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CROP PRODUCTION

Shadowing of a bioenergetic species in soybean development: an analysis of the feasibility potential of this integration

Natanielly Rodrigues Avelino[1*], Leonardo José Motta Campos[2], Danilo Marcelo Aires[3], Ricardo Siqueira da Silva[4] and Anderson Barbosa Evaristo[1]

[1]Universidade Federal dos Vales do Jequitinhonha e Mucuri, Campus Unaí, Av. Universitária, 1000, 38610-000, Unaí, Minas Gerais, Brazil. [2]Empresa Brasileira de Pesquisa Agropecuária, Embrapa Pesca e Aquicultura, Palmas, Tocantins, Brazil. [3]Universidade Estadual do Tocantins, Palmas, Tocantins, Brazil. [4]Universidade Federal dos Vales do Jequitinhonha e Mucuri, Campus JK, Alto da Jacuba, Diamantina, Minas Gerais, Brazil. *Author for correspondence. E-mail: natanielly.avelino@ufvjm.edu.br

ABSTRACT. There is currently a lack of information in the literature on the integrated production of macauba (*Acrocomia aculeata*) and soybean (*Glycine max*) crops, and the importance of expanding integrated production systems; therefore, the objective of this work was to identify the effects of macauba shading on growth, development, and productivity of different soybean cultivars. The experiment was carried out in a randomized block design in a factorial scheme (4 × 2), with four cultivars and two production systems (monoculture and crop-forest integration), and four replicates per treatment. All soybean cultivars in the crop-forest integration system showed plant stagnation due to the shade level of the palm trees, as well as a reduction in the leaf area index and chlorophyll content in the leaves. Regarding reproductive parameters, grain, and oil yield, the cultivars responded differently between the production systems, revealing an interaction between the genotype and the environment. Our methodology was not favorable to soybean production; therefore, the management of spacing between palm trees and the selection of soybean genotypes that are more adapted to shaded environments are strategies that can allow for the integrated production of these species.

Keywords: *Glycine max*; *Acrocomia aculeata*; silviagriculture systems; crop-livestock-forest integration; macauba.

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Introduction

Soybean (*Glycine max* (L.) Merrill) is one of the most cultivated crops worldwide, and has become the main Brazilian export in recent years (CONAB, 2020). Its production is destined for different industry sectors, with emphasis on grain processing to obtain oil and bran that is used in human and animal nutrition, and for the manufacture of biofuels (Souza, Marques, Souza, & Marra, 2010). Currently, soybean cultivation in Brazil is performed using different production systems, which are classified by the complexity and degree of interaction between the cultivation and breeding systems (Balbino et al., 2011). New models of the organization of the agricultural production structure have started to be implemented, seeking to increase productivity while still preserving the environment.

Integrated crop-livestock-forest systems (ICLF) have the principle of diversifying the activities carried out in the same area through consortium, rotation, or succession, promoting improvements in the soil and the use of nutrients, and reducing pressure by opening new areas for diversification and stabilization of producer income (Alvarenga, Porfírio, Gontijo Neto, Viana, & Vilela, 2010; Balbino et al., 2011; Gontijo Neto et al., 2014). When ICLF is adopted in the Cerrado biome, corn, sorghum, soybean, and rice are the most commonly used crops (Vilela et al., 2011). It is worth mentioning that studies with legumes in this system are still incipient; therefore the use of soybeans in ICLF should be more widely studied for better recommendations.

The integrated crop-forest (ICF) or silviagriculture system is an ICLF characterized by the intercropping of agricultural and forestry crops (Balbino et al., 2011; Nair, 1985). Several species can be used as the forest component of ICLF, particularly *Acrocomia aculeata* palm, known as macauba (Moreira et al., 2018; Nobre, Trogello, Borghetti, & David, 2014). Macauba is a promising species because of its potential for the production of biofuels and the diversity of co-products with added energy value (Evaristo et al., 2016; Lanes, Costa, & Motoike, 2014). Macauba is a rustic species widely distributed in Brazil (Cardoso, Santos, Favaro, Diniz, & Sousa, 2020), with extraction being the main means of its exploitation. The exploration of the macauba palm should be expanded through the implementation of high-yield production systems because of its agronomic potential.

