Revista Ciência Agronômica, v. 48, n. 2, p. 337-346, abr-jun, 2017
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Artigo Científico
ISSN 1806-6690

Productive and economic efficiency of carrot intercropped with cowpea-vegetable resulting from green manure and different spatial arrangements[1]

Eficiência produtiva e econômica do consórcio de cenoura x caupi proveniente de adubação verde e arranjos espaciais

Fernando Sarmento Favacho[2], Jailma Suerda Silva de Lima[3], Francisco Bezerra Neto[3], Josimar Nogueora da Silva[3]* and Aurélio Paes Barros Júnior[3]

ABSTRACT - The aim of this study was to evaluate the agro-economic efficiency of intercropping carrot with cowpea-vegetable in relation to the amounts of biomass of *Calotropis procera* (Ait.) R.Br. (known locally as *flor-de-seda*) incorporated into the soil, and to different spatial arrangements. The study was carried out under field conditions from August to November of 2014, at the Experimental Farm 'Rafael Fernandes' of the Rural Federal University of the Semi-Arid (RFUSA), in Mossoró, in the State of Rio Grande do Norte, Brazil. The experimental design was a randomised complete blocks in a 4 x 3 factorial, consisting of a combination of four different amounts of *flor-de-seda* biomass incorporated into the soil (20, 35, 50 and 65 t ha^{-1} of dry matter) and three spatial arrangements for the crop rows (2 x 2, 3 x 3 and 4 x 4). The carrot and cowpea cultivars used were 'Brasília' and 'BRS Itaim'. The characteristics under evaluation in the carrot were total, commercial and classified root production (scrap, short, medium and long). For the cowpea-vegetable, the following were evaluated: number, productivity and dry matter weight of green pods, number of grains per pod, 100-grain weight and yield of green grains. The agro-economic efficiency indices evaluated in the intercropping were: land equivalent ratio for the system and partial land equivalent ratios for the crops, monetary advantage and modified monetary advantage. The greatest agro-economic efficiency with the intercrop system was recorded in the biomass amount of 30 t ha^{-1} *flor-de-seda*. The 2 x 2 spatial arrangement resulted in greater system efficiency. The use of *flor-de-seda* as green manure is economically viable for the farmer when intercrop carrot with cowpea-vegetable.

Key words: *Daucus carota*. *Vigna unguiculata*. *Calotropis procera*. Intercropping.

RESUMO - O objetivo deste estudo foi avaliar a eficiência agro-económico do consórcio cenoura com caupi-hortaliça em relação às quantidades de biomassa de *Calotropis procera* (Ait.) R.Br. (conhecida localmente como *flor-de-seda*) incorporadas ao solo, e diferentes arranjos espaciais. O estudo foi conduzido em condições de campo no período de agosto a novembro de 2014, na Fazenda Experimental Rafael Fernandes da Universidade Federal Rural do Semi-Árido (UFERSA), Mossoró, RN. O delineamento experimental utilizado foi o de blocos completos casualizados em esquema fatorial 4 x 3, compreendendo a combinação de quatro quantidades de biomassa de *flor-de-seda* incorporadas ao solo (20; 35; 50 e 65 t ha^{-1} de matéria seca) e três arranjos espaciais de fileiras de plantas das culturas (2:2; 3:3; e 4:4). As cultivares de cenoura e caupi-hortaliça plantadas foram: 'Brasília' e 'BRS Itaim'. As características avaliadas na cenoura foram: produção total, comercial e classificada de raízes (refugo, curtas, médias e longas). No caupi-hortaliça avaliou-se: número, produtividade e peso da biomassa seca de vagens verdes, número de grãos por vagem, peso de 100 grãos e rendimento de grãos verdes. Os índices de eficiência agroeconômica avaliados no consórcio foram: índice de uso eficiente da terra, índices parciais de uso eficiente da terra da cenoura e do caupi-hortaliça, vantagem monetária e vantagem monetária corrigida. A maior eficiência agroeconômica do sistema consorciado foi registrada na quantidade de 30 t ha^{-1} de *flor-de-seda*. O arranjo espacial 2:2 proporcionou maior eficiência do sistema. O uso da *flor-de-seda* como adubo verde é economicamente viável ao agricultor na consorciação de cenoura e caupi-hortaliça.

Palavras-chave: *Daucus carota*. *Vigna unguiculata*. *Calotropis procera*. Cultivo consorciado.

DOI: 10.5935/1806-6690.20170039
*Autor para correspondência
Recebido para publicação em 30/03/2016; aprovado em 22/06/2016
[1]Parte da Tese de Doutorado do primeiro autor apresentada ao Programa de Pós-Graduação em Fitotecnia da Universidade Federal Rural do Semi-Àrido/UFERSA
[2]Instituto Federal de Educação, Ciência e Tecnologia do Pará-IFPA, Belém-PA, Brasil, ffeafc@hotmail.com
[3]Departamento de Ciências Vegetais, Universidade Federal Rural do Semi-Árido/UFERSA, Mossoró -RN, Brasil, jailma@ufersa.edu.br, bezerra@ufersa.edu.br, josimar2160@hotmail.com, aurelio.barros@ufersa.edu.br

INTRODUCTION

The production of vegetable crops is quite activity present in small farms and important in the introduction of cultivation systems that provides an increased production yields of crops per unit area. Among these farming systems is the intercropping, when performed properly presents economic and biological stability of the agro-ecosystem, as well as efficiency of the use of the available resources: soil, water, light and nutrients (SEDIYAMA; SANTOS; LIMA, 2014).

This cultivation system consists of an intermediary system between the monocrop and conditions of natural vegetation, where two or more cultures develops for a certain period of time, not being necessary to be planted at the same time, but which such plants cohabit much of its productive cycle and is practiced mainly by small producers (OLIVEIRA *et al*., 2013).

To reach satisfactory results in this cultivation system is essential to achieve well-managed agricultural practices to ensure a good crop yields, including, green manure and the use of spatial arrangements between the components cultures. Both factors may favor the success of intercropping system depending on its management regarding the choice of the cultures involved in the system (OLIVEIRA *et al*., 2015).

