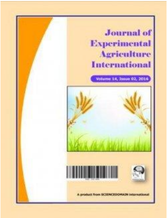

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Productivity and Economic Viability of Carrot Fertilized with *Calotropis procera* in Different Growing Seasons

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Authors' contributions

This work was carried out in collaboration between all authors. Author BNMM participated in designing the idea and management of the experiment, besides writing the article. Author ÊGFS was responsible for collecting, tabulating and analyzing the data, besides writing the article. Authors MGS and MB participated in the management of the experiment from the implantation to the data collection. Authors APBJ, LMS and FBN participated in the elaboration of the research project, conduction of experiments and writing of the article. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this work was to evaluate the productivity and economic viability of the carrot as a function of different amounts and times of incorporation to the soil of the green manure roostertree (*Calotropis procera*) in two growing seasons, in the semiarid region of Pernambuco, Brazil. The study was conducted in an experimental field belonging to the Federal Rural University of Pernambuco (UFRPE), in the autumn–winter (March to July 2012) and spring–summer (September 2012 to January 2013) periods. The experimental design was in randomized blocks, with three

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replications. The treatments were arranged in a 4 x 4 factorial scheme, with the first factor consisting of four amounts of roostertree biomass (5.4, 8.8, 12.2 and 15.6 Mg ha^{-1} on a dry basis), and the second factor consisting of four incorporation times of this fertilizer into the soil (0, 10, 20 and 30 days before sowing the carrot). The commercial productivity of carrot roots and production costs were evaluated, in addition to the following economic indicators: gross return, net return, rate of return and profit margin. The cultivation of the carrot fertilized with roostertree was economically viable, regardless of the quantity of green manure, of the time of incorporation into the soil or the time of cultivation. In autumn–winter, the lowest amount of roostertree (5.4 Mg ha^{-1}) associated with the incorporation time of 10 days before planting the carrot was considered ideal for the agro-economic viability of the crop. The carrot cultivation in spring–summer was most profitable when fertilized with 14.0 Mg ha^{-1} of roostertree on the same day of carrot planting.

Keywords: Daucus carota L.; economic efficiency; green manure; roostertree.

1. INTRODUCTION

The carrot (*Daucus carota* L.) is a vegetable crop belonging to the family *Apiaceae*, of the tuberous roots group, cultivated in Brazil, mainly in the Northeast, South and Southeast Regions [1]. It is originally from the region where Afghanistan is now located, and it is considered the main root vegetable crop in terms of nutritional value, as it is rich in minerals (K, Na, Ca, Fe, Mg, P and N), B vitamins, β-carotene (precursor of vitamin A) and vitamin C [2,3].

In order to achieve high productivity, producers are dependent on the use of mineral fertilizers and agrochemicals, whose intensive use of these products poses harm to the environment and increases the cost of the production system [4]. Over the years, with the increasing awareness of environmental issues and the intense search for healthy food, there has been an increase in demand for organic products. Along with this process, the price differentiation of these foods, which are generally more expensive, has been highlighted due to the rational use of the environment to produce healthier foods and reducing or eliminating the use of agricultural inputs, such as pesticides and fertilizers.

Alternatively, biological practices, such as green manure, have been used by some growers in vegetable cropping systems as a strategy to increase the amount of nutrients, organic matter and to decrease acidity and toxic aluminum in the soil; these benefits are very important for the sustainability of production systems [5]. In this sense, the use of spontaneous species of the Caatinga biome as green manure has been implemented as a viable alternative for agricultural production [6,7], since, in addition to being adapted to the soil and climatic conditions of the region, these species present high phytomass production, fast growth and a small C/N ratio [4]. The practice of using green manure can be of great value to small producers, since it would be a way of reducing dependence on external inputs and minimizing the costs of production, because the input would be collected near to the property [8,9].

There are several species with potential for use as green manure in the Brazilian semiarid region. Among these species, the roostertree [*Calatropis procera* (Ait.) R. Br.] is highlighted as being very adapted to the climatic conditions of the region, with high biomass production and vigorous regrowth, even under conditions of low rainfall [10]. In addition, this plant presents good macro- and micronutrient contents, and a good C/N ratio (<30), which contributes to faster decomposition [11], reaching a yield of 699.72 kg ha^{-1} of dry matter over 60 days, when cultivated in an area of 1.0 × 1.5 m [12].

Several studies have demonstrated the agronomic and economic feasibility of using roostertree in leafy and root vegetable crops in a single season of the year, disregarding the seasonality of product prices, such as lettuce [13], coriander [14], carrot [15], beet [7], and radish [6,16].

Due to the scarcity of results that address the real productive potential and the economic return of the carrot due to the use of green manure, the objective of this work was to agroeconomically evaluate the use of roostertree in different amounts and times of incorporation in two cropping seasons (autumn–winter and spring–summer).

