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Consortium of maize and cowpea in organic farming - dry grain production

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Intercropping of maize and cowpea is widely used by Brazilian family farmers. The aim of this work is to compare the grain yield of two maize cultivars, and one cultivar of cowpea in organic system. Treatments of monoculture of cowpea (Poços de Caldas) and maize ('BR106' and 'AG1051') and intercropping were used. A randomized block design with four replicates in an area under conversion to organic production system was used. The experiment was conducted in the period of October 2012 to March 2013, corresponding to the periods of spring/summer. The maize alone was on average, 26.5 cm taller and grain yield was 28% higher than in the intercropping. The cowpea intercropped with maize 'AG 1051' was 3.8 cm taller than the intercropped with 'BR 106'. In monoculture, the cowpea presented more (0.7 and 1.2 grain per pod when intercropped with 'AG 1051' and 'BR 106', respectively). The cowpea monoculture resulted in 2.4 pods per plant than in intercropping and productivity was 5.4 times higher than that of the intercropping. The cowpea intercropped with 'BR 106' was efficient, while that with 'AG1051' was inefficient in terms of land equivalent coefficient.

Key words: *Vigna unguiculata, Zea mays*, land equivalent coefficient.

INTRODUCTION

In Brazil, the consortium of corn and common bean (*Phaseolus vulgaris* L.) is very relevant, especially among family farmers. In the semi-arid region of northeastern Brazil, this practice is higher among maize and cowpea

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(*Vigna unguiculata* L. Walp) crops. Meanwhile, in the North of Rio de Janeiro, there is a large production of cowpeas, however, usually in monoculture.

Corn is one of the main cereals produced in the world and the most cultivated in Brazil, but it has enormous contrast of productivity between the different regions of the country. Corn crop production in Brazil in 2013/2014 was 79,905.5 thousand tons (CONAB, 2014). According to Freire Filho et al. (2011), cowpea production in 2009 in Brazil was approximately 523,890 tonnes. Cowpea plays a key role in organic production due to its symbiotic relationship with nitrogen-fixing bacteria.

Corn and cowpea bean, in general, present low productivity in family agriculture, both in intercropped and monoculture systems. Several problems may be associated with this and one of the factors is the use of cultivars unsuitable for the type of system. On the other hand, family farmers are currently looking for new techniques or agricultural systems, and one of the alternatives is organic farming with consociated systems. It is worth emphasizing that when the consortium is compared between crops and monoculture, the main advantage of the intercropping system is the more effective use of non-renewable resources (Brooker et al., 2015).

Organic farming seeks to utilize cultural practices such as intercropping, crop rotation, green manuring, biological control of pests and diseases, and nutritional balance and excludes the use of chemicals (Cieslik et al., 2009). When the producer decides to change the production system in an area where the conventional production system was used for an organic system, this area goes through a process called conversion or transition process. At the beginning of this process, there is usually a reduction in productivity, making it difficult to use this practice.

The objective of this work was to compare the response of two maize cultivars, intercropped with cowpea in a conversion area, from conventional to organic systems, by analyzing the development and yield of dry corn and cowpea beans.

MATERIALS AND METHODS

The experiment was carried out at the Research Support Unit of the Center for Agricultural Sciences and Technologies, State University of Norte Fluminense Darcy Ribeiro (CCTA/UENF), Campos dos Goytacazes– RJ, 21°44 '47" South latitude and 41°18'24" West longitude, with altitude of 12 m in the period of October 2012 to March 2013, corresponding to the spring/summer periods (Figure 1). The study was carried out in the field in the spring/summer period. The climate of the region is classified as Aw (Köppen), that is, humid tropical climate, with rainy summer, dry winter, average annual temperature of about 24°C, with maximum temperatures of about 40°C in summer.

The soil where it was installed was classified as Cambisol Hapic, and after the soil sampling, the 0 to 20 cm depth and subsequent chemical analysis with the following chemical were obtained: pH (H_2O) = 5.3; P = 4 mg dm^{-3}; K, Ca and Mg = 2.3; 38.2 and 36.0 $mmol_c$ dm^{-3}; Fe, Cu, Zn and Mn = 109.8; 2.5; 5.0; and 69.0 mg dm^{-3}; M.O. = 26.9 g dm^{-3} and CTC and SB = 120.0 and 78.5 $mmol_c$ dm^{-3}, respectively.