In integrated production systems, such as ICLF, the association of different species can promote synergistic effects. Tree components can contribute to mitigating the climatic effects on crops in years of adverse climate by reducing fluctuations in air and soil temperatures, soil moisture, and wind speed close to the soil surface (Böhm, Kanzler, & Freese 2014; Lin, 2007). In addition, the use of palm trees such as macauba as arboreal components favors understory culture, as their leaf and canopy architecture allow light to enter the understory, without completely shading it. Similarly, crops grown in the understory, such as soybeans, can benefit tree species in this production system, since soybeans grown in integrated production systems contribute to the enrichment of soils with nitrogen (N) due to the association with bacteria of the genus *Bradyrhizobium* (Schreiner, 1989), as well as with the absorption and use of phosphorus, nitrogen, and potassium (Fan et al., 2020).

With ICLF, different planting patterns result in different light environments in the understory, which consequently affects soybean productivity (Yang et al., 2015), as plant growth and development can be altered by shading (Kurepin et al., 2012). However, soybean cultivars have high plasticity, a characteristic that allows them to adapt to the conditions of the environment in which they are cultivated through changes in morphology and yield components (Pires, Costa, Thomas, & Maehler, 2000; Zhu, Werf, Anten, Vos, & Evers, 2015). Soybean cultivars grown in a low-light environment can change their developmental pattern from the beginning of the stress period to reduce the negative effects of shading (Wu et al., 2017).

Given the importance of soy cultivation in Brazil and the lack of information regarding the use of the macauba palm as a forest component of a crop-forest integration system, the objective of this study was to identify the effects of shading on the growth, development, and productivity of soybean cultivars from different groups based on maturation and growth habits. The hypothesis is that there is phenotypic variability between soybean cultivars when grown in shaded environments, promoting morphophysiological changes that alter performance between cultivars in these environments.

Material and methods

The field research was conducted in Palmas, Tocantins State, Brazil (10°29′02″ S, 8°20′05″ W, 247 m), in the 2016/2017 crop in a randomized block design, with treatments configured in a 2 × 4 factorial scheme (two production systems and four soybean cultivars) with four replications. The climatic data for the experimental period are shown in Figure 1.

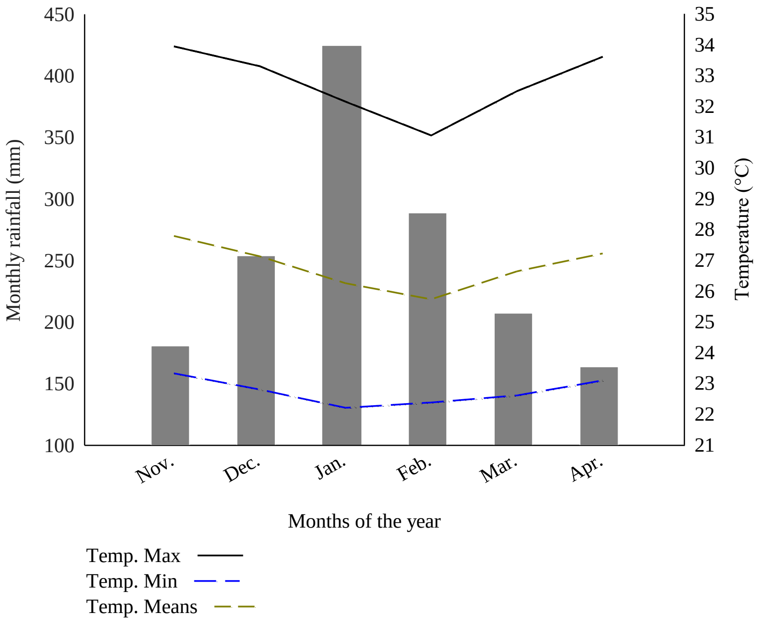

Figure 1. Climatic data for the 2016/2017 harvest. Precipitation data (mm) and maximum, means, and minimum temperature (°C) data for November and December 2016 and January to April 2017.

