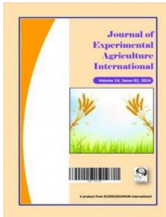

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Agronomic Efficiency of Organic Fertilised in the Production of the Intercropping of Coriander and Mint in the Northeastern Brazil

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Oleric plants are grown in a system intercropping by family farmers in organic production areas in the region northeastern Brazil. The experiment was conducted in an experimental area belonging to a semi-arid rural federal university. The study was carried out in the period from August 2014 to November 2014, in order to evaluate agronomic efficiency of organic fertilised in the production of the intercropping of coriander and mint in the northeastern Brazil. The study area was designed in a

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randomized block area, arranged in a 2 x 4 factorial scheme set up, with three replications. The first factor set up consisted of single crop and intercropping of coriander and mint, and the second was hairy woodrose (*Merremia aegyptia* L.) added to cattle manure in the amounts (0.0, 2.0, 4.0 and 6.0 kg/2.0 m^2). The evaluated characteristics for the coriander crop these were plant height, number of stems, green mass, number of bunches and dry mass. The evaluated characteristics for the mint crop these were biomass height, green mass, number of bunches, dry mass, oil content and yield oil. The agronomic efficiency of mint and coriander in intercropping was was obtained with the addition of 6.0 kg/2.0 m^2 of organic fertilised incorporated into the soil. The equivalent area ratio was agronomically efficient, with equivalent area ratio (EAR) of 1.66.

Keywords: Medicinal plant; spice; agroecological production; family farmers.

1. INTRODUCTION

Coriander (*Coriandrum sativum*, Apiaceae) originates from the territories of the Mediterranean Basin. In Brazil, this herb was introduced at the beginning of colonisation [1], produced by family farmers, the most produced vegetable in the region of Mossoró-RN [2,3]. Another species widely cultivated and marketed in the region is mint (*Mentha piperita*), used in juices and salads, and is highly appreciated by consumers.

These species have the potential to be produced in a consortium, since they have different phenological cycles, coriander, 30 to 35 days after sowing and mint, 60 days after transplant, causing competition for water and nutrients at different times in the cultivation, guaranteeing agronomic performance.

The crop consortium is an important component of sustainable farming systems, which include organic farming. It is an agricultural practice in small production units in tropical regions, especially family-based ones [4]. This system consists in the simultaneous cultivation of two or more species in the same space within the phenological cycle of the crops, being able to be sown simultaneously or different sowing times, guaranteeing a higher income to the farmers [5].

Within this context, the use of plant material of species available in production areas is of great importance to family farmers. Among the species with potential for phytomass production, jitirana, a spontaneous species from the northeastern semi-arid region of predominance in the rainy season, stands out for dry matter production of 4000 kg/ha with nitrogen concentration of 22.0 g/kg. It can be incorporated into the soil or left in the cover, becomes a viable option to be used as an organic fertiliser [6].

The mixture of organic fertilisers of vegetal and animal origin potentiates the production making the system more efficient, reducing the costs in the acquisition of agricultural inputs. The use of alternative sources as organic fertiliser in the production of vegetables has been studied by several researchers, beet [7,8]; carrot [9]; coriander [2] and lettuce [10].

Due to the importance of using the combination of fertiliser sources for the nutritional supply of the cultivation system, the objective was to evaluate agronomic efficiency of organic fertilised in the production of the intercropping of coriander and mint in the northeastern Brazil.

2. MATERIALS AND METHODS

2.1 Characterisation of the Experimental Area

The experiment was conducted in the research area of the Rafael Fernandes Experimental Farm of the Federal Rural Semi-Arid University (UFERSA), in the period from August 2014 to November 2014, in soil of the experimental area was classified as Eutrophic Red Yellow Argissolo, caatinga hyperxerophilic phase and flat relief [11,12]. The area is located in the Alagoinha district, 20 km from the Mossoró, Northeastern Brazil. The farm comprises of some 400 hectares [11].

According to the classification of Köppen, the local climate is BSwh ', dry and very hot, the dry season being normally from June to January, and a rainy season being from February to May. The average annual rainfall is 673.9 mm and the average relative humidity is 68.9% [13].

