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Intercropping maize and cowpea cultivars: II. Dry grain yield[1]

Consorciação de cultivares de milho e feijão-caupi: II. Rendimentos de grãos secos

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ABSTRACT - There is interest in identifying the best maize and cowpea cultivars to be used in monocropped and intercropping systems for the production of dry grain. In order to meet this interest, two monocrops of cowpea (the traditional varieties, Corujinha and Sempre Verde) were evaluated with two monocrops of maize (the AG 1051 double hybrid and the AL Bandeirante variety) and four intercrops (combinations of the cowpea varieties and the maize cultivars). Under the intercropping systems, the maize and cowpea occupied alternating rows. A completely randomized block design with six replications was used. Grain growth and yield were higher in the AG 1051 hybrid than in the AL Bandeirante variety in both the monocropped and intercropping systems. For medium-sized maize grain, the growth and yield were higher in the monocrops than in the intercrops. It is unimportant which variety of cowpea, Corujinha or Sempre Verde, is used with each maize cultivar in the intercropping systems, as there was no interaction between the maize cultivars and the cowpea cultivars. In the monocropped systems, the grain yield of the Corujinha cultivar was greater than that of the Sempre Verde cultivar. Mean grain yield in the monocrops was greater than in the intercrops. Both cowpea cultivars showed better performance when intercropped with the AL Bandeirante maize cultivar than with the AG 1051 cultivar. The value of the land equivalent ratio was greater than 1.0 only for the combination of the AL Bandeirante variety of maize and the Sempre Verde variety of cowpea.

Key words: *Zea mays*. *Vigna unguiculata*. Monocrops. Land Equivalent Ratio.

RESUMO - Existe interesse na identificação das melhores cultivares de milho e de feijão-caupi para serem exploradas em monocultivos e em consorciação visando a produção de grãos secos. Visando atender a esse interesse, foram avaliados dois monocultivos de feijão-caupi (variedades tradicionais Corujinha e Sempre Verde), dois monocultivos de milho (híbrido duplo AG 1051 e variedade AL Bandeirante) e quatro consórcios (combinações das variedades de feijão-caupi com as cultivares de milho). Nos consórcios, milho e feijão-caupi ocuparam fileiras de plantas alternadas. Utilizou-se o delineamento experimental de blocos completos casualizados com seis repetições. O crescimento e o rendimento de grãos foram maiores no híbrido AG 1051 do que na variedade AL Bandeirante, nos monocultivos e nos consórcios. O crescimento e o rendimento de grãos médios do milho foram maiores nos monocultivos do que nos consórcios. Nos consórcios é indiferente usar as variedades Corujinha ou Sempre Verde de feijão-caupi, com qualquer uma das cultivares de milho porque não existiu interação cultivares de milho x cultivares de feijão-caupi. O rendimento de grãos da cultivar Corujinha foi superior ao da cultivar Sempre Verde, em monocultivo. O rendimento médio de grãos dos monocultivos foi superior ao dos consórcios. As duas cultivares de feijão-caupi foram melhores na consorciação com a cultivar de milho AL Bandeirante do que com a cultivar AG 1051. O valor do uso eficiente da terra foi superior à unidade apenas na combinação variedade AL Bandeirante de milho com a variedade de feijão-caupi Sempre Verde.

Palavras-chave: *Zea mays*. *Vigna unguiculata*. Monocultivos. Uso eficiente da terra.

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INTRODUCTION

The Brazilian Legal Amazon (BLA) (Law 124 of 2007), comprises nine states: Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, Tocantins and part of Maranhão. The BLA covers an area of 5 million km², which represents almost 60% of the country (BRASIL, 2016), with various aspects having been characterized (BRASIL, 2013; BRASIL, 2016). Cowpea (*Vigna unguiculata* (L.) Walp.) is grown in all states of the BLA, with Pará included among the states with the largest cultivated areas (FREIRE FILHO *et al*., 2015). Maize (*Zea mays* L.) is also cultivated in all states of the BLA and occupies a prominent position in terms of cultivated area in the state of Pará (PA) (BRASIL, 2016).

Various systems for the production of maize and cowpea are used in Pará (ALVES *et al*., 2009), where the crops are grown as monocrops and intercrops. Both types of cropping systems are used in the production of green and dry grain. The two crops are exploited using low levels of technology, and technical assistance is lacking.

