

## Combination of lettuce and rocket cultivars in two cultures intercropped with carrots

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### ABSTRACT

The intercropping practice is a viable technological option for the production of vegetables and the success of the association between crops will be greater the greater the complementarity between them. The present work was conducted from June to November 2006, at Universidade Federal Rural do Semi-Árido, Rio Grande do Norte State, Brazil, to evaluate the productive performance of two lettuce and two rocket cultivars in two cultures in strip-intercropping systems. The experimental design was randomized complete blocks, with five replications and treatments arranged in a 2 x 2 + 2 factorial. The treatments consisted of the combination of two lettuce cultivars (Babá de Verão and Tainá) and two of rocket (Cultivada and Folha Larga) intercropped with carrot 'Brasília' plus two additional treatments (two lettuce cultivars or two rocket cultivars grown in sole crop). In each block a plot with carrot in sole crop was grown. The evaluated traits in lettuce were plant height and diameter, number of leaves per plant, productivity and shoot dry matter mass. In rocket were evaluated plant height, number of leaves per plant, green mass yield and shoot dry matter mass; and in carrot: plant height, total and marketable productivity, besides root classes, in long and medium roots, short roots and scrap roots. The Tainá lettuce cultivar had the best yield performance both in sole crop and intercropping system. The Cultivada and Folha Larga rocket cultivars had similar yield performance in both cropping systems. Both lettuce and rocket crops had better productive performance in the second culture. The mean production of carrot marketable roots in intercropping systems was 68.3%, being 48.6% for long and medium roots and 19.7% for short roots, while in the sole crop the mean production of marketable carrot roots was of 75.0%, being 51.7% for long and medium roots and 23.3% for short roots.

**Keywords:** *Lactuca sativa*, *Daucus carota*, *Eruca sativa*, agronomic efficiency, combined analysis.

### RESUMO

#### Combinação de cultivares de alface e rúcula em dois cultivos em consórcio com cenoura

A prática de consórcio é uma opção tecnológica viável para a produção de hortaliças e o sucesso da associação entre as culturas será tanto maior quanto maior a complementaridade entre elas. O presente trabalho foi realizado de junho a novembro de 2006, na Universidade Federal Rural do Semi-Árido, Mossoró, Brasil, para avaliar o desempenho produtivo de duas cultivares de alface e duas de rúcula consorciadas em faixas com cenoura em dois cultivos. O delineamento experimental foi em blocos completos casualizados com cinco repetições, com os tratamentos arranjos em esquema fatorial 2 x 2 + 2. Os tratamentos consistiram da combinação de duas cultivares de alface (Babá de Verão e Tainá) e duas de rúcula (Cultivada e Folha Larga) consorciadas com cenoura 'Brasília', mais dois tratamentos adicionais (duas cultivares de alface ou duas cultivares de rúcula cultivadas em cultivo solteiro). Em cada bloco foi inserida uma parcela com a cenoura em cultivo solteiro. As características avaliadas na alface foram altura e diâmetro de plantas, número de folhas por planta, produtividade e massa da matéria seca da parte aérea; na rúcula: altura de plantas, número de folhas por planta, rendimento de massa verde e massa da matéria seca da parte aérea, e na cenoura: altura de plantas, produtividade total e comercial, percentual de raízes longas e médias, de raízes curtas e de refugo. A cultivar de alface Tainá teve melhor desempenho, tanto em cultivo solteiro como consorciado. As rúculas 'Cultivada' e 'Folha Larga' tiveram desempenho produtivo semelhante em ambos os sistemas de cultivo. As culturas de alface e rúcula tiveram melhor desempenho produtivo no segundo cultivo. A produção de raízes comerciais de cenoura nos sistemas consorciados foi de 68,3%, dos quais 48,6% foram de raízes longas e médias e 19,7% de raízes curtas. A produção de raízes comerciais de cenoura no sistema solteiro foi de 75,0%, dos quais 51,7% foram de raízes longas e médias e 23,3% de raízes curtas.

**Palavras-chave:** *Lactuca sativa*, *Daucus carota*, *Eruca sativa*, eficiência agrônômica, análise conjunta.

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The use of vegetables in intercropping systems has shown several advantages in production, nutritional, economic and environmental aspects. When establishing a combination of plants that will use the same

space, nutrients and sunlight, there is consequently a higher yield per area, which brings benefits from a plant to another, through the control of weeds, pests and diseases (Souza & Resende, 2003).

