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Intercropping of Cowpea with Eucalyptus in Northern Brazil

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Abstract

Intercropping consist in growing two or more species with different vegetative cycles and architectures, simultaneously cultivated in same field and same period of time, not necessarily having been sown at the same time. The objective of this study was to evaluate different populations of cowpea development intercropped with Eucalyptus, in order to determine the number of rows of cowpea generates higher grain productivity. This work was carried out at Universidade Federal do Tocantins, in Gurupi, Tocantins, Brazil. The treatments were arranged for different densities of cowpea rows: eight rows, six rows, and four rows of cultivars BRS Nova Era and BRS Sempre Verde, also a control in conventional cropping. The cowpea sowing occurred after 12 months eucalyptus planting. The evaluated characteristics were Flowering (FLOW), Mass of 100 grain (GM), Number of grains per green pod (NGP), Chlorophyll Index (CI) and Grain yield (GY). The density of eight rows have obtained better results for most characteristics, being the density limiting factor for bean production could unfeasible the intercropping system. The BRS Nova Era responds better on most characteristics, probably for a better adaptation to the environment and hold superior characters than BRS Sempre Verde.

Keywords: *Vigna unguiculata* (L.), crop associations, agro-sylviculture, density, agroecosystems

1. Introduction

Cowpea *Vigna unguiculata* (L.) Walp, is an import source of protein for human. In Brazil, the season harvest 2016/2017 have cultivated approximately 1.1 million ha, and the production was 1.4 million tones (productivity 921.2 kg ha^{-1}). In Tocantins, the planted area was 4800 ha, production of 3100 thousand tons and productivity of 642 kg ha^{-1} (CONAb, 2017). According to Benvindo et al. (2010), in the North and Northeast of Brazil, cowpea crop generally has low yield (around 300 kg ha^{-1}), mainly due to climate conditions, as well as low level of technology and using seeds from successive crops.

Intercropping can be defined as a cultivation system which two or more crops, with different vegetative cycles and plant architecture, are concomitantly harvested in same area (Machado Filho & Silva, 2012). Sown not necessarily at same time, however for a part of plant developmental there is simultaneity, causing interaction between crops. There are different types of intercropping. In intercropping at least, one crop is growth in rows. In striped crops are planted in broad strips to allow for independent management of each crop, however narrow allowing interaction between crops (Vieira, 1985).

Although not attractive to small farmers, traditional reforestation has as a limitation, time-consuming return on investment. Intercropping annual crops with forest emerges as an alternative for generation of more immediate income, defraying part of the expenses incurred at the initial stage. In this way, cowpea is one of the main crops used in this type of intercropping. Cowpea presents a short cycle, uncompetitive, sown at different times of the year and relatively tolerant to competition by plant intercropped, besides being a basic foodstuff of Brazilian people and often reaching good prices in the market (Vieira, 2006).

Using cowpea in intercropping system with eucalyptus has already been demonstrated viability in other studies (Schreiner & Balloni, 1986; Passos, 1990; Couto et al., 1995; Ceccon et al., 1999), there are few information about new cowpea cultivars, as well as distribution of plant population, and focused on the conditions of Tocantins.

Given these points, the objective of this work was to evaluate the cowpea development in intercropped with eucalyptus in different populations in order to determine the number of intermediate rows of cowpea that provides higher grain yield.

2. Material and Methods

The study was carried out at the experimental area of the *Universidade Federal do Tocantin*s (UFT), campus Gurupi, with the coordinates 11°46′26.1″ S and 49°03′05.9″ W, and altitude of 294 m. The soil was classified as *Latossolo vermelho amarelo distrófico* (Embrapa, 2013). Data concerning average temperature, precipitation and air relativity humidity during the study conduction are present in Figure 1.