Factorial arrangement (2 x 2) + 1 whose factors and levels were: corn cultivars (‘AG 1051’ and ‘BR 106’) and cultivation system (monoculture and consortium with cowpea), was used. Besides these treatments, one more treatment with monoculture of cowpea was installed. The experimental design adopted was of randomized blocks with four replicates.

All experimental units were 5 m in length, and the consortium system was 6.4 m wide with eight rows. Monoculture of bean cowpea was 3.6 m wide with six rows, while monoculture maize was 3.2 m wide with four rows. As a useful area, for maize in monoculture and in consortium, the two central lines were considered, being 0.5 m at their extremities, 6.4 m², while the cowpea beans were 1.5 m from the ends of two central lines with a floor area of 2.4 m² in the monoculture and 3.2 m² in the consortium (Figure 2).

The consortium consisted of a row of cowpea between double rows of maize (1C:2M). The row spacing used, regardless of the cultures, was 0.80 m. Soil preparation was mechanized by performing a plowing at 20 cm depth, followed by two harrows. Maize and cowpea had density of 4.0 and 8.0 plants per meter, respectively.

In the area, two fertilizations were carried out with bovine manure, applying 1 L per linear meter of furrow as Guedes et al. (2010). The dry manure used in fertilization had the following characteristics: N, P_2O_5, K_2O, Ca, Mg and C = 1.18; 0.87; 1.20; 0.85; 0.55 and 10.89%; Fe, Cu, Zn and Mn = 7; 20; 140 and 68 mg dm^{-3}. Three manual weeding was carried out in all the plots. All the experimental areas received additional irrigation by sprinkling according to the water requirement of the crops.

To avoid pest infestations in both crops, spraying was carried out according to organic production systems: in the corn crop, an aqueous extract with dry leaves of neen (*Azadiracta indica*) was applied to control the caterpillars; in the cowpea culture, three sprays were applied at four days interval with neutral detergent aqueous solution to control the aphids (*Aphis* spp.). For the control of coleoptera (kitty, *Diabrotica speciosa*), three applications of shredded kit were made according to Martinez (2003). The applications were satisfactory in the control of insect pests. The evaluations of maize and cowpea were done in the two central lines of each experimental unit, that is, in the useful area, using the lateral lines as a border. The maize crop evaluations were used for all plants of the useful area, totaling 32 plants. When in the R2 stage, the height of the plant and the diameter of the stem were evaluated. When the grains reached the R7 stage (physiologically ripe), the weight of 100 grains and the yield of grains were evaluated.

In the cowpea culture, sixteen plants of the useful area of each experimental plot were evaluated, at the point of physiological maturation: plant height, number of leaves and length of main branch and, when the plants were dry: the number of seeds per pod, the number of pods per plant, the weight of one hundred grains and productivity.

In order to compare consortia and monocultures, the area equivalence index (AEI) was used to estimate the area required for monoculture yields equal to that obtained in intercropping (Moura, 1984). The AEI is derived from the equation:

$$AEI = CA/MA + CB/MB = IA + IB$$

CA = Cowpea bean yield in consortium; MA = cowpea bean yield in monoculture; CB = corn yield in consortium; MB = corn yield in monoculture; IA = individual index for cowpea beans; IB = individual

Figure 1. Map of the Research Support Unit of the Center for Agricultural Sciences and Technologies at the campus of the Northern Fluminense State University, Darcy Ribeiro (CCTA / UENF), Campos dos Goytacazes – RJ.

