
EVALUATION OF YIELD ADVANTAGE INDEXES IN CARROT-LETTUCE INTERCROPPING SYSTEMS

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SUMMARY

The aim of this study was to estimate the effect of the association between carrot and lettuce crops in several intercropping systems through different yield advantage indexes, as well as to assess which system is better for the environmental resources management with respect to productivity and economic indicators. A 'group balanced block' experimental design was used, with four replications. Cultivars of lettuce crisp-leaf ('Lucy Brown', 'Tainá', 'Laurel' and 'Verônica') and looseleaf ('Babá de Verão', 'Maravilha das Quatro Estações', 'Elisa' and 'Carolina') groups were evaluated in intercropping systems with

'Alvorada' and 'Brasília' carrot cultivars. The land equivalent ratio (LER) and yield efficiency index (YEI) were estimated, besides economic indicators such as gross (GI) and net (NI) income, modified monetary advantage (MMA), return rate (RR) and profit margin (PM). The evaluated indexes showed that carrot is the dominant and lettuce the dominated crop. Higher biological/agronomic efficiency indexes and economic indicators were observed in intercropping systems with 'Brasília' carrot as component crop and that based on the crisp-leaf lettuce group.

Introduction

The use of intercropping systems has been one of the strategies used by producers in order to reach high productivity and promote sustainability of their agricultural production systems. The main given reason for the utilization of these systems is that they enable efficiency increase in the use of the environment resources (Park *et al.*, 2002). As a consequence, an increase in the total biological productivity per area unit of land and in sustainability occurs. Recently, the interest in cropping systems with crop associations involving vegetables has received more attention; these associations have contributed to an increase in the vegetable

activity, especially because of the economic advantages, due to the intensive use of renewable or non-renewable resources (Cecílio Filho and May, 2002).

The efficiency and the advantage of an intercropping system are fundamentally dependent of the complementarities between the component crops. In ecological terms, complementarities minimize the overlap of niches among associated species, reducing competition. When the period of greater demand for environmental resources by the component crops is not coincident, competition among such crops can be minimized. This situation can be named as temporal complementarity (Montezano and Peil, 2006).

On the other hand, when differences in plant architecture of the component crops help a better utilization of the available resources, or when biochemical differences exist among crops in their response to environmental resources, spatial or physiological complementarity occurs (Liebman, 2002). Several factors, such as competition among crops, type of sowed cultivar and spatial arrangement of planting, can have a significant impact in yield and growth rate of component crops in the intercrop (Dima *et al.*, 2007).

Lettuce and carrot are examples of vegetables that can be combined, due to biological, nutritional, economic and social reasons, representing an alternative for food produc-

tion and income (Oliveira *et al.*, 2005a, b; Barros Júnior *et al.*, 2005; Bezerra Neto *et al.*, 2005a, b). With the development of new lettuce and carrot cultivars and their adaptation to the northeastern Brazil conditions, information is needed concerning competition indexes and advantage indicators of the systems, and comparative data about the behavior of the materials used in the intercropped agro-systems is required.

Several indexes have been developed in order to quantify competition and agro-economic advantage in intercropping systems; among them are the relative crowding coefficient, aggressivity, competitive ratio, actual yield loss, land equivalent ratio, yield efficiency in-

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EVALUACIÓN DE LOS ÍNDICES DE VENTAJAS DE LOS RENDIMIENTOS DE SISTEMAS DE ASOCIACIÓN DE CULTIVOS DE ZANAHORIA Y LECHUGA

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RESUMEN

Se evaluó cuál es el efecto de la asociación entre los cultivos de zanahoria y lechuga en diferentes sistemas de asociaciones de cultivos a través de diferentes índices de ventajas de rendimientos, así como cuál es el mejor sistema para el manejo de los recursos ambientales en relación a la productividad, y los correspondientes indicadores económicos. El diseño utilizado fue el de bloques balanceados en grupos, con cuatro repeticiones. Para ello se utilizaron las cultivares de lechuga pertenecientes a los grupos cressa (Lucy Brown, Tainá, Laurel e Verônica) y lisa (Babá de Verão, Maravilha das Quatro Estações, Elisa e Carolina) en asociación con las variedades de zanahoria Brasi-

lia y Alvorada. Las variables analizadas fueron el índice de uso eficiente de la tierra (UET) y el índice de eficiencia productiva (IEP); además fueron calculados indicadores económicos tales como ingreso bruto, ingreso neto, ventaja monetaria, tasa de retorno, e índice de rentabilidad. Los resultados indicaron que la zanahoria es el cultivo dominante y el de lechuga el dominado. Los mayores índices de eficiencia biológica/agronómica fueron observados en los sistemas de asociaciones de cultivos que presentaban la zanahoria Brasília como cultivo componente, y aquellos que tenían por base el grupo de lechuga tipo cressa.