In Brazil the legumes are the species most commonly used as green manure, but other species have been studied, including grasses (BEZERRA NETO *et al*., 2011). But when it comes to semi-arid northeast, spontaneous plants or exotic with high productive potential of plant biomass have been highlighted as a source of green manure in the state of Rio Grande do Norte, promoting satisfactory results in crop yields.

Among these works, we can highlight the Linhares *et al.* (2008, 2012) and Bezerra Neto *et al*. (2014), who have obtained promising yields of coriander, arugula and carrot fertilized with hairy woodrose, and those performed by Silva *et al.* (2013), Almeida *et al.* (2015) and Oliveira *et al.* (2015), which yielded promising results in the productivity of marketable carrot roots in monocrop, agronomic efficiency in the lettuce-arugula intercropping and agronomic viability in the polyculture of arugula, carrot and lettuce, both fertilized with *flor-de-seda*.

On the other hand, the spatial arrangements when properly applied, can contribute to that different combinations of species can increase the crop yields compared to the monoculture. It is known that the spatial arrangements can affect the production characteristics and productivity of many crops (BEZERRA *et al*., 2014), establishing the relationship between the production components resulting in a productive response (PIVETTA *et al*., 2012). The best spatial arrangement is one that provides a more uniform distribution of plants per area, allowing better use of light, water and nutrients (ARGENTA *et al*., 2001).

The research objective was to evaluate the agro-economic efficiency of intercropping of carrot and cowpea-vegetable as a function of *flor-de-seda* biomass amounts incorporated into the soil and spatial arrangements.

MATERIAL AND METHODS

The study was conducted at the Experimental Farm 'Rafael Fernandes' of the Rural Federal University of the Semi-Arid (UFERSA), Mossoró, RN, Brazil, from August to November 2014. Prior to the installation of the experiment in field, soil samples were collected at a 0-20 cm depth. These samples were processed and analyzed in the Laboratory of Chemistry and Fertility of Soil and Plant Nutrition of the UFERSA, providing the results as shown in Table 1.

The experimental design was a randomized block in a factorial 4 x 3, with four replications. The first factor was constituted by four amounts of *flor-de-seda* dry biomass incorporated into the soil (20; 35; 50; 65 t ha^{-1}) and the second factor of three spatial arrangements of plant rows of the crops (2 x 2, 3 x 3, 4 x 4).

The intercropping was established in alternate rows as the spatial arrangement between the carrot and the cowpea-vegetable, being 50% of the area for the carrot and 50% for cowpea-vegetable, flanked by two guard-rows of each culture, with 25 plants of carrot and 10 of cowpea-vegetable per linear meter, with one plant per hole.

The total area of the parcels in the spatial arrangements 2 x 2; 3 x 3; 4 x 4 were 2.40 m^2, 3.00 m^2 and 3.60 m^2 with a harvest area of 1.00 m^2, 1.50 m^2 and 2.00 m^2 containing 50; 75 and 100 plants of carrot and 20; 30 and 40 plants of cowpea-vegetable in the spacings 0.25 m x 0.04 m and 0.25 m x 0.10 m, respectively.

In each block, plots in sole crop of carrot and cowpea were planted for the obtainment of the intercropping efficiency indices, as recommended by Bezerra Neto *et al.* (2012). For carrot, the total area of the plot was 1.44 m^2, with harvest area of 0.80 m^2, spaced 0.20 m x 0.10 m. For the cowpea-vegetable, the total area was 3.60 m^2, with harvest area of 2.00 m^2, spaced 0.50 m x 0.10 m.

The soil preparation consisted of harrowing, followed by the lifting of beds with a seedbed-tiller of six spades. Subsequently, one solarization was held in their pre-planting according to the method of Silva *et al.* (2006).

Table 1 - Chemical composition of soil samples from the experimental area before the incorporation of the flor-de-seda biomass amounts (*Calotropis procera* (Ait.) R.Br.)

pH	O.M.	N	P	K^+	Na^+	Mg^{2+}	Ca^{2+}	SB	CEC	ECEC	E.C.	ESP	BS
H_2O	g kg^{-1}		mg dm^{-3}				cmol$_c$ dm^{-3}				dSm^{-1}	%	
6.12	7.82	0.59	3.75	70.82	7.8	0.68	1.98	2.88	3.48	2.88	0.18	1.0	83

P, K and Na: extracted with Mehlich solution; Ca and Mg: extracted with KCl mol L^{-1}; water pH; CEC at pH 7.0

The *flor-de-seda* plants were collected near the city of Mossoró, RN (37°31’16” `S and 5°27’34’’ `W, 34 m altitude), and manually cut with the aid of machete, extracting only the green part of the plant. The material was triturated in a mechanical fodder and subjected to the drying process in full sun up to obtain about 10% moisture. Material samples were taken and sent to the Laboratory of Soil Fertility and Plant Nutrition of the UFERSA where took place the chemical analyses, providing the results shown in (Table 2).

The manuring was performed in two stages, with 50% of the amounts of *flor-de-seda* incorporated at 20 days before planting and the remaining 50% was incorporated at 45 days after planting. The amounts of *flor-de-seda* biomass used in monocrop of carrot and cowpea-vegetable were 42 and 51 t ha^{-1}, respectively, based on the optimization recommendations of Silva (2014) and Vieira (2014).

The irrigations were made in two shifts (morning and afternoon), providing a water slide of about 8 mm day^{-1} (LIMA *et al.*, 2010), in order to promote the microbial activity of soil in the process of decomposition. During the experiment, hand weedings were performed. The carrot and cowpea-vegetable cultivars planted were 'Brasília' and 'BRS Itaim' adapted for cultivation in the Northeast Brazil.

The carrot and cowpea-vegetable sowings were held in simultaneously cultivation, on 1 September 2014, in holes of approximately 3 cm in depth, putting three and two seeds per hole for carrot and cowpea-vegetable, respectively. At 17 and 7 days after sowing (DAS), it was carried out the thinning of carrot and cowpea-vegetable plants, respectively.

At 50 DAS, five plants per row of cowpea-vegetable in each plot were randomly marked to obtainment the data. The harvest of cowpea-vegetable was held in the period 55-65 DAS, and was made four harvests. The harvest of carrot was held at 104 DAS.