2. MATERIALS AND METHODS

Two experiments were conducted under field conditions in two growing seasons, autumn–winter (March to July 2012) and spring–summer

(September 2012 to January 2013), at the Federal Rural University of Pernambuco (UFRPE), Academic Unit of Serra Talhada (UAST) in Serra Talhada-PE, located at 7°57'15" south latitude and 38°17'41" west longitude, at 461 m altitude, in the micro-region of Sertão do Pajeú, north of Pernambuco. The local climate, by Köppen classification, is Bwh (semiarid, summer rains, hot and dry, respectively), with annual thermal averages of 24.7°C and an average annual precipitation of 642.10 mm [17,18]. Average temperatures were 25.6 and 28.1°C in autumn–winter and spring–summer, respectively.

The soil of the experimental area is classified as a Cambissolo Háplico Ta Eutrófico [19]. Before the installation of the experiments, soil samples (sandy loam texture) were collected at a depth of 0–0.20 m, whose chemical characteristics in the autumn–winter experiment were as follows: pH in H_2O (1:2.5) = 6.5; O.M. = 12.70 g kg^{-1}; P = 20.0 mg dm^{-3}; K^+ = 0.45 cmol$_c$ dm^{-3}; Ca^{2+} = 3.40 cmol$_c$ dm^{-3}; Mg^{2+} = 2.0 cmol$_c$ dm-3; Al^{3+} = 0.0 cmol$_c$ dm^{-3}; and in the spring–summer, characteristics were as follows: pH in H_2O (1:2.5) = 6.60; O.M. = 8.40 g kg^{-1}; P = 15.0 mg dm^{-3}; K^+ = 0.59 cmol$_c$ dm^{-3}; Ca^{2+} = 3.40 cmol$_c$ dm^{-3}; Mg^{2+} = 2.0 cmol$_c$ dm^{-3}; Al^{3+} = 0.0 cmol$_c$ dm^{-3}.

The experimental design was in randomized blocks, with three replications. The treatments were arranged in a 4 x 4 factorial scheme, with the first factor consisting of four amounts of roostertree biomass (5.4, 8.8, 12.2 and 15.6 Mg ha^{-1} on a dry basis), and the second factor consisted of four incorporation times of this fertilizer into the soil (0, 10, 20 and 30 days before sowing the carrot). Each experimental unit had a total area of 1.44 m^2 (1.20 m x 1.20 m), with a harvest area of 0.80 m^2, with six rows of plants. The carrot cultivar used was 'Brasília', indicated for the conditions of the northeastern semiarid region, at a spacing of 0.20 m x 0.10 m. Soil preparation in each experiment consisted of lifting the beds using hoes.

The roostertree was collected from native vegetation in localities close to the UAST and then crushed in a conventional forage machine, obtaining fragments between 2.0 and 3.0 cm and set to dry until reaching hay conditions (10% humidity). The material was analyzed, and it showed the following nutrient contents in dry matter at 70ºC: N = 17.4 g kg^{-1}; P = 4.4 g kg^{-1}; K = 23.5 g kg^{-1}; Ca = 14.3 g kg^{-1}; Mg = 23.0 g kg^{-1}; Fe = 463.0 mg kg^{-1}, Zn = 40.0 mg kg^{-1}; Cu = 29.0 mg kg^{-1}; Mn = 90.0 mg kg^{-1}; B = 71.0 mg kg^{-1}; Na = 1,640.0 mg kg^{-1}, O.M. = 764.0 mg kg^{-1} and C/N = 25/1.

The incorporation of the vegetal biomass was carried out in the 0–0.20 m layer of the soil in the experimental plots, according to the treatments. Daily irrigations were carried out in two shifts with the purpose of favoring the microbial activity of the soil in the organic matter mineralization process.

The planting of the carrot in the first growing season (autumn–winter) was carried out on March 29, 2012, while in spring–summer, it was done on September 24, 2012. Direct sowing was performed at a 2 cm depth, sowing three seeds per hole. After ten days of emergence, thinning occurred, leaving one plant per hole. The irrigations were carried out by a micro sprinkler system, with a daily watering schedule divided into two applications (morning and afternoon), according to crop evapotranspiration and rainfall. Hand weeding was performed whenever necessary.

In autumn–winter, carrot harvesting was performed 96 days after sowing (DAS), while in spring–summer, it was at 89 DAS. Productivity was estimated for each experimental unit, based on the commercial root productivity (Mg ha^{-1}) of the harvest area, considering the corrections for 70% of the area planted. They were considered as commercial productivity, roots free of defects, such as cracks, bifurcations, nematodes and mechanical damage. Economic indicators were used to evaluate the efficiency of treatments. The production costs were calculated and analyzed at the end of the production process. The cost modality analyzed in this study corresponded to the total expenditure per hectare of cultivated area, which includes services provided by the stable capital, i.e. the contribution of working capital and the value of alternative or opportunity costs. Similarly, the returns refer to the value of the production of one hectare.

