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Greenhouse crops of radish under organomineral fertilization sources in the Brazilian semiarid region

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ABSTRACT

The cultivation of radish in an organic system has potential for production to such a degree that alternatives of cultivation have been used to improve productivity in relation to fertilization. Therefore, the objective of this work was to evaluate the effect of organomineral fertilization on gas exchange, growth, and production of radish. The experiment was carried in non-climatized greenhouse crop, with a metallic structure in form of arc, covered with 150 mm low-density polyethylene, in greater length-oriented East-Oste direction of Science and Technology Center of Federal University of Campina Grande, using the Crimson Gigante variety. The soil used experiment was fluvic neosol. The experimental design used was the completely randomized with three replications, using the Crimson Gigante variety. Seven treatments were used, which consisted of three doses of cattle manure (37.5; 75.0, and 150g per pot), three concentrations of biofertilizer (5; 10 and 15%), and mineral fertilization. This work analyzed the characteristics of growth, production, and gas exchange. The treatment (5% biofertilizer) provided greater height of the radish plants, however, the (75.0g manure per pot) resulted in a higher number of leaves. The concentration of 10% of the biofertilizer, obtained the largest diameter, fresh and dry matter of the tuberous root. The treatment presented higher fresh and dry matter of the leaves when compared with the other treatments. The use of organic fertilizers promoted greater production in the radish crop and can be used as an alternative to conventional fertilization.

INTRODUCTION

The radish (*Raphanus sativus* L.), a small brassica species, is one of the vegetables that have been grown for more than three thousand years in western Asia (China) and southern Europe (FILGUEIRA, 2008). In comparison to other vegetables, its consumption is not popular but it is as a good option for family farming whose main focus is the promotion of organic production in the countryside, without the use of pesticides and chemical fertilizers (SEDIYAMA et al., 2014).

Radish plants have high nutritional requirements which was reported by Basha and El-Aila (2015) in their work using foliar fertilization with amino acids and fertilizers. Therefore, it is clear that in some studies significant responses were observed in relation to the intercalated or not application of manure with biofertilizers (KUMAR et al., 2014).

The use of manure improves the physical and chemical characteristics of the soil, increasing the penetration and retention of water and the soil's microfauna providing a reduction in chemical fertilizers that can meet the demand by the crop (MEDEIROS et al., 2019). Another benefit provided by organic fertilization is the slow effect of nutrient release (YAGIOKA et al., 2014). This gradual release of nutrients to the plant allows economy in the use of fertilizers. Thus, the recommendation of Trani et al. (2018) is to apply 30 to 50 t ha^{-1} of tanned cattle manure. Silva et al. (2017), working with green manure found that the supply of nutrients by green manure and the period of maximum demand for radish was observed in the time of incorporation of 22 days before planting so that it provided greater commercial yields and total roots.

Another form of fertilization is the use of biofertilizers, which has been recommended to maintain the nutritional balance of plants. Thus, the use of this product by small farmers is a viable and economical alternative, as a recommended practice for fertilization purposes (ALGERI et al., 2020). Biofertilizers mainly consist of a positive alternative to chemical fertilizers. They can increase the biological fixation of N, the availability and absorption of nutrients besides stimulating natural hormones (MOSA et al., 2014). According to Sousa et al. (2016), cattle biofertilizer provides high values in the growth and productivity of radish.

On the other hand, mineral fertilization is widely used in the fertilization of radish. It is possible to mention several works that corroborate for the increase in the productivity. The increase in the nitrogen dose (from 0 to 100 kg ha^{-1}) in radish provided greater production of leaves and roots, as well as in the number of commercial roots (QUADROS et al., 2010). As a result, alterations may happen in the development, modifying the physiology and the morphology of the plant, as well as the soil, making it necessary, then, to carry out experiments to verify the effect of the combined use of organic fertilizers and mineral fertilizers, for the supply of nutrients, according to the growth and in the crop production (CORTEZ et al., 2010). The organic fertilizers added to the soil do not immediately make available the total amounts of nutrients to the plants, but they bring numerous benefits, so a continuous application of organic fertilizers tends to favor the gradual accumulation of nutrients in the soil, providing a residual effect for subsequent crops.