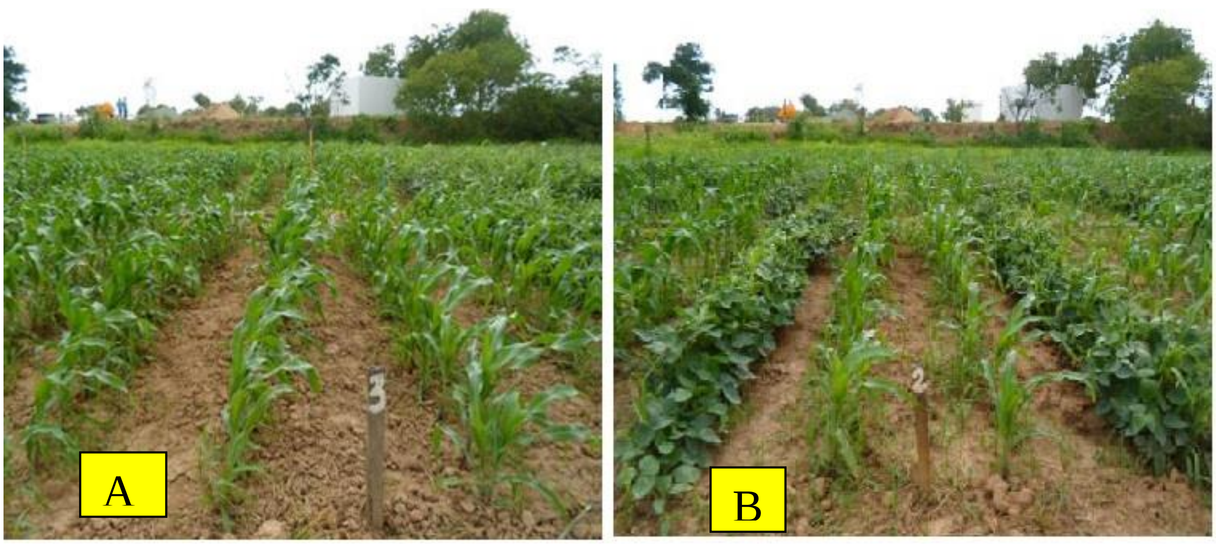

Figure 2. Corn monoculture ('AG 1051') (A) and maize consortium with cowpea (B).

index for corn.

The individual consortium is considered to be efficient when the AEI is greater than 1.0. For statistical analysis of maize variables, the experiment was considered as a factorial arrangement (2 x 2). Data were submitted to analysis of variance by the F test and, when interaction between factors was verified, the unfolding was performed. Meanwhile, for the analysis of cowpea variables, the experiment was considered to contain three treatments: cowpea in monoculture, in consortium with corn 'AG 1051' and in consortium with 'BR 106'. The analysis of variance was performed by the F test and when the effect of the treatments was significant, at a 5% probability level, the means were compared by the Tukey test, also at a 5% probability level.

Statistical analysis were performed with the aid of the computational app and performed with the aid of the computational application SAEG (Sistema para Análises Estatísticas e Genéticas) (Gomes et al., 1990).

RESULTS AND DISCUSION

The monoculture of Aguiar and Moura (2003) showed heights of corn plants higher than that observed in this experiment, where the plant height of 'AG 1051' and 'BR 106' varieties were 241 and 284 cm, respectively, under soil conditions of low fertility and with chemical fertilization. Both works were installed in soil with low fertility, but in this work, it was totally managed in an

Table 1. Plant height (AP) stem diameter (DC), weight of hundred grain (PCG) and grain yield (PRO) of corn cultivars grown in monoculture (Mono.) and intercropping (Cons.) with cowpea ('Poços of Caldas`).

Corn cultivation	AP (cm)			DC (mm)		
	Mono.	Cons.	Mean	Mono.	Cons.	Mean
'AG 1051'	232.1	212.8	222.5[a]	22.0	22.0	22.0[A]
'BR 106'	255.4	221.6	238.5[a]	22.1	21.5	21.5[A]
Mean	243.7[a]	217.2[b]	230.5	22.1[a]	21.5[a]	21.8
CV (%)		9.4			7.1	
		PCG (g)			PRO (kg ha^{-1})	
'AG 1051'	19.7	19.5	19.6[A]	6.330	4.411	5.371[A]
'BR 106'	20.8	19.4	19.4[A]	5.209	4.591	4.900[A]
Mean	20.2[a]	19.6[a]	19.9	5.769[a]	4.501[b]	5.135
CV (%)		5.8			17.3	

Averages followed by the same letters, uppercase in the column and lowercase in the row, do not differ by test F (p > 0.05).

organic way, using only cattle manure in the fertilization. In addition, the area was in the process of conversion to the organic production system, influencing the lower corn growth. Santos et al. (2010) compared production systems with organic fertilization or chemical fertilization. It was verified that the organic fertilization provided smaller, less developed corn plants with less production. Maize plants were, on average, 26.5 cm higher (p <0.05) than the consortium plants (Table 1). On the other hand, there was no significant difference between cultivar heights (Table 1). Possibly, corn intercropped with cowpea increased less due to competition with fabaceae. Viegas Neto et al. (2012) also observed a significant reduction (p <0.05) in corn plant height in a corn and bean intercropping system, in the row.