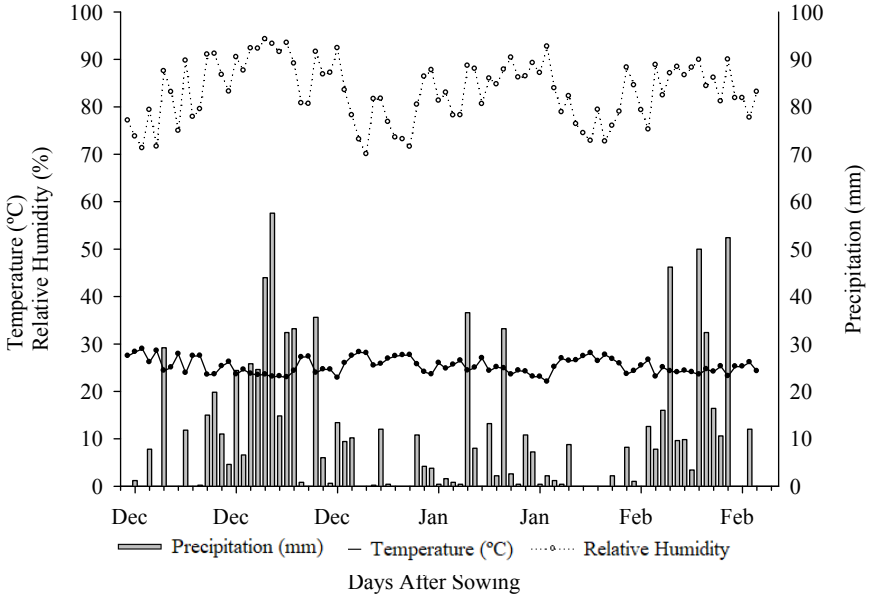

Figure 1. Temperature, relative humidity and precipitation

Note. Temperature, relative humidity and precipitation in Gurupi, Tocantins, Brazil, in the experimental period (December 2013 to February 2014). Source: INMET/UFT.

The soil analysis in the layer of 0-20 cm layer, presented in Table 1.

Table 1. Soil analysis (0-20 cm) of the studied area, in harvest season 2013/14, in Gurupi, Tocantins, Brazil

Ca+Mg	Ca	Mg	Al	H+Al	K	SB	CEC	CEC	pH	P	V	Sandy	Silt	Clay
---------- cmol dm^{-3} ----------							T	(t)	$CaCl_2$	mg dm^{-3}	---------- % ----------			
2.6	1.9	0.7	0.0	3.10	0.1	5.84	5.8	2.74	4.7	0.7	47	76.5	6.3	17.2

Note. Ca = calcium; Mg = magnesium, H = hydrogen; Al = aluminum; K = potassium; SB = Sum of Bases; CTC = soil cation exchange capacity; P = phosphorus; PH = hydrogenation potential; V = base saturation.

The cultivars planted were BRS-Nova Era and BRS-Semper Verde (Table 2), widely used by farmers in Brazil, presenting favorable agronomic characteristics, such as good adaptation to the edaphoclimatic conditions and good market acceptance.

Table 2. Information about cultivars BRS Nova Era and BRS Sempre Verde

Plant Characteristics	BRS Nova Era	BRS Sempre verde
Growth habit	Undetermined	Undetermined
Mien	Semi-erect	Semi-prostate
Cycle	65-70 days	70-75 days
Flower color	White	Purple

Note. By Freire Filho et al. (2005).

The experiment were carried out in randomized block, being planted in a strip, with five replications. Treatments arranged in factorial 4 × 2, with 3 different numbers of cowpea lines intercropped with eucalyptus (eight rows, six rows, and four rows), 2 cultivars (BRS Nova Era and BRS Semper Verde) and the 2 cowpea cultivar grown without intercropping (control). The production component data were obtained in central rows, with a useful area of 12 m^2.

Intercropped with cowpea densities was planted the eucalyptus hybrid VM-01 (*Eucalyptus urophylla* + *Eucalyptus camaldulensis*), being planted in February 2013 in single rows spaced in 6 × 1.5 meters and row spacing of 5.0 m. The cowpea sowing was performed manually on February 12 2013, with density of 12 plants per meter in all treatments. Fertilization and cultural treatments were carried out according to recommendations for the crop. Harvest performed at R9 when plants reached physiological maturity.

2.1 Evaluated Characteristics

Flowering (FLOW): evaluated when plants were with 50% of plants per plot in full flowering;

Mass of 100 grain (GM): taking one hundred grains of the useful area weighing and correcting humidity to 13%.

Number of grains per green pod (NGP): obtained by counting the number of grains in five pods.

