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Intercropping maize and cowpea cultivars: I. Green-grain yield[1]

Consorciação de cultivares de milho e feijão-caupi: I. Rendimentos de grãos verdes

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ABSTRACT - Green ears of maize are much appreciated all over Brazil and reach higher prices than dry grain. This also occurs with green cowpea grain, which is much appreciated in the north and northeast of the country. The aim of this study was to identify maize and cowpea cultivars that can be grown as monocrops or intercrops to produce green grain in the state of Pará (PA). An experiment was carried out in a randomized block design with six replications in Marabá, PA. Monocrops of traditional varieties of the cowpea ('Corujinha' and 'Sempre Verde') and the maize cultivars ('AG 1051' and 'AL Bandeirante'), and four alternating, intercropped rows of a combination of the varieties and cultivars were evaluated. The 'AG 1051' cultivar was more productive than the 'AL Bandeirante' cultivar, as both a monocrop and an intercrop. The cowpea cultivars showed a similar performance under both systems of cultivation. There was no interaction between the maize cultivars and cowpea cultivars. The monocrops were superior to the intercrops for green-ear, green-pod and green-grain yield. Considering the land equivalent ratio, if the aim is to produce green pods, intercropping is only beneficial in the AG 1051 + Corujnha combination. If the aim is for green-grain yield in the cowpea, intercropping is more advantageous when the 'AG 1051' cultivar is combined with any cowpea cultivar. The intercrop including the 'AL Bandeirante' cultivar is only beneficial with the 'Corujinha' cultivar, and if the aim is to market unhusked, green ears of maize.

Key words: *Zea mays*. *Vigna unguiculata*. Green maize. Green beans. Land equivalent ratio.

RESUMO - Espigas verdes de milho são muito apreciadas em todo o Brasil e alcançam preços superiores aos dos grãos secos. Fato semelhante ocorre com os grãos verdes de feijão-caupi, que são muito apreciados nas regiões Norte e Nordeste desse país. Objetivou-se identificar cultivares de milho e de feijão-caupi que possam ser cultivadas no estado do Pará, em monocultivo ou em consórcio, para produção de grãos verdes. Um experimento foi realizado no delineamento de blocos casualizados com seis repetições, em Marabá-PA. Monocultivos de variedades tradicionais de feijão-caupi (Corujinha e Sempre Verde) e de cultivares de milho (AG 1051 e AL Bandeirante) e quatro consórcios, em fileiras alternadas, das combinações das variedades e cultivares foram avaliados. A cultivar AG 1051 foi mais produtiva do que a cultivar AL Bandeirante, em monocultivo e em consorciação. As cultivares de feijão-caupi apresentaram desempenhos semelhantes nos dois sistemas de cultivo. Não houve interação cultivares de milho x cultivares de feijão-caupi. Os monocultivos foram superiores aos consórcios, quanto aos rendimentos de espigas verdes e de vagens e grãos verdes. Considerando-se a eficiência do uso da terra, se a exploração visar a produção de vagens verdes, a consorciação somente será proveitosa na combinação AG 1051 + Corujinha. Se a exploração visar o rendimento de grãos verdes de feijão-caupi, a consorciação será vantajosa com a cultivar AG 1051 for combinada com qualquer cultivar de feijão-caupi. O consórcio envolvendo a cultivar AL Bandeirante somente será proveitoso com a cultivar Corujinha e se a exploração do milho visar espigas verdes empalhadas comercializáveis.

Palavras-chave: *Zea mays*. *Vigna unguiculata*. Milho verde. Feijão verde. Uso eficiente da terra.

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INTRODUCTION

Cultivation of the cowpea [*Vigna unguiculata* (L.) Walp.], previously limited almost exclusively to the northeast of Brazil, is expanding to the region of the Cerrado, and to the north, northeast and mid-west of the country, where it is included in production managements as an off-season crop, after soybean and rice, and, in some places, as the main crop (FREIRE FILHO, 2011). Maize (*Zea mays* L.) is grown in all regions of Brazil, and is only surpassed in terms of cultivated area by the soybean (MÔRO; FRITSCHE-NETO, 2015).