Although cultivating maize and cowpea for the production of green grain is more profitable due to the prices reached by the products, dry-grain production in both crops takes priority, due to the need to store the grain; storing dry grain is easier compared to storing green grain.

Few studies were found in the literature on evaluating cowpea cultivars in Pará (SILVA JÚNIOR; LOPES; CARDOSO, 2015). Silva Júnior, Lopes and Cardoso (2015) saw similar grain yields in four cultivars. Comparisons of maize cultivars are also scarce. A recent study pointed out differences between cultivars, and that it is possible to identify cultivars that show good productive performance and good stability for grain yield (ALVES *et al*., 2017). No studies were found on the maize-cowpea intercropping that is carried out in Pará. There is, therefore, interest in carrying out such studies, so that recommendations of cultivars to be used in monocropped or intercropping systems can be made.

Studies carried out in other regions on intercropping maize cultivars with cowpea cultivars have shown that intercropping reduces the yields of both crops, and that these reductions depend on the variety of cowpea (EGBE; ALIBO; NWUEZE, 2010) and maize (EWANSIHA; KAMARA; ONYIBE, 2014; EWANSIHA *et al*., 2015). The studies also show that some cowpea cultivars can be recommended for use in both cropping systems (ADENIYAN; AYOOLA; OGUNLETI, 2011). Several authors have also found that, based on the land equivalent ratio, intercropping systems are often more advantageous than monocropped systems in using the resources for production (GHANBARI *et al*., 2010; MASVAYA *et al*., 2017).

The aim of the present study was to identify the best maize and cowpea cultivars to be used in monocropped and intercropping systems for producing dry grain. The treatments from the same experiment were also used to evaluate the green grain; however, this data will be presented in another article.

MATERIAL AND METHODS

The experiment was conducted from January to May 2015 on the Rural Campus of the Federal Institute of Education, Science and Technology of Pará (IFPA), in Marabá, Pará. The campus is located at 05°34’14.8” S and 49°06’02.3” W, at an m altitude of 95, and is 38 km from the centre of Marabá.

The wettest period in Marabá extends from December to April, and the driest from June to October. The highest rainfall (377 mm) is in March, with the lowest (12 mm) in August. The mean air temperature is 28 °C, with an average maximum temperature around 32.7 ºC and a minimum of 23.3 ºC. The monthly average relative humidity varies from 76% to 86%, with an annual average of 82%. The mean total annual insolation is 2263 hours (ALMEIDA, 2007). According to the Köppen classification and climate data obtained for 1986 to 2006, the climate in Marabá is classified as type Afi, Isothermal Tropical Rainforest. The classification of Charles Warren Thornthwaite, together with the climate data obtained for the above period, classifies the climate in the district of Marabá, PA, as subhumid, with little or no water deficiency and associated Humid Tropical Forest vegetation (C2A’ra’) (ALMEIDA, 2007). Data on various climate characteristics measured during the experimental period are shown in Table 1.

According to the Brazilian System of Soil Classification, the soil in the experimental area is classified as a Dystrophic Red-Yellow Latosol, with a sandy-clay texture and reddish color, deep, friable and highly erodible (EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA, 2013). Compound samples were taken for chemical and physical analysis at each of four soil depths in the experimental area. The results are shown in Tables 2 and 3, respectively.

The experiment was conducted in a randomized complete block design with six replications and eight treatments. The treatments resulted from two monocrops of maize (the AG 1051 and AL Bandeirante cultivars), two monocrops of cowpea (the Corujinha and Sempre Verde traditional varieties) and four intercropping systems. The

Table 1 - Climate data from January to May 2015 in Marabá, PA[1]

Month	Air temperature (°C)			Radiation (mj m^{-2} day^{-1})	Rainfall(mm)	Relative humidity (%)	
	Maximum	Mean	Minimum			Maximum	Minimum
January	30.9	24.5	20.9	14.38	184.6	94	87
February	30.6	24.5	21.3	12.70	246.2	94	88
March	30.7	24.7	21.6	13.01	278.2	95	89
April	31.7	25.2	21.9	13.52	145.2	98	91
May	33.2	25.6	21.5	13.72	134.2	96	90
Total	-	-	-	67.33	988.4	-	-