AVALIAÇÃO DE ÍNDICES DE VANTAGENS DE RENDIMENTO DE SISTEMAS CONSORCIADOS DE CENOURA-ALFACE

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RESUMO

Este trabalho teve como objetivo estimar o efeito da associação entre as culturas de cenoura e alface em diversos sistemas consorciados através de diferentes índices de vantagens de rendimento, bem como, avaliar qual sistema é melhor para o manejo dos recursos ambientais em relação a produtividade e indicadores econômicos. O delineamento experimental foi o de blocos balanceados em grupos, com quatro repetições. Avaliaram-se as cultivares pertencentes aos grupos cressa (Lucy Brown, Tainá, Laurel e Verônica) e lisa (Babá de Verão, Maravilha das Quatro Estações, Elisa e Carolina) em sistemas consorcia-

dos com as cultivares de cenoura Brasília e Alvorada. O índice de uso eficiente da terra (UET) e índice de eficiência productiva (IEP), além dos indicadores econômicos: renda bruta, renda líquida, vantagem monetária, taxa de retorno e índice de lucratividade foram estimados e avaliados. Observa-se pelos índices avaliados que a cenoura é a cultura dominante e a alface a dominada. Maiores índices de eficiência agrônoma e de indicadores econômicos são observados nos sistemas consorciados que tinham a cenoura Brasília como cultura componente, e aqueles baseados no grupo de alface cressa.

do by dea models, monetary advantage and intercropping advantage (Banik *et al.*, 2000; Park *et al.*, 2002; Weigelt and Jolliffe, 2003; Bezerra Neto *et al.*, 2007a, b, c; Dima *et al.*, 2007). However, the majority of these indexes has not been used in carrot and lettuce intercropping systems to evaluate competition among vegetables or to describe the advantages of the association.

The present work had the aim to estimate the effect of the association between the component crops in several carrot and lettuce intercropping systems, as well as to determine the best system for environmental resource management in regard to productivity and economic indicators.

Material and Methods

Two experiments, one in-

tercropped and other in sole crop, were carried out at the didactic vegetable garden of Departamento de Ciências Vegetais, Universidade Federal Rural do Semi-Árido (UFERSA), in Mossoró-RN, Brazil, from September to December 2002. The soil in the experimental area is a Eutrophic Yellow-Red Ultisols (Embrapa, 1999). Samples were taken in the experimental area and analyses were processed at the Soil Fertility and Chemistry Laboratory of the same institution, showing the following results for sole and intercropped culture experiments, respectively: pH (water 1:2.5)= 7.75 and 7.75; Ca= 7.40 and 7.12 cmol_c·dm⁻³; Mg= 4.30 and 4.22 cmol_c·dm⁻³; K= 2.00 and 1.42 cmol_c·dm⁻³; Na= 0.50 and 0.49 cmol_c·dm⁻³; Al= 0.00 and 0.00 cmol_c·dm⁻³ and P= 127.50 and 152.50 mg·dm⁻³.

A 'group balanced block'

experimental design was used in both experiments, with four replications. Cultivars of crisp-leaf ('Lucy Brown', 'Tainá', 'Laurel' and 'Verônica') and loose-leaf ('Babá de Verão', 'Maravilha das Quatro Estações', 'Elisa' and 'Carolina') groups were evaluated. In the intercropped experiment, a split-plot scheme was used, where 'Alvorada' and 'Brasília' carrot cultivars were the treatments assigned to the plots and the cultivars of crisp-leaf and loose-leaf lettuce groups were the treatments assigned to the subplots. In each block, one single plot in sole crop of 'Alvorada' and 'Brasília' carrot was planted to obtain data for the determination of yield advantage indexes.

