Asian Journal of Research in Crop Science

Volume 8, Issue 4, Page 302-311, 2023; Article no.AJRCS.105615
ISSN: 2581-7167

Green Manuring with Hairy Woodrose (*Merremia aegyptia* L.) Mixed with Rooster Tree (*Calotropis procera*) in the Agronomic Production of Kale Greens (*Brassica oleracea* L.) in the Semi-Arid Region of Brazil

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Authors' contributions

This work was carried out in collaboration among all authors. All activities, which included the planning, execution, and readaptation of the scientific article had the participation of all the authors, being of fundamental importance for the conclusion of the scientific article. All authors read and approved the final manuscript.

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Article Information

DOI: 10.9734/AJRCS/2023/v8i4210

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/105615

Original Research Article

Received: 24/06/2023
Accepted: 28/08/2023
Published: 31/08/2023

ABSTRACT

Aims: In the semi-arid region of Brazil, there are several species of spontaneous plants that develop during the rainy season, in the case of the hairy woodrose (Merremia aegyptia L.) and throughout the year, the rooster tree (Calotropis procera), these plants are being used as green manure in vegetable production. In this sense, the objective was to study the green fertilization with hairy woodrose (*Merremia aegyptia* L.) mixed with rooster tree on the productivity of the leafy vegetable kale greens in the semi-arid region of Brazil.
Place of Study: The experiment site was in the municipality of Mossoró, RN, Brazil, located at 5º 11' south latitude and 37º 20' west longitude and altitude of 18 m.
Study Design and Methodology: A completely randomized design was used, with treatments arranged in a 5 x 2 factorial scheme, with four replications. The first factor consisted of five amounts of green manure from the mixture of hairy woodrose (*Merremia aegyptia* L.) plus rooster tree (*Calotropis procera*) (0.0; 1.2; 2.4; 3.6 and 4.8 kg m^{-2} of area in green base) and the second factor by the forms of application to the soil (incorporated and cover).
Kale greens (*Brassica oleracea* L.) Evaluated Characteristics: At the time of harvest, the following characteristics were evaluated: plant height; number of leaves; weight of leaves; mass green of kale; Production of kale greens and dry mass.
Conclusions: The best productive performance of the leafy vegetable kale was observed in the amount of 3.6 kg m^{-2}, with values of 17.0 leaves/plant and 1080.25 g/m2 of area. Regarding the forms of application to the soil, the method of incorporation was superior to the application of fertilizers in coverage, values of 985.8 and 788.9 g m^{-2} of area, respectively. Hairy woodrose (*Merremia aegyptia* L.) and rooster tree (*Calotropis procera*) are promising species to be used as green manure.

Keywords: Agroecological production; spontaneous species of the semi-arid region and leafy vegetable.

1. INTRODUCTION

The organic production of vegetables is an activity of great importance for farmers working in the agroecological production system in the semi-arid region of Mossoró, RN, Brazil. This activity consists of adding organic residues of vegetable or animal origin to the soil as a source of nutrients, especially nitrogen, phosphorus and potassium.

One of the most used inputs is the sources of manure (beef, goat, sheep and poultry), however due to the scarcity of these materials, given the intensity in the production of vegetable crops, considering that these species have a development cycle that lasts in average of 30 to 40 days, such as arugula, radish and coriander, combined with planting density, there is a need to constantly add organic waste to the soil, which contributes to the increase in production costs [1].

Among the species of the Brassicaceae family, the production of kale (*Brassica oleracea* L.) stands out, of great importance for the vegetable market, being easy to cultivate agroecological production. As it is a leafy plant, collard greens are very demanding in terms of nitrogen, which requires that the source of fertilizer used has nutrient levels that meet the nutritional requirements of the crop.

Among the forms of fertilization in vegetables, green fertilization can be highlighted, which consists of the use of species rich in nitrogen with a carbon-nitrogen ratio between 20 and 30/1, being of paramount importance, as it contributes to the prevalence of mineralization in relation to immobilization, with availability of nitrogen in the soil to be absorbed by plants [2].

Among the promising species for this activity, the hairy woodrose (*Merremia aegyptia* L.) stands out, a spontaneous plant from the Brazilian semi-arid region with an abundance of green phytomass (40.000 kg ha^{-1}), being one of the first species to emerge during the first precipitations, with nitrogen and potassium contents above 22 and 20 g $kg^{-1,}$ respectively, and an average carbon-nitrogen ratio of 20/1 [3,4].