[1] Data from the Onça Puma weather station at the Vale Technological Institute (VALE-ITV)

Table 2 - Results of the chemical analysis of the soil in the experimental area

Depth (cm)	pH in $H_2$0	P	K	Ca	Mg	Al	H + Al	S	T	V%	OM %
		mg/dm^3		---------------------- $cmol_c/dm^3$ -------------------							
0 - 5	5.6	3.96	60	1.6	0.6	0.1	2.97	2.35	5.32	44.21	2.1
5 - 10	5.5	3.96	46	1.3	0.6	0.3	3.47	2.02	5.48	36.80	1.8
10 - 20	5.7	3.08	58	1.4	0.3	0.3	2.64	1.85	4.49	41.18	1.6
20 - 40	5.7	3.08	56	1.0	0.5	0.2	1.82	1.64	3.46	47.52	1.6

Table 3 - Results of the physical analysis of the soil in the experimental area

Depth (cm)	Sand	Clay	Silt
	------------------- % -------------------		
0 - 5	70.84	10.82	18.34
5 - 10	82.50	10.82	6.68
10 - 20	77.50	10.82	11.68
20 - 40	70.84	10.82	18.34

intercropping systems were obtained by combining the two maize cultivars with the two varieties of cowpea; six treatments were therefore evaluated for each crop. In the intercropping systems, the maize and cowpea occupied alternating rows. The Corujinha and Sempre verde cultivars were chosen among those most used by family farmers in the settlements close to the IFPA Campus. Both are creole varieties of indeterminate growth that, apparently, were brought from the northeast of Brazil by settlers. Both are used in the region in monocropped and intercropping systems to produce green grain and dry grain. The AG 1051 cultivar is a double hybrid with a semi-early cycle, recommended for the south, mid-west, southeast and northeast of the country, and for the state of Rondônia, as a normal and off-season crop. Despite there being no formal recommendation for the study region, the cultivar can be found on the local market, intended for the production of dry grain, whole-plant silage and green corn (CRUZ; PEREIRA FILHO, 2005). AL Bandeirantes is a free-pollinated, semi-early variety, used in conventional planting systems in normal and in off-season crops. It is apparently recommended for the whole of Brazil, and is also found on the local market, being used in the production of dry grain and whole-plant silage (CRUZ; PEREIRA FILHO, 2005).

The experimental plots were 6.0 m long, with the width varying depending on the treatment. The monocrops of maize and cowpea were evaluated in three and five rows, respectively, while the intercrops were evaluated in four rows. The greater number of rows in the monocropped cowpea was adopted to avoid border effects in the case of plots of cowpea coming between two plots of maize due to randomization. The working area was considered as comprising the central row in the monocropped maize and cowpea systems, and the two central rows in the intercropping systems. Under both types of cropping system, the plants at each end of the central rows were considered as borders and disregarded when collecting the data.

The experiment was conducted under rainfed conditions in an area that had received 2 t ha^{-1} limestone and cultivated with maize in 2012/1013 and 2013/2014. The soil was prepared by harrowing twice. When planting the maize, 40 kg N, 120 kg P_2O_5 and 40 kg of K_2O were applied per hectare as fertilizer. For the cowpea, 10 kg N, 120 kg P_2O_5 and 40 kg K_2O per hectare were applied when planting. In both the maize and cowpea, ammonium sulfate, single superphosphate and potassium chloride were used as sources of nitrogen, phosphorus and potassium, respectively. In both crops, the fertilizers were applied manually in furrows located next to and under the planting furrow.

The two crops were sown manually on February 4, 2015, using four seeds per hole: the maize at a spacing of 1.0 m x 0.4 m and the cowpea at a spacing of 1.0 m x 1.0 m, in both the monocropped and the intercropping systems. Twenty days after sowing, the plants were thinned, leaving two plants per hole. After thinning, the planting density of the monocropped maize and cowpea was 50,000 and 20,000 plants ha^{-1}, respectively. For the intercropped maize and cowpea, the respective densities were 25,000 and 10,000 plants ha^{-1}.

Weed control was by hoe, 20 and 40 days after sowing. A top dressing (ammonium sulfate) was applied after each weeding using 40 kg N ha^{-1} for the maize and 10 kg N ha^{-1} for the cowpea.