One of the characteristics of cowpea and maize production systems in Brazil is the exploitation of each crop to produce both green and dried grain. Green cowpea grain has a water content of around 60%, while green maize grain has a water content of around 70 to 80%. Green cowpea grain is much appreciated in the north and northeast of Brazil, and reaches higher prices than those of the dry grain. This also occurs with green ears of maize, which are consumed throughout Brazil.

Green maize and cowpea grain are produced from monocrops and intercrops. There is a growing interest in grass-legume intercropping for the following reasons: higher and more-stable yields and economic margins than those obtained under monocropping, and a better use of resources by the intercrops (BEDOUSSAC *et al*., 2015).

Studies on evaluating cultivars for green-grain production in the cowpea (ANDRADE *et al*., 2010; BASTOS *et al*., 2012; SILVA *et al*., 2013) and in maize (ALMEIDA *et al*., 2005; CASTRO; SILVA; CARDOSO, 2013) under monocropping, have shown that there are differences between cultivars in terms of green-grain yield. Intercropping for green-grain production in maize or the cowpea has been evaluated by few authors (GUEDES *et al*., 2010; SANTOS *et al*., 2014; SILVA, 2001), and such evaluations have shown that some combinations of cultivar are more advantageous than others; they have also demonstrated that under intercropping, the yield of both crops is lower than under monocropping, but that some maize-cowpea combinations allow a better use of resources for production (greater land equivalent ratio).

As such, there is an interest in identifying maize and cowpea cultivars that can be grown in the state of Pará, as monocrops or intercrops, to produce green grain. In the state, the regions where the two crops are exploited are generally characterized by subsistence farming and family farmers using low levels of technology (ALVES *et al*., 2017; COUTINHO *et al*., 2014; SOUZA *et al*., 2002; SOUZA *et al*., 2017).

The aim of the present study was to identify maize and cowpea cultivars that can be exploited as monocrops and intercrops to produce green grain.

MATERIAL AND METHODS

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

In the Köppen-Geiger classification, the climate in the region lies on the transition from type AW to type Am. The climate is considered Tropical (Subtype Aw), with both a wet and a dry season (rainy summer and dry winter). The wettest period extends from December to April, and the driest from June to October. March has the highest rainfall (377 mm) and August the lowest (12 mm). The average air temperature is 28 °C, with the maximum mean temperature around 32.7 °C and a minimum mean temperature of 23.3 °C. The mean monthly relative humidity ranges from 76 to 86%, while the annual mean is 82%. Total mean annual insolation is 2263 hours (ALMEIDA, 2007). During the experimental period (January to May 2015), the average air temperature ranged from 24.5 to 25.6 °C, the total radiation and rainfall were 67 mj m^{-2} day^{-1} and 989 mm respectively, and the relative humidity ranged from 87 to 98%. The data were obtained from the Onça Puma Weather Station of the Vale Technological Institute. The Onça Puma Station is located in the town of Ourilândia do Norte, PA (06°31’46” S 51°03’33” W, 259m), 394 km from Marabá - PA (TAVARES *et al*., 2018).

According to the Brazilian System of Soil Classification (EMBRAPA, 2013), the soil in the experimental area is classified as a Dystrophic Red-Yellow Latosol, with a sandy-clay texture and red coloration, deep, friable and highly erodible. Ten samples of the experimental soil were taken at random from a depth of approximately 0 to 25 cm, which were then combined to form a composite sample and submitted to chemical analysis. The results of this analysis were as follows: pH = 5.6 (H_2O); OM = 1.8 g kg^{-1}; P = 3.67 mg dm^{-3}; K^+ = 54.7 mg dm^{-3}; Ca^{2+} = 1.43 $cmol_c$ dm^{-3}; Mg^{2+} = 0.50 $cmol_c$ dm^{-3}; Al^{3+} = 0.02 $cmol_c$ dm^{-3}; H + Al = 3.03 $cmol_c$ dm^{-3}.