Another species that has been used for this purpose in providing edaphic conditions for the development of olericultural plants is the silk flower (*Calotropis procera*), a shrub totally adapted to the climate and soil conditions of the Brazilian semi-arid region, with availability of phytomass during every year, with nitrogen and potassium contents of 20 and 18 g kg-1 and an average carbon-nitrogen ratio of 23/1 [5].

Several works have been developed with these species in the production of vegetables, such as in the production of coriander [6-11]; arugula [12]; lettuce [13-15]; radish [16] and beetroot [17].

Given the importance of green manuring with spontaneous species present in the cultivation areas, the objective was to study the green manuring with hairy woodrose mixed with rooster tree in the agronomic production of collard greens (*Brassica oleracea* L.) in the semiarid region of Brazil.

2. MATERIALS AND METHODS

2.1 Location of the Experiment Installation

The experiment was conducted in the greenhouse of the Department of Agronomic and Forestry Sciences of the Universidade Federal Rural do SemiÁrido-UFERSA, campus Mossoró, RN, in soil classified as Red-Yellow Sandy Latosol [18]. For this purpose, the soil used in the experiment was collected at a depth of 0-20 cm at the Rafael Fernandes Experimental Farm, 20 km away from Mossoró-RN (5º 03′ 37" S and 37º 23' 50" W, with 70 m altitude) [19].

When the experiment was set up, soil samples were taken, dried in the air and sieved through a 2 mm mesh, subsequently analyzed at the Laboratory of Soil Chemistry and Fertility at UFERSA, the results of which were as follows: pH (water 1:2.5) = 6.4; Ca = 0.9 cmol dm^{-3}; Mg = 0.3 cmolc dm^{-3}; K = 12.0 mg dm^{-3}; Na = 5.0 mg dm^{-3}; P = 34.8 mg dm^{-3} and M.O. = 0.7 g kg^{-1}.

2.2 Experimental Design

A completely randomized design was used, with treatments arranged in a 5 x 2 factorial scheme, with four replications. The first factor consisted of five amounts of green manure from the mixture of hairy woodrose (*Merremia aegyptia* L.) plus rooster tree (*Calotropis procera*) (0.0; 1.2; 2.4; 3.6 and 4.8 kg m^{-2} of area in green base) and the second factor by the forms of application to the soil (incorporated and cover). Planting was carried out in each pot, opening two pits and sowing five pit^{-1} seeds. At the time of emergence, a transplant was carried out, leaving a pit^{-1} plant.

The experimental plots consisted of vases with 0.12 m^2 capacity and depth of 0.32 m, containing two $vase^{-1}$ plants. Each plot consisted of three pots, corresponding to six plants per replication. In all experimental plots, the green manure remained for a period of rest of thirty days for a greater availability of nutrients, as recommended by Linhares et al. [20].

The spontaneous species hairy woodrose (*Merremia aegyptia* L.) and rooster tree (*Calotropis procera*) were collected within the UFERSA campus. Jitirana was collected during the flowering period, when the species has the highest concentration of nutrients, as recommended by Linhares et al. [21]. The rooster tree was harvested from the apex of the plant to the insertion of the green part, as recommended by Linhares et al. [22]. After collecting the species, samples of the mixture of hairy woodrose and were taken and sent to the laboratory for chemical analysis, whose values were: 520 g kg^{-1} C; 25.0 g kg^{-1} N; 12.5 g kg^{-1} P; 18.0g kg^{-1}K; 12.0 g kg^{-1} Ca; 16.0 g kg^{-1} Mg and nitrogen/carbon ratio (21/1) (Fig. 1A and 1B).

Fig. 1. Illustration of the hairy woodrose (*Merremia aegyptia* L.) (A) and rooster tree (*Calotropis procera*) (B) species from the northeastern semi-arid region, present in the production areas of producers in the region of Mossoró, RN. Photograph: Researcher PhD Paulo César Ferreira Linhares

During the permanence of the residues in the soil, irrigation was carried out to maintain soil moisture, which is fundamental for the degradation process of the residues and the availability of nutrients for the soil. The experiment was carried out for a period of seventy-two days, with pest control using a neem formulation with neutral soap, prioritizing agroecological control.

2.3 Measurement of the Agronomic Characteristics of Kale Greens (*Brassica oleracea* L.)

At the time of harvest, the following characteristics were evaluated: plant height (taken from a sample of six plants per repetition, measuring from the base to the apex of the leaves, expressed in cm plant^{-1}); the number of leaves (all leaves of the six plants were counted, expressed in plant^{-1} units); the weight of leaves (leaves were weighed on a 1.0 g precision scale, expressed in g leaf^{-1}); mass green of kale (by weighing all the plants, expressed in g plant^{-1}); Production of kale greens (the production obtained in the plot (0.12 m^{-2}) was used and multiplied by the factor 8.33, to determine the yield in g m^{-2} of area) and dry mass (sample taken from each treatments, dried in an oven with forced air circulation at 65ºC until constant mass, being multiplied by the factor 8.33, to determine the yield in g m^{-2} of area).