The cost of acquisition was obtained by multiplying the price of the variable input used (seeds, fertilizers, casual labor etc.) by the quantity of the respective input, referring to the year 2012 and to the city of Serra Talhada-PE. The cost of one ton of green manure was adapted from [20], in which the labor required for the cutting, crushing, drying and bagging of the roostertree was estimated for each amount. In both growing seasons, the daily value paid to the rural worker in the region was R$ 30.00, and it cost R$ 80.00 to transport the fertilizer after the cut. In this way, the final cost of each treatment was determined according to the different amounts incorporated, the time taken for incorporation (variable as a function of quantity) and other production costs. It is also worth noting that the treatments corresponding to the incorporation periods (0, 10, 20 and 30 days) did not influence production costs. However, they participated in the combination of factors to determine the best economic efficiency in the cultivation of carrot using roostertree as fertilizer.

Depreciation, defined as the non-monetary fixed cost that reflects the loss of value of a produced good based on age, usage and obsolescence, was determined by the linear method or fixed-value method, which determines the annual depreciation value from the useful life time of the durable good, from its initial value and scrap. The latter was not considered, since the capital goods considered do not present any residual value [21]. Taxes and fees, as well as fixed labor, were determined by the value used in the current months to production of the crop. Fixed labor was destined to the management of productive activities, corresponding to the payment of a minimum wage per month during each productive cycle (R$ 622.00 for the year 2012 and R$ 678.00 for January 2013).

The opportunity cost, for the items of stable capital (construction, machines, equipment, etc.), corresponded to the annual interest that reflects the alternative use of capital. The chosen interest rate was 6% per annum, equivalent to the savings account gain. For the fixed capital remuneration, the interest was calculated from the current value of the crop. Regarding the opportunity cost of land, the lease of one hectare in the region (R$ 200.00) was considered as the equivalent of the alternative land cost used in the research.

Gross return (GR) was measured from the value of production per hectare in July 2012 (R$ 1.60 kg^{-1}) and January 2013 (R$ 2.30 kg^{-1}). The net return (NR) was calculated by the difference between the gross return (GR) per hectare and the total costs (TC) involved in obtaining it. The TCs were calculated for each treatment, taking into account the input cost coefficients and the services used in one hectare of carrot at the experimental level. The rate of return (RR) was obtained from the relationship between GR and TC, corresponding to how many reals (R$) are obtained for each real (R$) applied in the carrot cultivation as a function of the applied treatment factor. The profit margin (PM) consisted of the relationship between NR and GR, expressed as a percentage [22].

For each growing season, univariate analyses of variance were performed for the evaluated characteristics, using the Sisvar 5.6 software [23]. A joint analysis was performed for the characteristics for the homogeneity of variances between the growing seasons [24]. A response curve fitting procedure was performed between the evaluated characteristics and the quantitative factors using the SigmaPlot 12.0 program [25]. A Tukey test ($P < 0.05$) was used to compare the means of the qualitative factor (growing seasons).

3. RESULTS AND DISCUSSION

3.1 Joint Analysis of Variance

For commercial yield of carrot roots, homogeneity of variance was observed between the growing seasons, allowing joint analysis of the experiments (Table 1). There was an isolated effect of the amount of roostertree biomass and an interaction between the growing seasons and the times of incorporation of the green manure.

Commercial productivity of carrot roots increased with increasing doses of roostertree incorporated into the soil, reaching a maximum value (22.54 Mg ha^{-1}) in the amount of 15.6 Mg ha^{-1}, corresponding to an increase of 4.09 Mg ha^{-1} in relation to the smaller amount of roostertree used (Fig. 1A). This increase was probably due to a greater availability of nutrients provided by the dynamics of decomposition and mineralization of the green manure, as well as by the influence of the organic fertilization on the improvement of soil fertility through the promotion of biological activity in the soil that favored the solubilization of the nutrients and therefore increase of the absorption surface of the roots [6].

In autumn–winter, there was no regression equation adjustment for commercial productivity of carrot roots as a function of incorporation times, presenting a mean value of 23.72 Mg ha^{-1}, while in spring–summer, the response of this productivity was linear and decreasing (Fig. 1B). The commercial productivity of the carrot was higher in the autumn–winter season than in the spring–summer season, reaching its maximum average value (27.38 Mg ha^{-1}) at the incorporation time of 10 days (Table 2).

Table 1. Summary of the joint analysis of variance for commercial productivity of carrot roots fertilized with roostertree in two growing seasons

Sources of variation	Degrees of freedom	Commercial productivity
Blocks (Seasons)	4	2.14^{ns}
Seasons	1	95.98**
Amounts	3	7.19**
Times	3	7.53**
Seasons x Amounts	3	0.20^{ns}
Seasons x Times	3	3.01*
Amounts x Times	9	0.27^{ns}
Seasons x Amounts x Times	9	0.19^{ns}
Coefficient of variation (%)		15.75
Overall mean		20.49

*^{ns}, ** and *: no significantly different (P > 0.05), significantly different at the 1% and 5% probability levels by F test, respectively*