The experiment was carried out in a randomized complete-block design with six replications and eight treatments. The treatments were the result of two maize monocrops (the ‘AG 1051’ and ‘AL Bandeirante’ cultivars), two cowpea monocrops (the ‘Corujinha’ and ‘Sempre Verde’ traditional varieties) and four intercrops. The intercrops were obtained by combining the two maize cultivars with the two varieties of cowpea. Six treatments were therefore evaluated for each crop. For the intercrops, the maize and cowpea occupied alternating rows. ‘Corujinha’ and ‘Sempre Verde’ were chosen from among the varieties most used by family farmers in settlements neighboring the IFPA Campus. Both are Creole varieties of indeterminate growth, and are used in the region as monocrops and intercrops to produce both green and dry grain. The 'AG 1051' cultivar is a double hybrid with a semi-early cycle, recommended for "normal" and off-season crops in the South, Midwest, Southeast and Northeast, and the in state of Rondônia, (CRUZ; PEREIRA FILHO, 2006). 'AL Bandeirantes' is a open-pollinated variety with a semi-early cycle, used under conventional cropping systems as a normal and off-season crop (CRUZ; PEREIRA FILHO, 2006).

Each plot was 6.0 m in length, with the width varying according to the number of planted rows. This number differed and depended on the cropping system, and had the purpose of avoiding the border effect in the cowpea where plots of this crop came between two plots of maize. The monocrops of maize and cowpea were evaluated in three and five rows respectively, while the intercrops were evaluated in four rows. The working area was considered that occupied by the central row of the monocrops, and by the two central rows of the intercrops. Under both systems of cultivation, the plants from the end holes of each central row were considered borders and not included when collecting data.

The experiment was carried out under rainfed conditions in an area that received 2 t ha^{-1} limestone and had been cultivated with maize during the 2012/1013 and 2013/2014 seasons. The soil was harrowed twice, and received 40 kg N, 120 kg P_2O_5 and 40 kg of K_2O per hectare. In the cowpea, base fertilization included 10 kg N, 120 kg P_2O_5 and 40 kg K_2O per hectare. In the maize and cowpea, ammonium sulfate, simple superphosphate and potassium chloride were used as sources of nitrogen, phosphorus and potassium respectively. In both crops, the fertilizers were applied by hand below and to the side of the planting furrows. Weeds were controlled by hoeing 20 and 40 days after sowing. Cover fertilizer (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.

Both crops were sown by hand on February 4, 2015, using four seeds per hole. The spacing was 1.0 x 0.4 m for the maize, and 1.0 x 1.0 m for the cowpea, in both the monocrops and the intercrops. Twenty days after sowing, the crops were thinned, leaving two plants per hole. As such, after thinning, the planting density of the monocropped maize and cowpea was 50,000 and 20,000 plants ha^{-1} respectively; the respective densities of the intercropped maize and cowpea were 25,000 and 10,000 plants ha^{-1}.

The cowpea crop was sprayed twice, 18 and 25 days after planting (DAP), with 0.42% neem oil (*Azadiracta indica* A. Juss) to control aphids (*Aphis* spp. Linnaeus, 1758), the cucurbit beetle (*Diabrotica speciosa* Germar) and whitefly (*Bemisia argentifolii* Bellows; Perring). In the maize crop, colonies of the maize-leaf aphid (*Rhopalosiphum maidis* Fitchi, 1856) were seen; these were controlled by spraying twice with 0.42% neem oil, at 37 and 43 DAP.

In plots where green-grain yield was evaluated, six harvests were made, at 61, 65, 71, 77, 82 and 87 days after planting. The harvests were made when grains showed a moisture content of around 60%. Cowpea yield was measured from the weights of the pods and green grain. The number of pods per plant (based on the total pods collected in the plot), the number of grains per pod (based on ten pods from the third collection) and the 100-grain weight (based on five grain samples from pods from the third collection) were also evaluated.

