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TECHNICAL-ECONOMIC EFFICIENCY OF THE YIELD OF GREEN GRAINS OF COWPEA FERTILIZED WITH ROOSTERTREE[1]

FLAVIANA DE ANDRADE VIEIRA[2], FRANCISCO BEZERRA NETO[3]*, MAIELE LEANDRO DA SILVA[4], JAILMA SUERDA SILVA DE LIMA[3], AURÉLIO PAES BARROS JÚNIOR[3], ITALO NUNES SILVA[2]

ABSTRACT - This study aimed to determine the doses of maximum agronomic and economic efficiency as a function of different amounts of roostertree [*Calotropis procera* (Ait.) R.Br.] biomass added to the soil, that results in the maximum yield of green grains of cowpea in the semi-arid of Rio Grande do Norte state, Brazil. The experiment was conducted at the "Rafael Fernandes" Experimental Farm of the Universidade Federal Rural do Semi-Árido (UFERSA), Alagoinha, RN, from August to November 2013. In the experiment was used a randomized completely block design with 5 replicates. The treatments consisted of 20, 35, 50, and 65 t ha^{-1} (on a dry matter basis) of roostertree biomass added to the soil. The evaluated characteristics were: number of green pods per m^2, productivity and dry mass of green pods, number of green grains per pod, weight of 100 green grains, and dry mass of green grains. The following economic indicators were determined: gross and net incomes, production operational costs, rate of return, and profit margin. The maximum agronomic efficiency of the yield of cowpea green grain was reached at the yield of 3.05 t ha^{-1}, using 61.0 t ha^{-1} of roostertree biomass in the soil. The maximum economic efficiency yielded a net income of R$ 8,701.42, at the production of 3.02 t ha^{-1} green grains with 53.57 t ha^{-1} of roostertree biomass added to the soil. The use of roostertree as a green manure presents technical-economic feasibility in cowpea cultivation for green grains in the semi-arid conditions of Rio Grande do Norte.

Keywords: *Vigna unguiculata*. *Calotropis procera*. Green manuring.

EFICIÊNCIA TÉCNICO-ECONÔMICA DO RENDIMENTO DE GRÃOS VERDES DE FEIJÃO-CAUPI FERTILIZADO COM FLOR-DE-SEDA

RESUMO - Este estudo teve como objetivo determinar as doses de eficiência agronômica e econômica máximas em função de diferentes quantidades de biomassa de flor-de-seda [*Calotropis procera* (Ait.) R.Br.] adicionadas ao solo, que resultem no rendimento máximo de grãos verdes de feijão caupi no semiárido do estado do Rio Grande Norte, Brasil. O experimento foi conduzido na Fazenda Experimental "Rafael Fernandes" da Universidade Federal Rural do Semi-Árido (UFERSA), Alagoinha, RN, no período de agosto a novembro de 2013. No experimento foi usado um delineamento de blocos completos casualizados com cinco repetições. Os tratamentos consistiram de 20, 35, 50 e 65 t ha^{-1} (em base seca) de biomassa de flor-de-seda adicionada ao solo. As características avaliadas foram: número de vagens verdes por m^2, produtividade e massa seca de vagens verdes, número de grãos verdes por vagem, peso de 100 grãos verdes e massa seca de grãos verdes. Os seguintes indicadores econômicos foram determinados: rendas bruta e líquida, custos operacionais de produção, taxa de retorno e índice de lucratividade. A eficiência agronômica máxima do rendimento de grãos verdes de feijão-caupi foi alcançada com o rendimento de 3,05 t ha^{-1}, utilizando-se 61,0 t ha^{-1} de biomassa de flor-de-seda incorporada ao solo. A eficiência econômica máxima produziu uma renda liquida de R$ 8.701,42, no rendimento de grãos verdes de 3.02 t ha^{-1} com 53,57 t ha^{-1} de biomassa de flor-de-seda adicionada ao solo. O uso da flor-de-seda como adubo verde apresenta viabilidade técnico-econômica no cultivo do feijão-caupi para grãos verdes nas condições semiáridas do Rio Grande do Norte.

Palavras-chave: *Vigna unguiculata*. *Calotropis procera*. Adubação verde.