Before the installation of the field experiment, soil samples were collected to a 0-20 cm layer and then sent to be processed and analysed in the

UFERSA Water, Soil and Plant Analysis Laboratory, providing the following results: pH (water 1:2,5) = 6.65; exchangeable cations Ca = 0.60 $cmol_c/dm^3$; Mg = 0.75 $cmol_c/dm^3$; K = 40.2 mg/dm^3; Na = 9.5 mg/dm^3; P (Mehlich) = 8.6 mg/dm^3; organic matter = 1.20 g/kg; Coarse sand = 610 g/kg; fine sand = 290 g/kg; silte = 20 g/kg; clay = 70 g/kg, soil density = 1.42 g/cm^3.

2.2 Experimental Design and Treatments

The study area was designed in a randomized block area, arranged in a 2 x 4 factorial scheme set up, with three replications. The first factor set up consisted of single crop and intercropping of coriander and mint, and the second was hairy woodrose (*Merremia aegyptia* L.) added to cattle manure in the amounts (0.0, 2.0, 4.0 and 6.0 kg/2.0 m^2). The organic fertiliser remained incubated in the soil for a period of 30 days before planting [2].

The preparation of the soil consisted in the removal of the vegetal material and in the survey of the beds using rotocanteirador. Before sowing the coriander and transplanting the mint, the soil was kept moist, contributing to the mineralisation process [14].

For the coriander crop, the plot was 1.4 m x 1.4 m, with a total area of 1.96 m^2, containing 1560 coriander plants with 0.1 m x 0.05 m spacing with five plants per pit [3]. In intercropping, the coriander was placeding between the mint seeding rows. The coriander crop variety used was Verdão cultivar.

The cultivar "*Mentha piperita*" was used for the mint crop. The study plots were 1.4 m x 1.4 m, with a total area of 1.96/m^2, with 40 plants in each, spaced 0.35 m x 0.2 m respectively. The yielding area, was therefore 1.26/m^2, with 18 plants.

2.3 Chemical Composition of Organic Fertilisers

The hairy woodrose (*Merremia aegyptia* L.) was collected in june of 2014, in an area of semi-arid shrub vegetation in the flowering period. Soon after being harvested the material was crushed and dried in the sun, being packed in raffia bags to be used as an organic fertiliser. The material was sent to the soil fertility and nutrition laboratory at the Federal University of the Semi-arid Agricultural Sciences Center, with a chemical concentration of 22.5 g/kg of nitrogen (N); 890 g/kg of organic matter (OM); 412 g/kg of organic carbon (CO); 18/1 carbon/nitrogen ratio (C/N); 0.75 g/kg of phosphorus (P); 4.87 g/kg potassium (K^+); 1.20 g/kg sodium (Na^+); 0.32 g/kg of calcium (Ca^{2+}) and 0.08 g/kg of magnesium (Mg^{2+}).

The cattle manure used was stabilised and sourced from the heifers of the UFERSA cattle herd, which are raised in an intensive system, fed with corn-based concentrate, soy bean and wheat bran, and having as bulk Canarian grass (*Echinocloa polystochya*), with chemical concentration of: 16.5 g/kg of nitrogen (N), 890 g/kg organic matter (OM); 401 g/kg of organic carbon (OC); 25/1 of carbon/nitrogen ratio (C/N) 0.68 g/kg of phosphorus (P); 5.87 g/kg of potassium (K^+); 0.70 g/kg of sodium (Na^+); 0.23 g/kg of calcium (Ca^{2+}) and 0.05 g/kg of magnesium (Mg^{2+}), carried out in the soil fertility and plant nutrition laboratory of the agrarian science center of the Federal Rural University of the semi-arid.

2.4 Harvest and Evaluation of the Intercropping

The harvest was carried for culture of coriander, at thirty-five days after sowing and for mint crop to sixty days after transplanting. After harvesting, plants were transported to the Post-Harvest of Vegetables Laboratory of the Agrarian Science Center of the Federal Rural University of the semi-arid.

For the coriander crop, the following characteristics were evaluated: For the mint crop, the following characteristics were evaluated: *plant height* (was measured in the field, in centimeters using millimeter ruler, twenty plants per plot), *green mass production* (It was obtained through the cut of the aerial part, within the useful area, weighed in a precision scale of 1.0 g, expressed in kg/100 m^2); *number of bunches* (determined by the division of production in kg/100 m^2 per 50g, corresponding to the weight of the sauce in the supermarket of Mossoró, Northeastern Brazil); *dry mass production* (was obtained from a forced-air heating oven at 65 °C, to constant mass and expressed in kg/100 m^2).