Experiments regarding the combined use of organic fertilizers, manure and liquid fertilizers and their effects on short-cycle crops, such as radishes, are scarce (CORTEZ et al., 2010). Therefore, the objective of this work was to evaluate the gas exchange, growth, and production of the radish fertilized with cattle manure, biofertilizers, and mineral fertilization.

MATERIAL AND METHODS

Location and characterization of the experimental site

The experiment was em casa-de-vegetação não climatizada, com estrutura metálica em forma de arco, coberta com 150 mm de polietileno de baixa densidade (PBDE), com maior comprimento orientado no sentido Leste-Oste, using pots, at the Center for Science and Agri-Food Technology (CCTA) of the Federal University of Campina Grande (UFCG), Pombal campus Paraiba State (PB), Brazil (6°46'12" latitude S and 37°48'7" longitude W and an average altitude of 184 m). According to the Köppen's classification, the local climate is BSw'h', characterized as hot and dry semi-arid, with an average annual rainfall of 700 mm, high temperatures, leading to strong evaporation, the average annual temperature of 30.5°C, with only two well-defined climatic seasons throughout the year, one rainy season and the other is the dry season.

The soil of the experimental area, was characterized following the criteria of the Brazilian soil classification system (SiBCS) (EMBRAPA 2013), therefore classified as Fluvic Neosol. Prior to the experiment setting, a soil sample was taken to determine the following physical characteristics: Sandy-loam texture (sand = 0.81; silt = 0.03; clay = 0.15; and silt/clay ratio = 0.15 kg / kg^{-1}) and chemical analysis: pH (water) = 7.0; P = 28.6 mg dm^{-3}; K = 45.5; Na = 33.0; Ca = 4.20; Mg = 3.40; Al = 0.0; H + Al = 0.0; SB (sum of bases) = 7.86; t = 7.86; CEC = 7.86 cmolc dm^{-3}; V = 100%; m = 0%; PST = 2%.

Experimental design and treatments

The experimental design used in this work was the completely randomized, consisting of seven treatments and three replications, with three plants per plot. T1 = soil + cattle manure (37g equivalent to 15 t ha^{-1}); T2 = soil + cattle manure (75g equivalent to 30 t ha^{-1}, recommended dose); T3 = soil + cattle manure (150g equivalent to 60 t ha^{-1}); T4 = soil + 5%(v:v) biofertilizer; T5 = soil + 10% biofertilizer; T6 = soil + 15% biofertilizer; T7 = soil control + mineral fertilizer (coverage).

Experiment conduction and setting

The radish cultivar Crimson Gigante was used in the experiment. Sowing was performed in a pot with a capacity of 5 dm³, placing three seeds and, after total emergence, the plants were chopped leaving one plant per pot, being filled with soil. The experimental plot consisted of three plants.

First, the treatments that received cattle manure were previously incorporated fifteen days before the beginning of the experiment. The chemical characteristics were, as follows: EC: 4.12 dS m^{-1}; pH ($CaCl_2$) = 7.3; P = 244 mg dm^{-3}; K = 12.5; Na = 5.81; Ca = 5.20; Mg = 10.40; Al = 0.0; H + Al = 0.0; SB = 33.91; CEC = 33.91 cmol$_c$ dm^{-3}; OM = 362 g kg^{-1}. Then, all treatments received the mineral fertilizer at planting, using the following amounts: 1.7 g of Urea; 17.0 g of MAP and 4.25 g of KCl per pot, adapted according to Trani et al. (2018).