The characteristics evaluated in the carrot were: total and commercial, and classified productivities of roots (scrap, short, medium and long). The total productivity was determined by the fresh mass of the roots of the plants of the harvest area, expressed in t ha^{-1}. The commercial carrot productivity was quantified by fresh mass of roots long, medium and short of the harvest area of the parcel, free of cracks, bifurcations, nematodes and mechanical damage, and expressed in t ha^{-1}.

The classified productivity of roots was assessed according to the length and greater diameter in: long (length of 17 to 25 cm and diameter < 5 cm), medium (length 12 to 17 cm and diameter > 2.5 cm), short (length 5 to12 cm and diameter > 1 cm), and scrap, the roots that presented with cracks, bifurcations, nematodes and/or mechanical damage (VIEIRA *et al.*, 1997).

In cowpea-vegetable crop, we evaluated: number of green pods per m²; productivity and dry matter weight of green pods; number of grains per pod; 100-grain weight and yield of green grains.

For intercropping systems, we evaluated the partial land equivalent ratio for carrot (LER_c) and cowpea-vegetable (LER_{ch}) using the following equations: $LER_c = Y_{cch}/Y_{cc}$ and $LER_{ch} = Y_{chc}/Y_{chch}$, respectively, and for the system, $LER = LER_c + LER_{ch}$, where: Y_{cch} = commercial productivity of carrot roots in intercropping with cowpea-vegetable; Y_{cc} = commercial productivity of carrot roots in sole crop; Y_{chc} = yield of green grains of cowpea-vegetables in intercropping with the carrot and Y_{chch} = yield of green grains of cowpea-vegetable in sole crop.

The monetary advantage was obtained by the expression: MA = GI x (LER-1)/LER and the modified monetary advantage (MMA), obtained by the expression:

Table 2 - Chemical composition of *flor-de-seda* biomass (*Calotropis procera* (Ait.) R.Br.) incorporated into the soil

N	P	K^+	Ca	Mg	Fe	Mn	Zn	Cu	Na
		g kg^{-1}					mg kg^{-1}		
7.43	0.91	16.46	8.2	7.35	100.5	21.75	37.88	3.85	6085

P, K and Na: extracted with Mehlich solution; Ca and Mg: extracted with KCl mol L^{-1}; water pH; CEC at pH 7.0

MMA = NI x (LER-1)/LER, according to the methodology used by (OLIVEIRA *et al*., 2015), being the gross income (GI) equal to the crops productivity in each treatment multiplied by the product value paid to the producer, and the net income (NI), obtained by subtracting of the gross income, the costs of production, deriving from inputs more services.

Univariate analysis of variance was performed to evaluate the characteristics of the cultures and the agro-economic efficiency indices in the intercropping systems. The software used in the analysis was the SISVAR (FERREIRA, 2011). The Tukey test was used to compare the means between spatial arrangements. The adjustment procedure of regression curves was used to estimate the behavior of each feature or index as a function of the amounts of *flor-de-seda* biomass incorporated into the soil (JANDEL SCIENTIFIC, 1991).

RESULTS AND DISCUSSION

Carrot crop

There was no significant interaction between the *flor-de-seda* biomass amounts incorporated into the soil and the spatial arrangements between the component cultures in the studied variables (Table 3).

For the total and commercial productivities was observed increasing behavior as a function of the increase in the amounts of flor-de-seda biomass up to the maximum values of 35.77 and 33.06 t ha^{-1}, in the amounts of 27.60 and 26.31 t ha^{-1}, respectively, decreasing then, up to the last amount added to the soil (Figures 1A and B).

These results probably occurred due to the greater availability of nutrients provided by green manuring, which in addition to being good nitrogen suppliers also provide it by recycling of nutrients. Thus, when the supply of nitrogen quantities is adequate it favors vegetative growth, expands the active photosynthetic area and raises the productive potential of the crop.

Another aspect is that the increase of organic matter content in the soil can reduce the phosphorus retention on the surface of some clay minerals, increasing their availability to plants. In addition, the organic manuring functions as a source of energy for useful microorganisms, improves the structure and the aeration, and the capability to store moisture, as well as has a regulatory effect on the soil temperature, and helps to hold the potassium, calcium, magnesium and other nutrients in forms available for the roots (BATISTA *et al*., 2012).

In this sense, the observed positive behavior in this culture does not come only of the contents of nitrogen, phosphorus and potassium released by the amounts of *flor-de-seda* incorporated into the soil, but also by the synchrony in which these nutrients are released and absorbed by plants (SILVA *et al.,* 2013). Thus, once the plant is well nourished, consequently it has an adequate accumulation of dry matter in which corresponds a leaf area active photosynthetically with enough capacity for translocation of assimilates, which will result in a plant of productive high capacity.

For the productivity of long roots, it was observed an increasing behavior as a function of the amounts of added *flor-de-seda*, up to the maximum value of 12.97 t ha^{-1} in the amount of 31.19 t ha^{-1}, decreasing then, up to the greater amount of *flor-de-seda* studied (Figure 1C).

On the other hand, decrescent behavior in the productivity of medium roots was observed as a function of the flor-de-seda amounts, obtaining the maximum value 16.17 t ha^{-1}, in the amount of green manure 20 t ha^{-1} (Figure 1D). Regarding productivity of short carrot roots, there was no adjust of a response function. The mean value of this productivity was of 3.6 t ha-1 (Figure 1E).