The efficiency of an intercropping depends directly on the cultivation system, crops and cultivars involved and there is a need for complementarity between these crops (Bezerra Neto *et al.*, 2003; Gliessman, 2005). The large

challenge to the success of intercropping systems lies in the ability to determine the crops to be used, and specially the management of the intercropping, with a target maximizing the use of the area and meeting the interests of the producer (Ceretta, 1986). Therefore, the careful choice of component crops as well as of their association times or establishment is of paramount importance to provide the maximum exploitation of the advantages of the intercropping system (Rezende *et al.*, 2005). Thus, the advantage of a crop association is most evident when the crops involved present differences between their requirements faced to the available resources, either in quality, quantity or timing of demand (Rezende, 2008).

When choosing companion crops, it is extremely important to exist some complementarity between them. This is possible when the species have different ecological niches, thereby maximizing the use of light and absorption of nutrients in more than one crop in a certain area and time (Santos, 1998). As an example of companion crops, a study of evaluation of lettuce cultivars in an association with carrot in two cultures, revealed that the association did not affect the carrot yield (Caetano *et al.*, 1999). A similar result was found by Negreiros *et al.* (2002), when evaluating the performance of five cultivars of lettuce in sole crop and intercropping system with carrot under high temperature and high luminosity in Mossoró, Brazil.

With the appearance of new cultivars of lettuce, rocket and carrots, adapted to conditions of high temperature and ample sunlight in the Brazilian Northeast, it becomes important to search for informations and obtain comparative data on the behavior of these materials in sole crop and intercropped, seeking the high productivity and agri-economic efficiency of the cropping systems. It also seeks to get products with high quality and high nutritional value. Therefore, the objective of this study was to evaluate the combination of two lettuce cultivars (Babá de Verão and Tainá) and two rocket cultivars (Cultivada and Folha Larga) strip-intercropped with carrot cv. Brasília in

two cultures.

## MATERIAL AND METHODS

The research was conducted in the vegetable garden of the Universidade Federal Rural do Semi-Árido, in Mossoró, Rio Grande do Norte State, Brazil, from June to November 2006, ( $5^{\circ}11'S$ ,  $37^{\circ}20'W$  and 18 m of altitude), in a soil classified as Eutrophic Yellow-Red Ultisols (Embrapa, 1999). Samples were collected at the experimental area and mixed in order to obtain a composite sample, which was analyzed in the laboratory showing the following results: pH (1:2.5 water) = 7.83; Ca =  $4.80 \text{ cmol}_c \text{ dm}^{-3}$ ; Mg =  $0.60 \text{ cmol}_c \text{ dm}^{-3}$ ; K =  $0.40 \text{ cmol}_c \text{ dm}^{-3}$ ; Na =  $0.30 \text{ cmol}_c \text{ dm}^{-3}$ ; Al  $\text{cmol}_c \text{ dm}^{-3}$  = 0.00 and P =  $5.2 \text{ mg dm}^{-3}$ . The climate of the region is semi-arid and according to Köppen BSwh, dry and hot, with two weather stations: a drought, usually from June to January and a rainy season from February to May (Carmo Filho *et al.*, 1991). During this research, the temperatures maximum, mean and minimum were of 35.5, 27.1 and  $19.2^{\circ}\text{C}$  in the first culture of lettuce and rocket, and of 37.1, 28.5 and  $21.1^{\circ}\text{C}$  in the second culture, respectively. The daily sunshine was of 8.7 and 10.1 h and R.H. of 66.2% and 62.4% in these times of culture.

The experimental design was a complete randomized block with five replicates and treatments arranged in a factorial  $2 \times 2+2$ . The treatments consisted of the combination of two lettuce cultivars (Babá de Verão and Tainá) with two rocket cultivars (Cultivada and Folha Larga) intercropped with carrot Brasília plus two additional treatments (two lettuce cultivars or two rocket cultivars grown in sole crop). Also, in each block was grown a plot of carrot in sole crop to permit the comparison when the characteristics of this vegetable were analyzed. The lettuce and rocket cultivars were grown in two cultures during the cycle of carrot. The intercropping system was established by planting strips (four rows) of rocket and lettuce between strips of carrot (four rows also) in the harvest area of the plot, with 50% of the area occupied with the carrot (main

crop), 25% with lettuce and 25% with rocket (secondary crops). This harvest area of the plot was flanked by one strip of carrot (guard strip) in one side and one strip of rocket (guard strip) on the other side (Figure 1). The total area of each plot in the intercropping system was  $5.76 \text{ m}^2$ , with a harvest area of  $3.20 \text{ m}^2$ , containing 160 carrot plants and 160 rocket plants in the spacing of  $20 \times 5 \text{ cm}$  and 40 lettuce plants in the spacing of  $20 \times 10 \text{ m}$ .

