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Agronomic and economic feasibility indicators for cowpea-vegetable under green manure in a semiarid environment[1]

Indicadores de viabilidade agronômica e econômica para o caupi-hortaliça sob adubação verde em ambiente semiárido

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ABSTRACT - Two experiments were conducted in different areas of the Rafael Fernandes Experimental Farm, located in Lagoinha district, 20 km from Mossoró municipality (RN), in the period from June to September of the years of 2015 and 2016 with the objective of evaluating and estimating agronomic and economic feasibility indicators of cowpea-vegetable as a function of amounts of hairy woodrose (*Merremia aegyptia* (L.) Urb.) biomass incorporated into the soil in two crops. Treatments consisted of the following amounts of hairy woodrose biomass: 20, 35, 50 and 65 t ha^{-1} on a dry basis. The cultivar of cowpea-vegetable planted was "BRS Itaim". The evaluated characteristics were: length of green pods, number of green pods per m^2, productivity and dry mass of green pods, weight of 100 green grains, yield and dry mass of green grains. In addition, the following economic indicators were evaluated: gross income, net income, rate of return and profitability index. The optimization of the agronomic efficiency of the cowpea-vegetable was obtained in the amount of 45 t ha^{-1} of hairy woodrose biomass incorporated into the soil and the optimization of the agroeconomic viability of the cowpea-vegetable cultivation was reached in the quantity of hairy woodrose biomass of 37.70 t ha^{-1} added to the ground. The first growing crop yielded better agroeconomic efficiency of cowpea-vegetable than the second crop. The use of hairy woodrose as green manure is economically feasible and recommended to the farmer in the production of cowpea-vegetable under the evaluated conditions.

Key words: *Vigna unguiculata* (L.) Walp. *Merremia aegyptia* L.. Optimization of agroeconomic efficiency. Growing seasons.

RESUMO - Dois experimentos foram conduzidos em diferentes áreas da Fazenda Experimental Rafael Fernandes, localizada no distrito de Alagoinha, a 20 km da cidade de Mossoró, RN, no período de junho a setembro dos anos de 2015 e 2016, com o objetivo de avaliar e estimar indicadores de viabilidade agronômica e econômica do caupi-hortaliça em função de quantidades de biomassa de jitirana (*Merremia aegyptia* (L.) Urb.) incorporadas ao solo em duas safras. Os tratamentos consistiram das seguintes quantidades de biomassa de jitirana: 20, 35, 50 e 65 t ha^{-1} em base seca. A cultivar de caupi-hortaliça plantada foi a "BRS Itaim". As características avaliadas foram: comprimento de vagens verdes, número de vagens verdes por m^2, produtividade e massa seca de vagens verdes, peso de 100 grãos verdes, rendimento e massa seca de grãos verdes. Além disso, foram avaliados os seguintes indicadores econômicos: receita bruta, receita líquida, taxa de retorno e índice de lucratividade. A otimização da eficiência agronômica do caupi-hortaliça foi obtida na quantidade de 45 t ha^{-1} de biomassa de jitirana incorporada ao solo e a otimização da viabilidade agroeconômica do cultivo do caupi foi alcançada na quantidade de biomassa de jitirana de 37,70 t ha^{-1} adicionada ao solo. A primeira safra de cultivo rendeu melhor eficiência agroeconômica do caupi do que a segunda safra. O uso da jitirana como adubo verde é economicamente viável e recomendado ao agricultor no cultivo do caupi-hortaliça nas condições avaliadas.

Palavras-chave: *Vigna unguiculata* (L.) Walp. *Merremia aegyptia (*L) Urb. Otimização de eficiencia agroeconômica. Estações de cultivo.

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INTRODUCTION

In recent years, increased food consumption has been observed as a result of higher population growth, coupled with greater population awareness of a richer and healthier diet (OLIVEIRA *et al*., 2015). This higher requirement is also due to a greater concern with the environment and the damage to human health and well-being, resulting from the use of synthetic chemical inputs in food production (SEDIYAMA; SANTOS; LIMA, 2014).

In this sense farmers are developing agricultural practices that can provide a greater production of foods beneficial to human health without harming the environment. The great question is whether these practices are sustainable or not.

According to Feo and Machado (2013), development is sustainable when it reaches the economic, ecological and social dimensions. In the economic dimension, profitable productive activities are put into practice, but they are more intensely concerned with quality of life than with production. In ecological terms, the idea of ecosystem preservation and proper management of natural and social resources are manifested, and in the social dimension, it is considered if the development processes are compatible with the cultural values and expectations of society. Among the agricultural practices capable of promoting the sustainability of the system of production of food crops, is the green manure (ALTIERI; NICHOLLS; MONTALBA, 2017).