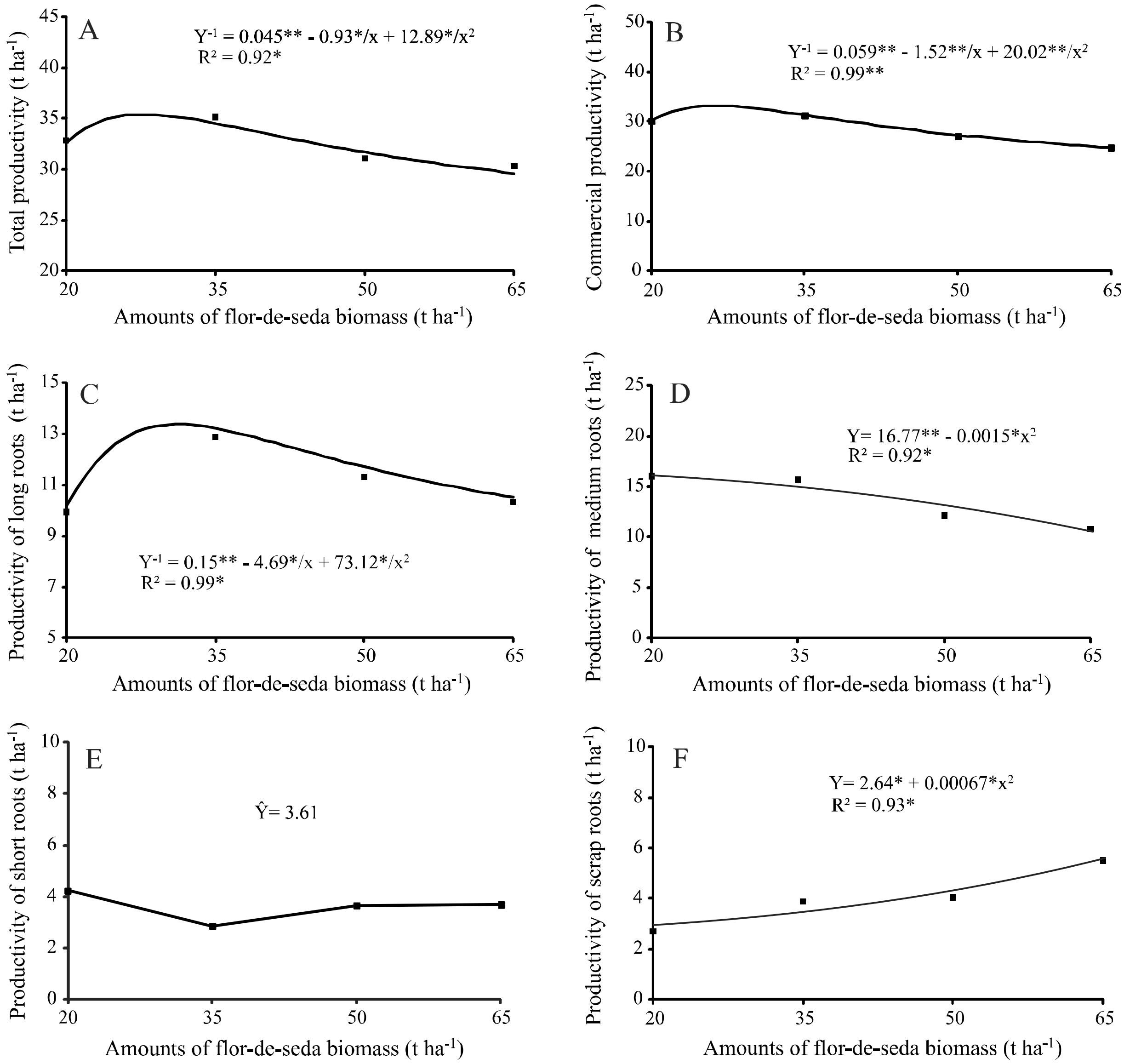
For productivity scrap carrot roots, there was an increase as a function of the *flor-de-seda* amounts, with a maximum yield of 5.45 t ha^{-1} in the amount of 65 t ha^{-1} (Figure 1F). This behavior is due to the increase in overall productivity resulting from the greater amounts of fertilizer,

Table 3 - "F" values for the total (PT), commercial (PC), and classified productivities of roots in: long (LR), medium (MR), short (SR) and scrap (ScR) of carrot (*Daucus carota* L.) as a function of *flor-de-seda* biomass amounts (*Calotropis procera* (Ait.) R.Br.) and spatial arrangements of the component cultures

S.V.	d.f.	PT	PC	LR	MR	SR	ScR
Blocks	6	1.78^{ns}	1.84^{ns}	2.42^{ns}	1.38^{ns}	0.78^{ns}	1.74^{ns}
Spatial arrangements (S)	3	1.74^{ns}	2.73^{ns}	4.88**	0.41^{ns}	1.66^{ns}	2.05^{ns}
Flor-de-seda Amounts (A)	2	0.75^{ns}	0.37^{ns}	1.40^{ns}	1.70^{ns}	3.50*	0.78^{ns}
S x A	3	1.46^{ns}	2.41^{ns}	1.00^{ns}	5.59**	1.24^{ns}	3.91*
CV (%)	-	19.46	23.67	41.10	28.40	50.60	51.10

** = P<0.01; * = P<0.05; ns = P>0.05

Figure 1 - Total (TP), commercial (CP), and classified productivities of roots in: long (LR), medium (MR), short (SR) and scrap (ScR) of carrot (*Daucus carota* L.) intercropped with cowpea-vegetable (*Vigna unguiculata* L.) as a function of *flor-de-seda* biomass amounts (*Calotropis procera* (Ait.) R.Br.) incorporated into the soil



which to increase the overall productivity naturally, increase the productivity of scrap roots.

No significant differences were observed between the means of the total, commercial, and classified productivities of carrot roots in: long, medium and scrap of the spatial arrangements. These results show that there was no influence of these spatial arrangements on these characteristics (Table 4).

Significant difference was recorded between the spatial arrangements only in the classified productivity of short roots of carrots, with the arrangement 3 x 3 standing out from the others (Table 4). This behavior is explained by the different dynamics of interspecific competition in the different intercrops with regard to major or minor dispute of the component crops by water, light and nutrients being favorable to the spatial arrangements of planting. It is likely that these arrangements proportionated a more uniform distribution of plants per area, thus enabling better use of environmental resources by crops (ARGENTA *et al*., 2001).

Cowpea-vegetable crop

There was no significant interaction between the amounts of *flor-de-seda* biomass incorporated into the soil and the spatial arrangements between component cultures for any of the evaluated characteristics (Table 5).