*Corresponding author
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[2]Universidade Federal Rural do Semi-Árido, Mossoró, RN, Brazil; flaviana_agrarias@hotmail.com, italonunessilva@gmail.com.
[3]Department of Crop Science, Universidade Federal Rural do Semi-Árido, Mossoró, RN, Brazil; bezerra@ufersa.edu.br, jailma@ufersa.edu.br, aurelio.barros@ufersa.edu.br.
[4]Department of Agronomy, Universidade Estadual de Mato Grosso do Sul, Aquidauana, MS, Brazil; maiele_engenharia@yahoo.com.br.

INTRODUCTION

Agricultural practices have been modified in the recent decades through the development of new technologies that are capable of boosting food production with low use of chemical inputs. Increasing public concern about the consumption of healthy food has led farmers to incorporate farming techniques for a clean production, which are based on a dynamic interaction between soil, plants, animals, people, ecosystem, and environment.

These novel agricultural technologies include plant- or animal-derived organic fertilization, with an emphasis on green manuring, which are common techniques used in the production of vegetable crops. Green manuring is the practice of adding plant residues (produced on-site or externally added) to the soil, with an aim to preserve or restore the organic matter and soil nutrient contents (OLIVEIRA et al., 2011). This technique promotes the cycling capacity and mobilization of nutrients, improves the nitrogen levels, and increases the water storage capacity and cation exchange, while decreasing the aluminum levels and controlling the growth of pests, diseases, and weeds (SILVA et al., 2010; GRAHAM; HAINES, 2006).

It is known, however, that the effects of green manuring on the soil chemical properties are quite variable, depending on several factors (BORGES et al., 2014), such as the species used, biomass management, time of planting and cutting of green manure, time of permanence of the residues in the soil, local conditions, and the interactions among them.

Legumes are the most commonly used plants for green manuring, because they contain a high percentage of phosphorus, potassium, calcium, and mainly nitrogen, given the symbiotic N fixation by the bacteria belonging to the genus Rhizobium that develop in its roots (TAVARES JUNIOR et al., 2015). Studies have shown that spontaneous species of the Caatinga biome may present the same performances of Leguminosae as green manure. (LINHARES et al., 2008; SILVA et al., 2013).

Promising results have been obtained for vegetable crop production with the spontaneous Caatinga species as green manure. Among the vegetables are lettuce (GÓES et al., 2011) and beet (SILVA et al., 2011) fertilized with hairy woodrose and radish manured with hairy woodrose (*Merremia aegyptia* L.), oneleaf senna (*Senna uniflora* L.), and roostertree (*Calotropis procera* (Ait.) R.Br.) (BATISTA et al., 2013). However, there is a lack of information in the literature on green manuring with roostertree for single-crop production of cowpea.

The roostertree is a tropical sub-shrub of the Apocynaceae family, native to tropical Africa, India, and Persia, and is found in all tropical regions of the world (MATOS et al., 2011). It occupies a prominent position among the several native and naturalized species in the Caatinga due to its ability to supply phytomass throughout the year (COSTA et al., 2009). Studies performed by EMPARN (2004) indicated a large variation in the availability of roostertree dry matter (DM) per hectare per cut, yielding 1 to 3 t DM/ha/cut at 70 and 120 days of regrowth. The authors also highlight the prospects of three cuts per year with a total estimate of 9 t DM/ ha/year. Its tissue has high concentrations of N, P, and K, which can reach values of approximately 22.7, 10.0, and 28.9 g kg^{-1}, respectively (SILVA et al., 2013).

The cowpea is tolerant toward different types of fertilization, since it requires less soil fertility and has a good ability to fix the atmospheric nitrogen via symbiosis with *Rhizobium* (ANDRADE JÚNIOR et al., 2007). It is known that soil fertility management promotes cowpea productivity, by modulating the supply of nitrogen that during the entire crop cycle. Proper soil nutrition also contributes to the production of high quality grains (DUTRA et al., 2012).

This study aimed to determine the doses of maximum agronomic and economic efficiency as a function of different amounts of roostertree biomass added to the soil, which results in the maximum yield of cowpea.