The cowpea crop was sprayed twice with 0.42% neem oil (*Azadiracta indica* A. Juss) 18 and 25 days after sowing (DAS) to control aphids (*Aphis* spp. Linnaeus, 1758), the curcubit beetle (*Diabrotica speciosa* Germar) and whitefly (*Bemisia argentifolii* Bellows; Perring). Colonies of the maize aphid (*Rhopalosiphum maidis* Fitchi, 1856) were seen in the maize crop at 36 DAS and controlled by two sprayings with 0.42% neem oil, at 37 and 43 DAS.

Three harvests were made in the plots used for evaluating the cowpea 68, 73 and 79 days after planting. The dry bean yield was determined from the weight of the pods and dry grain. In addition, the number of pods plant per plant was determined (based on the pods harvested in the working area) together with the number of grains per pod (based on ten pods from the third harvest) and the 100-grain weight (based on the grains from the above ten pods). The grain yield was corrected for a water content of 15.5% (wet basis).

The dry maize was harvested 105 days after sowing, when the grain had a moisture content of around 20%. The number of ears per hectare (based on ears harvested in the working area of each plot), ear length and diameter (with a digital caliper, in a sample of 10 ears taken at random), the 100-grain weight and the number of grains per ear were evaluated. The number of grains per ear was estimated indirectly from the number of rows of grain multiplied by the number of grains in each row, based on 10 ears taken at random per plot. The 100-grain weight was estimated based on the weight and number of grains of these 10 ears. The grain yield was corrected for a moisture content of 15.5% (wet basis) and based on the moisture of the grains in the plot. In order to estimate the moisture content of the grains in the plot, a sample of approximately 100 grams of grain (FM) was left in a drying and sterilization oven at 75 °C for three days to obtain the dry matter weight (DM). The moisture was then calculated from the formula: Moisture = 100 - [((100 x DM) / FM)]. To evaluate the forage potential of the maize after harvesting, two plants taken at random from different holes were cut close to the ground, weighed and crushed in forage maker. A 100 g sample was placed in a drying and sterilization oven at 75 °C for three days to obtain the dry matter weight.

The advantage of intercropping was evaluated using the Land Equivalent Ratio (LER) defined by Mead and Willey (1980): $LER = LER_A + LER_B$. $LER_A = A_c/A_m$ and $LER_B = B_c/B_m$, where A_c and B_c represent the yields of intercrops A and B, respectively, and A_m and B_m represent the respective yields of monocrops A and B.

Analysis of variance of the yield data and their components in the maize and cowpea were carried out using the Microsoft Excel (2010) software. In the maize crop, the five treatment degrees of freedom (2 monocrops + 4 intercrops - 1) were broken down as follows: one degree for comparing the monocropped and intercropping systems; one degree for comparing the monocrops; one degree for comparing the intercropped maize cultivars, considering the mean values for the cowpea cultivars; one degree for comparing the intercropped maize cultivars, considering the mean value for each cowpea cultivar; and one degree to assess the existence of the maize cultivar x cowpea cultivar interaction. In the cowpea crop, the degrees of freedom were broken down in a similar way with the exception of one degree for comparing the intercropped cowpea varieties, considering the mean values for the maize cultivars, and one degree for comparing the intercropped varieties of cowpea, considering the mean value for each maize cultivar. Student’s t-test was applied at 5% probability to each Land Equivalent Ratio, to check whether the mean values were greater than 1.0.

RESULTS AND DISCUSSION

The effect of the treatments on ear dimensions, plant height and shoot dry matter in the maize are shown in Table 4. For ear length, the only effect was from comparing the intercropped maize cultivars, where the ears of the AG 1051 cultivar were longer than those of the AL Bandeirantes cultivar (Table 5).

The monocropped and intercropped cultivars differed in ear diameter, with the AG 1051 cultivar always superior. Differences in the effect of the cultivars on ear length and diameter may be due to less precision when evaluating ear length. This can even be seen in the values for the coefficient of experimental variation (Table 5). The ear length was measured with a rule, while the diameter was measured with digital calipers.