Table 4 - Mean values for the total (TP), commercial (CP), and classified productivities of roots in: long (LR), medium (MR), short (SR) and scrap (ScR) of carrot (*Daucus carota* L.) intercropped with cowpea-vegetable (*Vigna unguiculata* L.) as a function of spatial arrangements of the component cultures

Spatial arrangements	TP (t ha^{-1})	CP (t ha^{-1})	LR (t ha^{-1})	MR (t ha^{-1})	SR (t ha^{-1})	ScR (t ha^{-1})
Arrangement 2 x 2	33.02 a	29.08 a	11.92 a	13.20 a	3.96 ab	3.94 a
Arrangement 3 x 3	33.24 a	28.74 a	9.56 a	15.04 a	4.20 a	4.50 a
Arrangement 4 x 4	30.80 a	27.74 a	11.84 a	12.68 a	2.67 b	3.62 a

*Means followed by the same lowercase letter in the column do not differ by Tukey test at 5% probability

Table 5 - Values of “F” for the number of green pods per m^2 (NGPm^2), productivity of green pods (PGP), dry weight of green pods (DWGP), number of green grains per pod (NGP), weight of 100-green grains (W100GG) and yield of green grains (YGG) of cowpea-vegetable (*Vigna unguiculata* L.) as a function of *flor-de-seda* biomass amounts (*Calotropis procera* (Ait.) R.Br.) and spatial arrangements of the component cultures

S.V.	d.f.	NGPm^2	PGP	DWGP	NGGP	W100GG	YGG
Blocks	3	0.50^{ns}	2.76^{ns}	0.19^{ns}	1.09^{ns}	0.22^{ns}	2.34^{ns}
Spatial arrangements (S)	2	55.01**	3.01^{ns}	4.14**	0.35^{ns}	6.07**	3.95*
Flor-de-seda Amounts (A)	3	4.05**	2.43^{ns}	6.13**	5.12**	2.45^{ns}	13.46**
S x A	6	0.55^{ns}	0.75^{ns}	0.91^{ns}	0.59^{ns}	1.90^{ns}	2.74^{ns}
CV (%)	-	23.94	25.59	20.44	7.60	31.86	18.21

** = P < 0.01; * = P < 0.05; ns = P > 0.05

Analyzing the isolated effect of each factor in the number of green pods per square meter, productivity and dry weight of green pods, it was registered a crescent response with increase in the *flor-de-seda* biomass amounts incorporated into the soil, reaching the maximum values of 83 pods per square meter, and of 2.30 and 0.28 t ha^{-1}, respectively, in the amount of 65 t ha^{-1} of *flor-de-seda* biomass added to the soil (Figures 2A, B and C).

This same crescent response was also observed as a function of the green manure amounts incorporated into the soil for number of green grains per pod, weight of 100 green grains and yield of green grains up to the maximum values of 7 grains, 39.31 g and 3.69 t ha^{-1}, respectively, in the amounts of 58, 48.84 and 61 t ha^{-1} of *flor-de-seda* added to the soil (Figures 2D, E and F). It is possible to have occurred an adequate synchrony between the decomposition and mineralization of the manure added to the soil, showing a nutritional supply for the plants of carrot and cowpea-vegetable (FONTANETTI *et al*., 2006).

The crescent response to these characteristics evaluated as a function of the increase in the flor-de-seda amounts is due to the beneficial effects of green manuring. In addition, this response provides the improvement of the structure and of the aerating the soil and of its capacity to store moisture (SILVA *et al.*, 2013). Thus, these benefits of green manuring were converted in higher yields by the cultures.

There was no significant difference between the spatial arrangements for the number of green pods, productivity of green pods, number of grains per pod and dry weight of green grains of cowpea-vegetable intercropped with the carrot. These results indicate that there was no competitive influence of these arrangements in these evaluated traits. On the other hand, for the dry weight of green pods and weight of 100 green grains, there was significant difference between arrangements, with the arrangement 2 x 2 standing out from the others (Table 6).

This behavior observed in the arrangement 2 x 2, can is associated with the greater shading and competition for nutrients provided by the spatial arrangements with high populations. It is likely that in the smaller populations, the decreasing of the density of plants has been compensated with the highest concentration of assimilates in the roots, due to better use of resources such as light, nutrients, water, oxygen and inputs available (TEIXEIRA; MOTA; SILVA, 2005).

Agro-economic efficiency

There was no significant interaction between the amounts of *flor-de-seda* and spatial arrangements in the agro-economic efficiency indices evaluated in intercropping system (Table 7).

Crescent behavior was observed in the LER and LER_c, as a function of the amounts of *flor-de-seda*

Figure 2 - Number of green pods per square meter (A), productivity of green pods t ha^{-1} (B), dry weight of green pods t ha^{-1} (C), number of green grains per pod (D), weight of 100 green grains in g (E), and yield of green grains t ha^{-1} (F) of cowpea-vegetable (*Vigna unguiculata* L.) intercropped with carrot (*Daucus carota* L.) as a function of the *flor-de-seda* biomass amounts (*Calotropis procera* (Ait.) R.Br.) incorporated into the soil