The production systems evaluated were an integrated crop-livestock-forest (ICF) and a monoculture (M). The soybean cultivars used were: M8644 IPRO, maturation group 8.6 and type of growth determined; ST797 IPRO, maturation group 8.6 and type of growth undetermined; Desafio RR, maturation group 7.4 and type of growth undetermined; and TMG 1288 RR, maturation group 8.8 and type of growth determined. In the ICF system, the tree species used was the macauba palm, planted in March 2009 in 6 × 5 m spacing with rows arranged in a north-south direction. During the experiments, the palm trees had an average height of 3.9 m and an average canopy projection diameter of 5.03 m.

The soil preparation for the cultivation of soybeans in both production systems started 90 days before sowing. Soil correction and fertilization recommendations were made according to the nutritional requirements of soybean crops.

Seed treatment was performed with Bendazol fungicide (1.0 mL kg^{-1}), Fipronil insecticide (0.5 mL kg^{-1}), cobalt, and molybdenum fertilizer (1.5 mL kg^{-1}) and a liquid-based inoculant of *Bradyrhizobium japonicum* (SEMIA 5079 and SEMIA 5080) at a dosage of 8 mL kg^{-1}. The sowing was performed manually. Before sowing, 333 kg ha^{-1} of formulated 5-25-15 (NPK) plus 400 kg ha^{-1} of simple superphosphate (18% P_2O_5) was applied to the planting line.

The plots of soybean cultivars were composed of eight lines 5 m in length with a spacing of 0.5 m between the lines. The number of soybean plants per hectare was determined according to the recommendations of each cultivar. At 29 days after sowing (DAS), 94 kg ha^{-1} potassium chloride (58% KCl) was applied to the soybean cultivars. In macauba plants, tree cover fertilization was performed with 500 g of urea (45% N), 900 g of simple superphosphate (18% P_2O_5), and 900 g of potassium chloride (58% KCl). The experiment was monitored daily, handling pests, diseases, and invasive plants as needed.

During the experiment, the following parameters were evaluated in the soybean culture: (i) diameter of the hypocotyl (D): with a digital caliper, the diameter was measured in ten plants of the two central rows at 27, 34, 41, and 60 DAS; (ii) height of the plant (H): in ten plants of the two central rows, the height of the plants was measured from the ground level to the apex of the plant at 27, 34, 41, and 60 DAS; (iii) leaf area index (LAI): the LAI was measured with the LI-COR equipment (model LAI-2200). Measurements were made at 46 and 67 DAS, from three measurements, in three different positions below the line and between the lines of the two soybean central lines; (iv) leaf chlorophyll content (LCC): LCC was measured at 46 and 67 DAS using the SPAD equipment (Minolta 509), which provided the SPAD index. The reading was performed in the third fully expanded clover's central leaflet and removed at random from the two central rows. The SPAD index was transformed into chlorophyll content (mg dm^{-2}), using the equation: $y = -0.152 + 0.0996x$, proposed by Barnes, Balaguer, Manrique, Elvira, and Davison (1992); (v) final population of plants (FPP): the number of plants per harvest line was evaluated in the two central lines, converting the data into plants/hectare; (vi) number of pods per plant (NPP): carried out on ten plants harvested consecutively on the central line of each plot, counting the number of pods per plant; (vii) mass of a thousand grains (MTG): determined by the weight of a thousand grains in an analytical balance; (viii) grain production per plant (GPP): ten plants from the two central lines were removed at random, and the mass of the grains was verified; (ix) grain yield (GY): obtained from the threshing of plants in the four central rows. The grain mass of the plot was measured, and the moisture content of the grains was determined. To quantify productivity, production moisture was adjusted to 13% of the grains and expressed as kg ha^{-1}; and (x) oil yield (OY): a grain sample was set aside in each plot to determine the oil content of the grains. The oil content of the grains was determined in undamaged soybeans using the technique of reflectance in the near-infrared (RNI) according to Heil (2010), using Thermo equipment (model Antaris II) equipped with an integration sphere with a resolution of 4 cm^{-1}. OY was calculated by multiplying the GY by the grain oil content, expressed in kg ha^{-1}.

The data were subjected to analysis of variance and regression. For the qualitative factor, means were compared using Duncan's test at 5% significance. For the quantitative factor, the models were chosen based on the significance of the regression coefficients, using the "t" test, coefficient of determination (R^2), and the biological phenomenon. Regardless of whether the higher-level interaction is significant, it was unfolded for study. All analyses and tests were performed using the R statistical program (R Core Team, 2014).