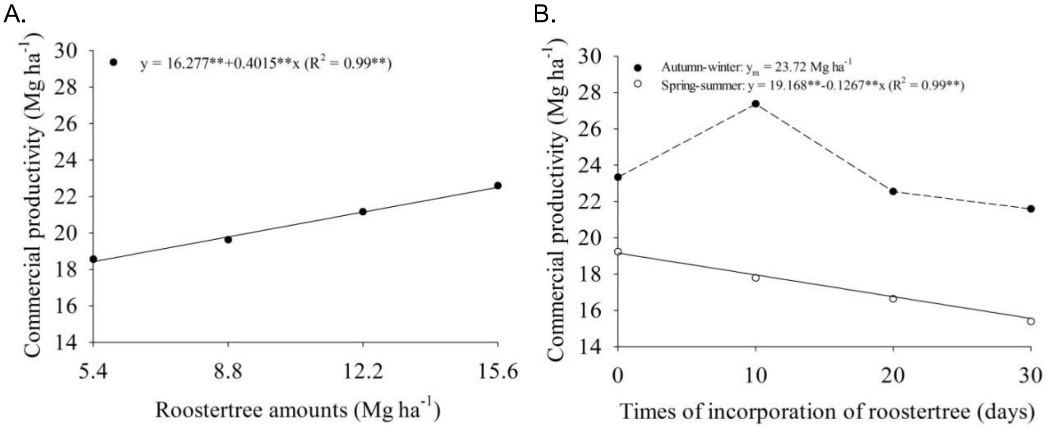


Fig. 1. Commercial productivity of carrot roots as a function of the amounts of roostertree biomass (A) and of the incorporation times within the growing seasons (B)
*** and *: significantly at the 1% and 5% probability levels by t test, respectively.*

Table 2. Mean values of commercial productivity of carrot roots in the incorporation times to the soil of the roostertree within the growing seasons

Growing seasons	Times of incorporation of roostertree (days)			
	0	10	20	30
	Commercial productivity (Mg ha^{-1})			
Autumn–winter	23.34 a*	27.38 a	22.55 a	21.60 a
Spring–summer	19.24 b	17.79 b	16.64 b	15.40 b

**Means followed by the same lowercase letters in the column does not differ statistically from each other by the Tukey test at the 5% probability level.*

In the incorporation times into the soil of the roostertree, the carrot commercial productivities were different between the growing seasons, and their effects can be attributed to meteorological factors (solar radiation, photoperiod, air temperature, among others) on the mineralization of the green manure as well as its influence on the development of carrot plants. High temperatures in spring–summer may have promoted faster mineralization of the plant material added to the soil in relation to using green manure in autumn–winter. Therefore, the roostertree should be added on the day of sowing in spring–summer and 10 days before in autumn–winter, in order to coincide with the availability of nutrients with the period of maximum nutritional requirement of the vegetable [26].

The greatest development of the roots in autumn–winter is due to the occurrence of a photoperiod of less than 12 hours and cooler temperatures in comparison to spring–summer, promoting more adequate conditions for the development of the crop [27], such as minor variations in soil moisture. Possibly, the green manure also acts as mulch, reducing the thermal amplitude and water storage in the root system [9].

3.2 Individual Analysis of Variance

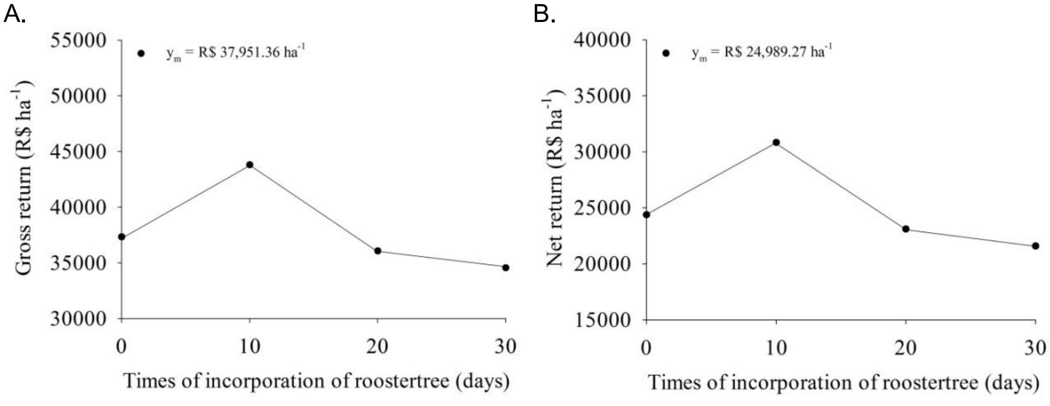
For the economic variables, no homogeneity of variance was observed between the experiments (growing seasons). In this way, an analysis of variance was performed for each experiment. In autumn–winter, there was an influence of the incorporation times to the soil of the roostertree on these variables (Table 3). In the spring–summer period, there was an interaction between the amounts and incorporation times of green manure for gross and net returns, as well as isolated effects of the amounts and incorporation times on the variables of rate of return and profit margin (Table 3).

In the autumn–winter cultivation, the isolated effect of the incorporation times of the roostertree did not allow the adjustment of regression equations for the economic variables evaluated in the production of one hectare of carrot, with the highest average gross incomes (R$ 43,810.33) and net (R$ 30,848.24), rate of return (3.37) and profit margin (69.01%) being observed at 10 days (Fig. 2). The good agronomic performance of the carrot at this incorporation time was reflected in monetary terms.