MATERIAL AND METHODS

The study was conducted at the Experimental Farm Rafael Fernandes, located in the Alagoinha district, 20 km away from the city of Mossoro (5°11′S and 37°20′W, 18 m above the sea level), Brazil, from August to November 2013, in a soil classified as Udox dystrophic (EMBRAPA, 2006). The climate, according to the Koppen classification system, is BShw, i.e., dry and very hot with rainy season in the summer, with the average, maximum, and minimum temperatures of 28.5, 33.4, and 23.03 °C, respectively. June and July are the coldest months, and the average annual rainfall is approximately 825 mm.

The experimental design was a randomized block completely design with 5 replicates. The treatments consisted of the following amounts of roostertree biomass added to the soil: 20, 35, 50, and 65 t ha^{-1} on a dry matter basis. Each plot had a total area of 3.6 m^2 (3.00 m × 1.20 m), with a harvest area of 2.00 m^2, containing 40 cowpea plants spaced at 0.50 m between rows and 10 plants per meter (linearly), yielding a density of 200,000 plants ha^{-1} (EMBRAPA, 2009). The planted cowpea cultivar was BRS Itaim, which is recommended for the North and Northeast regions of Brazil. This cultivar has shown good growth patterns, erect plants, and high resistance to lodging (EMBRAPA, 2009).

Prior to the experiment, soil samples were collected from a depth of 0–20 cm, and subsequently analyzed in the Laboratory of Plant Nutrition, Department of Plant Sciences, UFERSA. The following results were obtained: pH (water) = 7.09, organic matter (OM) = 11.5 mg dm^{-3}, N = 0.04 g kg^{-1}, Ca = 1.84 cmol$_c$ dm^{-3}, Mg = 1.39 cmol$_c$ dm^{-3}, K = 50.5 mg dm^{-3}, Na = 4.1 mg dm^{-3}, P = 15.14 mg dm^{-3}, and CEC = 3.38 cmol$_c$ dm^{-3}.

The soil preparation involved plowing of the area, followed by harrowing and lifting of the beds. Next, we carried out a pre-planting solarization with transparent plastic type Vulcabrilho Bril Fles (30 µ) for 30 days, with the aim of eliminating nematodes and plant parasites in the 0–10-cm layer of the soil, especially *Meloidogyne* spp.

A micro-sprinkler irrigation system was used, with two shifts of daily watering, one in the morning and the other in the afternoon, supplying a water sheet layer of 8 mm day^{-1} (FREITAS et al., 2009), with the aim of maintaining the soil moisture between 50%–70% of the field capacity. This is the ideal condition for the nitrification process, which involves nitrite formation in the soil and the conversion of ammonia into nitrate (NOVAIS et al., 2007). As cultural treatments were performed weekly, manual weeding was performed in the beds, and when the weeds appeared.

Roostertree was collected from the native vegetation of the municipalities Quixeré-CE, Tibau and Mossoró-RN, and then crushed in conventional forage machine, which produced particles of size 2.0–3.0 cm. They were allowed to dry at ambient temperature until they reached the point of haymaking, and were stored with final moisture content. Samples of this green manure were collected at random for the quantitation of the nutrients, which yielded the following results: N = 15.3 g kg^{-1}, P = 4.0 g kg^{-1}, K =15.7 g kg^{-1}, Ca = 9.3 g kg^{-1}, and Mg = 7.03 g kg^{-1}, with a C/N ratio of 20:1.

Initially, on August 22, 2013, 30% of the designated roostertree amount was added in all plots (20 days before planting). During this decomposition time, daily irrigation was performed in two shifts, in order to promote microbial activity during the decomposition process. Twenty days after sowing, the remaining 70% of the roostertree amounts were added between the lines of the plots, as recommended by the previous tests.

Sowing was conducted on September 10, 2013, at an approximate depth of 5 cm, by placing two seeds per hole. The thinning was carried out between 8–10 days after planting, leaving only one plant per hole.

The harvest of cowpea were performed on November 04 (56 days after sowing - DAS), 11 (63 DAS), 14 (66 DAS), and 18, 2013 (70 DAS). The point of pod harvest was determined by observing the color of the pods, when they were green and not yellowish.