Results

When comparing the mean values of the hypocotyl diameter (D) of soybean produced in different production systems, the monoculture system (M) provided the highest D in all the analyzed periods (27, 34, 41, and 60 days after sowing (DAS)) when compared to the crop-forest integration system (ICF) (Figure 2). The highest D achieved by the ICF was 4.48 mm at 60 DAS, while in the M system a similar value (4.57 mm) was found at 34 DAS.

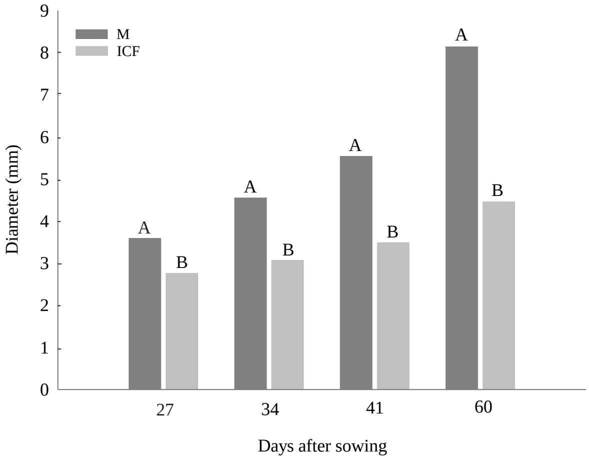

Figure 2. Mean values of the hypocotyl diameter (mm) of soybean produced in monoculture (M) and integration crop-forest (ICF) evaluated in four periods after harvest seeding. Note: A joint analysis of the data of the four varieties was carried out during each evaluated period. Means followed by the same letters do not differ according to Duncan's test at 5% significance.

The behavior of soybean growth to height for each cultivar in the different production systems (F = 3.801, p = 0.0004) is shown in Figure 3. In all cultivars in both production systems, there was a linear behavior at the height (H) of the soybean plants. This type of behavior was expected due to the method of growth and development of soybean plants. The cultivars TMG1288 and M8644 showed higher (H) over the evaluation period of plants in the crop-forest integration system (ICF) when compared to cultivation in the monoculture system (M) (Figure 3A and D). This behavior was not observed for the cultivars ST 797 and Desafio, where in the M system, the plants obtained greater heights after 51 and 58 DAS, respectively (Figure 3B and C).

The leaf area index (LAI) and leaf chlorophyll content (LCC) were higher in the monoculture production system (M) both 48 and 67 days after sowing (DAS), regardless of the cultivar (Figure 4A and B). Although the LAI and LCC increased between the flowering period (48 DAS) and the full flowering period (67 DAS) in both production systems, the difference was not statistically significant.