This is a practice of incorporating plants produced at the place of origin or not, with the purpose of increasing or preserving the organic matter contents of the soils. This assumes a preponderant role in the development and production of the crops aiming at maximizing the use of resources available in the agricultural property (OLIVEIRA *et al.*, 2011), in addition to promoting improvements in the structure, aeration and soil moisture storage capacity, with regulatory effect in its temperature (SILVA *et al.*, 2013).

However, the choice of plants to meet these goals depends, among other factors, on the potential for phytomass production and on the capacity of absorption and accumulation of nutrients. These factors are of great importance for the soil-plant system because they are related to nutrient cycling and increase of their availability to cultivated plants (ALBUQUERQUE *et al*., 2013).

In this context, the green manuring with spontaneous species of the Caatinga biome has been used with great success (ALMEIDA *et al.*, 2015), because these species, in addition to being adapted to the edaphoclimatic conditions of the region, present high phytomass production, fast growth and close carbon/nitrogen ratio (LINHARES *et al.*, 2012).

Among these spontaneous species that have a high potential for use as green manure, is found the hairy woodrose (*Merremia aegyptia* L.) (SILVA *et al.*, 2011), has a green phytomass productivity around 36 t ha^{-1}, (LINHARES *et al.*, 2012), with nutrient contents of 15.3 g kg^{-1} of nitrogen; 4.0 g kg^{-1} phosphorus; 15.7 g kg^{-1} potassium; 9.3 g kg^{-1} of calcium and 7.03 g kg^{-1} of magnesium, with a carbon/nitrogen ratio of 25: 1 (SILVA *et al*., 2017), which makes this plant a great source of plant biomass with great nutritional potential to give support to the plants of agricultural interest.

Thus, the objective of this study was to evaluate and estimate agronomic and economic feasibility indicators of cowpea-vegetable as a function of amounts of hairy woodrose biomass incorporated into the soil in two crop seasons.

MATERIAL AND METHODS

Two experiments were conducted in different areas of the Rafael Fernandes Experimental Farm, located in Lagoinha district, 20 km from Mossoró municipality (RN) (5º03' S, 37º25' W, 72 m altitude), in the period from June to September of the years of 2015 and 2016, in soil classified as typical dystrophic Red Argisol (RÊGO *et al*., 2016).

The climate of the region is semiarid and according to Köppen is BShw, dry and very hot, and with rainy season in the summer delaying to autumn, presenting annual average temperature of 27.4 ºC, annual rainfall quite irregular, with mean of 673.9 mm and relative humidity of 68.9% (DIAS *et al*., 2010). The mean temperatures and relative humidity during the experimental period are represented in (Figure 1).

Before the installation of the experiments, the soil preparation was done with a harrowing, followed by the raising of the beds with the aid of a machine to make seedbed. Subsequently, soil samples were collected in the 0-20 cm depth, which were air dried, sieved in a 2 mm mesh, processed and analyzed in the Laboratory of Soil Chemistry and Fertility of the Universidade Federal Rural do Semi-Árido (UFERSA), revealing the results represented (Table 1).

Physical attributes of the soil profile of the experimental area in the depth of 0-20 cm were: 729, 192, 20, 59 g kg^{-1} of coarse sand, fine sand, silt and clay, respectively.

The experimental design used was in randomized complete blocks, with four treatments and five replications. The treatments consisted of four amounts of hairy woodrose biomass incorporated into the soil (20; 35, 50

Figure 1 - Data of average temperature and relative humidity during the cowpea cycle in the 2015 and 2016 cultivation years