For plant height and ear insertion, the effects of the treatments were similar to their effects on ear diameter, except for the effects on plant height when comparing the monocropped and intercropping systems (Table 4), i.e. there was a difference between the monocropped and intercropped cultivars, with the AG 1051 cultivar superior to the AL Bandeirante cuktivar (Table 5). On average, the monocropped systems were

Table 4 - Summary of the analysis of variance for height and ear dimensions in two maize cultivars grown as monocrops and intercropped with two cowpea cultivars[1]

Source of variation	DF	Mean squares				
		Ear dimensions (cm)		Height (cm)		Shoot dry matter (kg ha^{-1})
		Length	Diameter	Plant	Ear insertion	
Blocks	5	0.98^{ns}	1.31^{ns}	168.83^{ns}	133.72^{ns}	1149201.0^{ns}
Treatments	5	8.31**	68.01**	6919.83**	4019.98**	10797559.2**
Monocrops	1	2.08^{ns}	87.91**	10680.33**	7105.33**	14399252.1**
Monocrops *vs*. Intercrops	1	2.35^{ns}	0.64^{ns}	1241.68**	21.13^{ns}	35302403.6**
Intercrops	3	12.38**	83.83**	7559.04**	4324.49**	1428713.4^{ns}
Intercropped maize (mean values for the cowpea cultivars)	1	35.04**	248.20**	22632.04**	12742.04**	3396032.7*
Intercropped maize (mean values for each cowpea cultivar)	1	0.04^{ns}	0.02^{ns}	5.04^{ns}	9.38^{ns}	873253.5^{ns}
Maize x cowpea interaction	1	2.04^{ns}	3.27^{ns}	40.04^{ns}	222.0^{ns}	16854.0^{ns}
Error	25	0.92	1.31	122.31		764776.3

[1] n.s.; *; **: not significant; significant at 5% and 1% probability, respectively, by F-test

Table 5 - Mean values for ear dimensions, plant height and ear insertion in two maize cultivars grown as monocrops and intercropped with two cowpea cultivars

Comparison		Ear dimensions (cm)		Height (cm)		Shoot dry matter (kg ha^{-1})
		Length	Diameter	Plant	Ear insertion	
Monocropped maize cultivars	AG 1051	14 a	5.0 a	210 a	111 a	5795 a
	AL Bandeirante	13 a	4.5 b	151 b	63 b	3604 b
Intercropped maize (mean values for the cowpea cultivars)	AG 1051	16 a	5.1 a	199 a	108 a	2975 a
	AL Bandeirante	13 b	4.4 b	137 b	62 b	2223 b
Intercropped maize (mean values for each cowpea cultivar)	Corujinha	14 a	4.7 a	168 a	85 a	2408 a
	Sempre Verde	14 a	4.8 a	167 a	86 a	2790 a
Monocrops *vs*. Intercrops	Monocrop	14 a	4.7 a	180 a	87 a	4699 a
	Intercrop	14 a	4.8 a	168 b	85 a	2599 b
Coefficient of variation (%)		6.8	2.4	6.4	9.7	24.0

[1]Mean values followed by the same letter, within each comparison, do not differ at 5% probability by F-test

superior to the intercropping systems in terms of plant height.

There was an effect on shoot dry matter in the maize from the monocropped and intercropped cultivars, and from the mean comparison between the monocrops and intercrops (Table 4). The AG 1051 cultivar was superior, both as a monocrop and an intercrop. Dry matter yield was higher in the monocrops than in the intercrops (Table 5).

In terms of growth, the AG 1051 cultivar was superior to the AL Bandeirantes cultivar as a monocrop and as an intercrop. In the maize, the mean superiority of the monocrops over the intercrops, in terms of plant height and shoot growth, shows that the cowpea contributed to a reduction in maize growth. This reduction must have been due to competition for water, light and nutrients, and, possibly, to allelopathy (ADLER; CHASE, 2007). It was found that the branches of the Corujinha cultivar often “used” the maize plants for support, i.e. plants of that cultivar became entwined in the maize. This shaded the maize, reducing its photosynthetic activity and, as a result, reducing its growth. It should be noted however, that the greater dry matter production per unit area in the maize seen in the monocrops was possibly due primarily to the larger monocropped maize population (50 thousand plants ha^{-1}) compared to the intercropped maize population (25 thousand plants ha^{-1}). Other authors found that dry matter yield in maize depends on the planting season. In one year, the intercrop was superior, but the following year, the monocrop surpassed all the intercropping systems with cowpea (DAHMARDEH *et al*., 2009).