2.4 Statistical Analysis

Statistical analysis was performed according to conventional methods of analysis of variance [23], using ESTAT statistical software [24]. The response curve fitting procedure was performed using the ESTAT Software [24]. For the qualitative factor (incorporated and coverage) the F test of the analysis of variance was performed at $P< 0.05$.

3. RESULTS AND DISCUSSION

For all the evaluated characteristics of the collard greens culture, a significant effect was observed at the level of $p< 0.01$ of probability for the amounts of the mixture of hairy woodrose with rooster tree (Figs. 2 to 6). For the factor forms of application to the soil (incorporated and coverage) they differed by the F test at the level of $p< 0.05$ of probability.

For the characteristic plant height, it was observed that there was a linear adjustment for the amounts of the mixture of hairy woodrose plus rooster tree (Fig. 2), with a maximum value of 28.9 cm plant^{-1}, corresponding to an average increase of 19.71 cm plant^{-1} in relation to the treatment without fertilization. Regarding the forms of application to the soil of the mixture of hairy woodrose with rooster tree, a statistical difference was observed, with values of 27.6 and

23.4 cm plant^{-1} for incorporation and coverage, respectively (Table 1).

This characteristic is greatly influenced by the availability of nitrogen in the soil, this element being of paramount importance for leaf expansion [25]. Mascari et al. [26] studying the development of kale (*Brassica oleracea* L.) under different doses of biofertilizers grown in a wick system, found a plant height of 23.4 cm plant^{-1}, which is lower than the referred research. Moura et al. [27] evaluating the productivity of Brassica oleracea in an organic transition system in southern Brazil, found a plant height of 40 cm plant^{-1} when using limestone, which differs from the aforementioned research.

There was a point of maximum leaf production, in the amount of 3.6 kg m-2, with a maximum value of 17.08 plant^{-1} units (Fig. 3). Regarding the forms of application to the soil of the mixture of hairy woodrose with rooster tree, a statistical difference was observed for the number of leaves, with values of 17.0 and 16.0 cm plant^{-1} for incorporation and coverage, respectively (Table 1). Linhares et al. [28] studying kale fertilized with woods pasture (*Senna uniflora*) under different amounts and forms of application to the soil found 21.6 leaves plant^{-1}, which is higher than the referred research. This superiority is probably due to the quantities of wood used, contributing greatly to a greater availability of nutrients to the soil. Mascari et al. [29] studying the development of kale greens (*Brassica oleracea* L.) under different doses of biofertilizers grown in a wick system, with a number of leaves of 17.6 plant^{-1} units, which is similar to the aforementioned research. Moura et al. [27] evaluating the productivity of Brassica oleracea in an organic transition system in southern Brazil, found a number of leaves of 15 plant^{-1} units, which differs from the aforementioned research. Silva et al. [30] studying kale production in response to the application of bovine manure, found a number of leaves of 13.25 plant^{-1} units at a dose of 100 g dm^{-3}, which is similar to the aforementioned research.

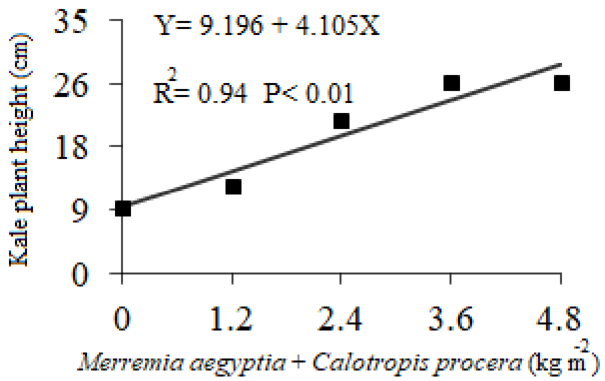

Fig. 2. Height of leaves of the leafy vegetable kale (*Brassica oleracea* L.) plant as a function of the mixture of hairy woodrose (*Merremia aegyptia* L.) plus rooster tree (*Calotropis procera*)