For the mint crop, the following characteristics were evaluated: *biomass height* (was measured in the field, in centimeters using millimeter ruler, twenty plants per plot), *green mass production* (It was obtained through the cut of the aerial part, above 5 cm, within the useful area, weighed in a precision scale of 1.0 g, expressed in kg/m^2); *number of bunches* (determined by the division of production in kg/m^2 per 100g, corresponding to the weight of the sauce in the supermarket of Mossoró, Northeastern Brazil); *dry mass production* (was obtained from a forced-air heating oven at 65 °C, to constant mass and expressed in kg/m^2), *Oil content* (It was defined by the ratio between the mass in grams of essential oil by the mass of dry leaves inserted into the distillation flask x 1000, being expressed in g/kg) and *Oil production* (It was determined by the oil content in g/kg x the production of dry mass in kg/m^2, being expressed in g/m^2).

For the determination of oil content and yield, dry leaves were used, that the water content in the leaves, after drying, allows the vapor stream generated in the extractor to remove the volatile substances stored in cells, when compared to the green material [15]. Due to the high moisture content in the plants, there is a strong tendency to agglutinate preventing the steam from penetrating more easily of form uniform in plant tissues [16].

In determining the essential oil content and yield, dry mass samples were subjected to hydrodistillation in a modified Clevenger apparatus for 1.5 h, using 600 mL of distilled water in 1 L distillation flask [17].

It was also determined the efficiency of the intercropping through the ETS, defined as the relative area of land under isolated planting conditions required to provide the productivities reached in the consortium [18]. Defined by the following expression: ETS = (Yccm/Ysc) + (Ymcc/Ymsc), where the following is true: Yccm = productivity of coriander consorted with mint; Ysc = productivity of coriander in single crop; Ymcc = productivity of mint consorted with coriander; Ymsc = productivity of mint in single crop.

2.5 Statistical Analysis

An analysis of variance was performed on each feature of mint, through the application ESTAT [19]. Those of a quantitative nature (mixture of hairy woodrose with cattle manure), the procedure for adjusting the response curve was performed using the Table Curve [20] application. For the qualitative characteristics (single cropping and intercropping of coriander and mint), the Tukey test ($p<0.05$).

3. RESULTS AND DISCUSSION

3.1 Cultivation of Mint

Significant interaction was observed for characteristic yield of oil (Table 1). However, there was an isolated effect at the level of probability ($p<0.01$) in the different amounts of organic fertiliser for all characteristics studied (Table 1). In relation to the cultivation systems (single crop, and intercropping), there was a statistical difference in the level of probability ($p<0.01$), for the characteristics of green mass, number of sauces, dry mass, percentage and yield of oil (Table 1), probably due to interspecific competition for water, nutrients and physical space, demonstrating the exploitation capacity of the cultivated area.

There was an increasing effect due to the different amounts of organic fertiliser at plant height, with a value of 29 cm, in the amount of 6.0 kg/2.0 m^2 (Fig. 1). In relation to the cultivation systems (single crop and intercropping), there was a statistical difference, with a mean value of 32.3 and 28.2 cm, respectively (Table 2).

Table 1. F values for biomass height, expressed in cm (BH), green mass, expressed in kg/2.0 m^2 (GM), number of bunchs, expressed in units/2.0 m^2 (NB), dry mass, expressed as g/2.0 m^2 (DM), percentage of oil, expressed as% (PO) and oil yield, expressed in g/2.0 m^2 (OY) of mint as a function of organic fertilisation

Causes of variation	GL	BH	MV	NM	MS	PO	RE
Amounts of fertilisers (A)	3	9.33^{**}	12.82^{**}	12.59^{**}	9.19^{**}	2.71^{ns}	6.86^{*}
Cultivation system (B)	1	8.17^{**}	13.13^{**}	12.90^{**}	8.07^{**}	1.51^{ns}	7.55^{*}
A X B	3	1.86^{ns}	2.00^{ns}	1.66^{ns}	1.50^{ns}	0.93^{ns}	0.90^{ns}
Treatments	7	----	----	----	----	----	----
Blocks	2	4.64^{*}	5.29^{*}	4.10^{*}	6.65^{*}	0.78^{ns}	5.80^{*}
Residue	14	----	----	----	----	----	----
CV (%)	----	13.41	11.70	12.3	10.70	8.88	6.95

*** = P <0.01; * = P <0.05; ^{ns} = not significant*

Behavior lower, with values of 24.7 and 23.7 cm in single crop and intercropped cultures was observed by Carvalho et al. [21], in the cultivation of mint. Almeida [22] evaluating the production of mint under doses of jitirana and harvesting times, with biomass height of 34.6 cm at 90 days after transplanting, value exceeding this research.