The plots in sole crop had a total area of  $1.44 \text{ m}^2$ , with a harvest area of  $0.64 \text{ m}^2$  for the lettuce, containing 16 plants in the spacing of  $20 \times 20 \text{ cm}$ , and for the rocket and carrot a harvest area of  $0.80 \text{ m}^2$ , containing 80 plants of rocket in the spacing of  $20 \times 5 \text{ cm}$ , and 40 plants of carrot in the spacing of  $20 \times 10 \text{ cm}$ . The population of plants recommended for sole crop in the region is approximately 500,000 plants  $\text{ha}^{-1}$  for carrot (Barros Júnior *et al.*, 2005), 250,000 plants per hectare for lettuce (Oliveira *et al.*, 2005) and 1,000,000 plants per hectare for the rocket (Moura *et al.*, 2008), not considering 30% of traffic area, composed by corridors and roads.

The soil preparation consisted of harrowing followed by the construction of beds. Before installation of the field experiment a solarization on the beds with transparent plastic Vulcabrilho Bril Fles of 30 microns for 56 days was conducted, with the aim of reducing the population of soil phytopathogens, which would undermine the productivity of crops. Shortly after, fertilization was performed with  $80 \text{ t ha}^{-1}$  of cattle manure. A week before planting, fertilization was done in all plots, with  $30 \text{ kg ha}^{-1}$  of nitrogen, as urea,  $60 \text{ kg ha}^{-1}$  of  $\text{P}_2\text{O}_5$  as single superphosphate and  $30 \text{ kg ha}^{-1}$  of  $\text{K}_2\text{O}$  as chloride potassium, according to the analysis of soil and recommendations of the Instituto de Pesquisas Agronômicas (IPA, 1998).

The lettuce cultivars in the first planting were sown on July 3, 2006, in cups of 150 mL containing the substrate Plantmax, with three to five seeds, leaving one seedling per container after the second thinning. The lettuce seedlings were produced under shade, using a greenhouse covered by a white nylon screen, and transplanted for the

plots on July 24, 2006, 21 days after sowing in the cups. The rocket cultivars in the first planting and carrot were sown directly in the plots on July 24, 2006. Three to five seeds of rocket and carrot per hole were sown and at eight days after emergence was performed the thinning of the rocket, keeping two seedlings per hole in the intercropping plots, and only one seedling in the sole crop plots. The thinning in carrot was held 25 days after sowing, leaving one plant per hole in both cropping systems. In both cropping systems, two foliar fertilizations were done with 30 mL/20 L of water in the formulation 14% N, 4% P<sub>2</sub>O<sub>5</sub>, 6% K<sub>2</sub>O, 0.8% S, 1.5% Mg, 2% Zn, 1.5% Mn, 0.1% B and 0.05% Mo at 10 and 20 days of lettuce transplanting and rocket sowing, respectively. In the plots with carrot in sole crop and intercropped two N fertilizations in coverage were done, one 25 days after sowing and the other 45 days after sowing, with 40 kg N ha<sup>-1</sup>.

The second sowing of lettuce was held on September 17, 2006 and the lettuce transplanting was performed on October 7, 2006, 21 days after sowing the seedlings. The second seeding of the rocket was held at the same day of the lettuce transplanting. Both the lettuce transplanting as the rocket planting in the second culture were done at the same areas where the treatments were applied. A week before lettuce transplanting and rocket seeding, in all plots, fertilization was done, with 30 kg ha<sup>-1</sup> of nitrogen, as urea, and 30 kg ha<sup>-1</sup> of K<sub>2</sub>O as chloride potassium. Two foliar fertilizations were also carried out in the lettuce and rocket with the same product described before, at the same times of lettuce transplanting and rocket seeding. The thinning in the rocket was performed in the same way used in the first culture.

During the research, three hand weedings and two irrigations daily by micro-sprinkler system with a water sheet of about 8 mm were done. Two sprays were performed with the mixture of neem (*Azadiracta indica*) to combat aphids in the rocket. The proportion used was 40 grams of dried leaves of neem for each liter of water.

The harvest of lettuce in the first crop was held on August 20, 2006 and that

of rocket on August 26, 2006, 48 days after sowing the lettuce and 34 days after planting the rocket. The harvest of carrots was held on October 18, 2006, 87 days after planting. The harvest in the second culture of lettuce was held on November 6, 2006, 50 days after sowing and the rocket on November 11, 2006, 35 days after planting.