The following characteristics were evaluated in the cowpea crops: number of green pods per square meter (quantified as the number of green pods harvested in the harvest area), productivity (quantified as all pods harvested from plants of the harvest area, expressed in t ha^{-1}), dry mass of green pods (obtained from a random sample of 20 plants from the harvest area and expressed in t ha^{-1}), number of green grains per pod (obtained from a random sample of 20 pods from the harvest area of each plot, by counting the number of grains from the threshed pods and dividing it by 20), weight of 100 green grains (taken of four samples of 100 grains, which were weighed and determined the average weight in grams), yield of green grains (quantified as all green grains harvested in the pods of the plant harvest area, expressed in t ha^{-1}), and dry weight of the green grains (obtained from a sample of 20 plants, measured as the weight of grains after drying in an oven with forced air circulation at a temperature of 65 °C until constant weight, expressed in t ha^{-1}).

The assessed economic indicators were: gross income (determined by multiplying the yield of green grains for each treatment by the value of the product paid to the producer in the region, in November 2013, which was R$ 7.00 per kg of green grains, and expressed in ´Reals´), net income [obtained by subtracting the production costs (PC) from inputs and services from the gross income (GI)], rate of return [quantified as the ratio between the gross income (GI) and the production costs (PC) of each treatment; this variable expresses how many Reals are obtained in return for each Real applied in the system], profit margin [obtained as the ratio between the net income (NI) and the gross income (GI), expressed in percentage]. The methodology used in the calculation of these indicators was recommended by Bezerra Neto et al. (2010). The product price and of the production costs per hectare for this cropping system, as used in the calculations of the indicators, was obtained during the months of experiment cultivation.

Regression analyses were performed using the data of the evaluated characteristics, and fitting of the response curves, for each characteristic as a function of the roostertree amounts added to the soil, was performed by the software 'Table Curve' (JANDEL SCIENTIFIC, 1991).

RESULTS AND DISCUSSION

Crescent linear response was observed in the number of green pods per m^2 and in the productivity of green pods with increasing amounts of roostertree biomass added to the soil. For each ton of increase in the amount of roostertree, an increase of 0.06 pods per square meter in the number of pods and 0.04 tonnes in the productivity of green pods was recorded (FIGURES 1A and 1B). A productivity of 6.12 t ha^{-1} was obtained at the maximum dose of 65 t ha^{-1} of the green manure (FIGURE 1B). The productivity of green pods obtained in this study was higher than that observed by Ramos (2011), where a maximum value of 3.9 t ha^{-1} of green pods was obtained using the BRS Paraguaçu cultivar.