Table 3. Summary of the analysis of variance for gross return, net return, rate of return and profit margin in the production of one hectare of carrot fertilized with roostertree, in two growing seasons

Sources of variation	Degrees of freedom	Gross return	Net return	Rate of return	Margin profit
			Autumn–winter		
Amounts	3	1.53^{ns}	0.55^{ns}	0.19^{ns}	0.51^{ns}
Times	3	3.80*	3.80*	3.85*	3.03*
Amounts x Times	9	0.19^{ns}	0.19^{ns}	0.13^{ns}	0.21^{ns}
CV (%)		19.04	28.92	18.55	10.14
Overall mean		37,951.36	24,989.27	2.93	64.73
Sources of variation	**Degrees of freedom**		**Spring–summer**		
Amounts	3	106.92**	61.87**	8.29**	7.10**
Times	3	75.33**	75.33**	70.79**	64.34**
Amounts x Times	9	2.60*	2.60*	1.79^{ns}	1.29^{ns}
Coefficient of variation (%)		3.79	5.63	3.85	1.99
Overall mean		39,711.89	26,693.71	3.04	66.86

*^{ns}, ** and *: no significantly different (P > 0.05), significantly different at the 1% and 5% probability levels by F test, respectively*



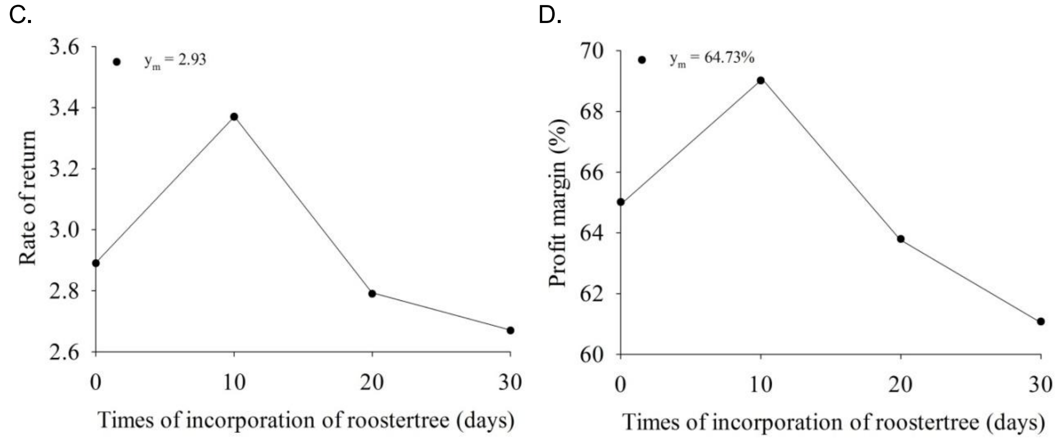


Fig. 2. Gross return (A), net return (B), rate of return (C) and profit margin (D) in the production of one hectare of carrot as a function of the incorporation times to the soil of the roostertree in the autumn–winter season

*** and *: significantly at the 1% and 5% probability levels by t test, respectively*

The sum of variable, fixed and opportunity costs was R$ 10,427.40 (Table 4) and the total cost of production of one hectare of carrot fertilized with roostertree was estimated for each quantity incorporated in the soil. The following values were observed: R$ 11,708.40; R$ 12,543.24; R$ 13,381.10 and R$ 14,215.96 in the amounts of 5.4; 8.8; 12.2 and 15.6 Mg ha^{-1}, respectively (Table 5).

In autumn–winter, the economic variables of carrot cultivation were not influenced by the amounts of roostertree biomass, indicating that the use of the lowest dose (5.4 Mg ha^{-1}) promoted similar profitability to the use of high amounts, with a lower production cost (R$ 11,708.40 ha^{-1}). Such information can assist the farmer in making decisions regarding the capital available for investment in the activity. In addition, when using the lowest dose, the farmer can have satisfactory carrot productivity, storing the surplus of green manure in the form of hay, for further cultivation.

In spring–summer cultivation, as the amount of green manure was increased, there was an increase in gross return (Fig. 3A). The treatment that consisted of fertilization with 15.6 Mg ha^{-1}, associated with the incorporation time of 0 days, promoted the highest gross return for the carrot (R$ 50,974.62 ha^{-1}), which represents an increase of 67.75% in relation to the lowest dose of green manure. On the other hand, gross return peaks were obtained at the 0 day time for all factorial combinations (Fig. 3B). The incorporation time of 0 days, together with the amount of 15.6 Mg ha^{-1} of roostertree, provided a higher gross return result in carrot production (R$ 50,559.10 ha^{-1}).

In this study, the results show that the gross return also increased with the increase of the amount of green manure from the Caatinga in the production of carrot [28], beet [29], radish [9] and arugula [8]. In relation to the incorporation time, [29] also identified that the green manure hairy woodrose (*Merremia aegyptia* L.) incorporated on the day of the planting of beet promoted greater gross return to the cultivation realized in the spring and in Mossoró-RN.