In the intercropped experiment, each plot consisted of four alternate strips ("strip-intercropping"), two with car-

rot and two with lettuce, with four rows each. The total plot area was 3.84m² (3.20×1.20m), with a harvest area of 1.60m² (1.60×1.00m), containing 80 carrot and 40 lettuce plants. In the strips, the carrot spacing was 0.20×0.05m and lettuce was spaced 0.20×0.10m. The sole carrot plots were constituted by five rows with a total area of 1.20m² (1.00×1.20m) and a harvest area of 0.60 m² (0.60×1.00m), containing 30 carrot plants with a 0.20×0.10m spacing. In the experiment with lettuce as sole crop, each plot consisted of five rows, with a total area of 1.20m² (1.00×1.20m) and a harvest area of 0.48m² (0.60×0.80m), containing 12 lettuce plants spaced 0.20×0.20m. According to Barros Júnior *et al.* (2005) the recommended population for lettuce and carrot in sole crop in the region is 250000 and

500000 plants per ha, respectively, without consideration of 30% traffic area, made of corridors and roads. However, for the crop characteristics evaluated, corrections were made to 70% of the cultivated area.

Solarization of the experimental area was accomplished during 50 days to pre-planting for soil disinfection, aiming at control of phytopathogens. During the experiment, manual hoeing and irrigation by micro sprinkler system were performed. At 30cm height of shoot carrot, a narrow ribbon was placed enveloping the plants, with the purpose of allowing a more erect growth, decreasing the shadowing of lettuce plants located in adjacent areas to the carrot ones (strip intercropping). To the intercropped and sole crop carrot and lettuce cultures, 80t·ha⁻¹ of cattle manure, 40kg·ha⁻¹ of N in urea form, and 30kg·ha⁻¹ K₂O in KCl form, were applied (IPA, 1998). Additional N fertilization in carrot was done 37 days after sowing, using 45kg·ha⁻¹ of urea. For lettuce, leaf fertilization was applied 28, 39 and 44 days after sowing, with 30ml of a solution containing 14% N, 4% P₂O₅, 6% K₂O, 0.8% S, 1.5% Mg, 2% Zn, 1.5% Mn, 0.1% B and 0.05% Mo, diluted in 20 liters of water.

In the intercropped experiment, lettuce cultivars were transplanted to the strips adjacent to the carrot plants, in two steps: the first one was done seven days after carrot planting (Sept 25, 2002), and the second 82 days after carrot planting (Dec 08, 2002). This intercropping of lettuce with two different ages and only one carrot culture was done in order to establish a weak competition pressure with the main crop (carrot), so that productivity was the maximum possible when compared to the sole cultivation crop. This allowed a better performance of the intercropped system. In each cropping, lettuce was sowed in 150ml plastic cups containing a substrate composed by

vermiculite and humus (1:2). Three to five seeds per recipient were seeded, and two thinnings were performed at 8 and 15 days after sowing, keeping one seedling per recipient. Seedlings were produced under shade, using a greenhouse covered by a white nylon screen, and transplanted to the strips adjacent to carrot 21 days after seeding. In the sole experiment, lettuce cultivars were seeded and transplanted in the same dates as the plants used in the intercropped experiment. Carrot was sowed in only one cropping on Sept 18, 2002. Two thinnings were done, 22 and 30 days after seeding, remaining one plant each 0.05m.

For the first lettuce cultivation, harvest was accomplished on Oct 16-21, 2002, 28 days after carrot seeding, and between 41 and 46 days after lettuce sowing. Carrot harvest was done on Dec 17 and 18, 2002. For the second culture, lettuce harvest took place on Dec 23-24, 2002, nearly one week after carrot harvest, and 39 and 40 days after lettuce seeding, respectively.

The evaluated characteristic in the lettuce was leaf yield (shoot fresh mass), determined in all plants of the harvest plot. In the carrot, it was the commercial root productivity of plants of the harvest plot, free of defects such as fissures, forks, nematode galls and mechanical injuries.

Agronomic/biological efficiency indexes and combined production of both crops were determined as:

Land equivalent ratio (LER). It was presented by Willey and Osiru (1972) for evaluation of advantage in experiments of maize and bean intercropping. It was defined by Willey (1979) as the relative land area, under sole crop conditions, required to provide the yield reached in intercropping. LER particularly indicates the biological efficiency of intercropping for using the resources of the environment, as compared to sole crop (Mead and Willey, 1980).