The green maize was harvested 70, 72 and 74 days after planting, when the grain had a moisture content of between 70 and 80%. Green-maize yield was evaluated from the total number and weight of the ears, and the number and weight of marketable husked and unhusked ears. Marketable husked ears were considered those of suitable appearance and with a length of 20 cm or more. Marketable unhusked ears were considered those whose health and grain production were suitable for marketing, and whose length was 17 cm or over (criteria used in the region).

To evaluate the forage potential of the green maize, two plants, taken at random from different holes after the final collection, were cut close to the ground, weighed and crushed in a forage maker. A 100 g sample was placed in a sterilizing and drying oven at 75 °C for three days to obtain the dry weight.

The advantage of intercropping over monocropping was evaluated using the land equivalent ratio (LER) defined by Mead and Willey (1980): LER = $LER_A + LER_B$. $LER_A = A_i/A_m$ and $LER_B = B_i/B_m$, where Ai and Bi represent the yields of intercrops A and B respectively, and A_m and B_m represent the respective yields of monocrops A and B. The values for LER were calculated from the pod yield and green-grain yield in the cowpea, and from the yield (in terms of weight) of total and marketable husked and unhusked ears in the maize.

Analysis of variance of the data for the maize and cowpea grain was 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 monocrops *vs*. intercrops; one degree for comparing monocrops; one degree for comparing maize cultivars under intercropping, considering mean values in the cowpea cultivars; one degree for comparing maize cultivars under intercropping, considering mean values for each cowpea cultivar; and one degree for evaluating the existence of the maize cultivar x cowpea cultivar interaction. In the cowpea crop, the degrees of freedom were similarly broken down, except for one degree for comparing cowpea varieties under intercropping, considering mean values in the maize cultivars, and one degree for comparing cowpea varieties under intercropping, considering mean values for each maize cultivar. Student's t-test was applied at 5% probability to the mean values of the Land Equivalent Ratio to verify whether they were greater than 1.0.

RESULTS AND DISCUSSION

For the total number of green ears of maize, the analysis of variance showed an effect from a comparison of the monocrops and intercrops only (Table 1). On average, the monocrops were superior to the intercrops (Table 2). The effects of the treatments on the number of marketable unhusked ears were similar to those of the treatments on the number of marketable husked ears (Table 1). There was no effect on these characteristics from a comparison of the maize cultivars within each of the cowpea cultivars or from their interaction. As a

Table 1 - Summary of the analysis of variance of the data for the number of green ears in monocropped maize cultivars and intercropped with cowpea cultivars[1]

Source of variation	Degrees of freedom	Number of ears ha^{-1}		
		Total	Marketable unhusked	Marketable husked
		Mean square		
Blocks	5	5371856.3^{ns}	5279295.3^{ns}	12091789.3^{ns}
Treatments	(5)	1161329244.9**	891959031.8**	782128705.7**
Monocrops	1	7975590.8^{ns}	908941320.3**	1498075840.3**
Monocrops vs. Intercrops	1	5788503406.1**	3099350790.0**	1872281425.7**
Intercrops	(3)	3389075.8^{ns}	150501016.3**	180095420.8**
Intercropped maize cultivars (mean values for the cowpea cultivars)	1	5913315.4^{ns}	445714347.0**	532578552.0**
Intercropped maize cultivars (mean values for each cowpea cultivar)	1	1174395.0^{ns}	3495303.4^{ns}	1812251.0^{ns}
Maize x cowpea interaction	1	3079517.0^{ns}	2293398.4^{ns}	5895459.4^{ns}
Error	25	9220671.1	10304166.4	14969866.2

[1] ^{ns}; *; **: not significant; significant at 5% and significant at 1% probability respectively by F-test

Table 2 - Mean values for the number of green ears in monocropped maize cultivars and intercropped with cowpea cultivars[1]