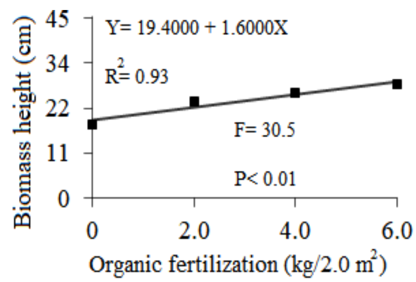

Fig. 1. Mint biomass height as a function of amounts of organic fertiliser

For green mass and number of bunches, the dose of 6.0 kg/2.0 m^2 of organic fertiliser, contributed the largest increase, with an average of 3.94 kg/2.0 m^2 and 39.4 units de bunches/2.0 m^2, respectively (Figs. 2A and 2B). The single crop was statistically higher to the intercrop, with mean values of 4.1 and 3.2 kg/2.0 m^2 for green mass, corresponding to 41.0 and 32.0 mint sauces, respectively (Table 2).

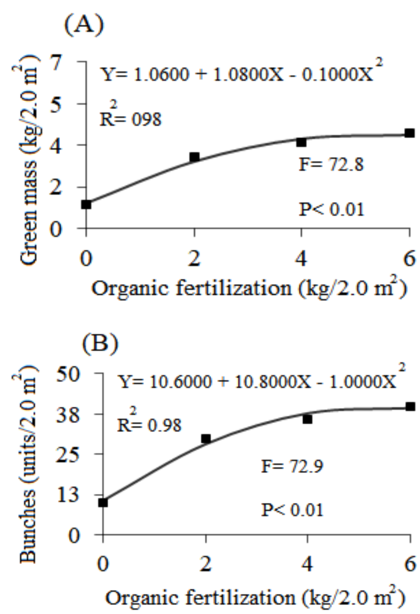

Fig. 2. Green mass (A) and number of bunches (B) of mint as a function of amounts of organic fertilizer

The number of mint sauces is of paramount importance to family farmers because it represents the form of commercialisation in supermarkets and agro-ecological fairs. Completed searches found green mass of 322.5 g/m2 in the cultivation of peppermint intercropped with lettuce, being less than said research [23].

There was an increase of 270.6 g/2.0 m2, in the dry mass between the amounts of 0 kg/ 2.0 m2 and 6.0 kg/2.0 m2, adjusting a linear equation of 1 degree, with a maximum value of 396.1 g/2.0 m^2 (Fig. 3). The single crop was statistically superior to the intercropping with values of 412.5 and 374.2 g/2.0 m^2 (Table 3). The dry mass is the best way to evaluate plant growth, considering that this characteristic is not influenced by soil moisture [24].

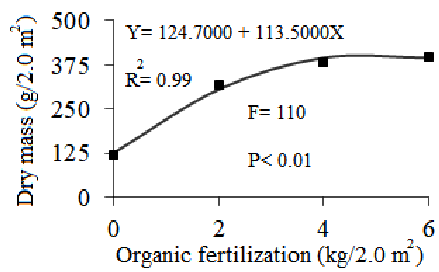

Fig. 3. Dry mass of mint as a function of amounts of organic fertiliser

No statistical difference was observed for the oil content, with average value of 2.1 g/kg. Similar behavior was observed in the cultivation system (single crop and intercropped) with mean values of 2.1 and 2.0, respectively (Table 3). According to Chagas et al. [25], the essential oil content constitutes a genetic characteristic, not changing as a function of the amount of biomass produced.

Unfolding the amounts of organic fertiliser within the cropping system (single crop and intercropping), with average values of 8.69 and 4.58 g/2.0 m^2 (Fig. 4). For the crop system (single crop and intercropping) there were unfolding within of the amounts, being the single crop superior statistically to the intercropping in the amounts of 0.0; 2.0; 4.0 and 6.0 kg/2.0 m^2 (Table 3). The increase in the yield of essential oil, possibly occurred to the increase in the production of green mass and dry mass of the plants, as a function of the amounts of organic fertilised incorporated to the soil. Results lower was observed by Sousa [26], with a value equivalente of 4.0 g/2.0 m^2. Almeida [22] evaluating the production of mint under doses of jitirana and harvesting times, with oil yield of 3.7 g/2.0 m^2 at 90 days after transplanting, lower than said research.