In spring–summer, variable, fixed and opportunity costs accumulated R$ 10,483.40 (Table 4) and the total cost of production of one hectare of carrot fertilized with roostertree was estimated for each quantity incorporated in the soil: R$ 11,764.40; R$ 12,599.10; R$ 13,437.10 and R$ 14,271.96 in the amounts of 5.4; 8.8; 12.2 and 15.6 Mg ha^{-1}, respectively (Table 5).

Harvesting activities for the preparation of green manure were responsible for 10.9, 16.8, 21.9 and 26.5% of the total costs of increasing quantities of roostertree. Between growing seasons, the cost became somewhat higher in the spring–summer due to the readjustment of the minimum wage paid to the administrative assistant in January 2013. The daily expenses varied between 62 and 67% of the total costs between the lowest and the highest amount of roostertree biomass (Table 2 and 3). Some studies of this green manure have obtained results that corroborate those found in the present study, with labor being the most costly operational cost, corresponding to an average of 68% of the costs in the cultivation of radish [9] and 69% in arugula production [8].

[30], when evaluating the conventional production of arugula, found that the components that contributed most to the total operational cost were labor, machinery, implements, fertilizers and pesticides. In the cultivation of carrot fertilized with roostertree, the cost of labor was increased due to the manual execution of the collection/preparation/distribution of green manure and other agricultural practices.

The net return in the spring-–summer cropping presented the same statistical behavior as that observed for the gross return of carrot, since this variable is due to the difference between the gross return and the total costs of production. There was an increasing behavior of the net return of the carrot roots with the increase of the roostertree, reaching a maximum value of R$ 36,702.37, when the crop was fertilized with 15.6 Mg ha^{-1} of the spontaneous species, on the same day as planting (Fig. 3C). The net return of the carrot crop decreased as the permanence time of the green manure in the soil before planting, with the highest net return (R$ 36,287.13 ha^{-1}) obtained at the time of 0 days and fertilization with 15.6 Mg ha^{-1} of roostertree (Fig. 3D). According to [31], the optimization of economic performance by the crop is expressed by net return, which is considered one of the indicators that best demonstrates the economic value of crop systems in relation to gross return, since the production costs are deducted.

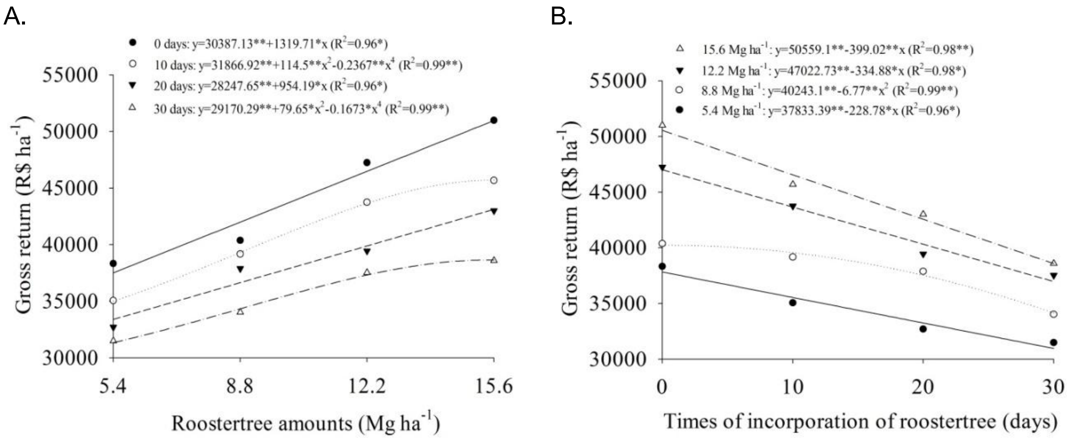
Table 4. Coefficients of the variable, fixed and opportunity costs in the production of one hectare of carrot as a function of growing season

Components of production cost	Unity	Amount	Total (R$)	
			Autumn–winter	Spring–summer
Variable costs			6,723.40	6,723.40
1-Inputs			250.00	250.00
Seeds: Carrot cv. Brasilia	kg	5.0	250.00	250.00
2-Labor			6,150.00	6,150.00
Manufacture of beds	day	40	1,200.00	1,200.00
Carrot Seeding	day	20	600.00	600.00
Carrot thinning	day	10	300.00	300.00
Hand weeding	day	15	450.00	450.00
Moulding up	day	20	600.00	600.00
Irrigation	day	45	1,350.00	1,350.00
Carrot harvest	day	50	1,500.00	1,500.00
Carrot transport	day	5	150.00	150.00
3-Power			323.40	323.40
Energy used for irrigation	kW	1470.0	323.40	323.40
Fixed costs			3,104.00	3,160.00
4-Depreciation			606.00	606.00
Irrigation pump	month *	4	230.00	230.00
Irrigation Pipes	month	4	14.00	14.00
Parts of connections	month	4	52.00	52.00
Microsprinklers	month	4	160.00	160.00
Forage machine	month	1	150.00	150.00
5-Taxes and fees			10.00	10.00
Rural territorial tax	ha	1	10.00	10.00
6-Fixed labor force			2,488.00	2,544.00
Administrative support	salary	4	2,488.00	2,544.00
Opportunity costs			600.00	600.00
7-Remuneration of the land			200.00	200.00
Lease	ha	1	200.00	200.00
8-Remuneration of fixed capital (0.5% per month)			400.00	400.00
Infrastructure and equipment	R$ 100.00 $month^{-1}$**	4	400.00	400.00
Total Costs (Variable Cost + Fixed Cost + Opportunity Cost)			10,427.40	10,483.40

