Viability of polycultures of arugula-carrot-coriander fertilized with hairy woodrose under different population densities

Lúcio J. de Oliveira[1], Francisco Bezerra Neto[2], Jailma S. S. de Lima[2],
Eliane Q. de Oliveira[3], Joserlan N. Moreira[3] & Ítalo N. Silva[2]

[1] Instituto Federal de Educação, Ciência e Tecnologia do Ceará/Campus Iguatu. Iguatu, CE. E-mail: lujoliveira@yahoo.com.br
[2] Universidade Federal Rural do Semi-Árido/Centro de Ciências Agrárias/Departamento de Ciências Agronômicas e Florestais. Mossoró, RN. E-mail: netobez@gmail.com; jailma@ufersa.edu.br (Corresponding author); italonunessilva@gmail.com
[3] Instituto Federal de Educação, Ciência e Tecnologia da Paraíba/Campus Souza. Souza, PB. E-mail: eliqueiroga04@yahoo.com.br; joserlan.moreira@ifpb.edu.br

Key words:

Eruca sativa
Daucus carota
Coriandrum sativum
Merremia aegyptia
multiple cropping

ABSTRACT

Polycultures from broadleaves with tuberoses are being used in vegetable crop production systems in the semiarid region of Potiguar. The challenge is to determine whether these systems are productively viable when fertilized with organic matter produced by spontaneous species of the Caatinga biome. The objective of this study was to evaluate the agro-economic performance of arugula (A), carrot (C), and coriander (Co) polycultures fertilized with hairy woodrose biomass incorporated into the soil under different population densities among the component crops. The experimental design was a randomized complete block with four replications, with the treatments arranged in a 4×4 factorial scheme, from the combination of four amounts of hairy woodrose biomass incorporated into the soil (7.5, 15.0, 22.5, and 30.0 t ha^{-1} on a dry matter basis), with four population densities (20A-50C-20Co%, 30A-50C-30Co%, 40A-50C-40Co%, and 50A-50C-50Co% of the recommended population in the single crop). The efficiency of polycultures was evaluated through indexes and agro-economic indicators. The most productive agro-economic performance was obtained with a biomass of 18.21 t ha^{-1} of hairy woodrose incorporated in the soil and a population density of 50A-50C-50Co%.

Palavras-chave:

Eruca sativa
Daucus carota
Coriandrum sativum
Merremia aegyptia
Cultivo múltiplo

Viabilidade de policultivos de rúcula-cenoura-coentro adubados com jitirana sob diferentes densidades populacionais

RESUMO

Policultivos de folhosas com tuberosas estão sendo utilizados nos sistemas de produção de hortaliças na região semiárida Potiguar. O desafio é determinar se esses sistemas são produtivamente viáveis quando fertilizados com matéria orgânica produzida por espécies espontâneas do bioma Caatinga. O objetivo deste trabalho foi avaliar o desempenho agroeconômico de policultivos de rúcula (R), cenoura (C) e coentro (Co) adubados com biomassa de jitirana incorporada no solo sob diferentes densidades populacionais entre as culturas componentes. O delineamento experimental foi de blocos completos casualizados com quatro repetições, com os tratamentos arranjados em esquema fatorial 4 x 4, provenientes da combinação de quatro quantidades de biomassa de jitirana incorporadas ao solo (7,5; 15,0; 22,5 e 30,0 t ha^{-1} em base seca) com quatro densidades populacionais (20R-50C-20Co; 30R-50C-30Co; 40R-50C-40Co e 50R-50C-50Co (%) da população recomendada no cultivo solteiro - PRCS). A eficiência dos policultivos foi avaliada através de índices e indicadores agroeconômicos. O desempenho agroeconômico mais produtivo foi obtido com uma biomassa de 18,21 t ha^{-1} de jitirana incorporada ao solo e uma densidade populacional de 50R-50C-50Co (%).

Introduction

Polyculture is a practice that is characterized by diversification, whereby different species of plants can be exploited at the same time and in the same space, showing more stability in their production than monoculture systems and presenting more effective mechanisms for providing and fixing of nutrients (Bezerra Neto et al., 2012).

In polyculture, in addition to the appropriate choice of combinations of species or cultivars, or of their establishment times, there are two important factors to be evaluated: population densities and adequate amounts of fertilizers to be applied to the soil (Lima et al., 2013). However, it is known that polyculture efficiency depends directly on the crops and management involved, thus requiring complementary interaction between them (Bezerra Neto et al., 2003).

Bezerra Neto et al. (2005), studying the combination of population densities of carrot and lettuce in a strip-intercropping system, observed that the increase in the association of population densities of carrot and lettuce increased the total and commercial productivity of carrot roots (i.e., the percentage of short roots).