The evaluated variables were: 1) lettuce: plant height and diameter, number of leaves per plant, productivity and shoot dry matter mass; 2) rocket: plant height, number of leaves per plant, yield of green mass and shoot dry matter mass; 3) carrot: plant height, number of stems per plant, shoot and root dry matter mass, total productivity of roots, marketable productivity of roots (free of cracks, bifurcations, nematodes and mechanical damage); and classified productivity of roots according to the length and greater diameter (long, 17-25 cm and diameter <5 cm; medium, 12-17 cm and diameter >2.5 cm; short, 5-12 cm and diameter >1 cm, and scrap) according to Vieira *et al.* (1997). This productivity was expressed as a percentage.

A combined analysis of variance for a randomized complete block experiment with a 2×2+2 factorial arrangement of treatments was performed to evaluate each variable determined in the lettuce and rocket crops in two cultures. A univariate analysis of variance for a randomized complete block was used to evaluate the carrot variables. Tukey test ( $p \leq 0.05$ ) was used to compare the means of the treatment-factors. The software used was SAS (Cody & Smith, 2005). A univariate variance analysis for randomized blocks in factorial scheme was used to evaluate the characteristics of the three cultures; Tukey test ( $p \leq 0.05$ ) was used to compare the means of the treatment-factors. The software used was SAS (Cody & Smith, 2005).

## RESULTS AND DISCUSSION

### Lettuce crops

For height and diameter of lettuce plants significant interaction between lettuce cultivars and rocket cultivars was not observed, and between cultures and any of these treatment-factors. However,

significant interaction was observed only between cultures and cropping systems for these variables of lettuce (Table 1). Partitioning the interaction cropping systems within cultures, a higher mean value for height of lettuce plants in sole crop in the second culture was observed; there was no significant difference between the average heights of plants in sole crop and intercropping system in the first culture. Larger diameters of plants were recorded in the intercropped system in the first culture and in sole crop in the second culture (Table 1). Partitioning the interaction cultures within cropping systems, higher height of plants in the first culture in the intercropping system and similar heights between cultures in sole crop were found. For the diameter of plants, higher mean values were recorded in the first culture in the intercropping system and in the second culture in sole crop (Table 1). These differences in behavior in these characteristics can be explained by weather conditions between the cultures.

Furthermore, there was a significant difference between cultivars of lettuce and between cultures only for plant height, with the cultivar Babá de Verão outperforming the Tainá and the highest height of plants in the first culture (Table 1). The highest plant height of the Babá de Verão cultivar is due to its ideotype because this cultivar has more upright plants than the Tainá cultivar. According to Steiner (1982), characteristics such as morphology and growth habit of the plant mean that some species are better utilized when intercropped. For a strip-intercropping system with four alternating rows of carrots and lettuce, average height of lettuce (14.1 cm) was close to those obtained in this study (Andrade *et al.*, 2004). The authors argue that these results probably are due to low interspecific competition. Lower values were obtained by Oliveira *et al.* (2004), for lettuce cultivars in two cultures in intercropping with carrot (values ranging from 10.4 to 12.2 cm).

Significant interaction was also observed between cultures and cultivars of lettuce in sole crop only in the diameter of lettuce plants. Partitioning this interaction, significant difference between cultivars in sole crop within

**Table 1.** Mean values of plant height (PH), plant diameter (PD), number of leaves per plant (NLP), productivity (PROD) and dry matter mass of lettuce shoot (DMMS) depending on cultivars of lettuce and rocket intercropped with carrot, cultures of lettuce, lettuce cultivars in sole crop and cropping systems (valores médios de altura (AP) e diâmetro de plantas (DP), número de folhas por planta (NFP), produtividade (PROD) e massa da matéria seca da parte aérea (MMSPA) de alface em função de cultivares de alface e de rúcula consorciadas com cenoura, cultivos de alface, cultivares de alface solteira e sistemas de cultivos). Mossoró, UFERSA, 2008.

Treatments	PH		PD		NLP	PROD		DMMS	
	(cm)		(cm)			(t ha <sup>-1</sup> )			
<b>Lettuce cultivars in intercropping system with carrot</b>									
Babá de Verão	16.3a		21.5a		23.0a		5.6a	0.3a	
Tainá	15.0b		22.6a		13.9b		6.8a	0.4a	
<b>Rocket cultivars in intercropping system with carrot</b>									
Cultivada	15.2a		21.8a		190a		6.6a	0.4a	
Folha Larga	16.1a		22.3a		17.9a		5.9a	0.4a	
<b>Cultures of lettuce</b>									
1 <sup>st</sup> Culture	16.8a		24.5a		15.2b		13.4b	0.8a	
2 <sup>nd</sup> Culture	14.5b		19.6b		21.1a		17.2a	0.8a	
<b>Lettuce cultivars in sole crop</b>									
		<b>1° Cult</b>	<b>2° Cult</b>	<b>1° Cult</b>	<b>2° Cult</b>				
Babá de Verão	15.7a	24.8aA*	24.1aA	27.6aA	30.0aA		19.5b	1.2a	
Tainá	16.5a	12.4 bB	26.5aA	29.9aA	18.6bB		29.2a	1.3a	
<b>Cropping systems</b>									
	<b>1° Cult</b>	<b>2° Cult</b>	<b>1° Cult</b>	<b>2° Cult</b>	<b>1° Cult</b>	<b>2° Cult</b>	<b>1° Cult</b>	<b>2° Cult</b>	
Intercrop	16.8aA	14.5bB	24.5aA	19.6B	15.8bB	21.1aA	7.0bA	5.5bA	0.4b
Sole crop	15.9aA	16.4aA	18.6bB	25.3aA	28.8aA	24.4aA	19.8aB	28.9aA	1.3 a
CV(%)	11.16		9.87		10.64		35.67		25.83