Aguiar and Moura (2003) obtained heights of corn plants higher than that observed in this experiment, where the plant height of 'AG 1051' and 'BR 106' varieties were 241 and 284 cm, respectively, under soil conditions of low fertility and with chemical fertilization. Both works were done in soil with low fertility, but in this work, it was totally managed in an organic way, using only cattle manure in the fertilization. In addition, the area was in the process of conversion to the organic production system, influencing the lower corn growth. Santos et al. (2010) compared production systems with organic fertilization or chemical fertilization. It was verified that the organic fertilization provided smaller, less developed corn plants with less production.

It is interesting to consider that, in intercropping, intercropping species usually differ in height, among other morphological characteristics, that can make plants to compete for light energy, water and nutrients. The division of the solar radiation incident on the plants, in a consortium system, is determined by the height of the plants and the efficiency of light interception. The shade caused by the highest crop reduces both the amount of solar radiation to the lowest crop and its leaf area (Flesch, 2002). Thus, within certain limits, reduction in maize height, when in consortium, may be beneficial to cowpea, because it certainly reduces the shading and negative effects on the Fabaceae.

There was no significant effect (p> 0.05) of cropping system and of maize cultivars on stem diameter (Table 1). The corn plants presented approximately 21.8 mm of stem diameter.

On the other hand, Viegas Neto et al. (2012) verified a significant reduction in stalk diameter in a corn intercropping system. Santos et al. (2010) verified that among seven maize cultivars, 'AG 1051' stood out in all variables, presenting a significantly larger stem diameter of 23.3 mm. However, in this work (Table 1), as already mentioned, there was no difference between cultivars and between cropping systems for stem diameter for the weight of one hundred grains of maize (Table 1) with no difference in effects (p > 0.05) in cultivation system and maize cultivars. The weight of one hundred grains remained as an average of 19.9 g.

The values of one hundred grains obtained (Table 1) were lower than those observed in the literature (Aguiar and Moura, 2003; Távora et al., 2007), which is possibly related to the low availability of nutrients, due to the fact that only organic fertilization was used in the first year of conversion to the organic system. F were lower than those observed in the literature (Aguiar and Moura, 2003; Távora et al., 2007), which is possibly related to the low availability of nutrients, due to the fact that only organic fertilization was used in the first year of conversion to the organic system or the weight of one hundred grains of maize by Aguiar and Moura (2003) under conditions of low fertility soils and mineral fertilization which were 25.3 g for 'AG 1051' and 23.1 g for 'BR 106'. Távora et al.

(2007) obtained 30.2 g for hybrid corn 'Cargill-435', in a system consortium with cowpea and using a plant population similar to this work.

Regarding the average yield of maize grains, there was no significant effect (p> 0.05) of maize cultivars (Table 1) with a mean of 5,135 kg ha^{-1}. Contrary to the current study (Table 1), Aguiar and Moura (2003) obtained 4,210 and 2,836 kg ha^{-1}, respectively, for 'AG1051' and 'BR 106' in low fertile soils with mineral fertilization; 'BR106' produced 32.6% less than 'AG1051'.

'BR 106' is an open pollinated variety, while 'AG 1051' is a double hybrid, which generally has higher yields. However, BR 106 has lower cost of seeds, since it can be produced by the producer itself, does not require high production technology, has the capacity to adapt to different environmental conditions, among other aspects, therefore favoring its adoption, and contributes to the choice of this variety by family farmers.

However, in an analysis by Santos et al. (2009b) on review of several studies, concluded that the hybrid 'AG1051' was shown to be promising for family farming. When comparing 'AG 1051' with 'BR 106', it was found that, even in conditions of low soil fertility, the hybrid had a grain yield higher than the variety.

The crop system significantly affected (p <0.05) corn grain yield (Table 1). Monoculture yielded 28% more maize grain than the consortium (Table 1). The reduction in maize productivity in the consortium (Table 1) was possibly caused mainly by reduction in the population of maize plants, which in the consortium was approximately two thirds of the monoculture population. However, on average, both 'BR106' and 'AG1051' were negatively affected by the insertion of cowpea into the system, as they presented lower plants (Table 1) and did not fully express their productive capacity by area (Table 1).

In general, the relationship between population density and crop productivity is direct. However, there are some crops that have high phenotypic plasticity, alter their production components as a function of spatial arrangement without modifying productivity (Mauad et al., 2010), and this characteristic can vary among cultivars of the same species.