Research regarding green manure in intercropping with vegetable crops has been successfully carried out in northeastern Brazil. Some authors, using hairy woodrose in carrot (Oliveira et al., 2011), beet (Silva et al., 2011), and beet and radish (Batista et al., 2013, 2016) obtained satisfactory yields under the conditions prevalent in Mossoró, RN, indicating that using green manure with hairy woodrose may be a promising practice for those using vegetable crops in successive cropping systems.

This work aimed to study the agro-economic feasibility of polycultures using the bicropping of arugula and coriander intercropped with carrot, with different amounts of hairy woodrose biomass incorporated into the soil at different population densities between component crops in semiarid conditions in the Rio Grande do Norte state of Brazil.

Material and Methods

The study was conducted on the experimental farm "Rafael Fernandes" of the Universidade Federal do Semi-Árido, in the Alagoinha district, 20 km from the municipality of Mossoró, RN (5° 11' S, 37° 20' W; altitude, 18 m), from September 2010 to February 2011.

The climate in this region by the Köppen classification is BShw, dry and very hot, with two seasons: a dry season, which usually runs from June to January, and a rainy season, from February to May (Alvares et al., 2014). During the driving period of the experiment, the average maximum temperature ranged from 32.1 to 34.5 °C with a minimum average of 21.3 to 23.7 °C.

Before the installation of the field experiment, simple samples of a Yellow-Red Latosol Argisolic were collected and sent for analysis to the Laboratory of Soil Fertility and Plant Nutrition of the Instituto Federal de Educação (Ciência e Tecnologia do Ceará, campus Iguatu), whose results were as follows: pH (water) = 7.7, OM = 4.34 g kg^{-1}, P = 3.0 mg dm^{-3} (H+Al) = 0.66 cmol$_c$ dm^{-3}, K = 0.016 cmol$_c$ dm^{-3}, Ca = 3.54 cmol$_c$ dm^{-3}, Mg = 1.67 cmol$_c$ dm^{-3}, Na = 0.029 cmol$_c$ dm^{-3}, sum of bases = 5.255, cation exchange capacity (CEC) = 5.915 cmol$_c$ dm^{-3}, base saturation = 88.84%, and electrical conductivity = 1.77 dS m^{-1}.

The pH analysis was performed using a potentiometer in a soil suspension of 1:2.5 in water. For P and K content, the Mehlich solution (HCl 0.05 mol L^{-1} H$_2$SO$_4$ + 0.025 mol L^{-1}) extractor was used and P and K were determined by calorimetry and flame photometry, respectively. The content of calcium and magnesium was obtained by extraction with 1 mol L^{-1} KCl and quantified by atomic absorption spectrophotometry and by titration with 0.01 mol L^{-1} NaOH, respectively. The percentage of carbon was determined by dichromatometry and N$_{total}$ by the Kjeldahl method. Sodium was determined by dilute hydrochloric acid solution and was subsequently determined using flame spectrophotometric apparatus. The sum of bases was obtained by applying the following formula: SB = Ca^{+2} + Mg^{+2} + K$^+$ + Na$^+$ and the CEC was determined based on the adsorbed cations removed by saline solutions of ammonium, calcium, and diluted acid solutions and subsequently determined by titration volumetry and flame spectrophotometry methods. The percentage of base saturation was obtained using the following formula: V (%) = (SB/CECpH7) × 100, and electrical conductivity was measured using a conductivity meter (EMBRAPA, 2009).

The experimental design was a randomized complete block with treatments arranged in a 4 × 4 factorial scheme with four replications. The first factor was the amounts of hairy woodrose incorporated into the soil (7.5, 15.0, 22.5, and 30.0 t ha^{-1} on a dry basis) and the second factor was the population densities of arugula (A), carrot (C), and coriander (Co) (20A-50C-20Co%, 30A-50C-30Co%, 40A-50C-40Co%, and 50A-50C-50Co% of the recommended populations in sole crops).

The soil preparation consisted of manually cleaning the experimental area with a tractor with an attached plow, followed by harrowing and constructing the beds. After this, a 30-day solarization pre-planting took place with transparent plastic-type 30-μm (Vulca Brilho Bril Fles) to reduce nematodes, especially *Meloidogyne* spp, and plant parasites in the top 0 to 10 cm of the soil (Oliveira et al., 2012).