\*Means followed by different lowercase letters in the column and capital letters in row are significantly different ( $p \leq 0.05$ ) by Tukey test (médias seguidas por diferentes letras minúsculas na coluna e letras maiúsculas na linha são significativamente diferentes ( $p \leq 0,05$ ) pelo teste de Tukey).

the first culture was observed, with higher average of Babá de Verão, and in the second culture these cultivars had similar plant diameters. Breaking the cultures within each cultivar of lettuce in sole crop, higher plant diameters in the second culture were found, with the cultivar Tainá and similar plant diameters between cultures in the cultivar Babá de Verão (Table 1). Furthermore, there was no significant difference between lettuce cultivars and rocket cultivars in intercropping with carrot in the diameter of lettuce plants. Significant difference was observed between cultures with larger diameter recorded in the first culture (Table 1). The largest diameter of plants obtained in this culture is due to the best weather conditions of temperature, humidity and luminosity recorded in this planting time, besides lower interspecific competition, since the carrot was at its early stage of development.

There was a significant interaction

between cultures and cropping systems for the number of leaves per plant and productivity of lettuce. A higher number of leaves per plant in sole crop in the first culture was observed and no significant difference between the cropping systems in the second culture. Higher productivity was registered in the first and second culture in sole crop (Table 1). Studying cultures within each cropping system, the greater number of leaves per plant was observed in the second culture in the intercropping system, while in sole crop, the number of leaves per plant was similar between cultures. Higher average productivity was registered in the second culture in sole crop, while in intercropping the productivity was similar between cultures. Significant interaction between cultures and lettuce cultivars in sole crop was also observed for the number of leaves per plant. There was greater number of leaves per plant in the Babá de Verão lettuce cultivar in the second

culture, and no significant difference between these cultivars in sole crop in the first culture. Studying the cultures within each cultivar, there was greater number of leaves per plant in the first Tainá cultivar culture, and no significant difference in this number of leaves for the Babá de Verão cultivar between cultures (Table 1). These results agree with those obtained by Barros Júnior *et al.* (2005), who found a maximum number of lettuce leaves (18), using the spacing 20 x 10 cm in the intercropping system of Brasília carrot with Tainá lettuce.

A significant difference was observed between lettuce cultivars in the number of leaves per plant and between cultures, both in the number of leaves per plant and productivity, and between lettuce cultivars in sole crop only in the lettuce productivity (Table 1). Greater number of leaves was recorded in cultivar Babá de Verão and in the second culture of lettuce. The

**Table 2.** Mean values of plant height (PH), number of leaves per plant (NLP), green matter mass yield (GMMY) and dry matter mass of rocket shoot (DMMS) depending on lettuce and rocket cultivars intercropped with carrot, cultures of rocket, rocket cultivars in sole crop and cropping systems (valores médios de altura de plantas (AP), número de folhas por planta (NFP), rendimento de massa verde (RMV) e de massa da matéria seca da parte aérea (MMSPA) de rúcula em função de cultivares de alface e de rúcula consorciadas com cenoura, cultivos de rúcula, cultivares de rúcula solteira e sistemas de cultivos). Mossoró, UFERSA, 2008.