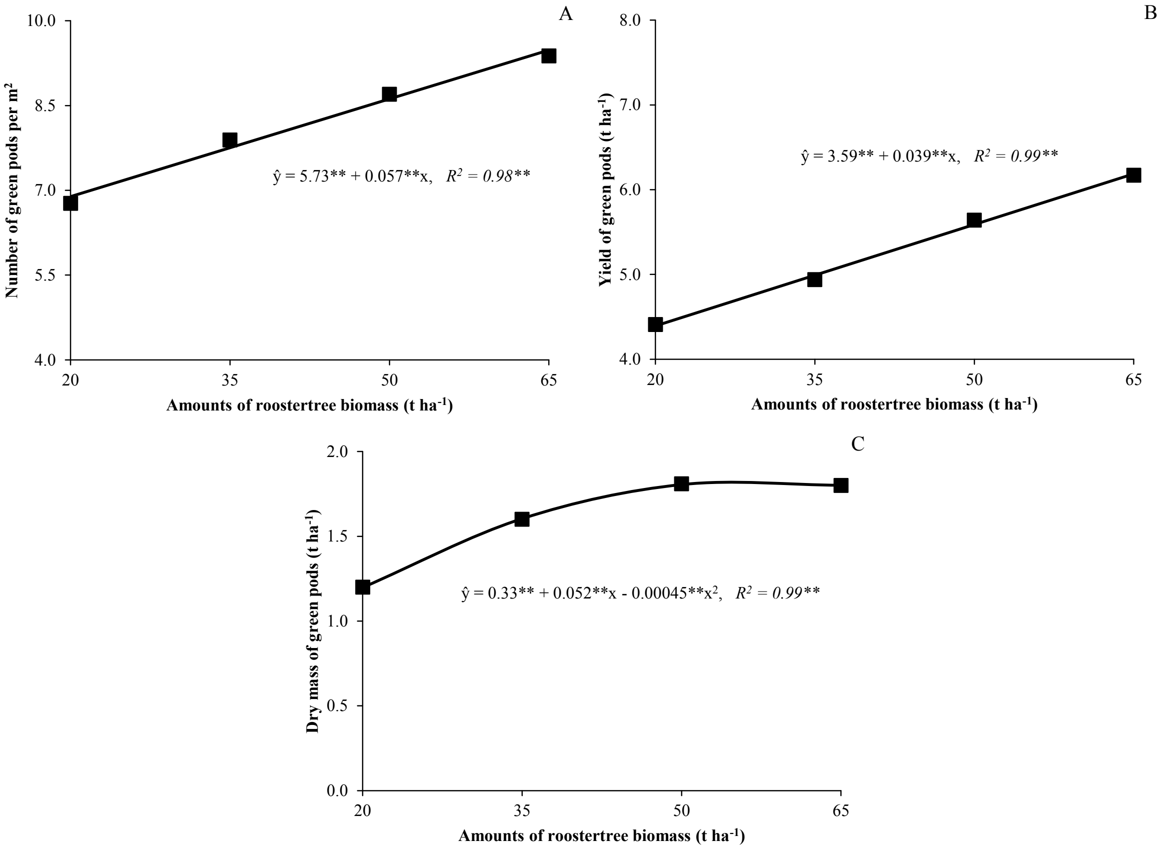

Figure 1. Number of green pods per m^2 (A), productivity of green pods (B) and dry mass of green pods (C) of cowpea as a function of roostertree biomass amounts added to the soil.

For the dry mass of the green pods, a quadratic behavior was observed against the quantities of roostertree biomass, reaching a maximum value of 1.83 t ha^{-1} at 57.21 t ha^{-1} of green manure, then decreasing until the last manure treatment (FIGURE 1C). This behavior, different from the productivity and the dry mass of green pods, can be explained by the amount of water evaporated of the dry mass of the cowpea pods, providing a quadratic fit.

On the other hand, these increases in these variables are due to the amounts of green manure added to the soil, which provided for the nutritional needs of the cowpea plants in a balanced way. The roostertree added to the soil had 15.3 g kg^{-1} of N, 4.0 kg^{-1} g of P, and 15.7 g kg^{-1} of K. This concentration of nitrogen favored plant growth and development, increasing the weight and number of green grains per pod. The potassium had a great influence on the photosynthesis of the plant, and phosphorus helped in the formation of fruits and seeds (TAIZ; ZEIGER, 2006).

For the number of green grains per pod, a quadratic function was observed, and for the yield of green grains and dry mass of green grains, a cubic function was obtained, against increasing amounts of roostertree biomass added to the soil; they registered an increase in their values until 6.96, 3.05, and 1.24 t ha^{-1} at the roostertree biomass amounts of 58.9, 61.0, and 57.3 t ha^{-1}, respectively (Figures 2A, 2C, and 2D). The values decreased thereafter, until the last green manure treatment. This behavior is probably due to the increased availability of nutrients released by the increasing amounts of roostertree added to the soil, but also by the synchrony between nutrient release and absorption by plants (SILVA et al., 2013).