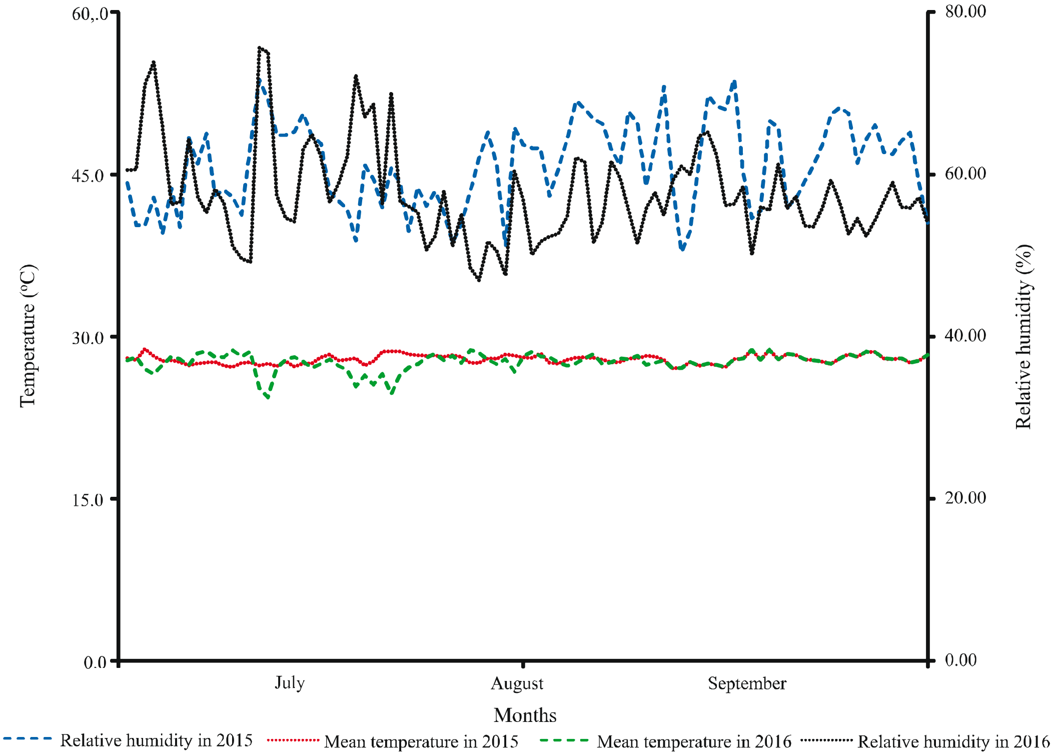


Table 1 - Results of chemical composition analyses of soil samples from the experimental area and of the hairy woodrose green manure incorporated to the soil in the first and second cultivation season

Chemical composition of the soil								
First season from June to September of 2015								
pH	O. M.	N	P	K^+	Na^+	Mg^{2+}	Ca^{2+}	CE
H_2O	g kg^{-1}		----------------- mg dm^{-3} -----------------			-------- $cmol_c$ dm^{-3} -------		dSm^{-1}
7.21	3.64	0.51	63.3	60.0	17.0	0.58	2.09	1.77
Second season from June to September 2016								
pH	O. M.		P	K^+	Na^+	Mg^{2+}	Ca^{2+}	CE
H_2O	g kg^{-1}		----------------- mg dm^{-3} -----------------			------- $cmol_c$ dm^{-3} --------		dSm^{-1}
6.60	3.65	0.42	34.2	69.2	19.0	0.80	3.10	1.05
Chemical composition of the hairy woodrose								
First season from June to September of 2015								
N		P		K^+	Ca	Mg		C:N
-- g kg^{-1} --								25:1
15.3		4.0		15.7	9.3	7.03		
Second season from June to September of 2016								
N		P		K+	Ca	Mg		C:N
-- g kg^{-1} --								25:1
11.40		2.36		10.5	8.30	9.75		

O. M. – Organic Matter; P, K and Na: extracted with Mehlich solution; Ca and Mg: extracted with KCl mol L^{-1}; pH in water and 65 t ha^{-1} in dry basis), in two crop seasons. The total area of the plot was 3.60 m^2, with six rows of plants and a harvest area of 2.00 m^2, consisting of the four central rows with 10 plants each. The spacing between rows and between cowpea-vegetable plants was 0.50 m x 0.10 m with a population of 200,000 plants per ha^{-1} (SANTOS, 2011).

The hairy woodrose used as green manure was collected from native vegetation near Mossoró-RN, at the beginning of flowering. After harvesting, the plants were ground in a conventional forage machine, obtaining fragmented particles with a particle size of 2.0 to 3.0 cm, which were dehydrated under sunlight until reaching a moisture content of 10% , then five samples of this material were submitted to the laboratory analyzes, whose chemical composition is represented in Table 1.

Green manure was incorporated into soil on July 15, 2015 and 2016 with 100% of hairy woodrose. Twelve days after the incorporation of the quantities of hairy woodrose biomass, it was performed the plantation of the cowpea-vegetable in 2015 and 2016 was carried out. The cultivar of cowpea-vegetable planted was the 'BRS Itaim', adapted for the cultivation in the northeast region. The thinning occurred 9 days after sowing (DAS) in both crop seasons, leaving one plant per hole. During the experiment conduction, irrigations were carried out in two irrigation shifts (morning and afternoon) and manual weedings to control invasive plants.

At 50 DAS were randomly selected 20 plants of cowpea-vegetable in the harvest area of each experimental plot, to obtain the data, for the two years. The harvest area was constituted of the four central rows of plants, excluding the first and last plants of each row, used as borders. Four harvests of the cowpea-vegetable were performed in each crop in the 50 to 68 DAS interval in 2015 and 55 to 69 DAS in 2016.

The characteristics evaluated in the cowpea-vegetable were: length of green pod (obtained with a ruler in a sample of 20 pods, selected randomly in the plants of the plot harvest area, expressed in cm); dry mass of green pods and of green grains (determined in the same random sample of 20 plants of the harvest area of the plot, with greenhouse aid with forced air circulation at 65 °C until reaching constant mass and expressed in t ha^{-1}); weight of 100 green-grains (obtained from a sample of 20 pods of the plot harvest area expressed in grams) and number of green pods per m^2, productivity of green pods and yield of green grains (measured in the pods taken from all plants of the plot harvest area expressed in number (N^o) and in t ha^{-1}, respectively).