Chlorophyll Index (CI) was determined at full bloom stage. The readings were made on first fully developed trifoliolate leaf, in five plants and one leaf per plant, in one of the central rows of the useful area. The readings were performed early in the morning with chlorophyll model Clorofilog CFL 1030 (Falker, 2008).

Grain yield (GY), made by the weight of grains of the useful area in kilograms, with correction for 13% of humidity, transforming data to kg ha^{-1}.

The data were submitted to variance analysis through F test, when significant, the averages were compared by Tukey test at 5% probability, using SISVAR statistical software (Ferreira, 2011).

3. Results and Discussion

According to the variance analysis (Table 3), a significant effect of cultivar versus number of row interaction was observed for flowering characteristics, chlorophyll index, number of grain per pods and grain yield evidencing interdependence of factors. While, there was no interaction effect for characteristic mas of 100 grains, showing that one factor is independent of other, being studied in isolation. When observing the isolated effect of the cultivar variable, there is a significant effect for the characteristic mass of 100 grains, default of responses to the variable can be associated to the similar development of cultivars, which belong to same genus, and are recommended to be cultivated in similar environments. However, density of planting rows (Table 3), a significant effect was observed only for grain yield.

Table 3. Values of F and significance level for Flowering, Mass of 100 grains, Number of grains per green pod and Grain yield by the cultivars BRS Nova Era and BRS Sempre Verde intercropped with eucalyptus. Gurupi, Tocantins, Brazil, harvest season 2013/14

SV	Values of F					
	GL	FLOW	CI	NGP	GM	GY
Cultivar	1	0.014^{ns}	1.556^{ns}	3.684^{ns}	247.322^{**}	1455755.187^{**}
Density	3	0.297^{ns}	12.886^{ns}	4.147^{ns}	48.227^{ns}	581138.440^{**}
Cultivar*Density	3	6.280^{**}	67.546^{**}	52.968^{**}	7.654^{ns}	369158.682^{**}
C.V. (%)		1.95	7.14	24.89	15.05	16.22

Note. S.V.: Source of variation; DF: Degrees of freedom; C.V.: Coefficient of variation; FLOW: Flowering; GM: Mass of 100 grain; NGP: Number of grains per green pod; GY: Grain yield; ** and * significant by 1 and 5% respectively; ^{ns}: no significant to F test.

Considering characteristic flowering (Table 4), when submitted to the densities of eight and six lines, the cultivars BRS Nova Era and BRS Sempre Verde, obtained similar results. According to Freire Filho et al. (2005), cowpea shows variation beginning and end of reproductive period, some genotypes may flourish 30 days after emergence, or even require 90 days to start this stage. As has been noted, it explains why even in intercropping system the characteristic has obtained significant response.

In the treatment with four rows observes a variation between evaluated cultivars, in effect that BRS Nova Era flourished at 48th day, two days after BRS Sempre Verde. Different from observed in cowpea cultivated without intercropping, with BRS Nova Era presenting longer vegetative cycle. In this case, these results show that intercropping with eucalyptus is not prejudicial to cowpea, because the flowering stage is in the same way to conventional cultivation (Oliveira, 2012).

Analyzing BRS Nova Era cultivar, within different densities, verified that the treatment eight and six rows, response in similar to the control. Probably because it received lighter and more incident temperature, which could be accelerating the photosynthetic process, whereas compared to the density of four rows, where they were closer to the eucalyptus plants, receiving greater shading, results in a later flowering. Moreover, low competitiveness among established plants, caused by smaller number of rows, probably provided a longer vegetative period. This fact can be observed verifying that in monoculture system, plants got a shorter cycle duration (46 days). The cultivar BRS Sempre Verde, presented a decrease amount treatments, there was a prolongation in the vegetative cycle.

Table 4. Flowering (Days after sowing) of cultivars BRS Nova Era and BRS Sempre Verde intercropped with eucalyptus. Gurupi, Tocantins, Brazil, harvest season 2013/14

Cultivar	Flowering (Days after sowing)			
	8 (rows)	6 (rows)	4 (rows)	Control
BRS Nova Era	47.20 aAB	47.20 aAB	48.00 aA	46.00 bB
BRS Sempre Verde	46.80 aAB	46.60 aB	46.60 bB	48.25 aA

Note. Average values followed by same letter (s) in each column are not significantly different at $P \leq 0.05$ by the Tukey test.