There was an effect on grain yield from the following comparisons: monocrops, intercrops vs. monocrops, and intercropped maize (Table 6). In both the monocropped and intercropping systems, the AG 1051 cultivar was superior to the AL Bandeirantes cultivar (Table 7). On average, the monocropped systems were superior to the intercropping systems (Table 7). For the number of ears per hector, the only effect was from the comparison between the monocropped and intercropping systems (Table 6), with the monocrops superior to the intercrops, probably due in large part to the greater plant population in the monocropped systems. There was an effect from the monocropped and intercropped cultivars on the number of grains per ear and 100-grain weight, (Table 6). The AG 1051 cultivar was superior in both characteristics. Therefore, the higher grain yield in the AG 1051 cultivar compared to the AL Bandeirante cultivar was due to the larger number of grains per ear and the 100-grain weight, since neither cultivar differed in the number of ears per hectare (Table 7). Despite the AG 1051 cultivar being superior to the AL Bandeirante cultivar in terms of grain yield, in an intercropping system it is unimportant which variety of cowpea, Corujinha or Sempre Verde, is used with each maize cultivar. This can be deduced from the fact that there were no effects from the maize cultivars on either of the cowpea cultivars under evaluation, nor from the maize cultivar x cowpea cultivar interaction (Tables 6 and 7).

In the monocrops and, particularly in the intercropping systems, many variables are involved, which

Table 6 - Summary of the analysis of variance for grain yield in two maize cultivars and their components grown as monocrops and intercropped with two cowpea cultivars[1]

Source of variation	DF	Grain yield (kg ha^{-1})	Number of ears ha^{-1}	Number of grain ear^{-1}	100-grain weight (g)
		Mean squares			
Blocks	5	114992.9^{ns}	5816022.6^{ns}	4251.9^{ns}	36.3^{ns}
Treatments	5	12066249.0**	893971921.9**	25892.8**	201.6**
Monocrops	1	9156027.0**	13033336.3^{ns}	9747.0*	308.1**
Monocrops *vs*. Intercrops	1	35528235.1**	4435187350.2**	2403.6^{ns}	22.2^{ns}
Intercrops	3	5215660.9**	7212974.3^{ns}	39104.4**	226.0**
Intercropped maize (mean values for the cowpea cultivars)	1	15451335.4**	14315970.7^{ns}	110432.7**	669.9**
Intercropped maize (mean values for each cowpea cultivar)	1	27812.0^{ns}	2824948.2^{ns}	864.0^{ns}	7.7^{ns}
Maize x cowpea interaction	1	167835.4^{ns}	4498004.2^{ns}	6016.7^{ns}	0.2^{ns}
Error	25	69049.2	4674657.6	1831.8	13.8

[1] n.s.; *; **: not significant; significant at 5% and 1% probability, respectively, by F-test

Table 7 - Grain yield and its components in maize cultivars grown as monocrops and intercropped with cowpea cultivars

Comparison		Grain yield (kg ha^{-1})	Number of ears ha^{-1}	Number of grains ear^{-1}	100-grain weight (g)
Monocrops	AG 1051	5749 a	48751 a	501 a	38 a
	AL Bandeirante	4002 b	46667 a	444 b	27 b
Intercropped maize (mean values for the cowpea cultivars)	AG 1051	3570 a	24936 a	558 a	39a
	AL Bandeirante	1965 b	23391 a	422 b	29 b
Intercropped maize (mean values for each cowpea cultivar)	Corujinha	2734 a	24506 a	484 a	34 a
	Sempre Verde	2802 a	23820 a	496 a	35 a
Monocrops *vs*. Intercrops	Monocrop	4875 a	47709 a	473 a	33 a
	Intercrop	2768 b	24163 b	490 a	34 a
Coefficient of variation (%)		7.6	6.8	8.8	11.1

[1]Mean values followed by the same letter, within each comparison, do not differ at 5% probability by F-test

makes it difficult to establish the possible causes of one cultivar being superior to another. However, it is worth noting that some authors found a positive correlation between yield and characteristics associated with growth, including plant height, leaf area, number of leaves per plant, shoot biomass, and ear length and diameter (GHASSEMI-GOLEZANI; TAJBAKHSH, 2012; RAFIQ *et al*., 2010; SOKOTO; ABUBAKAR; DIKKO, 2012; WANNOWS; AZZAM; AL-AHMAD, 2010). As already mentioned, the AG 1051 cultivar showed greater growth than the AL Bandeirante cultivar (Tables 4 and 5) for most of the characteristics under evaluation (Table 5). In maize, grain yield can be considered a result of components that occur during the various development stages in the life cycle of the plant. In other words, grain yield is the product of dry-matter accumulation (i.e. biomass) and the allocation of part of this total biomass to the grain (LEE; TOLLENAAR, 2007).