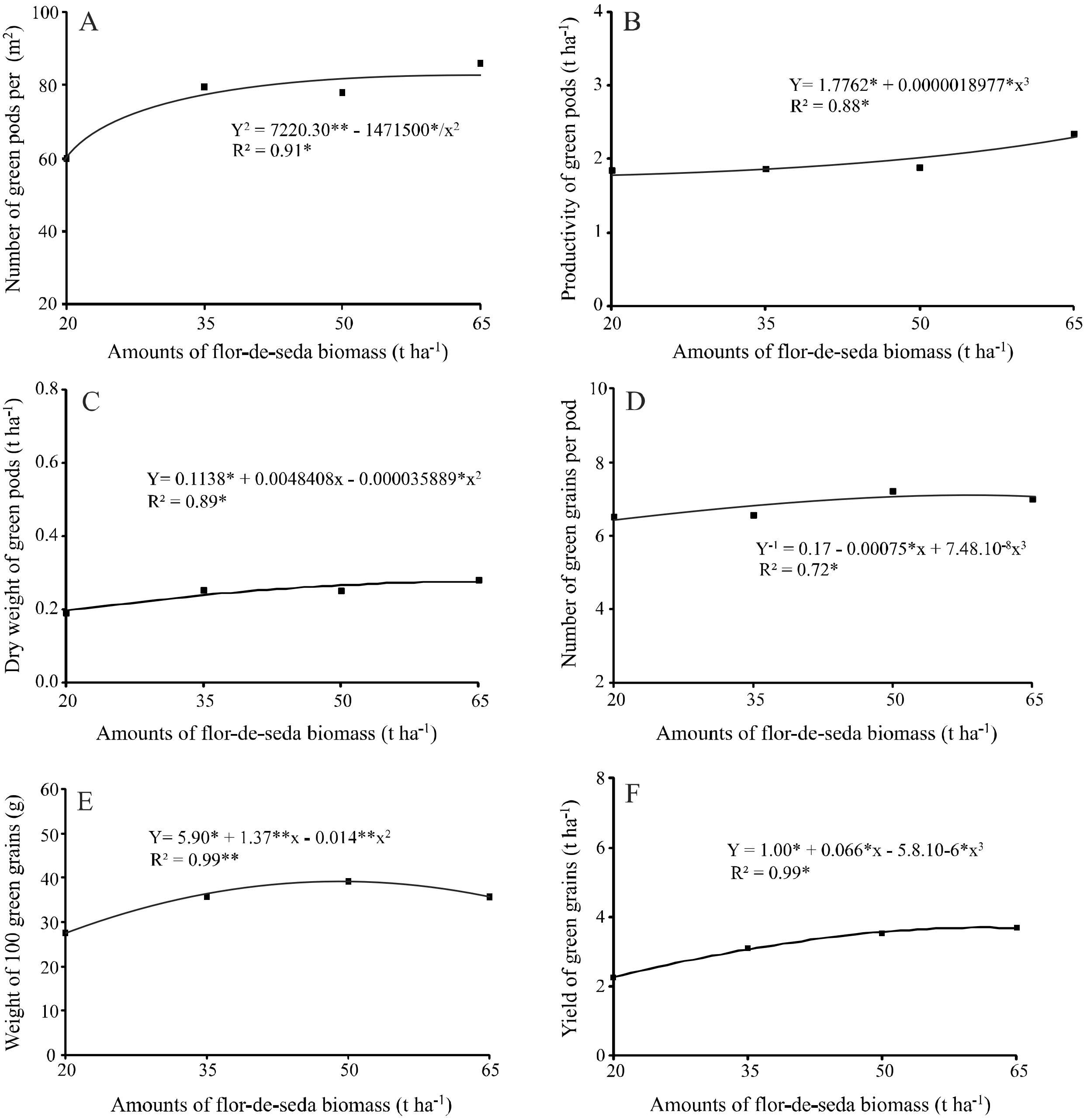


Table 6 - Mean values for the number of green pods per m^2 ($NGPm^2$), productivity of green pods (YGP), dry weight of green pods (DWGP), number of green grains per pod (NGGP), weight of 100 green grains (W100GG) and yield of green grains (YGG) of cowpea-vegetable (*Vigna unguiculata* L.) intercropped with carrot (*Daucus carota* L.) as a function of spatial arrangements of components cultures

Spatial arrangements	$NGPm^2$	PGP (t ha^{-1})	DWGP (t ha^{-1})	NGGP	W100GG (g)	YGG (t ha^{-1})
Arrangement 2 x 2	83.00 a	2.15 a	0.2720 a	6.74 a	41.70a	3.43 a
Arrangement 3 x 3	72.37 a	2.09 a	0.2438 ab	6.87 a	34.67ab	3.02 a
Arrangement 4 x 4	71.00 a	1.72 a	0.2180 b	6.87 a	28.05b	2.97 a

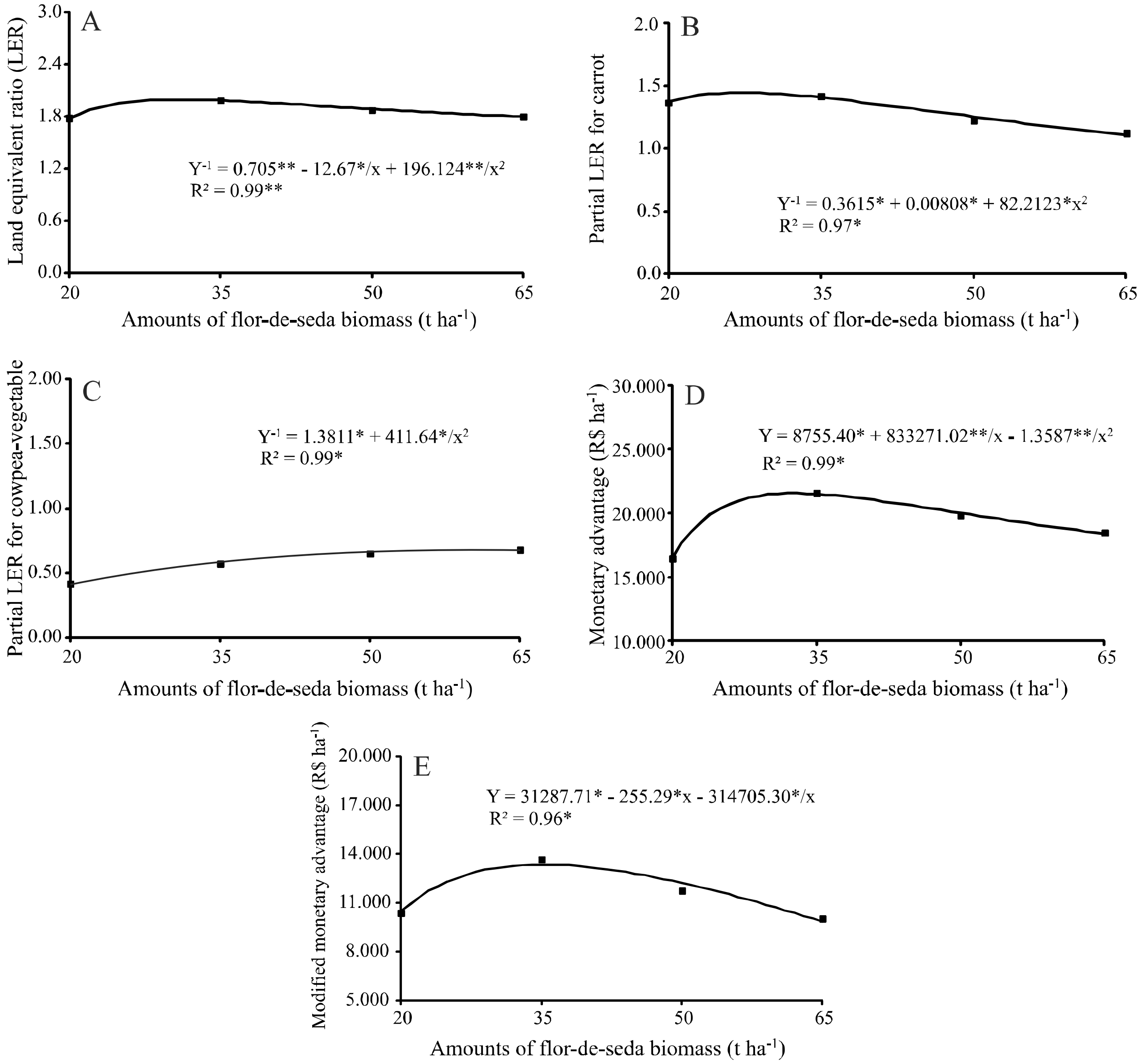
*Means followed by the same lowercase letter in the column do not differ by Tukey test at 5% probability