In fact, Chlorophyll indexes are important agronomic indicators. Chlorophyll is main pigment responsible for capture of light energy used in photosynthetic processes. Certainly, it is one of the main factors related to photosynthetic efficiency of plants and, in contrast to growth and adaptability to different environments, photosynthetic process, which can be a determining factor in productivity (Bastos et al., 2012).

Table 5. Chlorophyll Index (CI) of cultivars BRS Nova Era and BRS Sempre Verde intercropped with eucalyptus. Gurupi, Tocantins, Brazil, harvest season 2013/14

Cultivar	Chlorophyll Index (CI)			
	8 (rows)	6 (rows)	4 (rows)	Control
BRS Nova Era	51.73 aA	48.92 aA	46.90 bA	52.30 aA
BRS Sempre Verde	51.31 aAB	52.34 aA	52.05 aA	45.7 bB

Note. Average values followed by same letter (s) in each column are not significantly different at $P \leq 0.05$ by the Tukey test.

The densities eight and six rows did not differ statistically among the cultivars, probably because the amount of light is proportional to them, which allows such responses. As for the four rows, cultivar BRS Sempre Verde was more responsive than BRS Nova Era cultivar, possibly because it was semi-erect with less branching, unlike BRS Sempre Verde, which is semi-prostate, obtaining more branching conditions to search for light.

In relation to the control, the cultivar that showed the highest chlorophyll index was BRS Nova Era. The effect for chlorophyll index can be explained based on plant size. BRS Sempre Verde would use more energy to branch out, because it is semi-prostate, while BRS Nova Era presents a more erect shape, performing light absorption process more efficiently. In a lower density, the cultivar obtains smaller replenishments, due to its architecture, where it received more shading by eucalyptus.

Analyzing the cultivar BRS Nova Era within different levels of densities, was verified that there was no difference between the different numbers of established rows of cowpea. This fact is probably caused by the same being a cultivar of more modern (erect), presenting, better light use. However, BRS Sempre Verde obtained higher chlorophyll index in six and four rows, nevertheless these responses when compared with eight lines did not differ statistically. The different densities showed that BRS Sempre Verde had better use than conventional cultivation, which may have occurred because it did not suffer much stress in a monocrop system.

The number of grains per pod in analyzed on BRS Nova Era (Table 4), verified that only eight rows differed statistically from the control, showing that intercropping no indicate negative responses by the cultivar. For the cultivar BRS Sempre Verde there was a similar response among all treatments. Oliveira (2012) associates in one of his works that the cultivar BRS Sempre Verde produces a larger number of pods and it can be related to the greater number of branches produced during the cycle. If there are more pods, there will be a greater number of grains disagreeing with the present study, which verified for cultivar BRS Nova Era.

Table 6. Number of grains per green pod for cultivars BRS Nova Era and BRS Sempre Verde intercropped with eucalyptus. Gurupi, TO, Brazil, harvest season 2013/14

Cultivar	Number of grains per green pod (NGP)			
	8 (rows)	6 (rows)	4 (rows)	Control
BRS Nova Era	15.12 aA	13.24 aAB	12.610 aAB	8.750 bB
BRS Sempre Verde	11.00 bA	10.78 aA	10.60 aA	14.91 aA

Note. Average values followed by same letter (s) in each column are not significantly different at $P \leq 0.05$ by the Tukey test.

Passos (1990) in study carried out with cowpea intercropped with eucalyptus did not find significant differences in number of grains per pod, among the evaluated systems, however, were higher than in conventional cultivation.

Observing cultivars in density of eight rows, (Table 4), BRS Nova Era produced around three times more than BRS Sempre Verde, also superior to six rows and the control. It evidenced that independent of intercropping with eucalyptus, the cultivar BRS Sempre Verde is inferior to BRS Nova Era, possibly because it is a cultivar that converts a lot of energy in green matter, and not in reproductive characters, as BRS Nova Era.