The chemically enriched biofertilizer was obtained through anaerobic fermentation, using 200-L barrels for 30 days, with a hose connected to a transparent plastic bottle with water to remove methane gas through the fermentation of anaerobic bacteria. The biofertilizer was prepared using a mixture of cut leaves of leguminous species (2 kg), milled corn grains (2 kg), cattle milk (1 liter), cane juice (1 liter), ash (1 kg), fresh cattle manure (4 kg), borax and zinc sulfate (10 g each) and 500 g of urea, 500 g of ammonium phosphate and 500 g of KCl.

Over the experiment period, five applications of the biofertilizer solution were carried out on the radish plants, every seven days. The application was done in the coldest hours of the day, which was in the morning. The biofertilizer applications were carried out weekly with a volume of 150 ml of the solution in each pot. The T7 control treatment received five topdressing fertilization using 0.4g of urea and 0.22g of KCl. Each pot received, in each application, the solution of the nutrients diluted in water, promoting a better absorption by the radish plants. Also, five applications of Fe - EDTA iron were also carried out, where 1 ml of the stock solution was placed into 1 L of water, according to Trani et al. (2018).

After fermentation, three samples of the biofertilizer were collected in the upper, middle, and lower parts of the barrel and diluted in water at the proportion of 1:1 to evaluate the electrical conductivity, pH, and chemical composition. The electrical conductivity and pH of the biofertilizer at concentrations of 5, 10, and 15%, were respectively: 0.91; 1.47 and 2.03 dS m^{-1} and 6.01; 6.21 and 6.47. The results of the chemical analysis of the biofertilizer showed the following equivalent results: N = 7.0; P = 0.48; K = 126.2; Ca = 51.5; Mg = 28.0 g kg^{-1}.

Cultural management

In the first fifteen days of cultivation, irrigations supplying 70 mL were performed manually once a day (morning). After the fifteen days, the irrigations were carried out twice a day (morning and afternoon), supplying 14 mL. Other cultivation practices, weed control, and pest control were always carried out when necessary.

Evaluated parameters and statistics

The gas exchanges of the plants were determined using the LCPro + portable photosynthesis meter (ADC BioScientific Ltda), operating with irradiation of 1200 µmol photons m^{-2} s^{-1} and CO_2 from the environment at 3 m above the soil surface, obtaining the following variables: CO_2 assimilation rate (A) (µmol m^{-2} s^{-1}), transpiration (E) (mol of

H_2O m^{-2} s^{-1}), stomatal conductance (gs) (mol of H_2O m^{-2} s^{-1}) intercellular CO_2 concentration (Ci) (μmol m^{-2} s^{-1}). The readings were performed on the third leaf counted from the apex, 40 days after transplanting (DAT) of the radish plants.

The radish plants were harvested at 50 DAT and then the following were evaluated: i) plant height (HEIGHT), measured with a ruler graduated in centimeters (cm) from the base to the last photosynthetically active leaf; ii) the number of leaves per plant (NL), by counting mature leaves; iii) diameter of the tuberous root (TRD), measured with a digital pachymeter using the largest longitudinal diameter of the radish and expressed in centimeters (cm); iv) fresh and dry matter of the leaf (LFM and LDM) and fresh and dry matter of the tuberous root (TRFM and TRTD), obtained through the collecting of the material, then washing (running water, 3 ml L^{-1} of detergent solution, water current, 0.1 mol L^{-1} HCl solution and distilled water, respectively) followed by partition and finally drying it in a forced circulation oven at 65 ºC for 72 hours and weighing on an analytical scale, with values expressed in grams per plant (g plant^{-1}).

The data obtained were subjected to analysis of variance using the F test. For the significant evaluated characteristics, the Tukey test was applied to compare the means of the suggested treatments. All tests were performed at a probability level of 0.05 using the statistical software SISVAR version 5.1 (FERREIRA 2011).