The economic indicators evaluated were: gross income, net income, rate of return and profit margin. The amounts paid to cowpea-vegetable were R$ 7.00 and 7.50 kg^{-1}, which corresponded to the price paid to producers at the market level in September 2015 and 2016, respectively.

Gross income was obtained by multiplying the crop productivity in each treatment by the amount paid to the producer by the product; net income was calculated by subtracting from gross income, the production total costs from inputs and services; the rate of return was obtained by the ratio between gross income and total costs, which corresponds to how much reals is obtained for each real applied and the profit margin obtained by the ratio between net income and gross income, expressed as a percentage, according to Silva *et al*. (2017).

The prices of inputs and services in force in September 2015 and 2016, in the city of Mossoró, as described in Table 2, were considered.

Univariate analyzes of variance were performed to evaluate the characteristics of the cowpea-vegetable and the economic indicators of sustainability of the intercropping in each crop season. The software used in the analysis was SISVAR (FERREIRA, 2011). Then, a joint analysis of the experiments with homogeneity of variances between the harvests (PIMENTEL-GOMES, 2009) was performed for each variable. A regression curve fitting procedure was used to estimate the behavior of each characteristic or indicator as a function of the amounts of hairy woodrose biomass incorporated into the soil (JANDEL SCIENTIFIC, 1991).

RESULTS AND DISCUSSION

Agronomic characteristics of cowpea-vegetable

There was no significant interaction between the amounts of hairy woodrose biomass incorporated into the soil and the growing seasons in the studied variables of cowpea-vegetable (Table 3).

However, a polynomial regression was recorded between each determined characteristic and the increasing biomass amounts of the green manure (Figure 2).

For the green pod length, number of green pods per m^2, productivity and dry mass of green pods, weight of 100 green grains, yield and dry mass of green grains were observed an increasing behavior as a function of the increase of the amounts of hairy woodrose biomass, up to maximum values of 17.54 cm, 149.2 pods, 5.63 and 0.42 t ha^{-1}, 37.38 g and 2.39 and 0.77 t ha^{-1}, in the amounts of 46.97; 44.31; 45.36; 45.53; 47.54, 43.67 and 45.35 t ha^{-1} respectively, then decreasing to the last amount added to the soil (Figures 2A-F).

Table 2 - Production costs per hectare of cowpea-vegetable in the amounts of 20, 35, 50 and 65 t ha^{-1} of hairy woodrose biomass in the first and second season

