey test of probability at 5% of error.

the strip system, which can be justified by its closer spacing. This may also have not been sufficient to influence the MC and VS sugarcane in his first crop, however, demonstrated influence on subsequent years.

From the results obtained, it can be observed that the productive, morphological and qualitative characteristics, with the passing of sugarcane cultivation years, presented numerous variations, which are strongly influenced by tree species and agroforestry arrangement. The fact of the characteristics, especially productive characteristics (SW, JV, S), are relatively minor as compared to other studies, this does not prevent successful cultivation of sugarcane in these systems. The study sought to provide new sustainable alternatives for farmers, in order to increase the diversification of the rural property and maintain the preservation of existing agro-ecosystems.

Conclusions

The interception of photosynthetically active solar radiation by tree components is lower in the strip system, but increases over the years of sugarcane cultivation. Among the tree species, eucalypt is responsible for the highest values of interception.

When grown in the understory of angico, bracatinga and canafístula, sugarcane presents greater length, diameter and stem weight, juice volume and amount of sucrose, mainly from the second cultivation year than when under the other tree species. The cultivation of sugarcane in the strip system resulted in an increased stem weight and juice volume, from the second year of cultivation.

Conflict of Interests

The authors have not declared any conflict of interests.

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