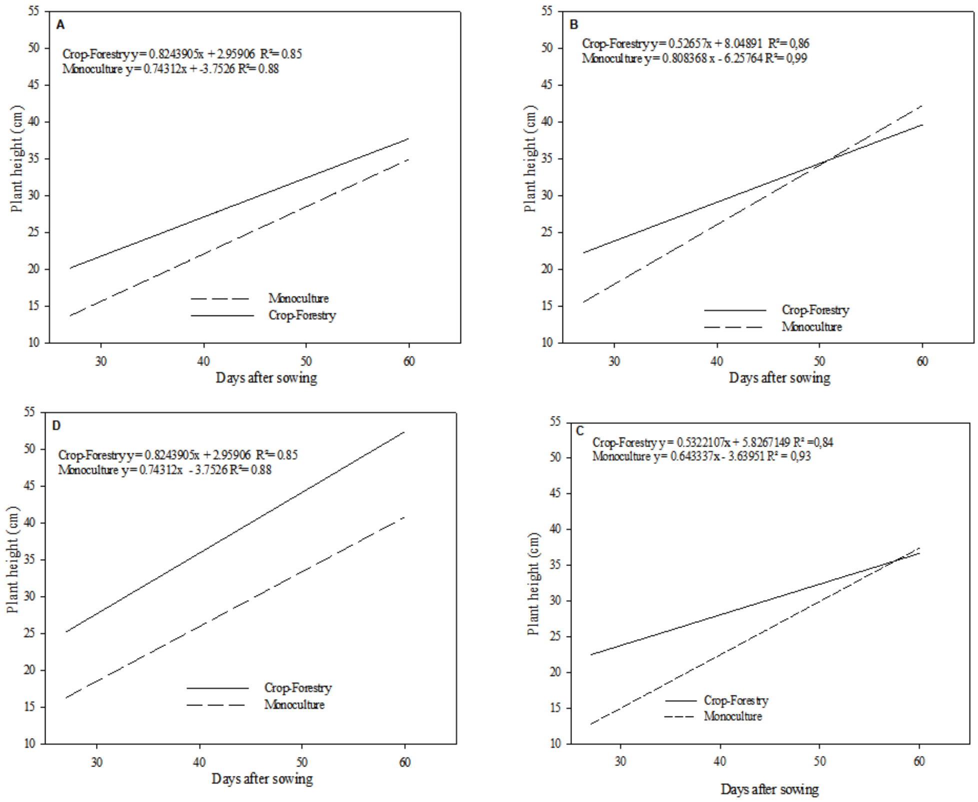

Figure 3. Means of height of soybean cultivars M8644 IPRO (A), ST 797 IPRO (B), Desafio (C), and TMG 1288 RR (D) produced in monoculture and in crop-forest integration evaluated in four periods after sowing.

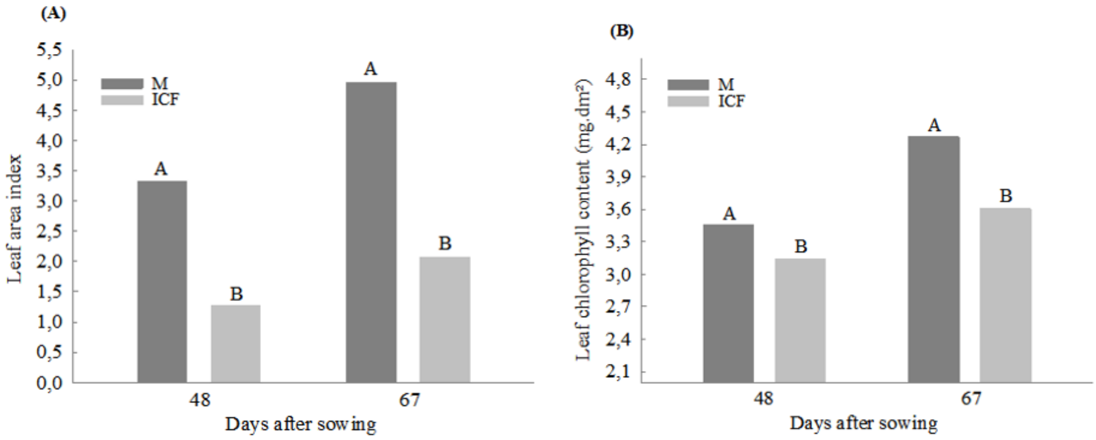

Figure 4. Means of leaf area index (A) and leaf chlorophyll content – mg dm^{-2} (B) in flowering (48 days after sowing) and full flowering (67 days after sowing) of soybean produced in monoculture (M) and integration crop-forest (ICF). Note: A joint analysis of the data of the four varieties was carried out for each evaluated period. Means followed by the same letters do not differ according to Duncan's test at 5% significance.

There were statistically significant differences in the final plant population (FPP) between the cultivar and production systems (Table 1). FPP was higher in the integrated crop-forest systems for all cultivars analyzed. The cultivar Desafio had the highest number of plants in both production systems, followed by cultivars ST 797 and TMG 1288.

The monoculture production system (M) had the highest number of pods per plant (NPP) for all the cultivars analyzed (Table 2). The cultivar M8644 had the highest NPP in the M system and TMG1288, ST797, and M8644 in the ICF. The Desafio cultivar had the lowest NPP among the analyzed production systems.

The ICF production system had the greatest thousand-grain mass (TGM) for cultivars ST797 and Desafio, and, the TGM did not differ statistically for the other cultivars between the two systems (Table 2). The cultivar Desafio had the highest TGM values among the analyzed production systems.