The hairy woodrose (*Merremia aegyptia* L.) used as green manure was collected before the start of flowering in various locations of the rural zone of the Iguatu-CE municipality. After collecting, the plants were crushed in a conventional forage machine to obtain fragmented particles approximately 2.0 to 3.0 cm in size, which were dried in sun to reach a moisture content of 10%; a sample of this material was then subjected to laboratory analyses, which revealed a chemical composition of: N = 19.76 g kg^{-1}; P = 3.79 g kg^{-1}; K = 34.28 g kg^{-1}; Ca = 8.93 g kg^{-1}; Mg = 5.0 g kg^{-1}; S = 1.3 g kg^{-1}; Fe = 321 g kg^{-1}; Zn = 18 g kg^{-1}; Cu = 8 g kg^{-1}; Mn = 30 g kg^{-1}; B = 38 g kg^{-1}; Na = 169 g kg^{-1} and a C/N ratio of 25/1. The chemical analyses for the determination of the nutrient contents present in each fraction were conducted using extracts obtained via sulfur digestion. Nitrogen was quantified by the Kjeldahl semi-micro method; phosphorus by the spectrometry method with vanadium yellow; potassium and sodium using the method of

emission flame spectrometry; calcium, magnesium, iron, zinc, copper, and manganese by the spectrometry method of atomic absorption; sulfur by the turbidimetry method; and boron by the azimetric method (EMBRAPA, 2009).

Intercropping was established in alternating strips, with 25% of the area occupied by arugula, 50% by carrot, and 25% by coriander, and each plot comprised four strips, with four rows per strip, with the side bands flanked by two rows of a leafy crop on one side and two rows of carrot on the other side, used as borders. The total area of the intercropping was 4.80 m², with harvest area of 3.20 m² (Figure 1). Plants were spaced at 0.20 m between rows; within-row spacing varied according to the population density of arugula or coriander being studied. Carrot plants were spaced at 0.05 m within a row. The harvest area comprised the four central strips of plants, excluding the first and last plants of each row, which were used as borders.

In each block, single plots of arugula, carrot, and coriander were planted to obtain agronomic indicators, as recommended by Oliveira et al. (2015). Six rows per plot were planted, with a total area of 1.44 m² and a harvest area of 0.80 m², spaced 0.20 × 0.05 m for the cultures of arugula and coriander, and 0.20 × 0.10 m for the carrot crop. The harvest area comprised four rows of central plants, excluding the first and last plants of each row, which were used as borders. The population densities used for the single crops in the region were 500,000 plants ha⁻¹ for carrot (Oliveira et al., 2012) and 1,000,000 plants ha⁻¹ for coriander and arugula (Lima et al., 2007; Freitas et al., 2009).

Two incorporations of the green manure were used in the intercropping and single crop carrot plots, with 50% of the hairy woodrose amounts incorporated at 20 days before planting (30 August 2010) and the remaining 50% incorporated at 55 days after planting (12 November 2010). For coriander and arugula, 15.6 t ha⁻¹ was used, as recommended by Linhares (2007).

Two daily irrigations were carried out using a micro-sprinkler system at about 8 mm d⁻¹ (Lima et al., 2010), in order to promote soil microbial activity during decomposition. Weed control was implemented by hand weeding.
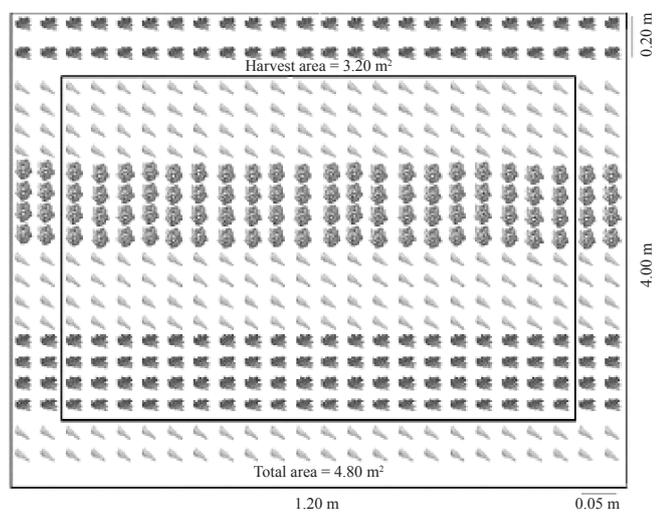
The carrot, coriander, and arugula used were Brasília, Verdão, and Cultivada, respectively, recommended for northeast Brazil. All crops were sown simultaneously on September 20, 2010, in holes about 3 cm deep with three to four seeds per hole. Arugula and coriander were thinned at 12 and 17 days after planting to leave only two plants per hole. The carrot crop was thinned 23 days after sowing to leave one plant per hole. The second cropping of arugula and coriander was carried out at 75 days post sowing for carrot, at which point carrot staking (lifting of the skirt) was conducted to avoid shading in the seedlings. Arugula and coriander were thinned during the second cultivation at 12 and 17 days, respectively, and were harvested at 34 and 39 days, respectively. Carrot was harvested 90 days after planting.