Comparison		Number of ears ha^{-1}		
		Total	Marketable unhusked	Marketable husked
Monocrops	AG 1051	54538 a	49359 a	45180 a
	AL Bandeirante	52908 a	31953 b	22833 b
Intercropped maize (mean values for the cowpea cultivars)	AG 1051	27320 a	25282 a	23419 a
	AL Bandeirante	26328 a	16663 b	13998 b
Intercropped maize (mean values for each cowpea cultivar)	Corujinha	27045 a	21355 a	18983 a
	Sempre Verde	26603 a	20591 a	18434 a
Monocrops vs. Intercrops	Monocrop	53723 a	40656 a	34007 a
	Intercrop	26824 b	20973 b	18708 b
Coefficient of variation (%)	8.5	15.1	16.3	

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

monocrop and as an intercrop, the ‘AG 1051’ cultivar was superior to ‘AL Bandeirante’ (Table 2). On average, the monocrops were superior to the intercrops (Table 2).

The effects of the treatments on total weight and on the weight of marketable husked and unhusked ears were similar (Table 3). That is, there was an effect from the monocropped and intercropped cultivars, and from the comparison of the monocrops with the intercrops. The ‘AG 1051’ cultivar was more productive than the ‘AL Bandeirante’ cultivar, both as a monocrop and intercrop (Table 4). Furthermore, the monocrops were better on average than the intercrops (Table 4). Several characteristics are responsible for the superiority of one cultivar over another in terms of yield. Characteristics of the root-system and shoots, as well as physiological characteristics, determine the differences in yield between cultivars (LYNCH, 2013; MI *et al*., 2010; QI *et al*., 2010). As such, suggesting causes for the superiority of the ‘AG 1051’ cultivar in relation to ‘AL Bandeirante’ is difficult.

The superiority of the monocrops in relation to the intercrops for all the characteristics used to evaluate green-ear yield, must have been due mainly to the larger plant population used in the monocrops (50 thousand plants ha^{-1}) compared to that adopted under intercropping (25 thousand plants ha^{-1}). It is possible that the competition caused by the cowpea due to production factors (water, nutrients and

Table 3 - Summary of the analysis of variance of the data for green-ear weight in monocropped maize cultivars and intercropped with cowpea cultivars[1]

Source of variation	Degrees of freedom	Ear weight (kg ha^{-1})		
		Total	Marketable unhusked	Marketable husked
		Mean square		
Blocks	5	816221.4^{ns}	855655.5^{ns}	434193.2^{ns}
Treatments	(5)	72795664.9**	77354594.3**	32054456.8**
Monocrops	1	52250133.3**	123123320.3**	71638533.3**
Monocrops vs. Intercrops	1	280102890.9**	193211929.4**	61049408.4**
Intercrops	(3)	10541766.8**	23479240.6**	9194780.7**
Intercropped maize cultivars (mean values for the cowpea cultivars)	1	30172837.5**	69298813.5**	26964280.0**
Intercropped maize cultivars (mean values for each cowpea cultivar)	1	682762.7^{ns}	781204.2^{ns}	385827.0^{ns}
Maize x cowpea interaction	1	769700.2^{ns}	357704.2^{ns}	234235.0^{ns}
Error	25	1068763.5	1254919.5	726994.6

[1] ^{ns}; **: not significant; significant at 1% probability respectively by F-test

Table 4 - Mean values for green-ear weight in monocropped maize cultivars and intercropped with cowpea cultivars[1]

Comparison		Ear weight (kg ha^{-1})		
		Total	Marketable unhusked	Marketable husked
Monocrops	AG 1051	14719 a	13915 a	8658 a
	AL Badeirante	10545 b	7509 b	3772 b
Intercropped maize (mean values for the cowpea cultivars)	AG 1051	7836 a	7497 a	4512 a
	AL Bandeirante	5593 b	4099 b	2392 b
Intercropped maize (mean values for each cowpea cultivar)	Corujinha	6883 a	5978 a	3579 a
	Sempre Verde	6546 a	5617 a	3326 a
Monocrops vs. Intercrops	Monocrop	12632 a	10712 a	6215 a
	Intercrop	6715 b	5798 b	3452 b
Coefficient of variation (%)	11.9	11.7	16.3	

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

light) also contributed to the reduction in maize yield in the intercrops. For a maize-soybean intercrop, Lv *et al*. (2014) found that below-ground competition was more relevant than above-ground competition. However, in the present study, it was seen that branches of the two cowpea cultivars "involved" the maize plants, which must have intensified the light competition. It should also be mentioned that the plants of the 'Corujinha' "involved" the maize plants more vigorously than did the 'Sempre Verde' cultivar.