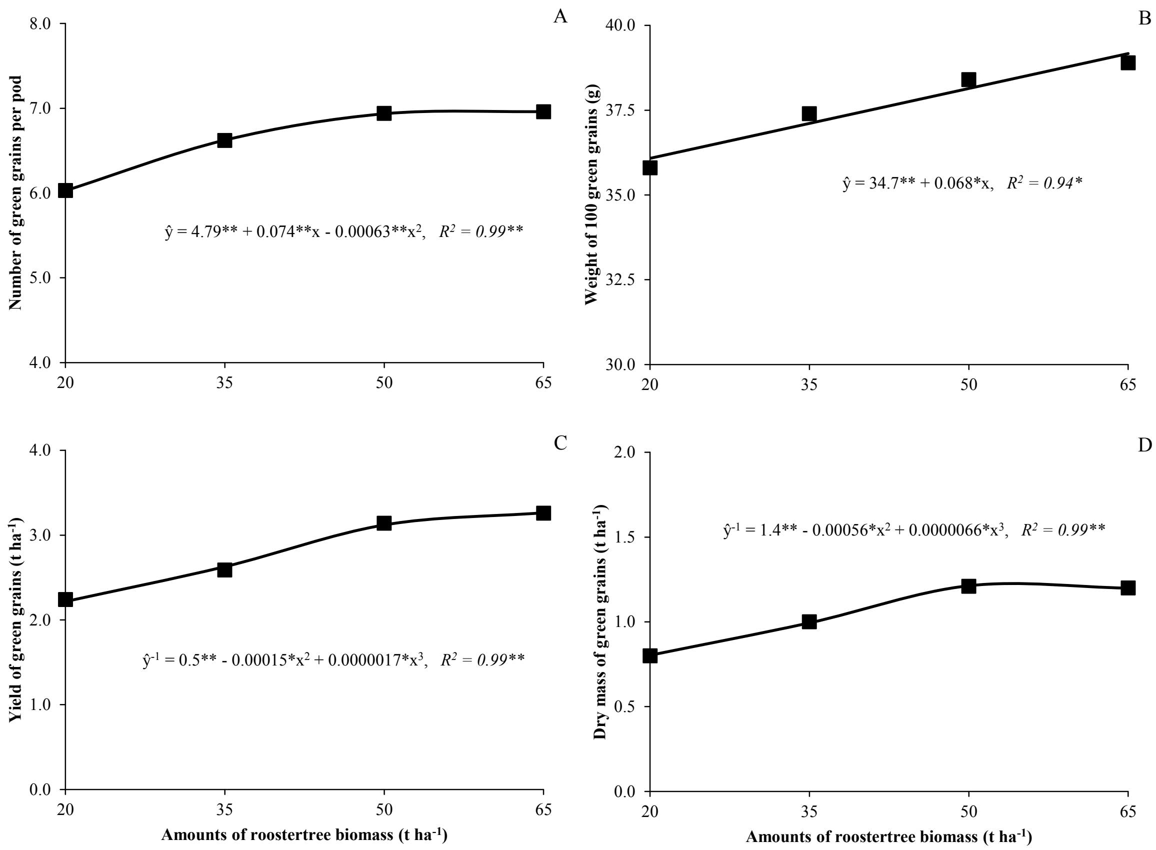

Figure 2. Number of green grains per pod (A), yield of green grains (B), weight of 100 green grains (C) and dry weight of green grains (D) of cowpea as a function of roostertree amounts added to the soil.

For the weight of 100 green grains, an increasing linear behavior was observed with the amounts of roostertree added to the soil. For each ton of increase in the amount of roostertree, an increase of 0.07 g in the weight of 100 green grains was recorded. A value of 39.12 t ha^{-1} was obtained at the maximum dose of 65 t ha^{-1} of the green manure (FIGURE 2B). It is known that a larger availability of phosphorus can proportionate a maximum expression of the weight of 100 grains.

This behavior is probably due to the absorption of this nutrient by the plant; of the total phosphorus available to the plant, it absorbs approximately 15%–25%, and the remaining is strongly fixed by the acidity of the soil, which is caused by high nitrogen content in the soil. Another factor that could have played a role was the high temperatures, because too high or too low temperatures limit the absorption of phosphorus (TAIZ; ZEIGER, 2006). Phosphorus is responsible for promoting flowering and fruiting, thus, directly influencing the yield, grain weight, and quality of the harvested products (AVALHAES et al., 2009).

A bi-quadratic model was obtained for gross and net incomes, rate of return, and profit margin. These indicators increased with increasing amounts of roostertree biomass added to the soil, up to the maximum values of R$ 22,827.47, R$ 8,701.42, 1.64 per invested Real, and 39.02%, at roostertree amounts of 59.16, 53.57, 49.32, and 49.50 t ha^{-1}, respectively, and then decreased until the last green manure treatment (Figures 3A, 3B, 3C, and 3D).

The optimum economic performance of cowpea was obtained by the addition of 53.57 t ha^{-1} of roostertree biomass. This concentration of roostertree biomass provided the highest net income, which is one of the best economic indicators to express the efficiency of the production system, since the production costs are taken into account (BEZERRA NETO et al., 2012). These results reflect the positive response of cowpea to the doses of green manure, provided by the roostertree biomass. Thus, the agronomic or physical efficiency of the productive performance of the cowpea translated well into economic efficiency.