For the broadleaves (arugula and coriander), the characteristic evaluated was crop production. The efficiency of the intercropping system was determined using the land equivalent ratio - LER = $Ya_1cc_{o1}/Yaa_1 + Ya_2cc_{o2}/Yaa_2 + Ycac_o/Ycc + Yc_{o1}ca_1/Yc_oc_{o1} + Yc_{o2}ca_2/Yc_oc_{o2}$, where Ya_1cc_{o1} and Ya_2cc_{o2} are the yields of the green biomass of arugula in the first and second harvests, respectively, when arugula is intercropped with carrot and coriander; Yaa_1 and Yaa_2 are the yields of arugula when grown as a sole crop in the first and second harvests; $Ycac_o$ is the yield of carrot roots when carrot is intercropped with arugula and coriander; Ycc is the yield of carrot roots when carrot is grown as a sole crop; $Yc_{o1}ca_1$ and $Yc_{o2}ca_2$ are the yields of green biomass of coriander in the first and second harvests, respectively, when intercropped with carrot and arugula; and Yc_oc_{o1} and Yc_oc_{o1} are the yields of coriander when grown as a sole crop in the first and second harvests. This index was defined by Asten et al. (2011) as the relative area of land under single crop conditions, and is required to estimate the productivities achieved when intercropping. The individual LERs in each plot were obtained considering the averages across the replications of the single-cropped vegetables over blocks in the denominator of the partial LERs as per Bezerra Neto et al. (2012). According to Mohammed (2012) the critical value of LER is 1 when LER > 1, intercropping promotes the development and yield of the species, and when LER < 1, intercropping negatively affects development and yield.

The productive efficiency index (PEI) was estimated to calculate the production efficiency of each treatment, using the DEA (Data Envelopment Analysis) model with constant returns to the scale (Soares de Mello et al., 2013), since there was no significant difference in the scales. The score of the canonical variable (Z) was also evaluated using a multivariate analysis of variance.

Gross Income (GI) was obtained via the production value per hectare and the price paid to the producer at market level in the region in February 2011. The amounts paid for carrot, coriander and arugula were R$ 0.80, 1.40 and 1.30 kg⁻¹ respectively. Net income (NI) was calculated by subtracting the production costs deriving from a greater input of services from the gross income. These costs were calculated for each treatment based on the input cost coefficients and services used to cultivate a hectare of carrot, coriander, and arugula per the amount of hairy woodrose used. Prices of inputs and valid services in February 2011 in the city of Mossoró, RN, were considered.

( ) for arugula, ( ) for carrot and ( ) for coriander

Figure 1. Graphical representation of an experimental plot of polycultures of arugula-carrot-coriander

The rate of return (RR) was determined via the ratio of the gross income to the total costs, corresponding to how many BRL (reals) were obtained for each real invested in the intercropping of carrot, coriander, and arugula as a function of the factor-treatments studied. The profit margin (PM) comprised the net income expressed as a percentage of the gross income.

Analyses of variance were conducted for the evaluated characteristics using the SISVAR software (Ferreira, 2011). Tukey's test at 5% probability was used for comparisons between the population densities of the component crops of the intercropping system. Response curve adjustment for the quantitative factor was performed using the Table Curve software (Systat Software Inc., 2002).

Results and Discussion

There was no significant interaction between the amounts of hairy woodrose incorporated into the soil and the population densities of the component crops in the land equivalent ratio, productive efficiency index, and score of the canonical variable (Figure 2 and Table 1).

Increases in the land equivalent ratio (LER), productive efficiency index (PEI) and score of the canonical variable (Z) were observed with increasing amounts of hairy woodrose added until maximum values of 1.61, 89.16, and 7.54 were obtained for hairy woodrose additions of 22.15, 19.43, and 22.18 t ha^{-1}, after which these parameters decreased with further increases in the incorporation of green manure in the ground. This indicates that, in this organic cropping system, the incorporation of these amounts of manure led to a better use of environmental resources.

The results can be explained by the findings of Bezerra Neto et al. (2010), who observed that in any comparison of benefits between intercropping systems with different land occupied areas, the advantage of intercropping via LER comes from two different sources—the land factor (the area occupied by each component culture) and biological/agronomic factor (arising from the treatment factors tested).

Significant differences between the population densities were observed in the land equivalent ratio, productive efficiency index and score of the canonical variable (Table 1). The highest LER, PEI and Z values were obtained in the combination 50A-50C-50Co (%).

These results are explained in terms of a better use of the environmental resources by highest population densities without an observable negative influence of competition for water and nutrients imposed on plants. The LERs were higher than 1, indicating the agronomic/biological superiority over monocultured crops by means of the optimal use of environmental resources in all population densities.