Currently, it is the most commonly used index more used for evaluating the efficiency of polyculture cropping systems. LER is calculated as $LER = LER_c + LER_a$, where LER_c and LER_a represent the LER of individual crops (carrot and lettuce, respectively, in the present work). Comparison of these individual indexes can indicate the relative competition ability between the component crops. Thus, $LER_c = Y_{ca}/Y_c$ and $LER_a = Y_{ac}/Y_a$. The value of unity is the critical value. When LER is >1 the intercropping favors growth and yield of component crops. In contrast, when LER is <1 the intercropping negatively affects the growth and yield of crops grown in the association (Caballero *et al.*, 1995).

A homogeneous standardization was used for obtaining the LERs of each plot, considering the mean value of replications of genotypes in sole crop over blocks in the denominator of LER_c and LER_a , according to Federer (2002). This standardization was used to avoid difficulties with the possibility of having a complex distribution of the sum of the quotients that define LERs, making non-representative the analysis of variance of such indexes. This would induce errors concerning the validity of the assumption of normality and homogeneity. Moreover, it was also used to allow the validation of significance tests and confidence intervals and, consequently, the comparison among the several intercropped systems of carrot and lettuce.

Yield efficiency index (YEI). It was calculated according to the data envelopment analysis of Charnes-Cooper-Rhodes models (DEA CCR; Charnes *et al.*, 1978), with single and unitary input (Lovell and Pastor, 1999), as was proposed by Gomes and Souza (2005), quoted by Bezerra Neto *et al.* (2007a, b, c). These models aggregate in a one-dimensional index treatments with multidimensional response due to the experimental situation,

as in the intercropping cases. The goal of DEA models is to calculate the relative efficiency of productive units, known as decision making units (DMU). Linear programming problem solving (LPPS) is used in DEA formulation in order to optimize each individual observation, to estimate the stepwise linear efficient frontier, composed by those units presenting better practices within the sample under evaluation (efficient units). The definition of efficiency is based in the relationship between results obtained and resources applied by each DMU under evaluation. As mentioned by Gomes and Souza (2005), quoted by Bezerra Neto *et al.* (2007c), univariate measures of yield efficiency generated by DEA models can be analyzed through standard variance and covariance analysis. In the case of experiments with a one-dimensional response, the analysis is equivalent to the usual practice. Besides generalizing the classical methods of experiment analysis, DEA confers optimum economic properties to these processes and facilitates the interpretation of complex experiments by reducing the dimension of the response vector.

In the present case, the units under evaluation were the treatments, totaling 64, from the combination of cultures of two carrot cultivars and eight lettuce cultivars, all with four replicates. The products were the ranks of response variables measured for each treatment, being in the present case carrot productivity, lettuce yield and profit margin of the system. This approach is justified by Souza and Souza (2007).

The choice of DEA CCR models is due to the absence of evidence of significant scale differences and to the fact that the available variables are, typically, values or quantities produced. In this model, the relative efficiency of DMU is defined as the ratio of the weighted sum of the components of the yield vector to the weighted sum of

the components of the input vector used in the production process (in this case, unitary). The weights applied to the inputs and to the products (shade prices) are distinct and obtained from the resolution of LPPs that attribute to each DMU the weights that maximize their efficiency, or are assigned in a more benevolent way to each DMU.

The solution of the input oriented DEA CCR model is defined in this case by the linear programming problem that maximizes

$$\sum_{j=1}^3 u_j y_{jo}$$

subject to the restrictions

$$\sum_{j=1}^3 u_j y_{jk} \leq 1, \forall k; u_j \geq 0, \forall j.$$

In these formulas, y_{jk} are the input j values, $j=1...3$, for treatment k , $k=1...64$; u_j is the weight attributed to output j ; O is the treatment under analysis. Description of general formulas and interpretation of the model can be found in Bezerra Neto *et al.* (2007a).