Grain production per plant (GPP) was higher in the M system for the four cultivars analyzed, and cultivar M8644 had the highest yield, at 31.2 g $plant^{-1}$ (Table 2). The GPP did not differ statistically between the cultivars analyzed in the ICF system, and its values were much lower than those found in the monoculture.

Grain yield (GY) was higher in the monoculture system (M), with cultivars M 8644 and ST 797 having the highest yields, and TMG 1288 showing the same GY in both production systems analyzed (Table 3). For GY, the highest oil yield (OY) was obtained for the M system (Table 3). The OY of cultivar TMG 1288 did not differ between the two production systems.

Table 1. Means of the final plant population of different soybean cultivars produced in monoculture (M) and in integrated crop-forest (ICF), and final population total of each cultivar (Means).

Cultivar	Production systems		Means
	M	ICF	
TMG 1288	176,667	220,000	198,333 bc*
ST 797	183,333	281,667	232,500 b
Desafio	293,333	401,667	347,500 a
M 8644	130,000	176,667	153,333 c
Overall average	195,833 B*	270,000 A	232,917

*Means followed by the same lowercase letter in the column or uppercase letters in the row do not differ by Duncan's test at 5% significance.

Table 2. Means of the number of pods per plant (NPP), thousand grain mass (TGM) in g, and grain production per plant (GPP) in g $plant^{-1}$ of different soybean cultivars produced in monoculture (M) and integration crop-forest (ICF).

Cultivar	Production systems					
	M	ICF	M	ICF	M	ICF
	NPP		TGM		GPP	
TMG1288	62.2 bA*	34.6 aB	75.6 bA	78.3 cA	12.9 cA	7.7 aB
ST797	75.4 bA	26.5 abB	84.8 bB	102.2 bA	18.8 bA	7.5 aB
Desafio	39.0 cA	11.4 bB	106.2 aB	140.4 aA	11.2 cA	4.8 aB
M8644	154.4 aA	38.1 aB	80.1 bA	81.61 cA	31.2 aA	7.2 aB

*Means followed by the same lowercase letter in the column or uppercase letter in the row do not differ by Duncan's test at 5% significance.

Table 3. Means of grain yield and oil yield of different soybean cultivars produced in monoculture (M) and integration crop-forest (ICF).

Cultivar	Production systems			
	M	ICF	M	ICF
	Grain yield (kg ha^{-1})		Oil yield (kg ha^{-1})	
TMG 1288	2,156 cA	1,625 abA	488.5 bA	390.5 abA
ST 797	3,372 abA	2,101 aB	787.3 aA	511.3 aB
Desafio	3,20 6bA	1,668 abB	750.5 aA	415.0 abB
M 8644	3,924 aA	1,268 bB	905.5 aA	392.0 bB

*Means followed by the same lowercase letter in the column or uppercase letter in the row do not differ by the Duncan's test at 5% significance.

Discussion

When soybeans are cultivated in an environment of low light availability, morphological changes occur that express characteristics of shade tolerance, such as a reduction of the hypocotyl diameter, the number of leaves, and lengthening of the stem (Page, Tollenaar, Lee, Lukens, & Swanton, 2010; Skálová, 2005). Smaller hypocotyl diameters (D) were found for all cultivars in the crop-forest integration (ICF) production system, corroborating the findings of Skálová (2005) and Page et al. (2010). In contrast to the D values, greater stem elongation of soybean plants was observed in the ICF in the first three evaluation periods for the four cultivars, whereas from the third evaluation the cultivars ST 797 IPRO and Desafio had higher H in the M system. Luminous stress suffered by soybean cultivars in the ICF system causes all genotypes to choose to allocate more photoassimilates for the growth of the stem in height, in detriment to the diameter, as an alternative to capture light, aiming to maintain their photosynthetic activities. Similar results were found by Zhang, Smith, Weiguo, Chen, and Wenyu (2011); taller plants and smaller hypocotyl diameters were obtained in the shade treatment. In a system of intercropped soybean-corn production, soybean plants under shade increased in height and had thinner stems, seeking to improve access to light (Yang et al., 2014).