According to Soares et al. (2011), when the LER is higher than 1, intercropping favors the growth and production of the component crops. The findings of Vandermeer (1990) indicate that intercropping is deemed efficient when the value of the LER is higher than 1, since the commercial standard of the crops is reached.
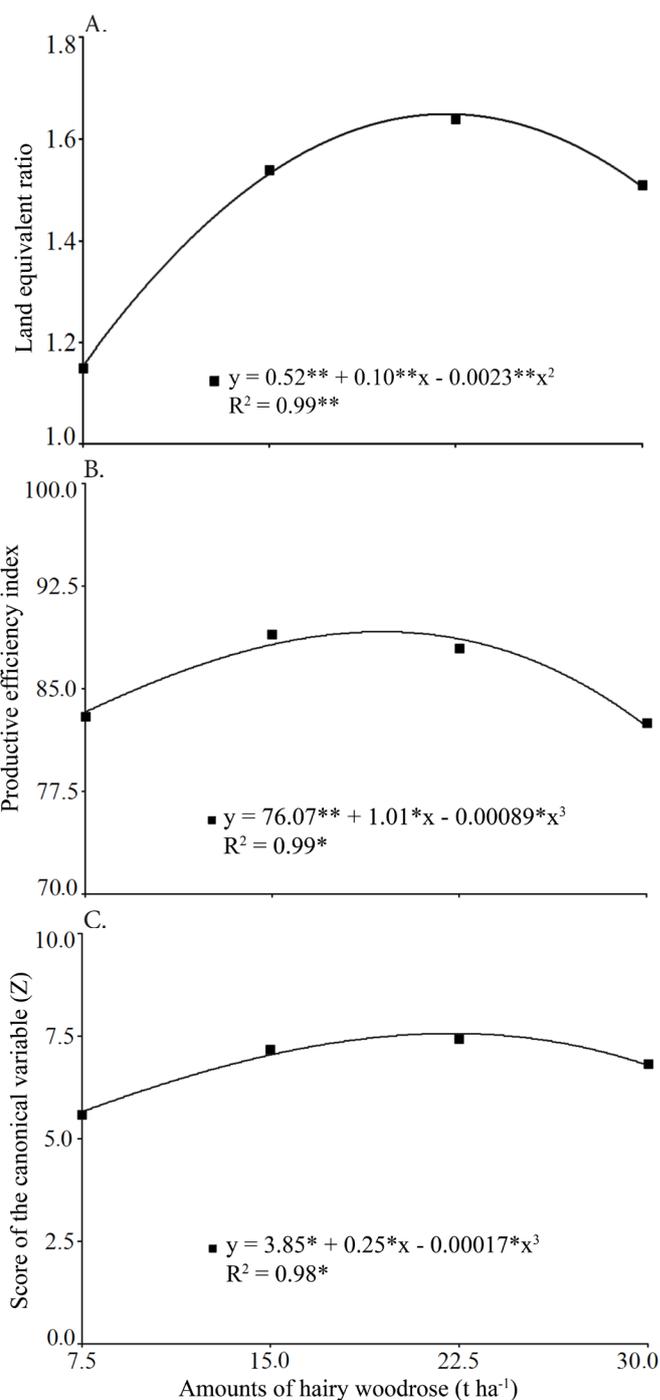
Figure 2. Land equivalent ratio (A), productive efficiency index (B) and score of the canonical variable (C) as a function of the amounts of hairy woodrose incorporated into the soil

Table 1. Land equivalent ratio (LER), productive efficiency index (PEI), and score of the canonical variable (Z) as a function of the population densities of arugula and coriander intercropped with carrot

Population densities (%)	LER	PEI	Z
20A-50C-20Co	1.25 b	81.48 b	5.69 c
30A-50C-30Co	1.31 b	83.96 b	6.17 bc
40A-50C-40Co	1.48 b	86.78 b	6.86 b
50A-50C-50Co	1.80 a	92.71 a	8.35 a
CV (%)	16.87	7.18	14.63

* Means followed by different small letters in the column differ statistically by Tukey test at 0.05 probability

Bezerra Neto et al. (2003) evaluated the agro-economic performance of the intercropping of carrot and looseleaf lettuce in two cropping systems, and observed advantages in the LER, the values of which ranged from 1.04 to 1.19. Oliveira et al. (2004), also evaluating the agronomic performance of the lettuce in bicropping in monoculture systems and in intercropping systems with carrot, observed better results with respect to LER, with values ranging between 1.45 and 2.16; these values are lower than those obtained in the present study.

There was no significant interaction between the amounts of hairy woodrose incorporated into the soil and the population densities of the component crops with respect to the gross income, net income, rate of return, and profit margin (Figure 3 and Table 2).