Treatments	PH (cm)	NLP	GMMY		DMMS		
			(t ha <sup>-1</sup> )				
<b>Lettuce cultivars in intercropping system with carrot</b>							
Babá de verão	17.0b	12.5a*	3.7a		0.4a		
Tainá	19.2a	12.3a	4.4a		0.4a		
<b>Rocket cultivars in intercropping system with carrot</b>							
Cultivada	18.8a	14.5a	4.1a		0.4a		
Folha Larga	17.4b	10.2b	4.0a		0.4a		
<b>Cultures of rocket</b>							
		<b>Cultivada</b>	<b>Folha Larga</b>				
1 <sup>st</sup> Culture	16.3b	19.7aA	11.9aB	3.9b	0.6b		
2 <sup>nd</sup> Culture	19.6a	9.3bA	8.4bA	10.5a	1.3a		
<b>Rocket cultivars in sole crop</b>							
		<b>1° Cult</b>	<b>2° Cult</b>				
Cultivada	17.3b	24.8aA*	12.4aB	10.2a	1.4a		
Folha Larga	18.4 a	8.8bA	8.80bA	10.6a	1.5a		
<b>Cropping systems</b>							
		<b>1° Cult</b>	<b>2° Cult</b>	<b>1° Cult</b>	<b>2° Cult</b>	<b>1° Cult</b>	<b>2° Cult</b>
Intercrop	18.1a	15.8aA	8.8aB	2.1Bb	6.0bA	0.3bA	0.5bA
Sole crop	18.0a	18.6aA	8.8aB	5.7aB	15.0aA	0.8aB	2.1aA
CV(%)	12.41	12.55		35.44		40.62	

\*Means followed by different lowercase letters in the column and capital letters in row are significantly different ( $p \leq 0.05$ ) by Tukey test (médias seguidas por diferentes letras minúsculas na coluna e letras maiúsculas na linha são significativamente diferentes ( $p \leq 0,05$ ) pelo teste de Tukey).

**Table 3.** Mean values of plant height (PH), total productivity of roots (TPR), marketable productivity of roots (CPR), long and mean roots (PLMR), short roots (PSR) and junk roots (PJR) depending on intercropping systems of carrot, rocket and lettuce, and carrot in sole crop (valores médios de altura de plantas (AP), produtividade total de raízes (PTR), produtividade comercial de raízes (PCR), percentual de cenouras longas e médias (PCLM), percentual de cenouras curtas (PCC) e percentual de cenouras refugo (PCR) em função de sistemas consorciados de cenoura, rúcula e alface e de cenoura em cultivo solteiro). Mossoró, UFERSA, 2008.

Intercropping systems of carrot, rocket and lettuce	PH	TPR	CPR	PLMR	PSR	PJR
	(cm)	(t ha <sup>-1</sup> )		(%)		
	60.5	13.9	9.5	48.6	19.7	31.7
Carrot Brasília + Rocket Cultivada + Lettuce Babá de Verão	61.3a	12.9a*	9.1a	49.0a	20.3a	30.7a
Carrot Brasília + Rocket Folha Larga + Lettuce Babá de Verão	59.6a	14.7a	10.0a	48.3a	19.1a	32.6a
Carrot Brasília + Rocket Cultivada + Lettuce Tainá	59.5a	14.2a	9.2a	48.7a	20.1a	31.2a
Carrot Brasília + Rocket Folha Larga + Lettuce Tainá	61.4a	13.7a	9.7a	48.6a	19.3a	32.1a
<b>Carrot in sole crop</b>						
Carrot Brasília	54.7 <sup>+</sup>	25.5 <sup>+</sup>	19.0 <sup>+</sup>	51.7	23.3	25.0
CV (%)	8.48	8.72	19.38	20.42	40.80	37.08

<sup>+</sup>Significant difference between the sole crop and intercropped system (diferença significativa entre o cultivo solteiro e o consorciado);

\*Means followed by same letter in column are not significantly different ( $p > 0.05$ ) by Tukey test (médias seguidas pelas mesmas letras na coluna não são significativamente diferentes ( $p > 0.05$ ) pelo teste de Tukey).

highest value of lettuce productivity was recorded in the Tainá cultivar in sole crop and the second culture. There

was no significant difference between cultivars of rocket tested in these variables. These results are similar

to those reported by Oliveira *et al.* (2004), who found the highest number of leaves per plant of lettuce in the

group of looseleaf cultivars and higher productivity in the crisphead cultivars, with the Tainá cultivar standing out.

These results corroborate with those reported by Santos (1998), who observed a greater productivity in the intercropping system when component crops have different requirements for resources, due to low competition or facilitation. When two or more crops are grown simultaneously, each one needs adequate space to maximize cooperation and minimize competition between them. For an intercropping system of high efficiency, it is necessary to take into account the spatial arrangement, the architecture and density of plants and the time of maturity of crops, in addition to careful selection of cultivars to be combined (Sullivan, 2001). When cultivars of different species are tested in intercropping, the efficiency of this system depends on the ability of combination of the materials tested, therefore, this ability to dictate

which have more or less intra-specific competition. The higher is the intra-specific competition the lower is the efficiency of the intercropping system. For the shoot dry matter mass there was only significant difference between cropping systems (Table 1), with higher average value recorded in sole crop (1.3 t ha<sup>-1</sup>) as compared with intercropped system (0.4 t ha<sup>-1</sup>).