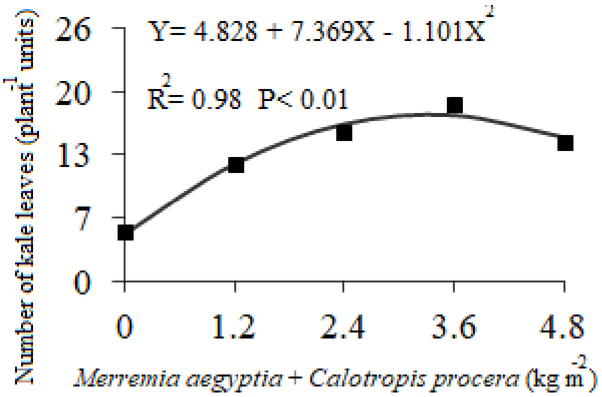

Fig. 3. Number of leaves of the leafy vegetable kale (*Brassica oleracea* L.) leaves as a function of the mixture of hairy woodrose (*Merremia aegyptia* L.) plus rooster tree (*Calotropis procera*) incorporated into the soil

The weight of leaves of the leafy vegetable kale varied according to the amounts of the mixture of hairy woodrose plus rooster tree with a maximum value of 13.84 g plant^{-1} in the amount of 3.6 kg m^{-2}, providing an average increase of 194.5% in relation to the absence of fertilization (Fig. 4). For leaf weight and fresh mass there was a similar behavior with statistical difference with values of 13.0 and 11.0 g leaf^{-1} and for weight the values were 183 and 165.5 g plant^{-1}, respectively (Table 1). Moura et al. [27] evaluating the productivity of Brassica oleracea in an organic transition system in southern Brazil, found a leaf weight of 14 g using limestone, which differs from the aforementioned research. This characteristic is of great importance, as it is the leaves that are sold.

A point of maximum production of green mass was observed in kale leaves plant^{-1} in the amount of 3.6 kg m^{-2} of the mixture of jitirana plus silk flower, with a maximum value of 188.75 g plant^{-1}, a value corresponding to 660% higher than the treatment without fertilization (Fig. 5). Linhares et al. [28] studying kale fertilized with forest pasture (*Senna uniflora*) under different amounts and forms of application to the soil, found 121.4 g plant^{-1}, a value below that of the referred research. Moura et al. [27] evaluating the productivity of Brassica oleracea in an organic transition system in southern Brazil, found plant weights of 200 g plant^{-1}, which is higher than the aforementioned research. Already, Silva et al. [30] studying the production of collard greens in response to the application of bovine manure, they found fresh mass of the area part of 91.5 g plant^{-1}, which is lower than the present work.

In relation to the productivity and dry mass of the leafy vegetable kale (kg m^{-2} of area), it was observed that the amount of 3.6 kg m^{-2} of the mixture of hairy woodrose with rooster tree, was what provided the higher increments, with maximum values of 1080.25 and 148.32 g m^{-2}, respectively (Fig. 6A, 6B). For the productivity and dry mass of the leafy vegetable kale, a

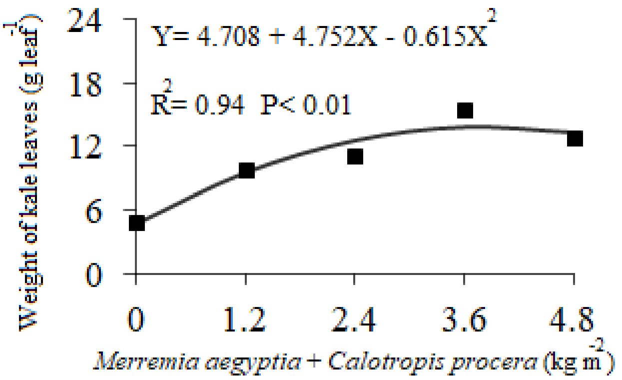

Fig. 4. Weight of leaves of the leafy vegetable kale (*Brassica oleracea* L.) leaves as a function of the mixture of hairy woodrose (*Merremia aegyptia* L.) plus rooster tree (*Calotropis procera*) incorporated into the soil

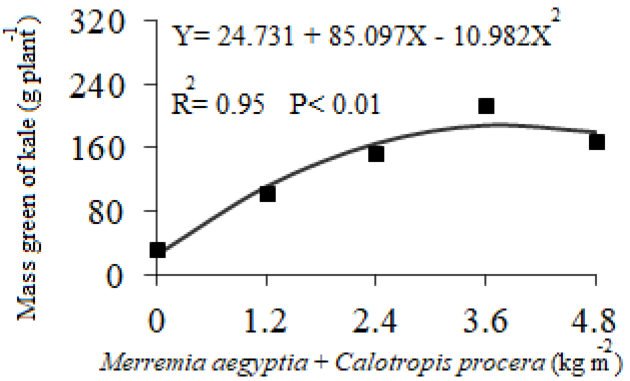

Fig. 5. Mass green of kale leafy vegetable (*Brassica oleracea* L.) leaves as a function of green manuring with different amounts of the mixture of hairy woodrose (*Merremia aegyptia* L.) and rooster tree (*Calotropis procera*)

