

Agro-economic Feasibility of Intercropped Systems of Radish and Cowpea-Vegetable Manured With Roostertree Biomass

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Abstract

The association of crops presents as one of the cultivation practices to be used in the systems of vegetable crop production in the northeast Brazil semiarid, fertilized with biomass of spontaneous species of the Caatinga biome as green manure. Under this approach, a study was performed during the period from June to December 2013, in the research area of the Experimental Farm belonging to the Universidade Federal Rural do Semi-árido, Mossoró, RN (Brazil), to assess the feasibility of the agro-economic efficiency of the radish × cowpea-vegetable association manured with different amounts of roostertree biomass in semiarid environment. A randomized complete block design was used with four treatments and five repetitions. The treatments were composed of four biomass amounts of roostertree incorporated to the soil (10, 25, 40 and 55 t ha⁻¹ on a dry basis). The highest agronomic and economic efficiencies of the intercropping of radish with cowpea-vegetable were obtained with the incorporation of 53 and 47 t ha⁻¹ of roostertree biomass added to the soil. The roostertree spontaneous species of the Caatinga biome it is showed as an efficient green manure in the association of radish with cowpea-vegetable.

Keywords: agro-economic efficiency, *Calotropis procera*, intercropping, *Raphanus sativus*, *Vigna unguiculata*

1. Introduction

The economic efficiency of agricultural production resulting from lower production unit costs (costs per unit of product), is related to the increased soil fertility and the optimization of acreage (Reis, 2002). Accordingly, the intercropping system can promote this optimization of the area through the complementary of the components crops as well as through manuring with native plant species (Batista et al., 2016; Silva et al., 2017).

The intercropping system in northeastern Brazil has recently been recognized as a potentially beneficial system of agricultural production of vegetable crops, because in a time unit increases overall crop yields per unit of land, in exclusive reason of spatial reorganization of plants in the cultivated area, i.e. no additional costs when compared with traditional monoculture system (Ribeiro et al., 2017). This possibility can be easily checked, since the spaces between the vegetable crops can be better utilized by means of cultivation with crops of short cycle such as radish and cowpea-vegetable.

Rezende et al. (2005) reported that intercrops of radish and lettuce were economically advantageous when compared to their monocultures, resulting from the higher increase in the revenue in relation to the increase observed in the cost of production. Catelan et al. (2002a), in an intercropping of lettuce and radish, obtained net income higher than monocultures in 73.13% considering the lettuce, and in 11.36% taking into account the radish crop.

On the other hand, it is known that one of the management practices of crop and soil that can further improve the agro-economic efficiency of the intercropping systems between vegetable crops is the fertilization with spontaneous species of Caatinga. This practice provides significant improvements in chemical, physical and biological characteristics of the soil.

The chemicals characteristics are benefited by the release of nutrients with the decomposition of waste, while the physicals are favored by soil aggregation, improved water retention, preventing it from erosion. The biomass of green manure improves soil biological characteristics thus becoming food for microorganisms (Nascimento & Mattos, 2007).

Other advantages of using green manures are: decreasing of the number of fungal pathogens with the waste decomposition (Wiggins & Kinkel, 2005); control of nematode and of some insects, by the increase of biodiversity (Caamal-Maldonado et al., 2001); lower soil thermal amplitude (Torres, 2003); decreasing of soil acidity, and raising pH (Nascimento et al., 2003). In this way, green manuring is an alternative to reduce the external energy supply to rural property, increasing the sustainability of the system.

Bezerra Neto et al. (2013a) studying the intercropping of beet with cowpea-vegetable manured with different amounts of roostertree, observed that the score of the canonical variable of the intercropping system, which measures the agronomic efficiency increased with increasing roostertree amounts, about 2.00 in its value between the lowest and the highest amount of green manure added to the soil, registering a maximum score of 3.95 obtained in the largest roostertree biomass amount of 55 t ha⁻¹. These same authors, working with the agronomic efficiency of carrot intercropped with cowpea-vegetable under different amounts of roostertree biomass, optimized the canonical variable score in value of 2.46 in the amount of 46.0 t ha⁻¹ of the green manure (Bezerra Neto et al., 2013b).

Thus, this study had the objective of assessing the feasibility of the agronomic and economic efficiency of the radish × cowpea-vegetable association manured with different roostertree biomass amounts in semi-arid environment.