There was an effect on grain yield in the cowpea from the monocrops, monocrops vs. intercrops and from the maize cultivars (Table 8). In monocropped systems the Corujinha cultivar was superior to the Sempre Verde cultivar (Table 9). This superiority was due to the greater number of pods and number of grains per pod, since the Sempre Verde variety surpassed the Corujinha cultivar in 100-grain weight (Table 9).

The monocropped systems were superior to the intercropping systems (Table 9). This was probably due to competition with the intercropped maize, and because

Table 8 - Summary of the analysis of variance for dry-grain yield in two cowpea cultivars grown as monocrops and intercropped with two maize cultivars

Source of variation	DF	Mean squares			
		Grain yield (kg ha^{-1})	(Total number of pods ha^{-1})	Number of grains pod^{-1}	100-grain weight (g)
Blocks	5	100737.7^{ns}	13688752964.6^{ns}	1.87^{ns}	3.28^{ns}
Treatments	5	738198.1**	227129285898.1**	6.40**	62.75**
Monocrops	1	1584133.3**	537942834530.1**	6.75**	132.67**
Monocrops *vs*. Intercrops	1	1507716.1**	458659292028.1**	10.13**	0.07^{ns}
Intercrops	3	199713.7^{ns}	46348100977.4*	5.04**	60.34**
Intercropped cowpea (Mean values for the maize cultivars)	1	215651.0^{ns}	84490785333.4*	15.04**	174.42**
Intercropped cowpea (Mean value for cowpea cultivar)	1	379765.0*	54312857265.4*	0.04^{ns}	5.51^{ns}
Cowpea x maize interaction	1	3725.0^{ns}	240660333.4^{ns}	0.04^{ns}	1.08^{ns}
Error	25	73688.9	11582014021.0	0.59	4.57

Table 9 - Grain yield and its components in cowpea cultivars grown as monocrops and intercropped with maize cultivars

Comparison		Grain yield (kg ha^{-1})	Number of pods ha^{-1}	100-grain weight (g)	Number of grains pod^{-1}
Monocropped cowpea cultivars	Corujinha	1346 a	693741 a	15 b	16 a
	Sempre Verde	620 b	270286 b	22 a	15 b
Intercropped cowpea culktivars (Mean values for the maize cultivars)	Corujinha	644 a	301905 a	15 b	18 a
	Sempre Verde	454 a	183238 b	21 a	16 b
Intercropped cowpea cultivars (Mean value for each maize cultivar)	AG 1051	423 b	195000 b	18 a	17 a
	AL Bandeirante	675 a	290143 a	19 a	17 a
Monocrops *vs*. Intercrops	Monocrop	983 a	482013 a	18 a	16 b
	Intercrop	549 b	242571 b	18 a	17 a
Coefficient of variation (%)		39.2	33.4	11.7	4.7

[1]Mean values followed by the same letter, within each comparison, do not differ at 5% probability by F-test

the cowpea population in the intercropping systems was smaller (10,000 plants ha^{-1}) than in the monocropped systems (20,000 plants ha^{-1}). The superiority of the monocrops was due to the greater number of pods, since there was no difference between cropping systems in the number of grains per pod, and the intercropping systems resulted in a greater value for the 100-grain weight (Table 9). Both cowpea cultivars showed better performance when intercropped with the AL Bandeirante maize cultivar than with the AG 1051 cultivar; the better performance, in terms of grain yield, of the cowpea cultivars was due to the greater number of pods per hectare, as there was no difference between the mean values of the two cowpea cultivars in the number of grains per pod or the 100-grain weight, whether intercropped with the AG 1051 or AL Bandeirante maize cultivars.