The average plant height varies between soybean genotypes and shows plasticity to environmental changes (Franchini, Balbinot Junior, Sichier, Debiasi, & Conte, 2014). Thus, it is believed that the ST 797 IPRO and Desafio genotypes are better developed in an environment with greater photosynthetically active radiation (PAR). Therefore, the higher (H) in the monoculture system at 51 and 58 DAS, respectively, may reflect the increase in PAR in the experimental area, which further favors the production and distribution of photoassimilates in these cultivars. However, taller plants are not synonymous with high yields, since shorter soybean plants have an increased number of grains per pod, grains per plant, and grain mass (Souza, Figueiredo, Coelho, Casa, & Sangol, 2013).

The leaf area index (LAI) is a parameter indicative of crop productivity, since the stages of photosynthesis are dependent on the intercepted light energy and conversion into chemical energy (Favarin, Neto, García, Nova, & Favarin, 2002). The LAI of the different soybean genotypes decreased under shade conditions (ICF) in the two periods evaluated, in contrast to cultivation in full sun (M). The LAI in the ICF system was low due to the shade conditions, since, in response to shading, the plants invested a large number of photoassimilates in the growth at the height of the stem, impairing the formation of the other organs of the plant involved in such processes as emission and leaf growth (Vidal, 2010). A low LAI is not ideal, as a reduction in LAI leads to less absorption of PAR and, consequently, less biomass production per plant (Su et al., 2014). Tagliapietra et al. (2018) demonstrated that the ideal LAI to reach yield potential is between 6.0 and 6.5 for indeterminate and determined cultivars, and the maximum LAI value obtained at the ICF was 2.087, well below the ideal value. Behling, Carvalho, Felipe, Farias, and Camargo (2019) grew soybeans in ICLF and found that shading caused less efficiency in light radiation interception and, consequently, lower LAI in the crop. Very high LAI can reduce productivity by high energy consumption via respiration and photorespiration to keep vegetative structures alive, and by the early senescence of the leaves, especially those in the shallow region.

The leaf chlorophyll content (LCC) was lower in the ICF system, both at the beginning of flowering and at full flowering of soybean. This result is different from what was found by Wu et al. (2016), who observed an increase in the leaf chlorophyll content in soybeans under shading conditions; the same result was observed by Effend, Harun, Budianta, and Munandar (2014) in the corn crop and by Laisk et al. (2005) in forest crops. The content of leaf chlorophyll is usually higher in shaded environments because plants invest in greater production of pigments that collect light energy to compensate for low radiation (Laisk et al., 2005). However, this is not a certainty since depending on the light availability in the understory, shaded plants may have different response patterns that can be additive, synergistic, or antagonistic (Zhang et al., 2011). It occurred in the ICF between soy and macauba, although the plants produced in the system had the alterations in the morphological characteristics of plants produced in shaded environments, such as higher heights of the aerial part and smaller diameters of the collection, the plants did not have the same response in the physiological characteristics of leaf chlorophyll content. Wu et al. (2016) stated that morphological characteristics can be more variable than physiological characteristics of soybean culture when produced under shading conditions.

The significant difference in the number of pods per plant (NPP) between the two production systems was caused by the shading from macauba in the crop-forest integration system (ICF), and the cultivars had a higher NPP in the monoculture production system (M). According to reports, the low availability of energy in the understory of intercropped systems means that the soybean crop does not reach its full phenotypic development (Melges, Nei, Lopes, & Marco, 1989; Su et al., 2014; Wu et al., 2017), resulting in a low crop yield (Dornelles, Mendez, Correa, & Schuch, 1997; Silva, Neves, Zucch, Rocha, & Matos, 2012). For the plant to express its productivity potential, it must be efficient in the interception and use of available solar radiation (Buzzello et al., 2015). Thus, low luminosity hinders the metabolic process, resulting in low production of pods per plant and, consequently, of grains (Effendy & Utami, 2020). The shading in the ICF inhibited the metabolic processes in the soybean plants, affecting the partitioning of the vegetable biomass for the pods.