**Relationship between the market value and the useful life of the equipment, multiplied by the time of use;*
***Regarding the value of fixed capital (R$ 20,000.00) multiplied by its remuneration over the crop cultivation*

Table 5. Total costs in the production of one hectare of carrot as a function of the amounts of roostertree incorporated into the soil in the growing seasons

Components of production cost	Unity	Amount	Total (R$)	
			Autumn–winter	Spring–summer
1 – 5.4 Mg ha^{-1} of roostertree			11.708,40	11.764,40
Cutting	day	20.0	600.00	600.00
Transport	freight	1.0	80.00	80.00
Crushing	day	2.5	75.00	75.00
Energy (forage)	kW	100	22.00	22.00
Drying	day	5.0	150.00	150.00
Bagging	day	1.0	30.00	30.00
Distribution and incorporation	day	10.8	324.00	324.00
Variable, fixed and opportunity costs			10,427.40	10,483.40
2 – 8.8 Mg ha^{-1} of roostertree			12,543.24	12,599.24
Cutting	day	32.6	978.00	978.00
Transport	freight	2.0	160.00	160.00
Crushing	day	4.1	123.00	123.00
Energy (forage)	kW	162.9	35.84	35.84
Drying	day	8.1	243.00	243.00
Bagging	day	1.6	48.00	48.00
Distribution and incorporation	day	17.6	528.00	528.00
Variable, fixed and opportunity costs			10,427.40	10,483.40
3 – 12.2 Mg ha^{-1} of roostertree			13,381.10	13,437.10
Cutting	day	45.2	1,356.00	1,356.00
Transport	freight	3.0	240.00	240.00
Crushing	day	5.6	168.00	168.00
Energy (forage)	kW	225.9	49.70	49.70
Drying	day	11.3	339.00	339.00
Bagging	day	2.3	69.00	69.00
Distribution and incorporation	day	24.4	732.00	732.00
Variable, fixed and opportunity costs			10,427.40	10,483.40
4 – 15.6 Mg ha^{-1} of roostertree			14,215.96	14,271.96
Cutting	day	57.8	1,734.00	1,734.00
Transport	freight	4.0	320.00	320.00
Crushing	day	7.2	216.00	216.00
Energy (forage)	kW	288.9	63.56	63.56
Drying	day	14.4	432.00	432.00
Bagging	day	2.9	87.00	87.00
Distribution and incorporation	day	31.2	936.00	936.00
Variable, fixed and opportunity costs			10,427.40	10,483.40