2. Material and Methods

2.1 Site Description

A study was performed from June to September 2013 in Mossoró, RN, Brazil (5°113' S and 37°20' W Gr) in the experimental area of the Universidade Federal Rural do Semi-Árido (UFERSA), where the climate of the region is of the BSh group, tropical and semi-arid (Batista et al., 2013). In the period of the experiment conduction, the average temperature was 27 °C; the minimum average 25 °C; the average maximum 31 °C; rainfall 0 mm; average solar radiation 918 kJ m⁻²; average relative humidity 66%; average atmospheric pressure 1011 hPa; average wind speed 4 m s⁻¹ and average temperature of the dew point 19 °C.

The research area soil was of the Dystrophic Yellow Red Latosol type (Oliveira et al., 2015), where fifty simple soil samples were taken to a depth of 0-20 cm, and posteriorly homogenized in order to obtain a composite sample, which after analyzed provided the following results: pH (in water) = 7.09; OM = 11.5 mg dm⁻³; N = 0.04 g kg⁻¹; P = 15.14 g kg⁻¹; K = 50.5 mg dm⁻³; Ca = 1.84 cmol_c dm⁻³; Mg = 1.39 cmol_c dm⁻³; Na = 4.1 mg dm⁻³ and CEC = 3.38 cmol_c dm⁻³.

2.2 Experimental Procedure

The experimental design used in this research was of randomized complete blocks with four treatments and five repetitions. The treatments were composed of four biomass amounts of roostertree added to the soil (10, 25, 40 and 55 t ha⁻¹ on a dry basis). These amounts were incorporated into the soil in each experimental plot at 20 days before sowing (Linhares et al., 2011). The area of each plot was of 3.60 m² (3.00 m × 1.20 m) with 2.00 m² of harvest area.

2.3 Management and Cropping System

The planting area of the research was cleaned with a tractor attached a plow. After this, a harrowing and beds lifting was performed. In all these beds was held a solarization with a plastic type Vulcabrilho Bril Fles of 30 microns during 35 days in order to strike the phytoparasites of the soil in the layer 0-10 cm to protect the crops (Linhares et al., 2017).

The green manure used in the fertilizing of this research was collected in the micro-region Mossoró-Apodi of the Rio Grande do Norte state, Brazil and ground up in 2-3 cm pieces and dried until to reach the point of hay at room temperature, and then stored with a moisture content around 9%. Subsequently, nutrient content analyzes were performed on samples randomly selected from this fertilizer, providing the following chemical composition: 15.3 g kg⁻¹ N; 4.0 g kg⁻¹ P; 15.7 g kg⁻¹ K; 9.3 g kg⁻¹ Ca; 7.03 g kg⁻¹ Mg, 4.39 g kg⁻¹ S, and a ratio of Carbon:Nitrogen of 20:1.

The establishment of the intercropping of radish with cowpea-vegetable was carried out in alternating strips of planting in the proportion of 50% of area occupied for each crop. Each strip was composed of four rows of each

culture and flanked by two guard rows of cowpea-vegetable on one side and two guard rows of radish on the other side, called of lateral borders.

The cultivated radish and cowpea-vegetable cultivars in the intercropping systems were respectively the 'Crimson Giant' and the 'BRS Itaim'. The radish crop was planted at the spacing of 0.25 m between rows, with 10 plants per linear meter, and the cowpea-vegetable with 25 plants per linear meter.

The planting of the cultivars of each culture in single crop was carried out in each block of the experiment in its optimum population recommended by the research in the semi-arid region of northeastern Brazil. The spacing of the radish crop was 0.20 m × 0.10 m and the cowpea-vegetable was 0.50 m × 0.10 m, thus providing a population density per hectare of 500,000 (Batista et al., 2013) and 200,000 plants, respectively. These same populations were used in each treatment of the radish × cowpea-vegetable intercropping. The planting of the radish and of the cowpea-vegetable was done on the same day, but specifically on 07/19/2013 and the thinning of these crops was carried out, respectively, at seven and ten days after the emergency.

The experiment was irrigated with micro-sprinklers in two shifts per day, one in the morning and another in the afternoon, with an average flow of water of about 8 mm a day, thus maintaining the soil of each experimental plot between 50 and 70% of the capacity of field, thus providing the ideal condition for the nitrification process (Meurer, 2007). Weeds were removed manually twice times.

The radish harvest was carried out 35 days after sowing. In the cowpea-vegetable harvesting, five harvests were performed, finishing the last one at 65 days after sowing.

2.4 Measured Characteristics

The characteristic evaluated in the radish crop was the productivity of commercial roots (obtained from the fresh mass weight of plant roots of the harvest area, free of cracks, bifurcations, nematodes and mechanical damage, expressed in t ha⁻¹) and in the culture of the cowpea-vegetable was the yield of green grains (determined of the weight of green grains of the harvest area of each plot, expressed in t ha⁻¹).