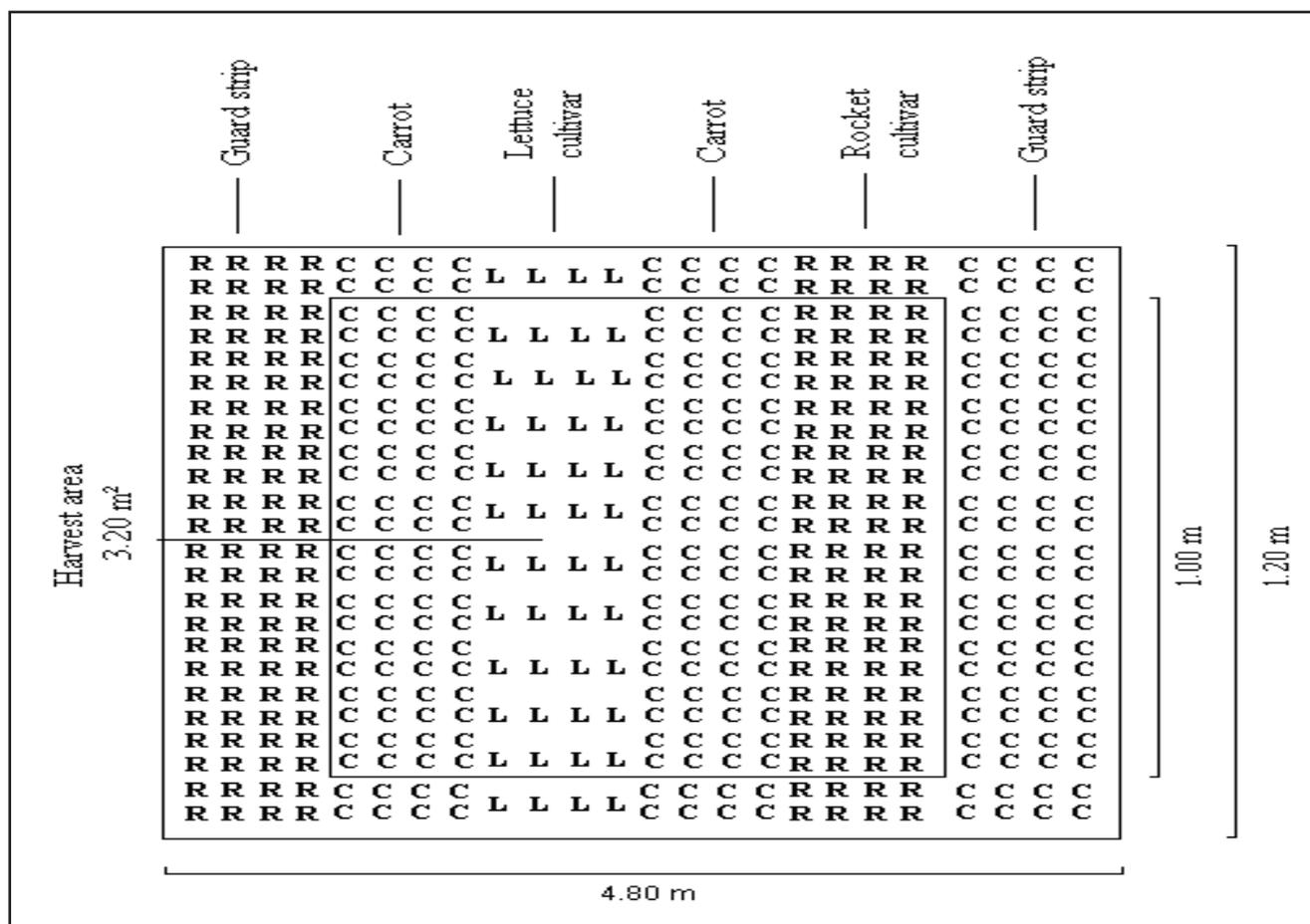
**Rocket crops**

There was no significant interaction between treatment-factors in the plant height of the rocket. However, significant differences were observed between the factors lettuce cultivars, rocket cultivars, cultures and cultivars of rocket in sole crop, with the highest values recorded for Tainá lettuce intercropped with carrot, Cultivada rocket intercropped with carrot, Cultivada rocket in sole crop, and the second culture (Table 2). This result can be explained by the increased competition for light in the second culture. Freitas *et al.* (2009),

for different spacing and times of cultivation of the rocket cv. Cultivada, also obtained greater heights in the second culture, showing the expression of productivity even in conditions of high temperatures. There was significant interaction between cultures and rocket cultivars, cultures and cropping systems, and cultures and cultivars of rocket in sole crop for the number of leaves per plant. A significant difference between cultivars in the first culture of rocket was observed, with the highest value recorded for cv. Cultivada, and no significant difference between rocket cultivars in the second culture (Table 2).