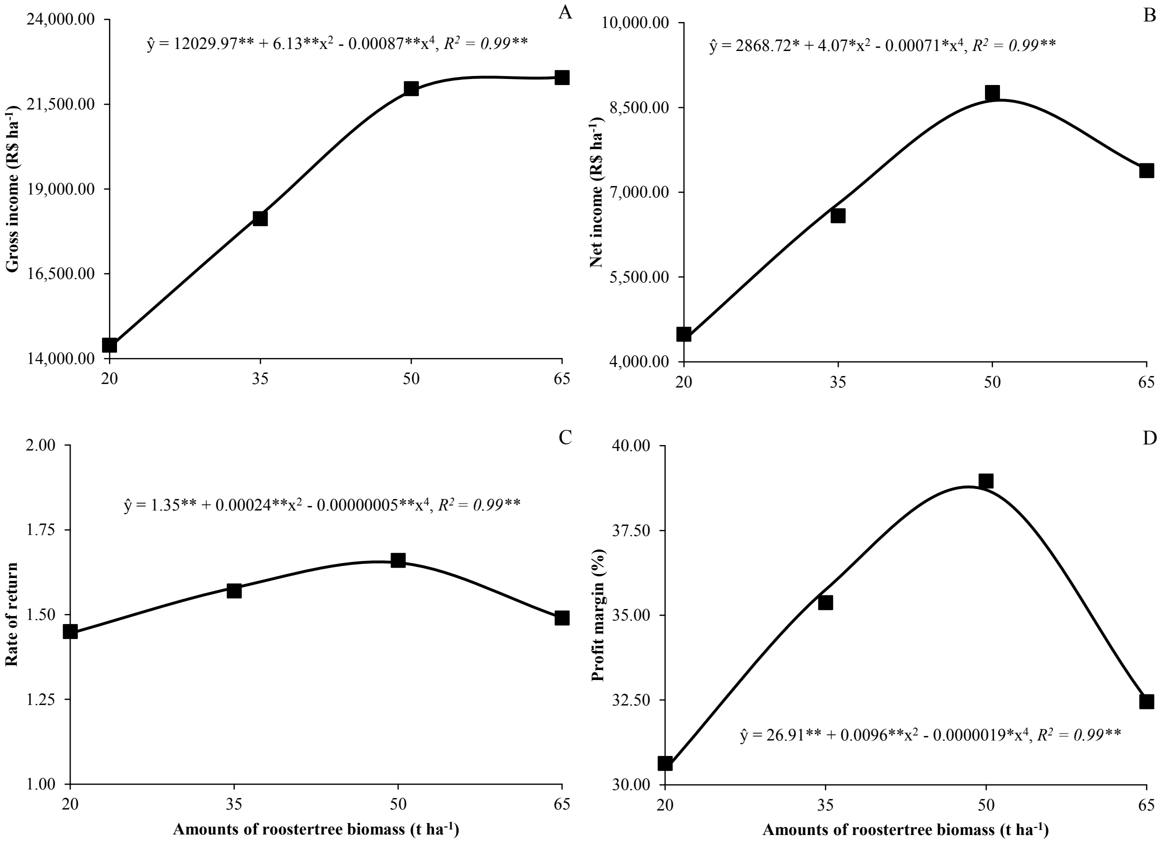

Figure 3. Gross income (A), net income (E), rate of return (C), and profit margin (D) of cowpea as a function of roostertree amounts added to the soil.

CONCLUSION

The maximum agronomic efficiency of the green grain yield of cowpea was obtained for the yield of 3.05 t ha^{-1}, with 61.0 t ha^{-1} of roostertree biomass added to the soil.

The maximum economic efficiency of the green grain yield of cowpea was obtained for the net income of R$ 8,701.42, provided by the production of 3.02 t ha^{-1} of green grains, with 53.57 t ha^{-1} of roostertree biomass added to the soil.

The use of roostertree as a green manure presents technical-economic feasibility in the cultivation of cowpea for the production of green grains in the semi-arid condition of Rio Grande do Norte.

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