In terms of pod yield and green-grain yield, the analysis of variance in the cowpea indicated an effect from a comparison of the monocrops with the intercrops only (Table 5). On average, the monocrops were superior to the intercrops for both characteristics (Table 6). The superiority of the monocrops must have been due mainly to the larger population of monocrops (20 thousand plants ha^{-1}) compared to that of the intercrops (10,000 plants ha^{-1}). Competition exerted by the intercropped maize must also have reduced cowpea yield. Similar results have been seen by other authors (NDAKIDEMI; DAKORA, 2007).

The greater pod yield and green-grain yield in the monocrops were due to the higher number of pods, since the 100-grain weight and number of grains per pod were greater in the intercrops (Tables 7 and 8). Therefore, compensation occurred between the principal yield

Table 5 - Summary of the analysis of variance of the data for pod yield and green-grain yield in monocropped cowpea cultivars and intercropped with maize cultivars

Source of variation	Degrees of freedom	Yield (kg ha^{-1}) Mean square	
		Pods	Grain
Blocks	5	2849299.8^{ns}	557296.3^{ns}
Treatments	5	6784695.7**	1323139.0*
Monocrops	1	1594323.0^{ns}	1239061.3^{ns}
Monocrops vs. Intercrops	1	28332882.7**	3778042.4**
Intercrops	3	1332090.9^{ns}	532863.8^{ns}
Intercropped cowpea (mean values for the maize cultivars)	1	506341.5^{ns}	448540.0^{ns}
Intercropped cowpea (mean values for each maize cultivar)	1	1462240.7^{ns}	910651.0^{ns}
Cowpea x maize interaction	1	2027690.7^{ns}	239400.4^{ns}
Error	25	1107598.3	368854.6

[1] ns; *; **: not significant; significant at 5% and significant at 1% probability respectively by F-test

Table 6 - Mean values for pod yield and green-grain yield in monocropped cowpea cultivars and intercropped with maize cultivars[1]

Comparison		Yield (kg ha^{-1})	
		Pods	Grain
Monocrops	Corujinha	4749 a	2388 a
	Sempre Verde	4020 a	1745 a
Intercropped cowpea (mean values for the maize cultivars)	Corujinha	2648 a	1516 a
	Sempre Verde	2357 a	1242 a
Intercropped cowpea (mean values for each maize cultivar)	AG 1051	2749 a	1574 a
	AL Bandeirante	2256 a	1184 a
Monocrops vs. Intercrops	Monocrop	4384 a	2066 a
	Intercrop	2502 b	1379 b
Coefficient of variation (%)		33.63	37.8

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

components for the pods and the green grain (number of pods per plant, number of grains per pod and grain weight). This compensation, which is common in many crops, occurs mainly under conditions of stress, such as those caused by competition with other cowpea plants (monocrops) or with other cowpea and maize plants (intercrops). As proposed by Adams (1967) for *Phaseolus vulgaris* L., the compensation seen in the present study is a result of the competition for metabolites, both organic and inorganic, by the three yield components.

The effect of the maize cultivar x cowpea cultivar interaction was not significant for the characteristics under evaluation (Tables 3, 5 and 7), demonstrating the similar behavior of the maize cultivars when intercropped with the cowpea cultivars, and vice versa. Similar results to those reported here, regarding the absence of the maize cultivar x cowpea cultivar interaction, were seen by Silva (2001). However, other authors have found that late-cycle maize genotypes are negatively affected when intercropped (SANTOS *et al*., 2014).