From the various phenological and morphological characteristics they evaluated, Zystro, Leon and Tracy (2012) found that plant height best explained the competitiveness of maize cultivars. In the present study, the AG 1051 cultivar not only showed the greatest plant height and highest ear insertion, but also greater growth in general (determined from the shoot dry matter) (Table 5). This superiority in terms of growth may be an indication that the AG 1051 cultivar is more competitive with the cowpea plants than is the AL Bandeirante cultivar. The greater competitive ability of the AG 1051 cultivar would explain the lower yields of the cowpea cultivars in the intercropping systems.

The maize cultivar x cowpea cultivar interaction was not significant for the characteristics under evaluation in either the maize or the cowpea (Tables 4, 6 and 8). This means that the behavior of the maize cultivars was similar whether intercropped with the Corujinha or Sempre Verde varieties of cowpea. Similarly, the behavior of the cowpea cultivars was similar when grown intercropped with the AG 1051 or AL Bandeirante varieties of maize. Studies on intercropping involving several maize cultivars and several cowpea cultivars appear to be rare. As in the present study, Silva (2001) also found the absence of any interaction between maize cultivars and cowpea cultivars. Such an interaction probably occurs when cultivars showing relevant differences are evaluated in terms of characteristics that are strongly associated with yield. It is also important that the experiment be sufficiently accurate for the effects of the interaction to be detected. Egbe, Alibo and Nwueze (2010), for example, found differing behavior in cowpea cultivars of different cycles when these were intercropped with the same maize cultivar.

The mean squares from the analysis of variance of the data for the land equivalent ratio (LER) were 0.26, 0.29 and 0.10, with 5, 3 and 15 degrees of freedom, respectively, for the blocks, treatments and error. Table 10 shows the values for LER in the four possible combinations of the two maize cultivars with the two cowpea cultivars. The only combination in which the LER value was significantly greater than 1.0 was the AL Bandeirante maize cultivar with the Sempre Verde cowpea cultivar. As such, the intercrop would only be advantageous using less competitive cultivars showing smaller growth (the Sempre Verde cultivar was relatively little entwined in the maize). It should be remembered, however, that for intercropping systems, in addition to competition, two other types of relationship may occur between the crops involved: competitive reduction and facilitation. Competitive reduction occurs when interspecific competition between the intercrops is less than the intraspecific competition in each monocrop. Facilitation occurs when one species has a positive effect on the others. Intercrops will outdo monocrops when the positive interactions are superior to the competitive interactions (SILVA; SILVA, 2014).

Table 10 - Mean values for land equivalent ratio calculated based on grain yield in maize and cowpea cultivars

Cultivar		Land equivalent ratio (LER)
Maize	Cowpea	
AG 1051	Corujinha	1.04^{ns}
AL Bandeirantes	Corujinha	1.15^{ns}
AG 1051	Sempre Verde	1.25^{ns}
AL Bandeirantes	Sempre Verde	1.55*
Coefficient of variation		25.35

$^{1*, ns}$ Mean values greater or equal to 1.0, respectively, at 5% probability by t-test

Some authors argue that intercropping is only advantageous under unfavorable conditions (KERMAH *et al*., 2017; TSUJIMOTO *et al*., 2015). Indeed, certain unfavorable conditions, such as low soil fertility, can influence intercropping systems as they affect the competitiveness of the crops involved. However, other conditions, such as density and sowing time, not necessarily unfavorable, but which affect competition, also have an influence on intercropping systems (YU *et al*., 2016).

CONCLUSIONS

1. Growth and grain yield were greater in the AG 1051 hybrid than in the AL Bandeirante variety, in the monocropped and intercropping systems;
2. Mean growth and grain yield in the maize were greater in the monocrops than in the intercrops. In the intercropping systems, it is unimportant which variety of cowpea, Corujinha or Sempre Verde, is used with each maize cultivar, as there was no interaction between the maize and cowpea cultivars;
3. In the monocropped systems, grain yield in the Corujinha cultivar was greater than in the Sempre Verde cultivar. The mean grain yield of the monocrops was higher than that of the intercrops. The two cowpea cultivars showed better performance intercropped with the AL Bandeirante maize cultivar than with the AG 1051 cultivar;
4. The value of the land equivalent ratio was greater than 1.0 only for the combination of the AL Bandeirante variety of maize and the Sempre Verde variety of cowpea.

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