Table 7. Grain Yield (kg ha^{-1}) of cultivars BRS Nova Era and BRS Sempre Verde intercropped with eucalyptus. Gurupi, Tocantins, Brazil, harvest season 2013/14

Cultivar	Grain Yield (kg ha^{-1})			
	8 (rows)	6 (rows)	4 (rows)	Control
BRS Nova Era	487.15 aB	330.15 aC	258.70 aC	1201.88 aA
BRS Sempre Verde	150.22 bB	145.21 bB	188.55 aAB	267.72 bA

Note. Average values followed by same letter (s) in each column are not significantly different at $P \leq 0.05$ by the Tukey test.

The cultivar BRS Nova Era grown in different densities (Table 4) showed decrease in grain yield. Among intercropping treatments, eight rows obtained highest values of yield, probably due to the greater amount of light absorbed because plants had received less shaded, corroborating with the responses found by Viana et al. (2012), in study with corn intercropped with eucalyptus, which obtained higher corn yields at larger spacing, probably due to the higher light incidence. Silva et al. (2006) also observed for beans cultivated in crop-livestock integration system, there was no difference growing in smaller spacing, there were higher yields only in larger spacing, which can be explained by more competition for light, water and nutrients in area under eucalyptus canopy, which may have affected the development of bean in this system.

Cultivar BRS Sempre Verde in densities of eight and six rows obtained smaller responses than four rows, however these very low compared to those found in BRS Nova Era. The control treatment obtained higher values above those observed in the intercropping system, in this case implies that BRS Sempre Verde can not be indicated as a responsive cultivar compared to BRS Nova Era.

The grain yield of cowpea in monocropping was better than that obtained in intercropping system, because cowpea was sown when eucalyptus was around 12 months old. Competition between species for water, light and nutrients may have negatively affected grain yield. According to Ceccon et al. (1999), observed that the average yield of cultivars in conventional systems showed about 87% higher than intercropping.

Schreiner and Balloni (1986) did not observe differences between the productions obtained with three population densities, however, there was a tendency to increase up the grain yield with population density of 200,000 plants per hectare, densities closer to conventional bean yield.

BRS Nova Era showed a better response for characteristic mass of 100 grain (Table 8) with a value of 22.31g while BRS Sempre Verde obtained a smaller response of 17.36 g, which directly reflects to the grain yield, because it is a quantitative characteristic, influenced by the environment. Possibly BRS Nova Era can achieve greater yields, as it observes potential superior to BRS Sempre Verde. In study carried out by Carvalho (2009) with common bean intercropping with eucalyptus eight months old, was found differences between cultivars where the best response obtained was 20.06 g for mass of 100 grain, similar to the values found in the present work.

Table 8. Mass of 100 grain (g) for cultivars BRS Nova Era and BRS Sempre Verde intercropped with eucalyptus. Gurupi, Tocantins, Brazil, harvest season 2013/14

Cultivar	Mass of 100 grain (g)			
	8 (rows)	6 (rows)	4 (rows)	Control
BRS Nova Era	24.47 aA	23.43 aA	22.86 aA	18.60 aB
BRS Sempre Verde	17.29 bA	17.73 bA	19.81 bA	14.63 bB

Note. Average values followed by same letter (s) in each column are not significantly different at $P \leq 0.05$ by the Tukey test.

The different densities (Table 8), the control was the only one that obtained a differentiated response, in fact, with a lower mass of 100 grain. The effect could have been caused by the smaller number of plants, thus being able to find grains with better formation and more reserve, which confers in higher mass of grain. However, along the time, plant can suffer several stresses, due to the eucalyptus shading, where it can reduce the viable pod index, decreasing yield, compared to conventional system.

According to Santos (2013), the increase of cowpea plant densities linearly reduces number of pods per plant, grain yield per plant and grain/pod ratio, and increases quadratic productivity of pods and grain yield per plant ha^{-1}.

4. Conclusion

The studied cowpea cultivars have higher yields cultivated without intercropping with eucalyptus.

The treatment eight rows intercropped with eucalyptus provided better responses for most evaluated characteristics when compared to four and six rows.

The cultivar BRS Nova Era response better to intercropping in most of the evaluated characteristics compared to BRS Sempre Verde.

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