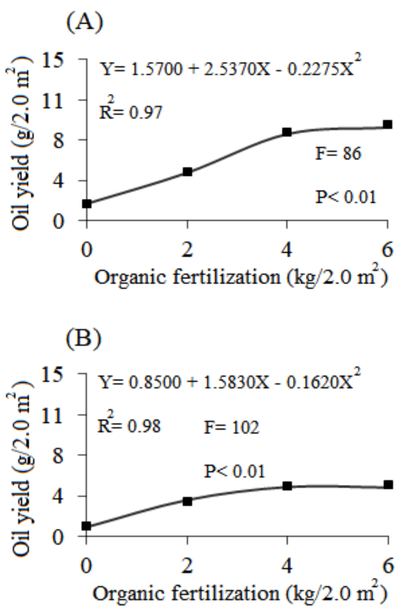

Fig. 4. Oil yield of mint as a function of amounts of organic fertiliser

3.2 Cultivation of Coriander

There was significant interaction for green mass, number of sauces and dry mass of coriander. For the factor amounts fertiliser organic and in the cultivation system (single crop and intercropping), a statistical difference was observed at the level of $p < 0.01$ (Table 4).

For plant height, it was observed a point of maximum height, with value of 19.2 cm/plant in the amount of 6.0 kg/2.0 m^2 of organic fertiliser (Fig. 5). In the cultivation system (single crop and intercropping) were statistically similar, with mean values of 19.0 and 18.6 cm/plant, respectively (Table 5), lower values were observed by Linhares et al. [27] and Linhares et al. [3], with mean values of 20.5 and 22.0 cm/plant of coriander, respectively. Height of plant is an important characteristic in the commercialisation of coriander, being the standard of commercialisation above 15 cm.

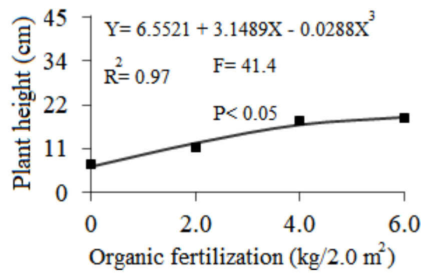

Fig. 5. Height of coriander plant as a function of organic fertilisation

The amount of organic fertiliser of 4.0 kg/2.0 m^2 contributed to a number of stems of 6.5 stems/plant (Fig. 6). In the cultivation system (single crop and intercropping), there was similarity between the observed data with values of 6.3 and 5.8 stems/plant, respectively (Table 5). Behavior superior to that found in the research was observed by Linhares et al. [27] in coriander and [2] in the coriander culture, with values of 6.0 and 8.5 stems/plant, respectively.

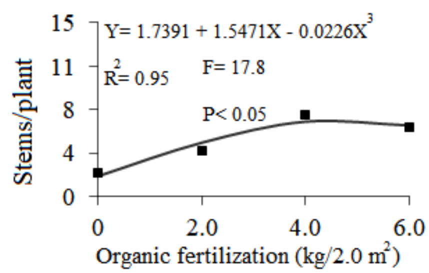

Fig. 6. Stems/plant of coriander as a function of organic fertilisation

When unfolding the interaction in the organic fertiliser quantities within the growing system (single crop and intercropping) was observed values of 1200 and 790 g/m^2 for green mass (Figs. 7A and 7B) and 500 and 350 units /2.0 m^2

Table 2. Evaluation of the characteristics biomass height, expressed in cm plant (BH), green mass, expressed in kg/2.0 m^2 (GM) and number of bunches, expressed in units/2.0 m^2 (NB) of mint as a function of organic fertilisation

Cultivation system	BH	GM	NB
Single	32.3 a	4.1 a	41.0 a
Intercropping	28.2 a	3.2 b	32.0 b

**Means followed by similar lowercase letters in the column differ statistically by Tukey test at 5% probability*

Table 3. Unfolding of the cropping system (single crop and intercropping) within of the amounts of organic fertilized

Cropping system	Amounts of organic fertilised (kg/2.0 m^2)			
	0.0	**2.0**	**4.0**	**6.0**
Single crop	1.6 a	4.52 a	8.20 a	8.69 a
Intercropping	0.78 b	3.15 b	4.70 b	4.75 b