In an organic production system of intercrop with cowpea, Guedes et al. (2010) found that the maize crop did not suffer losses in productivity and recommended that the sowing of the cowpea should be done three weeks before the maize in consortium between 'AG1051' and 'Mauá' cultivars. On the other hand, Flesch (2002) observed in the intercropping system of maize and beans, that the anticipated or simultaneous crops do not interfere with maize productivity. According to Portes (1984), corn is more demanding in light than beans, in order to reach maximum productivity, making solar radiation possibly the most important factor for the productive equilibrium of the system, which depends on the season of sowing of one crop relative to the other, and sowing density, which are related to the interception of light by the canopy of corn, and the amount of light reaching the bean canopy.

Cowpea intercropped with 'AG 1051' maize was 3.8 cm higher (p<0.05) than the 'BR 106' intercropped. Meanwhile, monoculture cowpea presented intermediate height which did not differ significantly from that in consortium with maize cultivars (Table 2).

The height of the 'Poços de Caldas' cowpea varies from 52 to 68 cm according to Bezerra et al. (2008). Thus, the values obtained (Table 2) were close to the lower limit of the cultivar, which is certainly related to the conversion process by which the experimental area was submitted. The number of leaves and length of the main branch did not present significant effects (p <0.05) of the treatments (Table 2).

Regarding the number of grains per pod, the values obtained (Table 2) were lower than those found by Silva (2015), who evaluated the types of cultivar system averaging 13.8 (Silva and Neves, 2011), 14.3 and the average found by Freire Filho et al. (2011) was 14.0 grains per pod. However, the average found in this study (Table 2) was close to the average observed by Silva et al. (2014), evaluating the agronomic potential of eight cultivars of cowpea, obtaining an average of between 5 and 8 grains per pod. In monoculture, the number of grains per pod was superior (p <0.05) to the consortia, producing 0.7 and 1.2 more grains per pod than when in consortium with AG 1051 and BR 106, respectively (Table 2).

According to Silva and Neves (2011), for manual harvesting, it is preferable to obtain more grains per pod and, consequently, the longer pod length. However, in semi-mechanized and mechanized crops, large pods are not very desirable. For these authors, smaller pods with smaller numbers of grains and, consequently, lighter ones, are preferred because they allow better sustentation, reducing the possibility of folding and breaking of the peduncle for the last two types of harvest. For the number of pods per plant, cowpea monoculture resulted in an average of 2.4 pods more than the plants in consortium with maize (p <0.05) (Table 2). In general, the numbers of pods per plant obtained in the experiment (Table 2) are similar to those reported in the literature. Santos et al. (2009a) found an average value of 10 pods per plant, while Silva et al. (2014), evaluating the agronomic potential and physiological quality of seeds of eight cultivars of cowpea, obtained from 12 to 22 pods per plant.

The weight of 100 grains was not significantly affected by the treatments (p> 0.05) (Table 2), with an average of 18.2 g. According to Silva and Neves (2011), the preference of the consumers for the weight of 100 grains is about 18 g. Távora et al. (2007) in a consortium system of corn and cowpea obtained an average value of 18.5 g. Silva et al. (2014) found a mean of 19.5 g, a similar result

Table 2. Plant height (AP), number of leaves per plant (NF), length of main branch (CRP), number of seeds per pod (NGV), number of pods per plant (NVP), weight of hundred grain (PCG) and productivity (PRO) of cowpea ('Pocos de Caldas') in monoculture and intercropping with corn cultivars 'AG1051' and 'BR 106'.

Farming system	AP (cm)	NF	CRP (cm)
Monoculture	53.1 AB	17.3 A	101.0 A
Consortium with 'AG1051'	56.0 A	16.4 A	100.1 A
Consortium with 'BR 106'	52.2 B	19.5 A	101.0 A
Mean	53.7	17.7	100.0
CV (%)	15.3	40.4	22.4

	NGV	NVP	PCG (g)	PRO (kg ha^{-1})
Monoculture	9.4 A	14.7 A	18.1 A	2.989 A
Consortium with 'AG1051'	8.7 B	13.0 B	18.4 A	657 B
Consortium with 'BR 106'	8.2 C	11.5 B	18.1 A	450 B
Mean	8.8	13.1	18.2	406
CV (%)	12.1	30.6	5.4	20.2

Averages followed by the same letters, uppercase in the column and lowercase in the row, do not differ by test F ($p > 0.05$).

Table 3. Individual index relative (IA and IB) and land equivalent ratio (IEA) of cowpea ('Pocos de Caldas') intercropped with corn cultivars 'AG1051' and 'BR 106'.