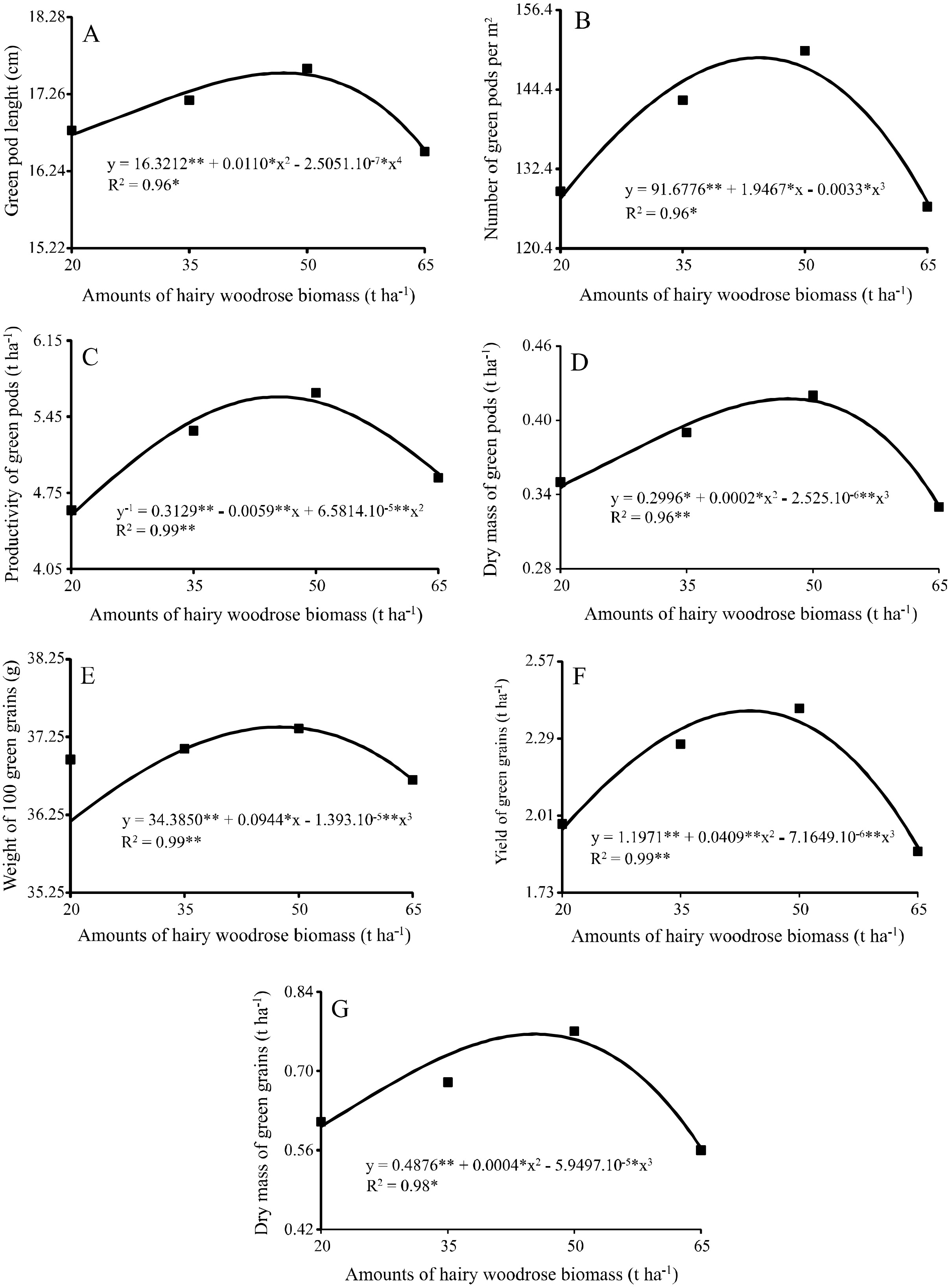
Components	First Season			
	Biomass amounts			
	20 t ha^{-1}	35 t ha^{-1}	50 t ha^{-1}	65 t ha^{-1}
Inputs	60.00	60.00	60.00	60.00
Labor	4,070.00	4,310.00	6,082.70	7,145.30
Electricity	230.70	241.70	252.70	263.70
Other expenses	120.60	120.60	120.60	120.60
Maintenance and conservation 1% and 7% year^{-1}	345.10	345.10	345.10	345.10
Depreciation	310.00	310.00	310.00	310.00
Taxes and fees	25.00	25.00	25.00	25.00
Fixed labor force	1,970.00	1,970.00	1,970.00	1,970.00
Opportunity Costs 6% year^{-1}	1,099.84	1,099.84	1,099.84	1,099.84
Total Costs	8,230.54	8,482.24	10,265.94	11,339.54
Components	Second Season			
	Biomass amounts			
	20 t ha^{-1}	35 t ha^{-1}	50 t ha^{-1}	65 t ha^{-1}
Inputs	60.00	60.00	60.00	60.00
Labor	3,596.60	4,064.60	5,858.90	7,025.00
Electricity	230.70	241.70	252.70	263.70
Other expenses	120.60	120.60	120.60	120.60
Maintenance and conservation 1% and 7% year^{-1}	345.10	345.10	345.10	345.10
Depreciation	310.00	310.00	310.00	310.00
Taxes and fees	25.00	25.00	25.00	25.00
Fixed labor force	2,200.00	2,200.00	2,200.00	2,200.00
Opportunity Costs 6% year^{-1}	1,099.84	1,099.84	1,099.84	1,099.84
Total Costs	7,987.84	8,466.85	10,272.14	11,449.25

Table 3 - F values and regression analysis for green pod length (GPL), number of green pods per m^2 (NGPm^{-2}), productivity of green pods (PGP), dry mass of green pods (DMGP), weight of 100 green grains (P100GG), yield of green grains (YGG), dry mass of green grains (DMGG) of cowpea-vegetable fertilized with different amounts of hairy woodrose biomass

SV	DF	GPL cm	NGP m^{-2}	PGP t ha^{-1}	DMGP t ha^{-1}	P100GG g	YGG t ha^{-1}	DMGG t ha^{-1}
Blocks (Season)	8	8	0.71^{ns}	0.51^{ns}	0.56^{ns}	1.44^{ns}	0.68^{ns}	0.53^{ns}
Cropping Seasons (S)	1	1	212.33**	39.98**	28.56**	10.50**	20.65**	47.13**
Amounts (A)	3	3	2.48^{ns}	2.50^{ns}	1.89^{ns}	0.28^{ns}	2.37^{ns}	4.34**
S x A	3	3	0.57^{ns}	0.75^{ns}	1.93^{ns}	0.02^{ns}	1.67^{ns}	2.43^{ns}
Regression (Polynomial)	2	2	180.97*	0.3285*	0.0023**	0.4097**	0.0857**	0.0132*
Error	2	2	8.05	0.0097	0.000089	0.000044	0.0030	0.00031
Cropping seasons					Mean values †			
First Season		16.31 b	189.07 a	6.07 a	0.45 a	36.17 b	2.49 a	0.80 a
Second Season		17.71 a	85.30b	4.17 b	0.29b	37.89 a	1.78 b	0.51 b
CV (%)		3.36	16.42	18.59	25.11	4.55	23.29	20.61