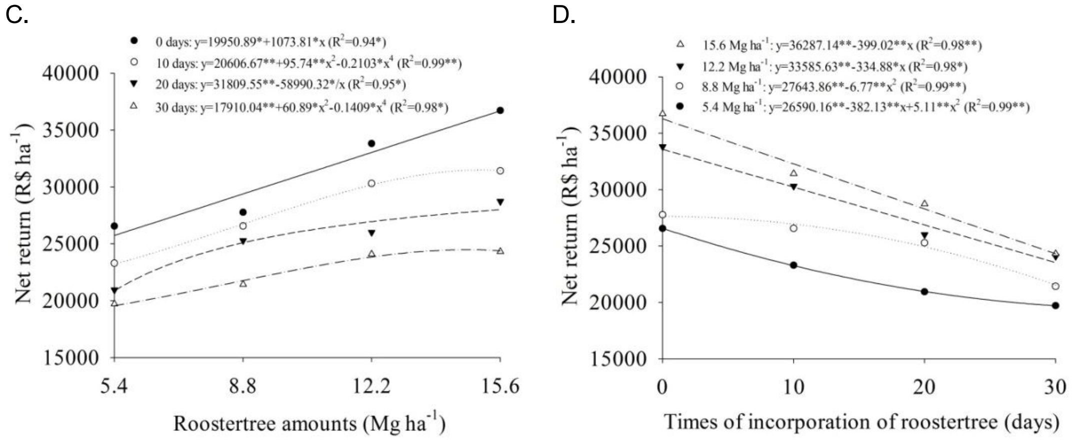


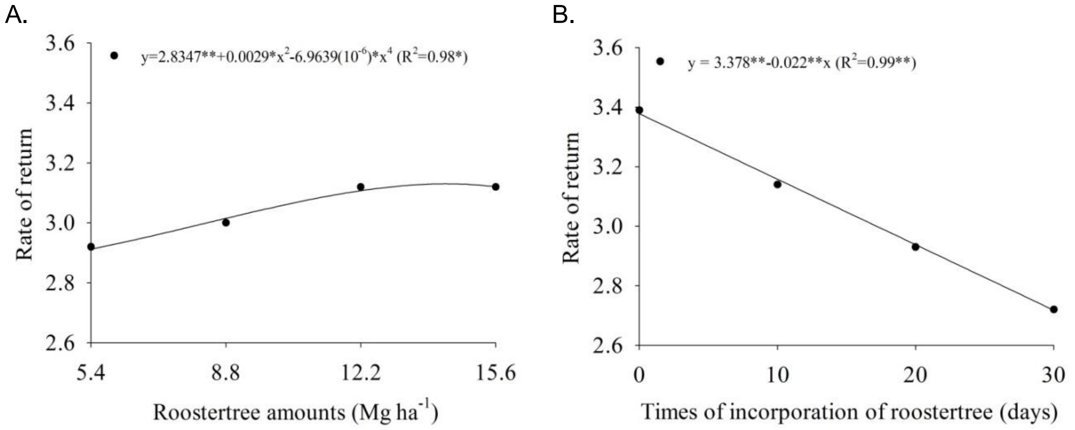
Fig. 3. Gross return (A and B) and net return (C and D) in the production of one hectare of carrot in the amounts of roostertree as a function of incorporation times to the soil in the spring–summer season

*** and *: significantly at the 1% and 5% probability levels by t test, respectively*

The rate of return and the profitability index presented similar statistical behavior, that is, there was a biquadratic effect of the quantities of roostertree, up to the maximum value estimates of 3.13 and 67.83% at the dose of 14.0 Mg ha^{-1} of green manure, respectively (Fig. 4A and 4C). The effect of the incorporation times on these same characteristics was linear and decreasing (Fig. 4B and 4D), in which the fertilization carried out on the day of sowing allowed higher rate of return (3.38) and profit margin (70.43%).

The estimated amount of 14.0 Mg ha^{-1} of roostertree allowed maximum agroeconomic efficiency in carrot cultivation, reaching values of rate of return and profit margin similar to those found in carrot fertilization [28] and beet [29,32] with hairy woodrose, and beet with roostertree [32]. Lower values were observed by [33], where the rate of return and profit margin were 1.97 per invested real and 49.40 per cent, respectively, in the summer crop of carrot fertilized with 13.0 Mg ha^{-1} of hairy woodrose. In this work, the authors showed high commercial root productivity (32.11 Mg ha^{-1}) and production costs of R$ 12,693.00 ha^{-1}, but the price paid for the product in January 2012 was only R$ 0.80 kg^{-1}, reducing the return on investment.

In general, based on economic analysis, it was verified that the agronomic superiority obtained translated into economic gain for the carrot crop, even using a larger amount of green manure, with a financial return compatible with the invested capital. Therefore, it becomes a good source of organic fertilizer for small producers, considering that these inputs are available in the localities and present a high potential for regrowth.



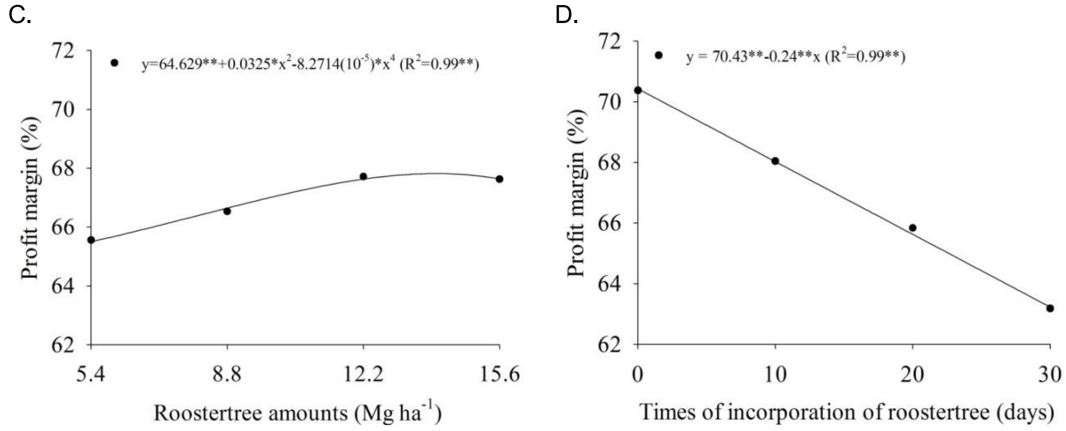


Fig. 4. Rate of return (A and B) and profit margin (C and D) as a function of the isolated effects of roostertree biomass amounts and of incorporation times of green manure in the spring–summer season

*** and *: significantly at the 1% and 5% probability levels by t test, respectively*

4. CONCLUSION

Cultivation of carrot fertilized with roostertree was economically feasible, regardless of the amount of green manure, the incorporation time to the soil and the growing season.

In autumn–winter, the lowest amount of roostertree (5.4 Mg ha^{-1}), associated with the incorporation time of 10 days before planting the carrot, was considered ideal for the agro-economic viability of the crop.

The carrot cultivation in spring–summer was most profitable when fertilized with 14.0 Mg ha^{-1} of roostertree on the same day as planting the carrot.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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