Relative individual index	Corn cultivars	
	'AG 1051'	'BR 106'
IA (cowpea)	0.22	0.15
IB (Corn)	0.70	0.88
AEI	0.92	1.03

presented by Freire Filho et al. (2011).

Bean cowpea productivity was significantly influenced ($p < 0.05$) by the consortium, with a reduction in productivity. On average, monoculture productivity was approximately 5.4 times higher than that of the consortium, being related to the lower number of pods per plant and grain per pod (Table 2).

Hamd-Alla et al. (2014) in their results obtained results contrary to those presented here, where they observed higher corn grain yield in consortium with cowpea as compared to single crop. This was possibly due to the lower competitive ability of the cowpea, relative to maize, by the factors of production, especially solar radiation. In addition, the population of plants in the consortium was one-third of the population in monoculture because of the ratio of two rows of maize to one of cowpea in the consortium. As already mentioned, the consortium consisted of a line of cowpea between double rows of corn (1C: 2M).

Silva and Neves (2011) evaluated twenty genotypes of cowpea and obtained yields varying from 658 to 1,070 kg ha^{-1}, while Silva (2015) obtained a productivity average of 752 kg ha^{-1}, with no statistical difference between cultivation systems. The consortium of cowpea bean with 'BR 106' was considered to be efficient, since the value of the AEI was higher than 1.0 (Table 3). However, the IEA of 'AG 1051' was less than 1.0, indicating that the consortium of this hybrid with cowpea was inefficient (Table 3). The relative individual indices (Table 3) show that the cowpea in the consortium produced 22 and 15% of that produced in the monoculture, respectively, in the consortia with 'AG1051' and 'BR106'. However, corn in consortium with cowpea had productivity of 70 and 88% of that obtained in monoculture. Thus, 'AG1051' was more negatively affected by the consortium, but less affected the cowpea, while 'BR106' was less affected by the consortium, but more negatively affected the cowpea. Therefore, only the consortium with the 'BR106' can be considered efficient.

Other authors obtained higher AEI, pointing to more efficient consortium systems than the one obtained in this experiment. Flesh (2002) evaluated intercropping consortia of corn and beans, using poultry manure in fertilization. The author obtained AEI ranging from 1.18 to 1.67. Guedes et al. (2010) evaluating the consortium of cowpea 'Mauá' and corn 'AG-1051', in organic cultivation, obtained AEI of 1.67, while Fernandes (2012) evaluating cowpea consortium (‘Siriri’, ‘Radiante’ and ‘Pérola’) and corn (‘AL Bandeirante’, ‘BR 106’ and ‘Sol-da-Manhã’) in an agro-ecosystem managed under ecological bases in the Dourados, Mato Grosso do Sul, obtained an average of AEI with the cultivar ‘BR 106’ of 1.22.

The AEI obtained in the experiment (Table 3), which is much lower than those observed by other authors, is possibly related to the area where the experiment was conducted, which is in the process of conversion to the organic production system. Certainly, the effects of corn competition on cowpea in the consortium were higher due to the system conversion condition, which led to lower numbers of grains per pod, pods per plant and, consequently, lower cowpea productivity (Table 2).

In the study developed by Santos et al. (2016), they obtained higher results from IEA, where the arrangement and density of plants in the area, with larger proximities between the root systems of the crops, together with a larger population of string bean plants and less corn, resulted in greater agronomic gains, contributing to a higher IEA.

On the other hand, Takin (2012), evaluating the consortium between maize and cowpea, found that the highest IEA occurred in cultivation with the row arrangement of maize for a row of cowpea and two rows of maize for a row of cowpea, 1.77 and 1.75, respectively.

Conclusion

The consortium of cowpea with the variety, BR 106 for marketing purposes of grain was considered efficient. Because it has the capacity to adapt to the different environmental conditions, among other aspects, this favor its adoption and contributes to the choice of this variety by family farmers. The hybrid AG1051 suffered from the cowpea competition and did not express its productive capacity. Thus, the IEA of AG 1051 were lower than 1.0 showing that the consortium of this hybrid with cowpea was inefficient.

In contrast to the results presented, there are possible recommendations to know more deeply, the physiological, biological, chemical and genetic characteristics of the species in areas of organic production, since this system of production is more dynamic and directly influence all the variables of production when compared with the monoculture area.

The main limitations of the study were shown in the low yields achieved in this study, due to the management applied between the transitional system for organic cultivation, given that the technological level is still insufficient for this level. Another limitation is the low level of knowledge of the conversion process to the organic production system, directly influencing the growth of the plants.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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