** = P < 0.01; * = P < 0.05; ns = P > 0.05 † Means followed by the same lowercase letter in the column do not differ from each other by the Tukey test at the 5% probability level

Figure 2 - Green pod length (A), number of green pods per m^2 (B), productivity (C) and dry mass of green pods (D), weight of 100 green grains (E), yield (F) and dry mass of green grains (G) of cowpea-vegetable as a function of amounts of hairy woodrose incorporated in the soil



The increases observed in these studied variables are due to the amounts of green manure added to the soil, which supplied the nutritional needs of the cowpea-vegetable plants in a balanced manner, as observed in the hairy woodrose chemical composition data in Table 1. On the other hand, the reduction in the values of these variables after the maximum point can be attributed to the law of maximum, where the excess of a nutrient in the soil can cause toxic effects and/or decrease the effectiveness of other nutrients, thus reducing the values of the analyzed variables. Another justification that may be related to this behavior and optimization is adequate synchrony between the period of higher nutrient demand by the cowpea-vegetable and the release of nutrients by the hairy woodrose biomass.

These results were probably due to the greater nutrient supply to the soil with the increase of the green manure amounts, which besides being excellent suppliers of nitrogen (N), also provide it by the recycling of nutrients, and when there is an adequate amount of nitrogen, there is a favoring of the vegetative growth of the plant, increasing its productive potential (FAVACHO *et al.*, 2017).

Studies conducted by Batista *et al.* (2016) in the same region of this research with different amounts of biomass of spontaneous species incorporated in the soil show that the green manure acts as a source of energy on soil colony forming units of bacteria, fungi and actinomycetes, improving the soil structure, aeration and the ability to store soil moisture, providing ideal conditions for the plant growth and development.

In this context, we can infer that green fertilization with hairy woodrose, by providing to the soil a concentration of 4.0 g kg^{-1} of P in the first season and of 2.36 g kg^{-1} of P in the second season, also contributed positively for the increase of cowpea-vegetable productivity. The P is a nutrient that acts in the process of cell energy transfer, respiration and photosynthesis, and acts as a structural component of the nucleic acids of genes and chromosomes, making it a crucial nutrient in the development of plant metabolism (GRANT *et al.*, 2001).

Avalhaes *et al*. (2009) comment that P is a responsible nutrient in promoting the flowering and fruiting. As a result, it has a direct influence on the yield, grain weight and quality of the harvested products, since the cowpea is a crop rich in amino acid; it demands high amounts of phosphorus and exports a lot as well.

Another nutrient that also contributed significantly to the increase in productivity of cowpea was potassium, with its addition of 15.7 g kg^{-1} of K in the first season and 10.50 g kg^{-1} of K in the second season. This nutrient is exported in greater amounts by the crop, which can compromise productivity when not supplied in adequate quantities (CAIONE *et al*., 2011). In addition, it acts directly on carbohydrate metabolism, acts as an activator of several enzymes, regulates the opening and closing of stomata, allowing the plant to use water more efficiently (LOPES, 1998).

Another factor that must be taken into account is the carbon: nitrogen (C:N) ratio of 25: 1 observed in the plant material used (Table 1). This relationship is linked to the decomposition rate of organic wastes. According to Bezerra Neto *et al*. (2014), when organic residues have a C:N ratio between 20:1 and 30:1, there is no predominance of immobilization or nitrogen mineralization (N). In this way, it is possible to have an adequate synchrony between the decomposition and mineralization of the hairy woodrose added to the soil, thus providing an adequate nutritional supply to the plants.

Thus, once the plant is well nourished, consequently, there is an adequate accumulation of dry matter, in which a photosynthetically active leaf area with sufficient capacity for the translocation of assimilated will provide a plant with high productive capacity (FAVACHO *et al*., 2017).

The average length of green pod of 17.54 cm, recorded in this work is in accordance with its characteristics of market launch, which is 16 cm for the same cultivar (FREIRE FILHO *et al*., 2011). For the productivity of green pods, dry mass of green pods, dry mass of green grains, weight of 100 green grains and yield of green grains the observed values of 5.63, 0.42 and 0.77 t ha^{-1}, 37.38 g and 2.39 t ha^{-1}, are similar to those obtained by Vieira *et al*. (2018) that when studying the agronomic and economic efficiency of cowpea-vegetable as a function of different amounts of roostertree, obtained values of 6.12, 1.83, 1.24, 39.12 and 3.05 t ha^{-1} respectively.

When analyzing the growing seasons of the cowpea-vegetable, there was a significant difference between them for all characteristics evaluated (Table 3). The first growing season stood out of the second season in the number of green pods per m^2, in the productivity and dry mass of green pods, in the yield and dry mass of green grains. Inverse situation was observed in the green pod length and in the weight of 100 green grains, where the second cropping season stood out of the first season (Table 3).