Among the production systems evaluated, the mass of one thousand grains (TGM) was higher in the ICF system, and among cultivars, Desafio obtained the highest TGM in both systems. The greatest TGM in ICF and the cultivar Desafio was probably due to the higher final plant population and the lower number of pods per plant obtained by the production system and by the cultivar during the experiment, since, according to Tourino, Rezende, and Salvador (2002), the mass of a thousand grains is greater when the planting density is higher, therefore, the number of pods per plant decreases, with a higher concentration of photoassimilates in a reduced number of grains.

For all cultivars, the production of grains per plant (GPP) was higher in the monoculture system (M), and in the ICF system the GPP was much lower than the values found in M. Soy plants produced under different levels of light have a significant reduction in grain productivity (Zhang et al., 2011), since the scarcity of light energy provides a lower rate of carbon assimilation (Matos et al., 2014). In systems that combine annual and forest species, the proximity of trees affects soybean productivity (Franchini et al., 2014), because it favors competition between plants for solar radiation. Tibolla et al. (2019) evaluated the performance of soy produced at different levels of artificial radiation (0, 30, 50 and 70 %) and found that the highest values of productivity, number of pods per plant, number of grains per plant, and mass of grains per plant were observed under 0 % and 30 % shading, which was significantly different from the results of the 70 % shading treatment.

The light environment during different periods of soybean growth is an important determinant of yield and yield components (Liu et al., 2015). Therefore, grain yield (GY) and oil yield (OY) were higher in the monoculture system (M), emphasizing that the shading promoted by the macauba palm on soybeans directly influenced the productivity of the crop. The reduction in the leaf area of the crop was likely the determining factor for the lower yield in the ICF, since a high LAI provides greater interception of incident solar radiation, increasing the photosynthetic rate and plant biomass. According to Effendy and Utami (2020), the yield and production of several soybean cultivars decreased with increasing shade intensity. The TMG 1288 cultivar had a statistically equal yield in both production systems, which highlights the importance of selecting cultivars that are more adaptable to shading conditions for use in ICLF systems.

The final plant population (FPP) was higher in the crop-forest integration system for all cultivars analyzed. The palm tree canopy probably created a more favorable environment, reducing air temperature and increasing soil moisture, leading to a greater emergence of seedlings and plant establishment thereby promoting a larger plant stand at harvest time. However, although the FPP was higher in the ICF, it was not able to compensate for the lower yield of the crop produced in this system because the shading caused a reduction in the leaf area index and, consequently, in the number of pods, leading to low grain production by plants in the ICF system. Several authors have found a reduction in soybean productivity when intercropped with tree species (Matos et al., 2014; Peng, Zhang, Cai, Jiang, & Zhang, 2009; Reynolds, Simpson, Thevathasan, & Andrew, 2007; Rivest, Cogliastro, Vanasse, & Olivier, 2009).

There was a reduction in the productivity of the soybean crop produced in the integrated system with the macauba palm, and different productivity responses between the soybean cultivars, showing that under the experimental conditions used, the integration between macauba and soybeans was not favorable to the soybean crop. However, there were different responses in all variables that effectively contributed to the grain yield in the cultivars analyzed in this study. This variability demonstrates that there is an effect of genotype and environment interactions that allow the selection and development of suitable cultivars for the integrated production system. In this context, future studies that evaluate the performance of soybeans in silviagricultural systems are necessary to obtain cultivars that are more tolerant to shading.

Another possibility is to create a more favorable environment for soybeans by increasing the spacing between the lines of the macauba palm. This increase can promote greater penetration of photosynthetically active radiation in the forest understory, which should increase the net photosynthesis of soybean plants and provide greater yields. We also emphasize the need for studies on the economic viability of this integration to assess whether the reduction in soybean productivity can be compensated for by the commercialization of products from the macauba palm in the medium and long term; therefore, our results serve as a foundation for further research.

Conclusion

The cultivars behaved differently in the two production systems analyzed, demonstrating that there is an interaction between the genotype and the environment. Among the four cultivars evaluated, cultivar TMG 1288 maintained the same productivity in both systems, demonstrating that it is a cultivar with high plasticity. The growth and yield characteristics of the soybean crop were influenced by the shade from the macauba. Thus, under the experimental conditions used here, the integration between macauba and soy did not favor the productivity of the soy crop.

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