Table 7 - Summary of the analysis of variance of the land equivalent ratio (LER), partial LER for carrot (LER_c) and for cowpea-vegetable (LER_{cv}), monetary advantage (MA) and modified monetary advantage (MMA) as a function of the *flor-de-seda* amounts (*Calotropis procera* (Ait.) R.Br.) and spatial arrangements of the component cultures

S.V.	d.f.	LER	LERc	LERcv	MA	MMA
Blocks	3	2.18^{ns}	2.92^{ns}	2.18^{ns}	1.94^{ns}	1.74^{ns}
Spatial arrangements (S)	2	1.21^{ns}	0.36^{ns}	1.21^{ns}	1.72^{ns}	1.75^{ns}
Flor-de-seda Amounts (A)	3	1.12^{ns}	2.33^{ns}	1.12^{ns}	1.36^{ns}	1.44^{ns}
S x A	6	1.65^{ns}	1.76^{ns}	1.65^{ns}	1.74^{ns}	1.82^{ns}
CV (%)	-	16.41	23.82	16.41	33.65	41.58

** = P < 0.01; * = P < 0.05; ns = P > 0.05

Figure 3 - Land equivalent ratios of the system (A), carrot (B) and cowpea-vegetable (C), monetary advantage (D) and modified monetary advantage (E) for the intercropping of carrot (*Daucus carota* L.) and cowpea-vegetable (*Vigna unguiculata* L.) as a function of *flor-de-seda* amounts (*Calotropis procera* (Ait.) R.Br.) incorporated into the soil



incorporated into the soil, obtaining maximum values of 1.99 and 1.44 in the amounts of green manure of 30.93 and 27.30 t ha^{-1}, respectively, decreasing thereafter (Figures 3A and B). When it increased the flor-de-seda amounts, there was an increase in the LER_{cv}, obtaining a maximum value of 0.68 in the amount of 65 t ha^{-1}.

The results found in the LER of 1.99 in the intercropping portray positive effect on food production per unit area, indicating that in this cropping system occurred a better use of environmental resources, as compared to the monocrop system.

The MA and MMA increased as there was an increase in the amounts of *flor-de-seda* incorporated into the soil, up to the maximum values of R$ 21,533.28 and R$ 13,360.92 ha^{-1} in the amounts of the green manure of 32.60 and 35.11 t ha^{-1}, respectively, decreasing thereafter (Figures 3D and E). These results are due to the fact of the intercropping to have responded very well to green manuring with *flor-de-seda*, thus, due to better use of environmental resources by carrot plants and cowpea-vegetable in those quantities tested.

On the other hand, the lowest value of MMA was observed in the amount of *flor-de-seda* of 65 t ha^{-1} and is related to their higher cost of production per hectare in this amount. However, in terms of LER, this amount of the green manure showed high yield potential, but in terms of economic index, the yield obtained in this amount was not able to turn this productive potentiality in economic terms equal to the amount of 35.11 t ha^{-1}.

Among the spatial arrangements, there was no significant difference in the LER, LER_c and LER_{cv}, MA and in the MMA of the intercropping of carrot and cowpea-vegetable (Table 8).

In the differentiated partitions of each culture, the carrot contributed with 1.32 and the cowpea-vegetable with 0.63 for LER of 1.95 in the arrangement 2 x 2. Thus, we can see that the carrot culture has contributed more to the advantage of the system. According Willey (1979), species with higher partial LER values are considered more competitive for limiting factors of the growth than the species with the lowest values of partial LER. According to Custodio *et al*. (2015), when the LER is equal to 1.0 there is no difference between the cropping systems. When the LER is greater than 1.0 the intercropping is advantageous and when lower 1.0 is detrimental in terms of production.

The value of the LER of 1.95 portrays the positive effects in food production per unit area by the use of this arrangement in the carrot and cowpea vegetable intercropping, indicating that occurred a higher utilization of environmental resources, showing greater viability of this arrangement, being necessary at least 195% more area for the crops in monocrop planting produce the equivalent to the production of this intercropping in a hectare.

Table 8 - Mean values for land equivalent ratios of the system (LER), carrot (LER_c) and cowpea-vegetable (LER_{cv}), monetary advantage (MA) and modified monetary advantage (MMA) of the intercropping of carrot (*Daucus carota* L.) and cowpea-vegetable (*Vigna unguiculata* L.) as a function of spatial arrangements of the components cultures

Spatial arrangements	LER	LERc	LERcv	MA	MMA
Arrangement 2 x 2	1.95 a	1.32 a	0.63 a	21,230.61 a	13,158.01 a
Arrangement 3 x 3	1.86 a	1.30 a	0.56 a	18,954.43 a	11,225.31 a
Arrangement 4 x 4	1.78 a	1.23 a	0.55 a	17,022.65 a	10,032.89 a

*Means followed by the same lowercase letter in the column do not differ by Tukey test at 5% probability

CONCLUSIONS

1. An agro-economic optimization of the carrot and cowpea-vegetable intercropping was achieved in the amount of 30 t ha^{-1} of *flor-de-seda* biomass incorporated into the soil;
2. There was no influence of the spatial arrangements between the component crops in the agro-economic efficiency of the carrot and cowpea-vegetable intercropping;
3. The use of *flor-de-seda* as green manure is economically viable to the farmer in the intercropping of carrot and cowpea-vegetable.