The highest values observed in the first growing season in the number of pods per m^2, in the productivity and dry mass of green pods, in yield and dry mass of green grains, may be related to the amount of phosphorus present in the soil, with values of 63.3 mg dm^{-3} for the first season and 34.2 mg dm^{-3} for the second season, respectively. This information corroborates with those of Brasil and Nascimento (2010), where they report that this nutrient has great importance in the initial growth of plants to act in the process of storage and transfer of energy, being directly involved in the active absorption of nutrients.

Thus, the limitations on the availability of P at the beginning of the vegetative cycle may result in constraints in the development, from which the plant does not recover later, even increasing the P supply to adequate levels, being this adequate supply of P, essential from the initial stages of growth of the plant until the final phase (GRANT *et al*., 2001). For Fageria, Barbosa Filho and Stone (2003) the action of phosphorus in the common bean consists of the increase of dry matter production of shoot and elevation in the number of pods and mass of grains, essential components of productivity.

This higher amount of phosphorus present in the soil in the first growing season may have provided better-nourished cowpea-vegetable plants, because these plants present intense and short cycle development necessitating levels of phosphorus in the soil solution with faster replenishment of P-adsorbed when compared to the longer cycle plants. Thus, an adequate availability of this nutrient in the initial phase becomes of great importance for the development of metabolic functions and initial formation of plants, as well as for root growth.

Another factor that may have influenced the productive performance of cowpea is the relative humidity of the air, since it had average values of 61.17% and 57.62%, during the period of conduction of the experiments, for the years of 2015 and 2016 respectively. Bastos, Pacheco and Frazão (2002), report that the ideal relative humidity should be between 60% and 90%, avoiding a higher evaporative demand of the atmosphere causing an increase of the transpiration rate or the reduction of the transpiration of the plants that favors the spread of fungal diseases, respectively.

Economic indicators of sustainability

No significant interaction was observed between the amounts of hairy woodrose and the growing seasons in the economic indicators of sustainability evaluated in the cowpea-vegetable (Table 4).

However, a polynomial regression was recorded between each indicator and the increasing amounts of the green manure (Figure 3). Increasing behavior was observed in the gross income, net income, rate of return and profit margin as a function of the amounts of hairy woodrose biomass incorporated to the soil up to the maximum values of R$ 17,345.27 ha^{-1}; R$ 8,232.16 ha^{-1}; 1.75 and 43.85% in the amounts of hairy woodrose of 43.36; 37.70; 39.94 and 37.63 t ha^{-1}, respectively, decreasing to the last amount of hairy woodrose incorporated into the soil (Figures 3A-D).

The highest values obtained in the economic indicators of sustainability observed in the amounts of hairy woodrose of 43.36; 37.70; 39.94 and 37.63 t ha^{-1}, respectively, are due to the fact that cowpea-vegetable has responded very well to green manuring with hairy woodrose, due to the better use of environmental resources.

Among other factors that may have also provided these higher values recorded in these amounts of hairy woodrose - are a greater availability of the nutrients released, as well as the synchrony in which these elements were released and absorbed by the cowpea-vegetable plants (BEZERRA NETO *et al*., 2014). Thus, the agronomic efficiency obtained in the productive performance of the cowpea-vegetable translated into economic efficiency.

The values observed in this research for gross income, net income, rate of return and profitability index of R$ 17,345.27 ha^{-1}; R$ 8,232.16 ha^{-1}; 1.75 and 43.85% are similar to those observed by Vieira *et al*. (2018) that when studying the technical-economic efficiency of the yield of green grains of cowpea-vegetable fertilized with roostertree biomass under the same region, obtained values for the same indicators of R$ 22,827.47 ha^{-1}, R$ 8,701.42 ha^{-1}, 1.64 and 39.02%, respectively.

Significant differences in economic indicators of sustainability: gross income, net income, rate of return and profit margin were observed between growing seasons, with the first season standing out from the second season (Table 4).

This higher economic viability in the first season probably correlates with the better climatic conditions provided at that time of cultivation.

Thus, unfavorable climatic conditions correspond to one of the factors of great importance, which may limit the productivity of cowpea-vegetable. However, for this crop to produce satisfactorily, it is necessary to offer favorable climatic conditions at the time of the flowering and filling of pods, which are these most critical stages to obtain good productivity (SIMIDU *et al*., 2010).