The agronomic efficiency of the intercrops was obtained by the land equivalent ratio (LER), derived from the sum of the partial land equivalent ratios for radish (LER_r) and for cowpea-vegetable (LER_{cv}). These partial LERs were calculated by the following expressions: $LER_r = I_r/S_r$ and $LER_{cv} = I_{cv}/S_{cv}$, where, I_r represents the productivity of radish commercial roots in intercropping with cowpea-vegetable and S_r represents the productivity of radish commercial roots in single crop. On the other hand, I_{cv} represents the green grains yield of cowpea-vegetable intercropped with radish and S_{cv} represents the cowpea-vegetable green grains yield in single crop. LER is defined as the relative area of land in single crop that it is required for providing the same productivities achieved in intercropping system.

The economic efficiency of the intercrops studied was assessed through the following economic indicators: gross income, total costs, net income, rate of return and profit margin. The gross income was determined by product of the production value per hectare, based on the price paid to farmers in January 2014 in the city of Mossoró, RN (Brazil), which was R\$ 5.93 kg⁻¹ for radish roots and R\$ 5.00 kg⁻¹ for green grains of cowpea-vegetable, respectively. The exchange rate of the US dollar in this date was \$1 = R\$ 2.42.

The total costs were determined in each treatment, computing the costs of the inputs and services used in one hectare of radish and cowpea-vegetable in intercropping system in January 2014 in the city of Mossoró, RN (Brazil). The methodology for its obtainment was the one used by Silva et al. (2015).

The net income was obtained by subtracting from the gross income the total costs of production, from inputs and services, and the rate of return for each real invested per treatment was calculated by the ratio between the gross income and production total cost of each treatment. The profit margin was determined by the ratio between net income and gross income, and expressed in percentage.

2.5 Statistical Analysis

Regression analyzes were performed on the characteristics evaluated by the software 'Table Curve' (Systat Software Inc., 2011), and a response equation for each variable was adjusted as a function of the roostertree biomass amounts added to the soil.

3. Results and Discussion

3.1 Agronomic/Biological Efficiency Indices

The partial land equivalent ratio for radish and the land equivalent ratio for the intercrop increased with the amounts of roostertree biomass added to the soil, achieving the maximum values of 1.46 and 2.51 in the amounts

of biomass of 49.92 and 52.42 t ha⁻¹, respectively, diminishing then up to the last quantity of roostertree biomass incorporated (Figures 1A and 1C).

Differently from these ratios, it was observed an increase in the partial land equivalent ratio for cowpea-vegetable with increasing amounts of roostertree biomass of approximately 0.48, meaning 48% between the smallest (10 t ha⁻¹) and the largest amount (55 t ha⁻¹) incorporated to the soil, with a maximum ratio of 1.08 reached in the largest roostertree amount of 55 t ha⁻¹ (Figure 1B).