Increases in these variables were observed with increasing amounts of the green manure added, until maximum values of R$ 18,771.13, R$ 4,016.56, 1.31, and 20.62% were observed for hairy woodrose incorporation amounts of 20.70, 18.21, 17.84, and 17.99 t ha^{-1}, respectively, after which a decrease

Table 2. Gross income (GI), net income (NI), return rate (RR), and profit margin (PM) as a function of the population densities of arugula and coriander intercropped with carrot

Population densities (%)	GI	NI	RR	PM
	(R$ ha^{-1})			
20A-50C-20Co	12580.9 c	570.00 c	1.04 b	2.22 b *
30A-50C-30Co	14122.9 bc	1500.50 bc	1.11 b	8.48 b
40A-50C-40Co	15910.9 b	2753.40 b	1.21 b	14.75 ab
50A-50C-50Co	19087.0 a	5416.80 a	1.39 a	26.81 a
CV (%)	14.21	85.61	14.31	102.06

* Means followed by different small letters in the column differ statistically by Tukey test at 0.05 probability

was observed in these parameters with further increase in the amount of manure added to the soil (Figure 3, A-D).

These results, particularly those for net income, indicate the monetary advantage of using 18.21 t ha^{-1} of hairy woodrose incorporated into the soil; a quantity exceeding this becomes uneconomical owing to greater encumbrances on the cropping system.

Green manure at an incorporation amount of 18.21 t ha^{-1} possibly favored the increased availability of nutrients to plants, influencing the land equivalent ratio, productive efficiency index, score of the canonical variable, and the productivity of intercropping, and consequently the net income.

Significant differences were observed between the different population densities of the component cultures with respect to gross income, net income, rate of return, and profit margin, with the population density of 50A-50C-50Co being considerably higher than those of 40A-50C-40Co, 30A-50C-30Co and 20A-50C-20Co (Table 2).

The findings observed for economic indices, mainly the gross income, express in monetary terms the economic advantages of intercropping with the highest combination of population density owing to the limited competition for light, water, and nutrients between the plants, indicating that it is advantageous to the crops used in this system.

The agronomic results of this work agreed with the economic results. According to Bezerra Neto et al. (2012), the agronomic advantages associated with efficient land use are also reflected in economic advantages of the intercropping system.

A.

$y = 8817.18^{**} + 961.62^{**}x - 23.22^{**}x^2$
$R^2 = 0.99^{**}$

B.

$y = -2825.18^* + 751.75^{**}x - 20.65^{**}x^2$
$R^2 = 0.99^{**}$

C.

$y = 0.8^{**} + 0.057^{**}x - 0.0016^{**}x^2$
$R^2 = 0.99^{**}$

D.

$y = -18.80^{**} + 4.53^{**}x - 0.13^{**}x^2$
$R^2 = 0.99$
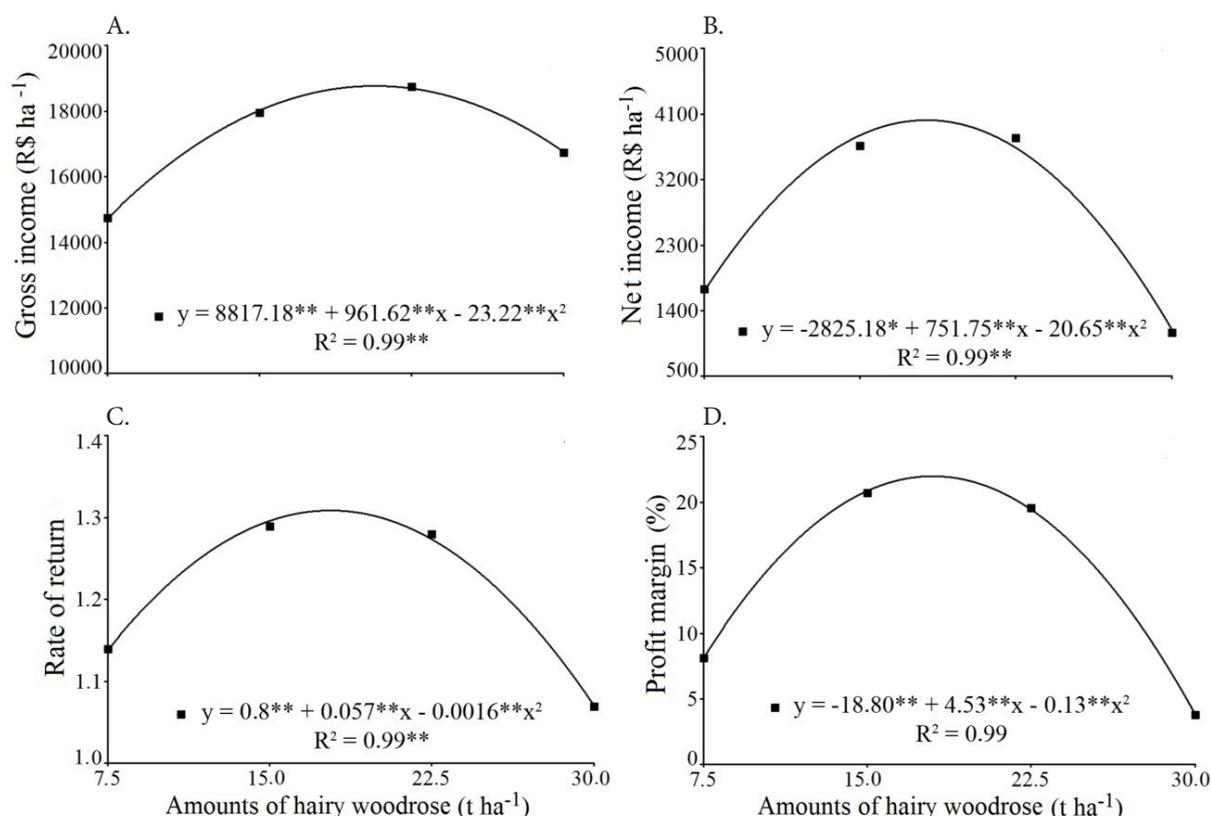
Figure 3. Gross income (A), net income (B), rate of return (C), and profit margin (D) as a function of the amounts of hairy woodrose incorporated into the soil