**Means followed by different lowercase letters in the column differ statistically by Tukey test at 5% probability*

Table 4. F values for plant height, expressed in cm plant (HP), number of stems, expressed in terms of average (NS), green mass of coriander, expressed in kg/2.0 m^2 (GM), number of bunches, expressed in units/2.0 m^2 (NB) and dry mass, expressed in g/2.0 m^2 (DM) of coriander as a function of organic fertilisation

Causes of variation	GL	HP	NS	GM	NB	DM
Amounts of fertilisers (A)	3	28.42^{**}	15.60^{**}	17.22^{**}	16.59^{**}	12.46^{**}
Cultivation system (B)	1	0.12^{ns}	1.10^{ns}	9.90^{**}	8.30^{**}	18.24^{**}
A X B	3	0.35^{ns}	0.54^{ns}	2.66^{*}	5.16^{*}	7.34^{**}
Treatments	7					
Blocks	2	5.6^{*}	6.8^{*}	4.10^{*}	5.08^{*}	4.70^{*}
Residue	14	----	----	----	----	----
CV (%)	----	20.4	16.9	17.4	17.9	13.8

*** = P<0.01; * = P<0.05; ^{ns} = não significativo*

for number of sauces of coriander (Figs. 8A and 8B). When unfolding the cultivation system (single crop and intercropping) in the different amounts of organic fertiliser, observed a statistically significant difference for the green mass (Table 6) and number of sauces (Table 7).

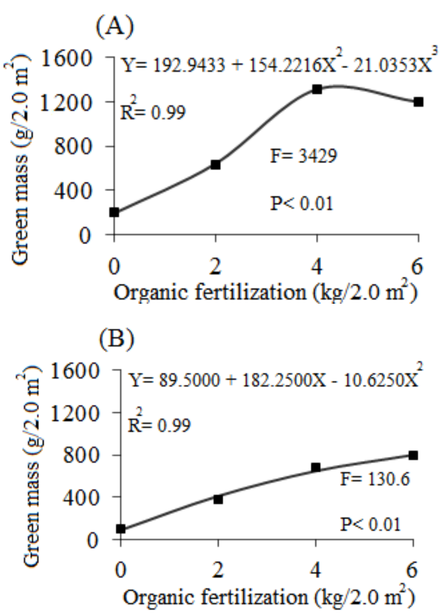

Fig. 7. Green mass of coriander as a function of single crop (A) and of cultivating intercropping (B) under amounts of organic fertiliser

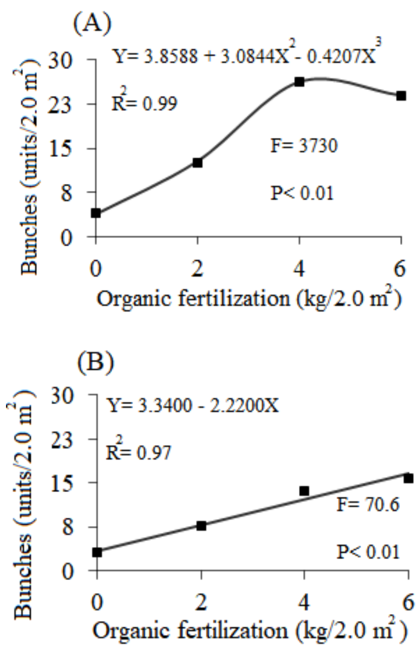

Fig. 8. Bunches of coriander as a function of single crop (A) and of cultivating intercropping (B) under amounts of organic fertiliser

The inferiority of the single crop system in relation to the consortium is probably due to the competition for water, light and nutrients, in addition, the number of plants was inferior to the consortium. The number of sauces is the form of commercialisation of the coriander in the gondolas of supermarkets and the agroecological fair, being of great importance for the family farmers in the region of Mossoró, RN, Brazil.

Linhares et al. [28], studying evaluating optimised amount of hairy woodrose (*Merremia aegyptia* L.) in the productivity of coriander cultivars, verifieding yiel of 98.6 kg/100 m^2, equivalent to 1972 g/2.0 m^2 and 39.4 coriander sauces, being higher than said research. Linhares [29], studying the roostertree (*Calotropis procera*) under different amounts and periods of incorporation on yield of coriander with an average yield of 4404 kg/ha, equivalent to 880 g/2.0 m^2, corresponding to 17,6 bunches, being lower the present research.