Further, none of the previous indexes provides any information on the economic advantage of the intercropping

system. The yield and economics of the intercropping were determined to decide whether carrot yield and lettuce yield are sufficient to justify recommending farmers to use this intercropping system. Thus, the following economic indicators were calculated:

Gross income (GI). It represents the value of combined yields in each intercrop system, irrespective of production costs (PC). It was obtained from $GI = Y_{ca} P_c + Y_{ac} P_a$, where Y_{ca} and Y_{ac} are the yields in ton per ha of carrot and lettuce, respectively, as intercrops, and P_c and P_a are prices of 1kg of carrot and lettuce in December 2007, received by farmers in Mosoró-RN.

Net income (NI). Calculated as $NI = GI - PC$, where PC is the summation of all expenses (inputs and labors) in each intercrop system.

Modified monetary advantage (MMA). Calculated using the formula proposed by Beltrão *et al.* (1984): $MMA = NI (LER - 1) / LER$. According to these authors the higher the MMA and NI, the more profitable is the intercropping system.

Return rate (RR). Obtained as $RR = GI / PC$ (Beltrão *et al.*, 1984).

Profit margin (PM). Derived as the ratio of the NI to GI, expressed as percentage.

A univariate analysis of variance for randomized complete block design was performed in order to evaluate LER_c , LER_a and YEI, once the assumptions of normality, homocedasticity and additivity were satisfied. Duncan test was applied to compare means at the level of the studied treatment-factors.

Results and Discussion

The biological/agronomic efficiency indexes of carrot and lettuce intercropped systems are presented in Table I. Similar behavior was observed among the indexes LER_c and LER_a in relation to YEI, in statistical terms, among the tested factors-treatments. These results confirm the dominance of the carrot crop over the lettuce crop in the tested intercropped systems (higher values for LER_c than LER_a). On the other hand, it was also verified that the LER indexes were >1 in the several tested intercropped systems. This indicates that in these systems a better utilization of the environmental resources took place, when compared to sole crops. According to Jagannath and Sunderaraj (1987) in any comparison of benefits between intercropped systems with different land occupation areas, the advantage of intercropping via LER stems from two different sources that are generally confused: a) from the land factor (area occupied by each component crop), and b) from the biological/agronomic factor (from tested factors-treatments). This advantage in LER ranged 15-26% in the studied intercropping systems (Table I), due to the biological/agronomic factor resulting from the carrot cultivars and lettuce cultivars groups and from the lettuce cultivars tested within each group, as the area occupied

for each crop was the same in the various systems.

The measures of efficiency calculated by DEA models, herein termed YEI, can be considered as competition indicators. These are calculated in a comparative or relative way; YEI of a given treatment is dependent upon the outputs of another treatment. In this case, the "competition" is among treatments and not directly among crops, as in the previously detailed indexes. The resulting values for YEI (Table I) showed that treatments considering 'Brasília' carrot cultivar presented superior mean efficiency (mean absolute value) than those cultivating 'Alvorada' carrot. Regarding lettuce cultivars, the highest average efficiencies were in treatments using 'Lucy Brown' crisp-leaf lettuce, followed by 'Carolina', 'Tainá', 'Maravilha das 4 Estações', 'Babá de Verão', 'Verônica', 'Laurel' and 'Elisa'. It should be emphasized, however, that, as shown in Table I, no significant statistical difference was found for the studied factors-treatments. Analyzing treatments, it can be observed that treatments using 'Brasília' carrot intercropped with 'Carolina', 'Maravilha das 4 Estações' and 'Lucy Brown' lettuce presented better performances (higher mean YEI). Comparing results of YEI and LER , indexes indicative of relative advantage of combined production, one can note that they both were coincident in identifying 'Brasília' carrot and crisp-leaf lettuce varieties, and among these, 'Lucy Brown', as those showing better performance, and 'Elisa' looseleaf variety having the worst performance. It must be noted that in YEI, besides crops productivities, profit margin was also considered, which adds the economic value of the treatment factor to this aggregate indicator.