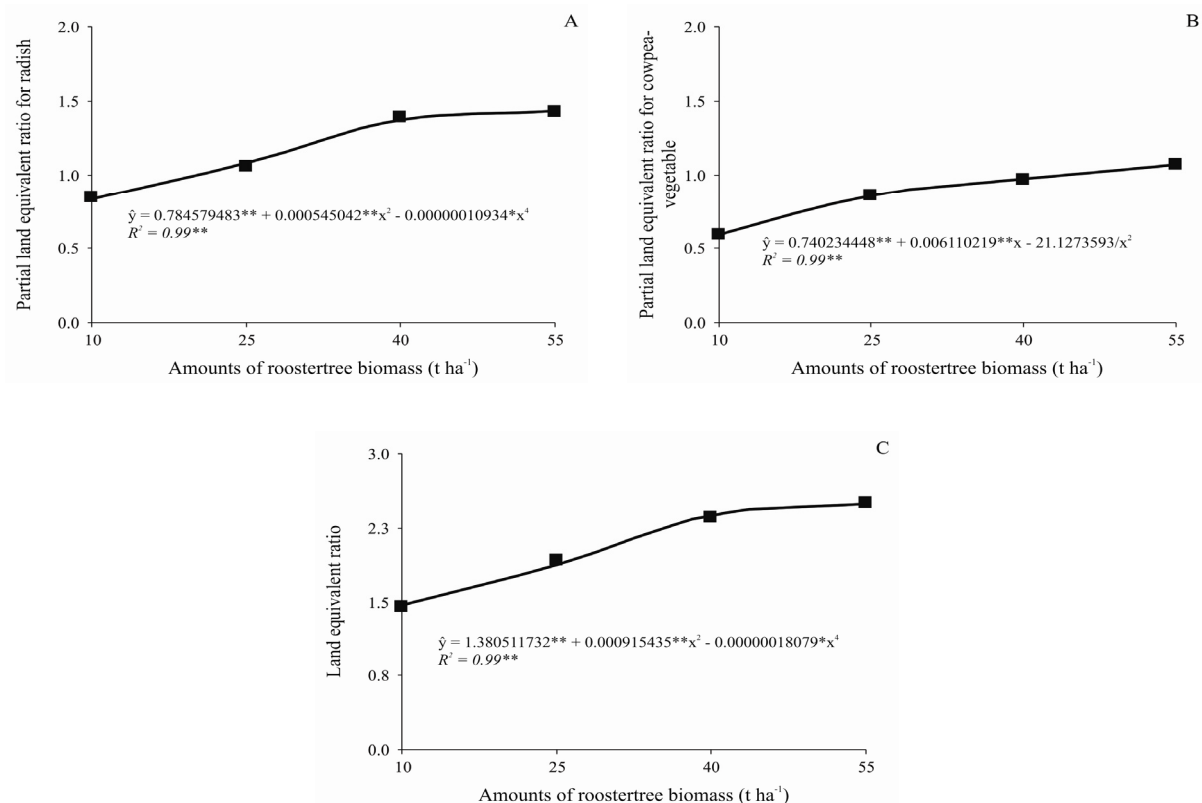


Figure 1. Partial land equivalent ratio for radish (A) and for cowpea-vegetable (B), and land equivalent ratio for the intercropping system (C) under different amounts of roostertree biomass added to the soil

The upward answer of these variables as a function of the increased quantities of roostertree can be attributed to higher nutritional supplying of the radish plants and cowpea-vegetable, and the proper synchronization between the decomposition and mineralization of the roostertree added and time of higher nutritional requirement of culture (Fontanetti et al., 2006; Batista et al., 2013).

According to Vale et al. (2004), the N mineralization is very influenced by the C:N ratio of the decomposing material. So, with the addition of waste of C:N ratio between 20:1 and 30:1, there is neither predominance of immobilization or mineralization of N. The C:N ratio of the roostertree was 25:1, therefore, within the range explained by the authors above.

All maximum values for partial land equivalent ratios of the component cultures (LER_r and LER_{cv}) and for the land equivalent ratio of the intercropping system were greater than unity, meaning that there was a better use of environmental resources and of the area by the crops, and of the hand labor in the various operations such as application of inputs and cultural practices with the use of the roostertree in the studied treatments when compared with their respective monocultures, indicating there is a complementarity between crops and an agronomic/biological advantage in the intercropping (Costa et al., 2017; Favacho et al., 2017).

Rezende et al. (2005) working with the radish and lettuce intercropping established in two row spacings and three lettuce transplanting times, observed that the intercropped systems established at zero day (with spacing of

0.30 × 0.30 m) and at 14 days after lettuce transplanting (with spacing of 0.40 × 0.30 m) had the highest land equivalent ratios of 1.76 and 1.61, respectively.

Zucchi et al. (2012) assessing the agronomic efficiency of the cowpea and okra intercropping obtained a land equivalent ratio of 1.44, a result similar to the land equivalent ratio for radish (1.46) and lower than that achieved for radish intercropped with cowpea-vegetable (2.51). This difference is due to the okra in the association.

3.2 Economic Efficiency Indicators

Analyzing the economic indicators for gross and net income, rate of return and profit margin, it was registered an increase in their values with increasing amounts of roostertree biomass added to the soil, up to the maximal values of R\$ 76.863,06 and 60.479,91 ha⁻¹ (corresponding to \$ 31,764.59 and 24,991.70 ha⁻¹); 3.60 by each real invested and of 72.73%, in the amounts of roostertree biomass of 50.19; 51.42; 50.52 and 46.41 t ha⁻¹, respectively, diminishing until the highest roostertree amount added to the ground (Figures 2A, 2B, 2C and 2D).