Similar behavior was observed for the dry mass of coriander, with values of 146.7 and 79.9 g/2.0 m^2, within the cultivation system (single crop and intercropping), respectively, in the amount of 4.0 kg/2.0 m^2 of organic fertiliser (Figs. 9A and 9B). In relation to the cultivation system (single crop and intercropping) within the amounts of organic fertiliser, the single crop was statistically superior to the intercropping, with values of 150 and 88 g/m^2, respectively. The dry mass is a characteristic that accurately measures plant growth, since it is not influenced by soil moisture conditions. Lower behavior was obtained by authors [2,29,30] evaluating spontaneous species in substitution of chemical fertilisation, with values below that research.

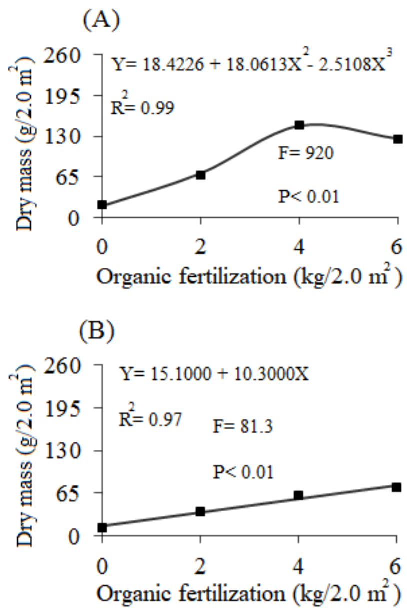

Fig. 9. Bunches of coriander as a function of single crop (A) and of cultivating intercropping (B) under amounts of organic fertiliser

Table 5. Evaluation of the characteristics plant height, expressed in cm plant (HP), number of stems, expressed in terms of average (NS) of coriander as a function of organic fertilisation

Cultivation system	HP	NS
Single	19.0 a	6.3 a
Intercropping	18.6 a	5.8 a

**Means followed by similar lowercase letters in the column differ statistically by Tukey test at 5% probability*

Table 6. Unfolding the interaction cultivation system (single crop and intercropping) in the different amounts of organic fertiliser in the green mass of coriander, expressed in kg/2.0 m^2

Cultivation system	Amounts of organic fertiliser (kg/2.0 m^2)			
	0	2.0	4.0	6.0
Single	150 a	610 a	1300 a	1200 a
Intercropping	90 b	390 b	390 b	830 b

**Means followed by different lowercase letters in the column differ statistically by Tukey test at 5% probability*

Table 7. Unfolding the interaction cultivation system (single crop and intercropping) in the different amounts of organic fertiliser in the number of sauces of coriander, expressed in kg/2.0 m^2

Cultivation system	Amounts of organic fertiliser (kg/2.0 m^2)			
	0	2.0	4.0	6.0
Single	4.0 a	13.0 a	26.0 a	23.0 a
Intercropping	3.0 b	8.0 b	13.0 b	16.0 b

**Means followed by different lowercase letters in the column differ statistically by Tukey test at 5% probability*

Agronomically, two crops are suitable to be intercropping, if the production has an equivalent area ratio greater than 1, indicating superiority to the single crop.

In this context, the consortium of condiment vegetables presented superiority to the single crop, with an equivalent area ratio of 1.66, in the amount of 4.0 kg/2.0 m^2 of organic fertiliser (Fig. 10). A single crop area of 66% would be required to have a similar production to the intercropping. For family farmers in the region Mossoro, RN, Northeast Brazil, who cultivate small areas, the use of two or more cultures in the same physical space, contributes to the best use of the area in the environmental and economic aspect.

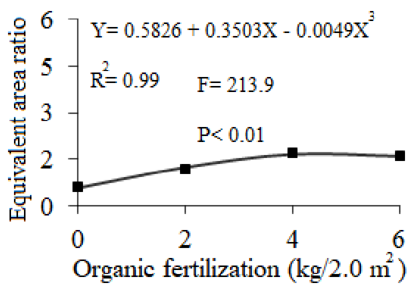

Fig. 10. Equivalent area ratio under amounts of organic fertiliser

4. CONCLUSION

The agronomic efficiency of mint and coriander in intercropping was obtained with the addition of 6.0 kg/2.0 m^2 of organic fertilised incorporated into the soil. The equivalent area ratio was agronomically efficient, with equivalent area ratio (EAR) of 1.66.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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