The indicators of monetary advantage (GI, NI, MMA, RR and PM) of the studied

TABLE I

LAND EQUIVALENT RATIO OF CARROT (LER_c),
LAND EQUIVALENT RATIO OF LETTUCE (LER_a),
LAND EQUIVALENT RATIO (LER) AND YIELD
EFFICIENCY INDEX (YEI) OF THE INTERCROPPING
SYSTEM, AS FUNCTION OF CARROT CULTIVARS,
LETTUCE GROUPS AND LETTUCE CULTIVARS
TESTED WITHIN EACH GROUP

Carrot Cultivars	LER_c	$\ddagger LER_a$	LER	YEI
Alvorada	0.77 a	0.41	1.18 a	0.59 a
Brasília	0.79 a	0.45	1.24 a	0.68 a
Groups /Lettuce cultivars				
Crisp-leaf	0.77 A	0.47	1.24 A	0.64 A
Lucy Brown	0.74 a	0.52	1.26 a	0.71 a
Tainá	0.77 a	0.46	1.23 a	0.66 a
Laurel	0.79 a	0.42	1.21 a	0.59 a
Verônica	0.80 a	0.45	1.25 a	0.61 a
Looseleaf	0.79 A	0.40	1.19 A	0.63 A
Babá de Verão	0.77 a	0.39	1.16 a	0.62 a
Maravilha das 4 Estações	0.73 a	0.46	1.19 a	0.65 a
Elisa	0.80 a	0.35	1.15 a	0.57 a
Carolina	0.84 a	0.40	1.24 a	0.67 a

* Within columns, means followed by different letters differ by Duncan test ($P < 0.05$).

† Characteristics missing (without) letters in the columns were not submitted to analysis of variance because did not satisfy the assumptions of normality, variance homogeneity or additivity.

TABLE II
MONETARY ADVANTAGE INDEXES OF INTERCROPPED SYSTEMS
FOR THE COMBINATION OF TWO CARROT CULTIVARS
WITH TWO GROUPS OF FOUR LETTUCE CULTIVARS

Intercropped Systems	GI R\$/ha	NI R\$/ha	MMA R\$/ha	RR	PM %
Systems with Alvorada carrot	29,057.58	12,645.46	2,794.79	1.77	39.83
Systems with Brasília carrot	31,785.67	15,392.05	4,175.96	1.94	44.02
Systems with Crispleaf group	32,180.35	15,152.98	4,132.74	1.89	42.51
Alvorada + Lucy Brown	35,994.12	17,814.50	5,250.88	1.98	45.59
Brasília + Lucy Brown	33,933.95	15,772.83	5,172.38	1.87	37.66
Alvorada + Tainá	32,599.89	16,424.27	4,035.02	2.02	46.73
Brasília + Tainá	33,132.77	16,975.66	3,829.64	2.05	48.45
Alvorada + Laurel	30,051.99	12,252.37	3,672.18	1.69	36.53
Brasília + Laurel	30,180.58	12,399.46	3,369.68	1.70	36.41
Alvorada + Verônica	27,654.22	11,662.60	2,183.64	1.73	39.58
Brasília + Verônica	33,895.30	17,922.18	5,548.51	2.12	49.17
Systems with Looseleaf group	28,662.90	12,884.53	2,838.01	1.82	41.33
Alvorada + Babá de Verão	28,055.74	12,274.12	2,200.01	1.78	39.33
Brasília + Babá de Verão	30,797.54	15,034.42	2,970.44	1.95	47.34
Alvorada + M. 4 Estações	25,763.99	10,094.37	1,312.67	1.64	35.46
Brasília + M. 4 Estações	35,162.60	19,511.48	5,923.26	2.25	51.60
Alvorada + Elisa	27,055.44	11,095.82	2,319.25	1.70	38.30
Brasília + Elisa	26,361.49	10,420.37	2,119.06	1.65	35.47
Alvorada + Carolina	25,285.28	9,545.66	1,384.64	1.61	37.11
Brasília + Carolina	30,821.12	15,100.00	4,474.74	1.96	45.65

* GI: gross income, NI: net income, MMA: modified monetary advantage, RR: return rate, PM: profit margin.

carrot and lettuce intercropping systems are presented in Table II. In a general sense, they indicate an evident gain with the intercropped systems. The highest indicators were obtained in the intercropped systems containing 'Brasília' carrot as a component crop. Between the lettuce groups, then crispleaf group exceeded the looseleaf one, in terms of these economic indicators. These results are in agreement with the result obtained with LER. Ghosh (2004), working with groundnut and fodder cereal intercropped in the semi-arid tropics of India, observed a significant economic benefit, expressed as higher values of MMA, for high values of LER. Analyzing the cultivars within the crispleaf group it can be seen that the system formed by 'Brasília' carrot + 'Verônica' lettuce exceeded the others, regarding NI, MMA, RR and PM. On the other hand, within the looseleaf group, systems formed by 'Brasília' carrot + 'Maravilha' das Quatro Estações' lettuce, followed by 'Brasília' carrot + 'Carolina'

lettuce were distinguished regarding all the indicators of profit advantage. These results expressed the advantage of LER and YEI in monetary terms, indicating that the agronomic superiority obtained in the systems studied resulted in economic advantages.