Conclusions

1. The best agronomic performance of the polycultures was obtained using 18.21 t ha^{-1} of green manure incorporated into the soil.

2. The population density that provided the best agro-economic performance was that of 50A-50C-50Co (%).

Acknowledgements

Literature Cited

Alvares, C. A.; Stape, J. L.; Sentelhas, P. C.; Gonçalves, J. L. de M.; Sparovek, G. Koppen´s climate classification map for Brazil. Metereologische Zeitschrift, v.22, p.711-728, 2014. https://doi.org/10.1127/0941-2948/2013/0507

Asten, P. J. A. van; Wairegi, L. W. I.; Mukasa, D.; Uringi, N. O. Agronomic and economic benefits of coffee-banana intercropping in Uganda's smallholder farming systems. Agricultural Systems, v.104, p.326-334, 2011. https://doi.org/10.1016/j.agsy.2010.12.004

Batista, M. A. V.; Bezerra Neto, F.; Ambrósio, M. M. Q.; Guimarães, L. M. S.; Saraiva, J. P. B.; Silva, M. L. da. Atributos microbiológicos do solo e produtividade de rabanete influenciados pelo uso de espécies espontâneas. Revista Horticultura Brasileira, v.31, p.587-594, 2013. https://doi.org/10.1590/S0102-05362013000400013

Batista, M. A. V.; Bezerra Neto, F.; Silva, M. L. da; Ambrósio, M. M. Q.; Cunha, J. L. X. L. Atributos de solo-planta e de produção de beterraba influenciados pela adubação com espécies da Caatinga. Revista Horticultura Brasileira, v.34, p.31-38, 2016. https://doi.org/10.1590/S0102-053620160000100005

Bezerra Neto, F.; Andrade, F. V.; Negreiros, M. Z. de; Santos Júnior, J. S. dos. Desempenho agroeconômico do consorcio cenoura x alface lisa em dois sistemas de cultivo em faixa. Revista Horticultura Brasileira, v.21, p.635-641, 2003. https://doi.org/10.1590/S0102-05362003000400012

Bezerra Neto, F.; Barros Júnior, A. P.; Negreiros, M. Z. de; Oliveira, E. Q. de; Silveira, L. M. da; Câmara, M. J. T. Associação de densidades populacionais de cenoura e alface no desempenho agronômico da cenoura em cultivo consorciado em faixa. Horticultura Brasileira, v.23, p.233-237, 2005. https://doi.org/10.1590/S0102-05362005000200014

Bezerra Neto, F.; Gomes, E. G.; Araújo, R. R. de; Oliveira, E. Q. de; Nunes, G. H. de S.; Grangeiro, L. C.; Azevedo, C. M. da S. B. Evaluation of yield advantage indexes in carrot-lettuce intercropping systems. Interciencia, v.35, p.59-64, 2010.

Bezerra Neto, F.; Porto, V. C. N.; Gomes, E. G.; Cecílio Filho, A. B.; Moreira, J. N. Assessment of agroeconomic indices in polycultures of lettuce, rocket and carrot through uni - and multivariate approaches in semi-arid Brazil. Ecological Indicator, v.1, p.11-17, 2012. https://doi.org/10.1016/j.ecolind.2011.07.006

EMBRAPA- Empresa Brasileira de Pesquisa Agropecuária. Manual de análises químicas de solos, plantas e fertilizantes. 2.ed. revisada e ampliada. Brasília: EMBRAPA, 2009. 627p.