RESULTS AND DISCUSSION

Growth and production

It was found that all the assessed characteristics were significant at 1% probability, by the ‘F’ test.

Having a larger number of leaves and a greater fresh and dry leaf matter, T2 (30 t ha^{-1} of manure) was enough to translocate the photoassimilates in the tuberous root, thus reflecting an increment in the production. On the other hand, T3 (60 t ha^{-1} of manure) expressed the lowest production in all the characteristics evaluated concerning T2, except for plant height and root diameter. The increase in the manure dose may have promoted a nutritional imbalance in the plant and a consequent reduction in production in the evaluated characteristics (Table 1). Similar results were observed by some authors, such as Cortez et al. (2010), and Lanna et al. (2018), who found a reduction in production as well as in the percentage of split roots with the increase in manure doses when working with doses of radish cattle manure. Sediyama et al. (2014) also points out that the nutritional balance provides greater productivity than separately greater amounts of macronutrients.

It was observed that the plant height was influenced by the treatments, so that the T4 (5% of the biofertilizer in the concentration of 52.5 mL L^{-1},) showed a higher mean although it did not differ from the treatments 1, 5, 6, and 7. The higher plant height may be related to the availability of nitrogen, an essential element in plant growth and responsible for leaf expansion, due to the supply through organic fertilization (SILVA et al., 2016). On the other hand, the use of biofertilizer in treatments 5, 6, and 7 improved the physical, chemical, and biological properties of the soil (data not shown), in addition to providing greater and better plant development, which was also observed by Pereira et al. (2013).

It was observed even though it did not differ from the T2, the T5 treatment showed better results of the diameter of the tuberous root, fresh and dry matter of the tuberous root, displaying means of 4.37cm; 41.82g and 2.91g, respectively (Table 1). The superiority of the T5 treatment may be related to the number of nutrients available in the biofertilizer. In this case, 10% of the biofertilizer, that is, 126.2 g kg-1 (data analysis of the biofertilizer) was sufficient to meet the needs of the crop, considered an organic fertilizer with readily available fertilizer with nutrients readily available to act as an alternative to mineral fertilizer for plants. The effect of applying biofertilizers to the soil has also been observed by some authors such as Santos et al. (2019), when working with yields of cattle-biofertilized strawberry found that the highest doses of biofertilizer imply maximum productivity. The reports in other cultures were observed by Freitas et al. (2011) when evaluating green manure, organic compost, and biofertilizer and found that the biofertilizer applied to broccoli promoted a greater production. Sediyama et al. (2014), report that one of the main alternatives for supplementing nutrients in organic vegetable production is the use of liquid organic fertilizers.

Table 1 Plant height (HEIGHT), Number of leaves (NL), Diameter of the tuberous root (TRD), leaf fresh matter (LFM) leaf dry matter (LDM), tuberous root fresh matter (TRFM) tuberous root dry matter (TRDM) in radish plants cultivated in a protected environment and fertilized with alternative sources organomineral

Treatments*	HEIGHT (cm)	NL	TRD (cm)	LFM (g)	LDM (g)	TRFM (g)	TRDM (g)
T1	19.17ab	7.67ab	4.12a	29.96 bc	2.44 bc	32.90 ab	2.25abc
T2	18.23 bc	9.67a	3.86ab	44.58a	3.74a	41.03 a	2.71ab
T3	16.10 c	6.67 b	3.12 b	13.60 d	1.34 d	17.73 d	1.28c
T4	21.27a	8.00ab	3.84ab	37.95ab	3.14abc	28.82 bc	2.03abc
T5	19.50ab	7.33ab	4.37a	40.41a	3.32ab	41.82 a	2.91a
T6	18.87abc	6.33 b	2.92 b	25.76 c	2.12 cd	18.38 cd	1.55 bc
T7	19.07abc	7.00 b	3.63ab	29.77 bc	2.75abc	29.97 b	2.41abc
DMS	3.02	2.51	9.52	8.24	1.05	10.70	1.19