In a general sense, it is observed that the evaluated indexes allow to quantify and to express several attributes of yield advantages in intercropping systems, including intensity and importance, effects and responses of the product of competition. Besides, several qualities must also be considered in selecting indexes to express advantages of intercropped systems. Among them are specificity and clarity of the meaning, and also the mathematical and statistical properties. It was evident that, in addition to any analysis about competition and yield advantage indexes of crop components in the various studied intercropped systems, some economic evaluation should be done in order to express the agronomic ad-

vantages in economic terms.

Conclusions

Through the evaluated yield advantage indexes, one can observe that carrot is the dominant crop and lettuce the dominated one. The highest agronomic efficiency indexes and economic indicators were observed in intercropping systems containing 'Brasília' carrot as component crop, and those based in the looseleaf lettuce group. Higher economic indicators were found in the systems formed by 'Brasília' carrot + 'Verônica' lettuce, within the crispleaf group; and 'Brasília' carrot + 'Maravilha das Quatro Estações' lettuce, within the looseleaf group. LER and YEI indexes indicate the extent of relative advantage of combined production, and can be applied to any intercropping cultivation situation. For LER, obtained through homogeneous standardization method using the mean value of replications of sole genotypes over blocks, assumptions of univariate analysis of variance were satisfied. The utilization of YEI (DEA models) seems to be relevant in the analysis of intercropped systems, when searching for the best combination of two or more crops.

REFERENCES

- Banik P, Sasmal T, Ghosal PK, Bagchi DK (2000) Evaluation of mustard (Brassica campestris Var. Toria) and legume intercropping under 1:1 and 2:1 row-replacement series systems. *J. Agron. Crop Sci.* 185: 9-14.
- Barros Júnior AP, Bezerra Neto F, Silva E de O, Negreiros MZ, Oliveira EQ de, Silveira LM da, Lima JSS de, Freitas KKC de (2005) Qualidade de raízes

de cenoura em sistemas consorciados com alface sob diferentes densidades populacionais. *Hort. Bras.* 23: 290-293.

- Beltrão NEM, Nóbrega LB da, Azevedo DMP de, Vieira DJ (1984) *Comparação entre Indicadores Agroecossistêmicos de Avaliação de Agroecossistemas Consorciados e Solteiros Envolvendo Algodão "Upland" e Feijão "Caupi"*. Boletim de Pesquisa Nº 15. CNPA. Campina Grande-PB, Brazil. 21 pp.
- Bezerra Neto F, Barros Júnior AP, Negreiros MZ de, Oliveira EQ de, Silveira LM. da, Câmara MJT (2005a) Associação de densidades populacionais de cenoura e alface no desempenho agrônomico da cenoura em cultivo consorciado em faixa. *Hort. Bras.* 23: 233-237.
- Bezerra Neto F, Barros Júnior AP, Silva, E de O, Silveira LM. da, Aroucha, EMM (2005b) Qualidade da alface em sistemas consorciados com cenoura sob diferentes densidades populacionais das culturas componentes. *Rev. Caatinga* 18: 169-175.
- Bezerra Neto F, Barros Júnior AP, Silva EO de, Negreiros MZ de, Oliveira EQ de, Silveira LM da, Câmara MJT, Nunes GHS (2006) Qualidade nutricional de cenoura e alface cultivadas em Mossoró-RN em função da densidade populacional. *Hort. Bras.* 24: 476-480.
- Bezerra Neto F, Gomes EG, Nunes MVR, Barros Junior AP (2007a) Análise multidimensional de consórcios cenoura-alface sob diferentes combinações de densidades populacionais. *Pesq. Agropec. Bras.* 42: 1697-1704.
- Bezerra Neto F, Gomes EG, Nunes GHS, Oliveira EQ de (2007b) Desempenho de sistemas consorciados de cenoura e alface avaliados através de métodos uni e multivariados. *Hort. Bras.* 25: 500-506.
- Bezerra Neto F, Gomes EG, Oliveira AM (2007c) Produtividade biológica em sistemas consorciados de cenoura e alface avaliada através de indicadores agroecômicos e métodos multicritério. *Hort. Bras.* 25: 193-198.
- Caballero R, Goicoechea EL, Hermaiz PJ (1995). Forage yields and quality of common vetch and oat sown at varying seeding rates and seeding rates of common vetch. *Crops Res.* 41: 135-140.
- Cecilio Filho AB, May A (2002) Produtividade das culturas de alface e rabanete em função da época de estabelecimento do consórcio. *Hort. Bras.* 20: 501-504.