Figure 3 - Gross income (A), net income (B), rate of return (C) and profit margin (D) of cowpea-vegetable as a function of amounts of hairy woodrose incorporated in the soil

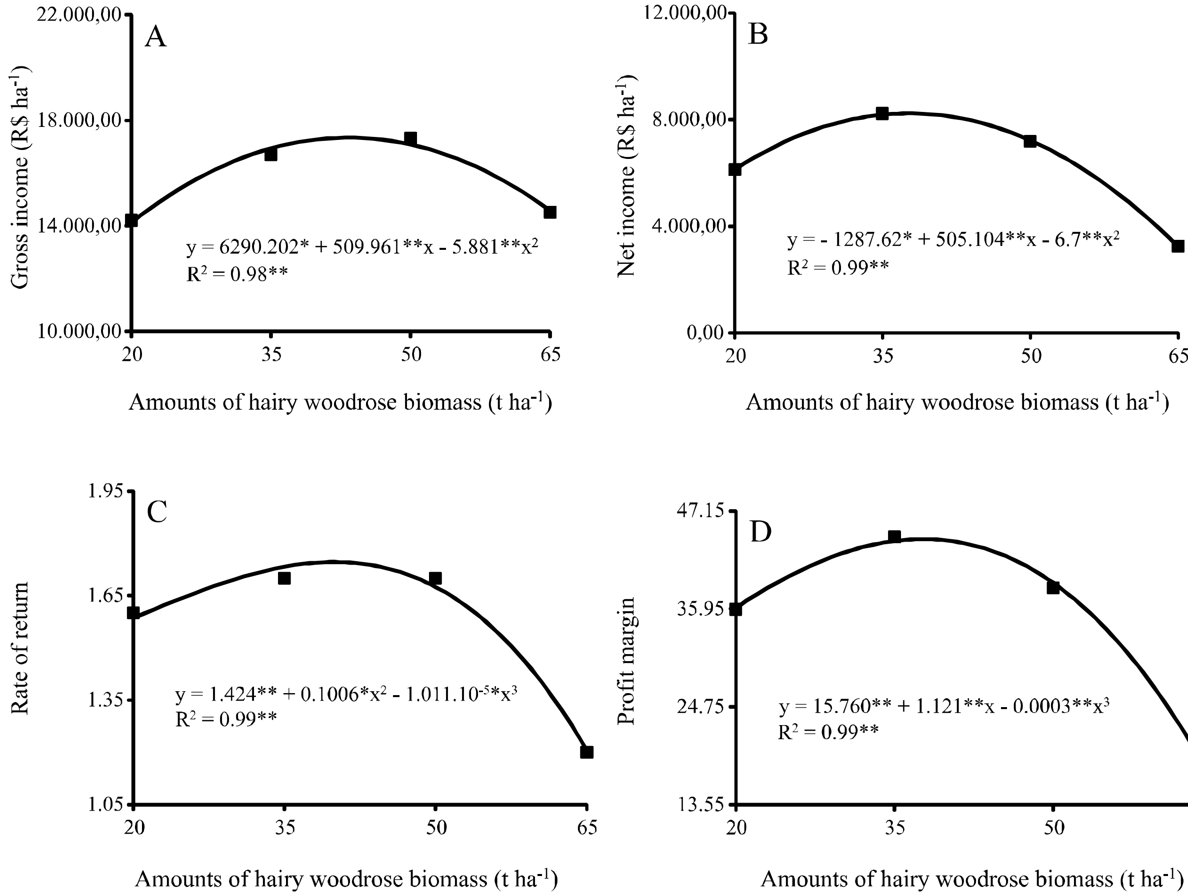


Table 4 - F values and regression analysis for gross income (GI), net income (NI), rate of return (RR) and profit margin (PM) of cowpea-vegetable fertilized with different amounts of hairy woodrose biomass

SV	DF	GI (R$ t ha^{-1})	NI(R$ t ha^{-1})	RR	PM (%)
Blocks (Season)	3	0.55**	0.55^{ns}	0.69^{ns}	0.21^{ns}
Cropping Seasons (S)	3	17.57**	17.31**	15.38**	13.56**
Amounts (A)	2	1.92^{ns}	3.65*	3.49*	3.11*
S x A	6	1.07^{ns}	1.45^{ns}	1.85^{ns}	0.56^{ns}
Regression (Polynomial)	2	3559028.9*	6877712.7**	0.08402*	215.97**
Error	2	63107.14	1628.18	0.00098	0.2993
Cropping seasons		Mean values†			
First Season		18,037.15 a	8,525.40 a	1.80 a	46.30 a
Second Season		13,336.65 b	3,860.65 b	1.30 b	21.50 b
CV (%)		22.60	57.25	26.06	63.70

** = P<0.01; * = P<0.05; ns = P >0.05 . † Means followed by the same lowercase letter in the column do not differ from each other by the Tukey test at the 5% probability level

CONCLUSIONS

1. The agronomic efficiency of cowpea-vegetable was obtained in the hairy woodrose biomass amount of 45 t ha^{-1} incorporated into the soil;
2. The agroeconomic viability was achieved in the amount of hairy woodrose biomass of 37.70 t ha^{-1} incorporated into the soil;
3. The first crop yielded the best agroeconomic efficiency of cowpea-vegetable;
4. The use of hairy woodrose as green manure is economically viable to the farmer in the production of cowpea-vegetable.

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