The analysis of variance of the data for land equivalent ratio (LER) calculated based on green-pod yield in the cowpea and on green-maize yield, is shown in Table 9. The corresponding mean values are presented in

Table 7 - Summary of the analysis of variance of the data for the production components of green grain in monocropped cowpea cultivars and intercropped with maize cultivars

Source of variation	Degrees of freedom	Mean square		
		Number of pods ha^{-1}	100-grain weight (g)	Number of grains pod^{-1}
Blocks	5	34108126602.1^{ns}	6.6^{ns}	0.32^{ns}
Treatments	5	142008149513.2**	41.7**	4.45**
Monocrops	1	63515988108.0^{ns}	74.0**	2.08*
Monocrops vs. Intercrops	1	519860905278.1**	16.1*	12.50**
Intercrops	3	42221284726.6^{ns}	39.5**	2.56**
Intercropped cowpea (mean values for the maize cultivars)	1	66622816876.0^{ns}	113.5**	6.00**
Intercropped cowpea (mean values for each maize cultivar)	1	36400411593.4^{ns}	4.9^{ns}	1.50*
Cowpea x maize interaction	1	23640625710.4^{ns}	0.2^{ns}	0.17^{ns}
Error	25	18901788430.5	2.8	0.28

[1] ns; *; not significant; significant at 5% and significant at 1% probability respectively by F-test

Table 8 - Mean values for the production components of green grain in monocropped cowpea cultivars and intercropped with maize cultivars[1]

Comparison		Number of pods ha^{-1}	100-grain weight (g)	Number of grains pod^{-1}
Monocrops	Corujinha	680625 a	22,1 b	16 a
	Sempre Verde	535119 a	27,1 a	15 b
Intercropped cowpea (mean values for the maize cultivars)	Corujinha	405642 a	23,8 b	17 a
	Sempre Verde	300268 a	28,2 a	16 b
Intercropped cowpea (mean values for each maize cultivar)	AG 1051	391900 a	25,6 a	17 a
	AL Bandeirante	314011 a	26,5 a	17 a
Monocrops vs. Intercrops	Monocrop	607872 a	24,6 b	16 b
	Intercrop	352955 b	26,0 a	17 a
Coefficient of variation (%)		31.39	6.5	3.2

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

Table 10. Although all LER values were greater than one, only those seen in the 'AG 1051' and 'Corujinha' intercrop were significant (Table 10), i.e. intercropping is only beneficial if the aim is to produce green pods and if the most-productive maize cultivar (AG 1051) is intercropped with the 'Corujinha' cultivar of the cowpea.

The analysis of variance of the data for land equivalent ratio (LER), calculated based on green-grain yield in the cowpea and on green-maize yield, is shown in Table 11. For this type of yield, intercropping continues to be beneficial if the most-productive maize cultivar (AG 1051) is intercropped with the two cowpea cultivars (Table 12). The intercrop involving the 'AL Bandeirante' maize cultivar is only beneficial when intercropped with the 'Corujinha' cultivar, and when the aim is to exploit the maize for marketable, unhusked, green ears (Table 12).

In the production of whole or marketable green ears, husked or unhusked, it can be seen that the 'AG 1051' maize cultivar is the best for monocropping or for intercropping with the 'Corujinha' cultivar of the cowpea. As a monocrop producing pods or green grain, it is unimportant whether the cowpea cultivars 'Corujinha' or 'Sempre Verde' are used, since they did not differ in

Table 9 - Summary of the analysis of variance of the data for land equivalent ratio (LER) calculated from green-grain yield in cowpea cultivars and green-ear yield in maize cultivars[1]

Source of variation	Degrees of freedom	Green-pod weight (cowpea)		
		Ear weight (maize)		
		Total	Marketable unhusked	Marketable husked
Blocks	5	0.05^{ns}	0.06^{ns}	0.11^{ns}
Treatments	3	0.03^{ns}	0.03^{ns}	0.03^{ns}
Residual	15	0.07	0.06	0.09

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

Table 10 - Mean values for land equivalent ratio calculated from green-grain yield in cowpea cultivars and green-ear yield in maize cultivars[1]