REFERENCES

ALMEIDA, A. E. S. *et al*. Eficiência agronômica do consórcio alface-rúcula fertilizado com flor-de-seda. **Revista Caatinga**, v. 28, n. 3, p. 79-85, 2015.

ARGENTA, G. S. *et al*. Resposta de híbridos simples de milho à redução do espaçamento entre linhas. **Pesquisa Agropecuária Brasileira**, v. 36, n. 1, p. 1-8, 2001.

BATISTA, M. A. V. *et al*. Efeito de diferentes fontes de adubação sobre a produção de alface no município de Iguatu-CE. **Revista Caatinga**, v. 25, n. 3, p. 8-11, 2012.

BEZERRA NETO, F. *et al*. Assessment of agroeconomic indices in polycultures of lettuce, rocket and carrot through uni - and multivariate approaches in semi-arid Brazil. **Ecological Indicators**, v. 1, n. 14, p. 11-17, 2012.

BEZERRA NETO, F. *et al*. Desempenho agronômico da alface em diferentes quantidades e tempos de decomposição de jitirana verde. **Revista Brasileira de Ciências Agrárias**, v. 6, n. 2, p. 236-242, 2011.

BEZERRA NETO, F. *et al*. Otimização agroeconômica da cenoura fertilizada com diferentes doses de jitirana. **Revista Ciência Agronômica**, v. 45, n. 2, p. 305-311, 2014.

BEZERRA, F. T. C. *et al*. Comportamento vegetativo e produtividade de girassol em função do arranjo espacial das plantas. **Revista Ciência Agronômica**, v. 45, n. 2, p. 335-343, 2014.

CUSTÓDIO, A. M. *et al*. Desempenho agronômico de consórcios entre rabanete e alface no Oeste goiano. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, v. 10, n. 5, p. 56-60, 2015.

FERREIRA, D. F. Sisvar: a computer statistical anlysis system. C**iência e Agrotecnologia**, v. 35, n. 6, p. 1039-1042, 2011.

FONTANÉTTI, A. *et al*. Adubação verde na produção orgânica de alface americana e repolho. **Horticultura Brasileira**, v. 24, n. 2, p. 146-150, 2006.

JANDEL SCIENTIFIC. **Table curve**: curve fitting software. Corte Madera, CA: Jandel Scientific, 1991. 280 p.

LIMA, J. S. S. *et al*. Productive performance of carrot and rocket cultivars in strip-intercropping system and sole crops. **Agrociencia**, v. 44, n. 5, p. 561-574, 2010.

LINHARES, P. C. F. *et al*. Quantidades e tempos de decomposição da jitirana no desempenho agronômico do coentro. **Ciência Rural**, v. 42, n. 2, p. 243-248, 2012.

LINHARES, P. C. F. *et al*. Resposta da rúcula (*Eruca sativa* Mill.) Folha Larga a adubação verde com jitirana (*Ipomoea glabra* L.) incorporada. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, v. 3, n. 2, p. 72-77, 2008.

OLIVEIRA, L. A. A. *et al*. Viabilidade agronômica de policultivos de rúcula/cenoura/alface sob quantidades de flor-de-seda e densidades populacionais. **Revista Caatinga**, v. 28, n. 4, p. 116-126, 2015.

OLIVEIRA, W. M. *et al*. Componentes morfológicos do coentro, cenoura e rúcula em função de sistema de cultivo e densidades populacionais. **Agropecuária Científica no Semi-Árido**, v. 9, n. 2, p. 5-9, 2013.

PIVETTA, L. G. *et al*. Avaliação de híbridos de girassol e relação entre parâmetros produtivos e qualitativos. **Revista Ciência Agronômica**, v. 43, n. 3, p. 561-568, 2012.

SEDIYAMA, M. A. N.; SANTOS, I. C.; LIMA, P. C. Cultivo de hortaliças no sistema orgânico. **Revista Ceres**, v. 61, p. 829-837, 2014. Suplemento.

SILVA, M. G. *et al*. Efeito da solarização, adubação química e orgânica no controle de nematóides em alface sob cultivo protegido. **Horticultura Brasileira**, v. 24, n. 4, p. 489-494, 2006.

SILVA, M. L. *et al*. Produção de cenoura fertilizada com flor-de-seda (*Calotropis procera* (Ait.) R.Br.). **Revista Ciência Agronômica**, v. 44, n. 4, p. 732-740, 2013.

SILVA, R. C. P. **Adubação verde com espécie espontânea no consórcio de cenoura e alface em bicultivo sob diferentes quantidades de biomassa e arranjos espaciais**. 2014. 71 f. Dissertação (Mestrado em Fitotecnia) - Centro de Ciências Agrárias, Universidade Federal Rural do Semi-Árido, Mossoró, 2014.

TEIXEIRA, I. R.; MOTA, J. H.; SILVA, A. G. Consórcio de Hortaliças. **Semina: Ciências Agrárias**, v. 26, n. 4, p. 507-514. 2005.

VIEIRA, F. A. **Dose de máxima eficiência agroeconômica de flor-de-seda no cultivo solteiro do caupi-hortaliça**. 2014. 55 f. Dissertação (Mestrado em Fitotecnia) - Centro de Ciências Agrárias, Universidade Federal Rural do Semi-Árido, Mossoró, 2014.

VIEIRA, J. V. *et al*. **Cultivo da cenoura (*Daucus carota* L.)**. Brasília: Embrapa Hortaliças, 1997. 19 p. (Instruções Técnicas, 13).

WILLEY, R. W. Intercropping - its importance and research needs. **Field Crops Abstracts**, v. 32, n. 1/2, p. 1-81, 1979.