- Charnes A, Cooper WW, Rhodes E (1978) Measuring the efficiency of decision-making units. *Eur. J. Operat. Res.* 2: 429-444.
- Dima KV, Lithourgidis AS, Vasila-koglou IB, Dordas CA (2007) Competition indices of common vetch and cereal intercrops in two seeding ratios. *Field Crops Res.* 100: 249-256.
- EMBRAPA (1999) *Sistema Brasileiro de Classificação de Solos*. Centro Nacional de Pesquisa de Solos. EMBRAPA. Brasília, Brazil. 412pp.
- Federer WT (2002) Statistical issues in intercropping. In El-Shaarawi AH, Piegorsch WW, Piegorsch W (Eds.) *Encyclopedia of Environmetrics*. 1st ed. Wiley. New York, USA. pp .1064-1069.
- Ghosh PK (2004) Growth, yield, competition and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. *Field Crops Res.* 88: 227-237.
- IPA (1998) *Recomendações de Adubação para o Estado de Pernambuco: 2ª Aproximação*. 2ª ed. Empresa Pernambucana de Pesquisa Agropecuária. Brazil. 198 pp.
- Jagannath MK, Sunderaraj N (1987) Productivity equivalent ratio and statistical testing of its advantage in intercropping. *J. Ind. Soc. Agric. Stat.* 39: 289-300.
- Liebman M (2002) Sistemas de policultivos. In Altieri M (Ed.) *Agroecologia: Bases Científicas para uma Agricultura Sustentável*. Agropecuária. Gauíba, Rio Grande do Sul, Brazil.. pp. 347-368.
- Lovell CAK, Pastor JT (1999) Radial DEA models without inputs or without outputs. *Eur. J. Operat. Res.* 118: 46-51.
- Mead R, Willey RW (1980) The concept of a land equivalent ratio and advantages in yields for intercropping. *Exp. Agric.* 16: 217-228.
- Montezano EM, Peil RMN (2006) Sistemas de consórcio na produção de hortaliças. *Rev. Bras. Agrociên.* 12: 129-132.
- Oliveira AM, Bezerra Neto F, Negreiros MZ, Oliveira EQ (2005a) Cultivares de alface americana em segundo cultivo nos sistemas solteiro e consorciado com cenoura. *Rev. Caatinga* 18: 47-51.
- Oliveira EQ de, Bezerra Neto F, Negreiros MZ de, Barros Júnior AP, Freitas KKC de, Silveira LM da, Lima JSS de (2005b) Produção e valor econômico no consórcio entre cultivares de coentro e de alface. *Hort. Bras.* 23: 285-289.
- Park SE, Benjamin LR, Watkinson AR (2002) Comparing biological productivity in cropping systems: a competition approach. *J. Appl. Ecol.* 39: 416-426.
- Souza WFS, Souza GS (2007) Infra-estrutura portuária nacional de apoio ao comércio exterior: hierarquização das unidades portuárias. *Engevista* 9: 4-13.
- Weigelt A, Jolliffe P (2003) Indices of plant competition. *J. Ecol.* 91: 707-720.
- Willey RW (1979) Intercropping - Its importance and research needs. Part 1. Competition and yield advantages. *Field Crop Abstr.* 32: 1-13.
- Willey RW, Osiru DJO (1972) Studies on mixtures of maize and beans (*Phaseolus vulgaris*) with particular reference to plant population. *J. Agric. Sci.* 79: 519-529.