Significant differences between cultures were observed in both Cultivada and Folha Larga cultivars, with the largest number of leaves observed in the first culture (Table 2).

There was a significant difference between the cultures within each cropping system with the highest number of leaves per plant observed in the first



**Figure 1.** Graphic representation of the experimental plot of an intercropping system of rocket, carrot and lettuce in strips (representação gráfica da parcela experimental de um sistema consorciado de rúcula, cenoura e alface em faixas).

culture both for intercropping and sole crop; however, no significant difference was found between intercropping system and sole crop in each culture (Table 2). For interaction between cultures and cultivars of rocket in sole crop, there was significant difference between rocket cultivars within each culture with the highest number of leaves per plant recorded in the cv. Cultivada in both cultures. Significant difference was observed between the first and second culture in the number of leaves per plant only for the Cultivada cultivar in sole crop, with the largest number recorded in the first culture (Table 2). This result in lower number of rocket leaves in the second culture (September-October) can be explained by an unexpected invasion of aphids on this crop during vegetative growing, which consequently contributed to low values of the evaluated rocket traits.

For the yield of green mass and dry matter mass of shoot only significant interaction between cultures and cropping systems was observed. A higher yield of green mass and larger amount of shoot dry matter mass of the rocket in sole crop was found in every culture. Furthermore, there was a significant difference between the cultures within each system with the highest yields of green mass in the second culture in both sole crop and intercropping system, with a larger amount of shoot dry matter mass in sole crop (Table 2). A significant difference was recorded only between cultures in both yield of green mass and amount of shoot dry matter mass, with the highest values of both characteristics recorded in the second culture (Table 2).

### Carrot crop

There was no significant interaction between lettuce cultivars and rocket cultivars, or an effect of these factors in the evaluated characteristics of carrot (Table 3). This means that the pressure exerted by combinations of competition among lettuce and rocket cultivars on the characteristics of the carrot was not enough to differentiate them. This result can be due to the root system of the carrot, which better exploits the deeper layer of soil. These results agree with Oliveira *et al.* (2004), who studied

lettuce and carrot in intercropping systems.

The height of carrot plants varied from 59.5 cm to 61.4 cm in intercropped treatments derived from the combination of lettuce cultivars and rocket cultivars. The total and marketable productivity in the intercropping systems was of 12.9 to 14.7 t ha<sup>-1</sup> and of 9.1 to 10.0 t ha<sup>-1</sup>, respectively. Marketable productivity was 68.5% of the total productivity of carrot. In these treatments, long and mean roots were of 48.3% to 49.0%, short roots of 19.1% to 20.3%, and junk roots of 30.7% to 32.6% (Table 3). These results disagree from those obtained by Andrade *et al.* (2004) who working with lettuce and carrot in intercropping, obtained the percentage ranging from 65 to 71% of the roots long and mean, of 25 to 32% of short roots and 3 to 4% of junk roots. This superiority in the results of Andrade's work was due to the use of high doses of N, P and K, which were approximately 7; 22 and 9 times the doses of these elements used in this study. According to Oliveira *et al.* (2001), fertilization in carrot with N, P and K in high doses increases the production of marketable roots.

Significant differences between cropping systems were observed in plant height and total and marketable productivity, with the highest average productivity recorded in sole crop, and greater value for the height of plants recorded in intercropping system. For classified productivity there was no difference between these two systems (Table 3).

The diversity of the intercropping system appears to correlate positively with the productivity and stability of crops. Santos (1998) states that: (a) when there is a clear domain in the intercropping by a crop but the other crop is still able to express part of its productive potential, then their competitive abilities or adaptive, or both, are fundamentals; and (b) when the intercropping is not apparently dominated by a crop, the mechanisms that lead them to avoid competition are the most important.

In conclusion, the Tainá lettuce cultivar had the best yield performance both in sole crop and intercropping

system. The Cultivada and Folha Larga rocket cultivars had similar yield performance in both cropping systems. Both lettuce and rocket crops had better productive performance in the second culture. The mean percentage of carrot marketable roots in intercropping systems was 68.3%, being 48.6% for long and mean roots and 19.7% for short roots, while in the sole crop the mean percentage of carrot marketable roots was of 75.0%, being 51.7% for long and mean roots and 23.3% for short roots.

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