Cultivar		Green-pod weight (cowpea)		
Maize	Cowpea	Ear weight (maize)		
		Total	Marketable unhusked	Marketable husked
AG 1051	Corujinha	1.26*	1.28*	1,26*
AL Bandeirante	Corujinha	1.16^{ns}	1.19^{ns}	$1,14^{ns}$
AG 1051	Sempre Verde	1.12^{ns}	1.12^{ns}	$1,11^{ns}$
AL Bandeirante	Sempre Verde	1.10^{ns}	1.13^{ns}	$1,19^{ns}$
Coefficient of variation (%)		22,58	21.29	25.40

[1]*, [ns] Mean values greater than or equal to 1.0 respectively, at 5% probability by t-test

Table 11 - Summary of the analysis of variance of the data for land equivalent ratio (LER) calculated based on green-grain yield in cowpea cultivars and green-ear yield in maize cultivars[1]

Source of variation	Degrees of freedom	Green-pod weight (cowpea)		
		Ear weight (maize)		
		Total	Marketable unhusked	Marketable husked
Blocks	5	0.11^{ns}	0.09^{ns}	0.12^{ns}
Treatments	3	0.05^{ns}	0.04^{ns}	0.03^{ns}
Residual	15	0.08	0.08	0.11

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

Table 12 - Mean values for land equivalent ratio calculated from green-grain yield in cowpea cultivars and green-ear yield in maize cultivars[1]

Source of variation	Degrees of freedom	Green-pod weight (cowpea)		
		Ear weight (maize)		
		Total	Marketable unhusked	Marketable husked
Blocks	5	0.11^{ns}	0.09^{ns}	0.12^{ns}
Treatments	3	0.05^{ns}	0.04^{ns}	0.03^{ns}
Residual	15	0.08	0.08	0.11

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

pod or green-grain yield; however, when intercropping, 'Corujinha' would be the recommended cultivar.

The superiority of intercrops over monocrops may be due to a reduction in competition, and to facilitation between the crops involved (SILVA; SILVA, 2014). A reduction in competition can occur spatially through stratification of the foliage or roots, and temporally due to phenological differences. In the experiment on which the present study was based, it was seen that flowering in the two cowpea varieties occurred at the same time, and before flowering occurred in the two maize cultivars, which also coincided with the flowering season. Although the two cowpea cultivars are of indeterminate growth, it was found that the 'Corujinha' cultivar had a longer production period and invaded the maize more intensely than the respective production and invasion periods of the 'Sempre Verde' cultivar. It was also found that the 'AG 1051' cultivar had larger plants than 'AL Bandeirante' (data not shown). Larger maize plants would tolerate invasion more than would smaller plants, while at the same time favoring greater cowpea production, which would then have a better opportunity to intercept the solar radiation. These characteristics would favor the superiority of the AG 1051-Corujinha intercrop.

Facilitation results from improving environmental conditions, increasing the availability of resources, eliminating potential competitors, introducing beneficial organisms (mycorrhizae and others) or protecting against herbivores (SILVA; SILVA, 2014). In the present study, such aspects have not been evaluated, but several factors associated with facilitation have been verified by other authors. Greater water and nutrient availability were found in the maize-cowpea intercrops in relation to the monocrops (DAHMARDEH *et al*., 2010; GHANBARI *et al*., 2010; LATATI *et al*., 2014).

CONCLUSIONS

1. The 'AG 1051' maize cultivar was more productive than the 'AL Bandeirante' cultivar, both monocropped and intercropped. The cowpea cultivars showed similar performance under both cropping systems;
2. On average, the monocrops were superior to the intercrops in terms of green-ear, green-pod and green-grain yield;
3. If the aim is to produce green pods, intercropping is only beneficial when the 'AG 1051' maize cultivar is intercropped with the 'Corujnha' cultivar. If the aim is green-grain yield, intercropping remains advantageous when the 'AG 1051' maize cultivar is intercropped with either of the two cowpea cultivars;
4. The intercrop including the 'AL Bandeirante' maize cultivar is only beneficial when it includes the 'Corujinha' cultivar, and if the aim is to market husked, green ears of maize.

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