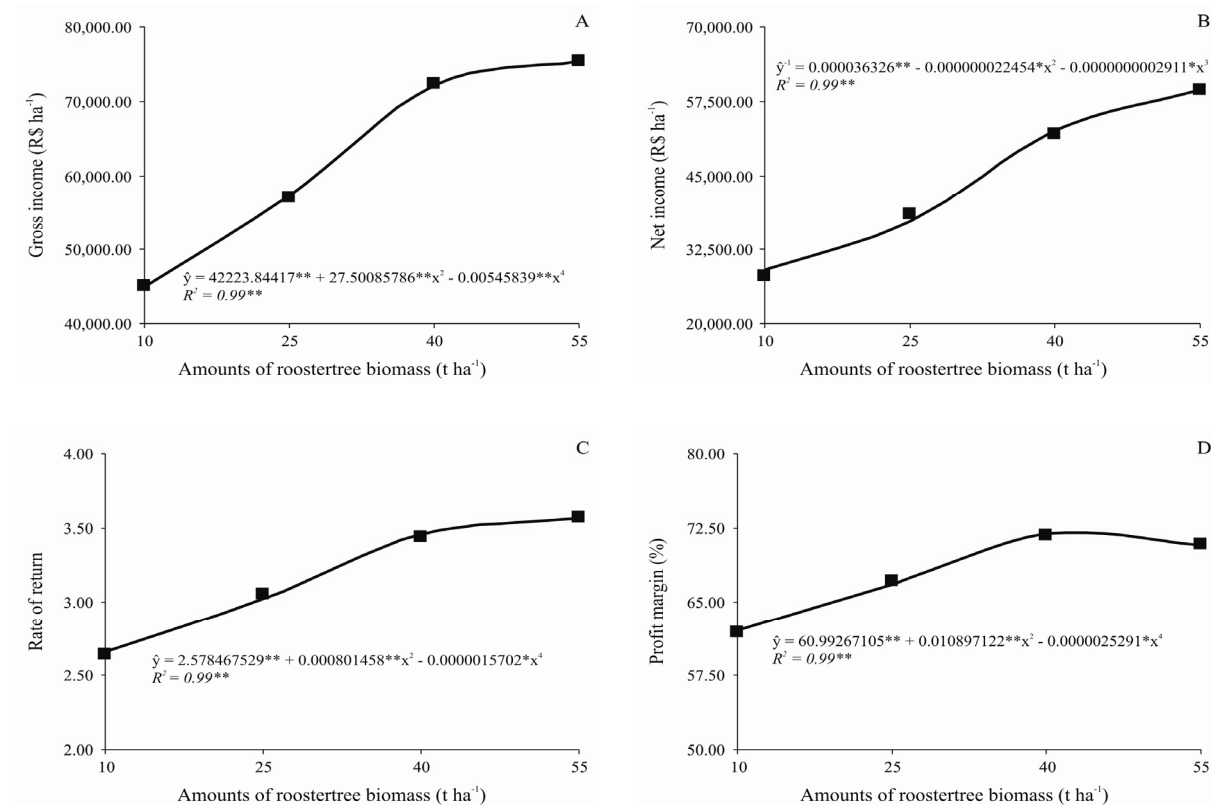


Figure 2. Indicators for gross income (A), net income (B), rate of return (C) and profit margin (D) under different amounts of roostertree biomass incorporated into the soil

It can be inferred from these results that the optimization of the economic performance of the association of radish with cowpea-vegetable was achieved by the incorporating of the biomass quantity of roostertree of 46.41 t ha⁻¹ to the soil, dictated by profit margin, considered a good indicator that best estimates the economic value of the crop association, since in it are deducted production total costs (Bezerra Neto et al., 2012).

These results are due to the fact that both the radish and the cowpea-vegetable (with LER values greater than 1) responded very well to the green manuring, indicating that the estimates of economic indicators came from the best use of the environmental resources by the cultures. Thus, the agronomic performance of the association of radish with cowpea-vegetable has been translated in terms of economic response.

The increasing productivity per unit of area is one of the important reasons for cultivating two or more crops in intercropping system. According to Oliveira et al. (2017), the cultivation of tuberous with leafy vegetables provides better use of the land and other available environmental resources, resulting in higher economic yield.

Rezende et al. (2005), estimating economic indicators in intercropping systems of radish with lettuce, obtained return rate of 4.13 and 4.53, and profit margin of 75.77 and 77.94% respectively, results these close to those obtained in this work. According to the authors, the lettuce and radish intercrops were economically advantageous when compared to their monocultures, due to higher increase in revenue compared to the observed increase in the cost of production.

4. Conclusions

(1) The highest agronomic and economic efficiencies of the intercropping of radish with cowpea-vegetable were obtained with the incorporation of 53 and 47 t ha⁻¹ of roostertree biomass added to the soil.

(2) The roostertree spontaneous species of the Caatinga biome it is showed as an efficient green manure in the association of radish with cowpea-vegetable.

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