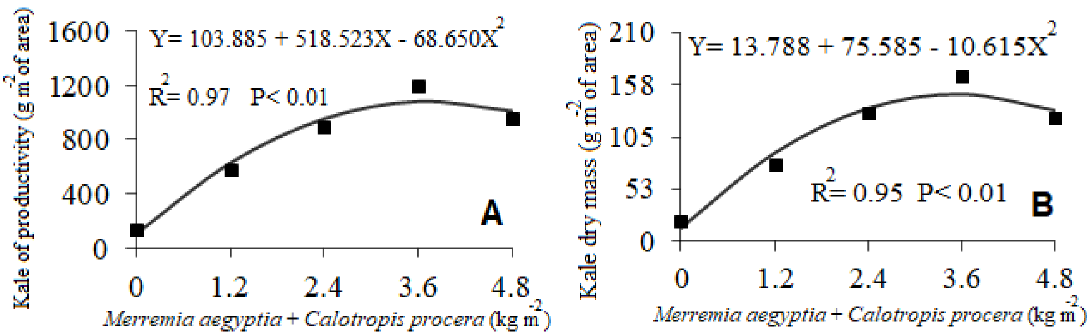

Fig. 6. Productivity (A) and dry mass (B) of the leafy vegetable kale (*Brassica oleracea* L.) as a function of green manuring with different amounts of the mixture of hairy woodrose (*Merremia aegyptia* L.) and rooster tree (*Calotropis procera*)

Table 1. Test of significance among different components of plant

Forms of application to the soil	AT	NF	PF	MV	PD	MS
Incorporated	27.6 a	17.0 a	13.0 a	183.0 a	982.0 a	130.0 a
Coverage	23.4 b	16.0 b	11.0 b	165.5 b	833.0 b	120.0 b

Different letters, differ by the F test, at the level of p<0.05 of probability
expressed in cm plant^{-1} (AT), number of leaves, expressed in plant^{-1} units (NF), leaf weight, expressed in g leaf^{-1} (PF), expressed in g plant^{-1} (MV), productivity, expressed in g m of area (PD) and dry mass, expressed in g m of area (MS)

similar behavior was observed in relation to the forms of application to the soil (incorporated and cover) of the mixture of hairy woodrose with rooster tree, with values of 982.0 and 833.0 g m^{-2} for productivity and 130.0 and 120.0 g m^{-2} for dry mass, respectively (Table 1). This statistical superiority of the incorporation in relation to the application of the green manure in coverage is probably due to the crop cycle (70 days), combined with the slower process of degradation of the material in coverage. It is worth mentioning that a spacing of 0.4 x 0.4 m was taken into account for the kale vegetable, which is widely used by family farmers, corresponding to six plants m^{-2}.

The production of the leafy vegetable kale in the region of Mossoró, Brazil, is of paramount importance for farmers who work in agroecological production, as it is part of their diet, in addition to commercialization in fairs of organic product. Linhares et al. [28] studying the leafy vegetable kale fertilized with forest pasture (*Senna uniflora*) under different amounts and forms of application to the soil, found productivity and dry mass per plant of 121.4 and 15.5 g plant^{-1}, corresponding to 728.4 and 93.0 g m^{-2}, being lower than the referred research. Sousa et al. (2002) studying the production of the leafy vegetable kale in response to the application of bovine manure, observed productivity of 91.5 and 8.25 g plant^{-1}, corresponding to 549 and 49.5 g m^{-2} for six plants, respectively, inferior to the present study.

4. CONCLUSION

The best productive performance of the leafy vegetable kale was observed in the amount of 3.6 kg m^{-2}, with values of 17.0 leaves/plant and 1080.25 g/m2 of area. Regarding the forms of application to the soil, the method of incorporation was superior to the application of fertilizers in coverage, values of 985.8 and 788.9 g m^{-2} of area, respectively. Hairy woodrose (*Merremia aegyptia* L.) and rooster tree (*Calotropis procera*) are promising species to be used as green manure.

ACKNOWLEDGEMENTS

To the Jitirana research group (CNPQ-National Council for Scientific and Technological Development, Brazil), a pioneer in Brazil in the use of spontaneous species from the semi-arid region as green manure in the agroecological production of leafy and root vegetables, and the Universidade Federal Rural do Semi-Árido-UFERSA, for the physical structure and granting of scientific initiation scholarships for the development of research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/105615