Ferreira, D. F. Sisvar: A computer statistical analysis system. Ciência e Agrotecnologia, v.35, p.1039-1042, 2011. https://doi.org/10.1590/S1413-70542011000600001

Freitas, K. K. C. de; Bezerra Neto, F.; Grangeiro, L. da C.; Lima, J. S. S. de; Moura, K. H. S. Desempenho agronômico de rúcula sob diferentes espaçamentos e épocas de plantio. Revista Ciência Agronômica, v.40, p.449-454, 2009.

Lima, J. S. S. de; Bezerra Neto, F.; Negreiros, M. Z. de; Freitas, K. K. C.; Barros Júnior, A. P. Desempenho agroeconômico de coentro em função de espaçamentos e em dois cultivos. Revista Ciência Agronômica, v.38, p.407-413, 2007.

Lima, J. S. S. de; Bezerra Neto, F.; Negreiros, M. Z. de; Ribeiro, M. C. C.; Barros Júnior, A. P. Productive performance of carrot and rocket cultivars in strip-intercropping system and sole crops. Agrociencia, v.44, p.561-574, 2010.

Lima, J. S. S. de; Chaves, A. P.; Bezerra Neto, F.; Santos, E. C.; Oliveira, F. S. de. Produtividade da cenoura, coentro e rúcula em função de densidades populacionais. Revista Verde de Agroecologia e Desenvolvimento Sustentável, v.8, p.110-116, 2013.

Linhares, P. C. F. Produção de rúcula em função de diferentes quantidades e tempos de decomposição de jitirana. Mossoró: UFERSA, 2007. 58p. Dissertação Mestrado

Mohammed, S. A. A. Assessing the Land Equivalent Ratio (LER) of two leguminous pastures (clitoria and siratro) intercropping at various cultural practices and fencing at zalingei-Western Darfur State - Sudan. ARPN Journal of Science and Technology, v.2, p.1074-1080, 2012.

Oliveira, E. Q. de; Bezerra Neto, F.; Negreiros, M. Z. de; Barros Júnior, A. P. Desempenho agroeconômico do bicultivo de alface em sistema solteiro e consorciado com cenoura. Revista Horticultura Brasileira, v.22, p.712-717, 2004. https://doi.org/10.1590/S0102-05362004000400009

Oliveira, L. A. de A.; Bezerra Neto, F.; Silva, M. L. da; Oliveira, O. F. N.; Lima, J. S. S. de; Barros Júnior, A. P. Viabilidade agronômica de policultivos de rúcula/cenoura/alface sob quantidades de flor-de-seda e densidades populacionais. Revista Caatinga, v.28, p.116-126, 2015. https://doi.org/10.1590/1983-21252015v28n413rc

Oliveira, M. K. T. de; Bezerra Neto, F.; Barros Júnior, A. P.; Lima, J. S. S. de; Moreira, J. N. Desempenho agronômico da cenoura adubada com jitirana antes da sua semeadura. Revista Ciência Agronômica, v.42, p.364-372, 2011. https://doi.org/10.1590/S1806-66902011000200015

Oliveira, M. K. T. de; Bezerra Neto, F.; Barros Júnior, A. P.; Moreira, J. N.; Sá, J. R. de; Linhares, P. C. F. Desempenho agroeconômico da cenoura adubada com jitirana (*Merremia aegyptia*). Revista Horticultura Brasileira, v.30, p.433-439, 2012. https://doi.org/10.1590/S0102-05362012000300013

Silva, M. L. da; Bezerra Neto, F.; Linhares, P. C. F.; Sá, J. R. de; Lima, J. S. S. da; Barros Júnior, A. P. Produção de beterraba fertilizada com jitirana em diferentes doses e tempos de incorporação ao solo. Revista Brasileira de Engenharia Agrícola e Ambiental, v.15, p.801-809, 2011. https://doi.org/10.1590/S1415-43662011000800006

Soares, M. B. B.; Finoto, E. L.; Martins, A. L. M. Produtividade e eficiência do uso da terra no consórcio entre mandioca e amendoim. Revista Pesquisa & Tecnologia, v.8, p.1-5, 2011.

Soares de Melo, J. C. C. B.; Gomes, E. G.; Abreu, U. G. P. de; Carvalho, T. B. de; Zen, S. de. Análise de desempenho de sistemas de produção modais de pecuária de cria no Brasil. Produção, v.23, p.877-886, 2013. https://doi.org/10.1590/S0103-65132013005000010

Systat Software Inc. Table curve 2D e 3D. San Jose: MMIV Systat Software Inc, 2002.

Vandermeer, J. H.; Intercropping. In: Carroll, C. R.; Vandermeer, J. H.; Rosset, P. (ed.), Agroecology. New York: McGraw Hill, 1990, p.481-516.