* T1 – 37 g cattle manure per pot (15 t ha^{-1}); T2 – 75 g cattle manure per m² (30 t ha^{-1}) recomended; T3 – 150 g cattle manure per m² (60 t ha^{-1}); T4 – 5% biofertilizer at a concentration of 52.5 mL L^{-1}; T5 – 10% biofertilizer at a concentration of 105 mL L^{-1}; T6 – 15% biofertilizer at a concentration of 157.5 mL L^{-1}; T7 – control (mineral fertilization). Means with different letters differ from each other by test of Tukey at 5% probability.

The T6 treatment presented values low the other treatments with biofertilizer. This reduction was probably caused by the electrical conductivity of the biofertilizer solution, obtaining 2.03 dS m^{-1}, which may have promoted a reduction in the evaluated characteristics. Similar results were observed by Sousa et al. (2016) where it was found that irrigation with brackish water in the radish crop in soil with organic fertilizers influenced the characteristics of the plant with an increase in salinity from 1.5 dS m^{-1}.

Plant Physiological evaluation

No significant influence ($p < 0.05$) was found in the treatments used in relation to gas exchange in radish plants. The highest values of the CO_2 assimilation rate (27.0 µmol m^{-2} s^{-1}), transpiration (5.01 mmol m^{-2} s^{-1}), stomatal conductance (0.57 mmol m^{-2} s^{-1}) and intercellular CO_2 concentration (250.0 µmol m^{-2} s^{-1}), were obtained in the T1, T5, T7, and T7 treatments, respectively (Table 2).

It was observed that in T1, the intercellular CO_2 concentration did not numerically follow the same behavior as the CO_2 assimilation rate, suggesting that the lower net photosynthesis (A) can be attributed to both stomatal limitations, due to the decrease in CO_2 availability in mesophyll and carboxylation sites, as non-stomatal, possibly determined by the partial inactivation of rubisco, as well as by the amount of this enzyme (FERREIRA et al., 2014).

The results indicate that fertilization with biofertilizer did not promote an increase in photosynthetic activity in relation to the other treatments, instead, it promoted an increase in the growth and production of radish plants, which can be attributed to the improvement in soil physical and chemical properties (GOMES et al., 2015; OLIVEIRA NETO et al., 2017). The literature shows results for which several authors obtained significant responses that stimulated the physiological activity of plants. Silva et al. (2010) in lettuce plants under organic fertilization with biofertilizer observed that the entrada application also stimulated the physiological activity of lettuce plants. Lima Neto et al. (2021) in pepper plants using the biofertilizer in the soil stimulated the plant's physiological activity (Table 1).

Although the use of biofertilizer has allowed an increase in the production of tuberous roots, it was not enough to keep the gas exchanges equal to those of T1 and T7 treatments, since there were lower values of A, gs, and E. These results allow us to infer that the radish is quite sensitive to fertilization variations, since the twice of the recommended manure fertilization (T3) was sufficient to cause significant negative effects on the gas exchange of these cultivars.

Table 2. Physiological variables of radish plants cultivated in a protected environment and fertilized with alternative sources organomineral. CO_2 assimilation rate (A), transpiration (E), stomatal conductance (gs), and intercellular CO_2 concentration (Ci)

Treatments	A (µmol m^{-2} s^{-1})	E (mmol m^{-2} s^{-1})	Gs (mmol m^{-2} s^{-1})	Ci (µmol m^{-2} s^{-1})
T1	27.00a	4.82a	0.47a	236.00a
T2	24.45a	4.91a	0.53a	249.50a
T3	18.78a	4.34a	0.46a	227.00a
T4	19.03a	4.56a	0.53a	229.67a
T5	19.11a	5.01a	0.51a	242.00a
T6	22.85a	4,.42a	0.39a	237.17a
T7	20.11a	4.95a	0.57a	250.00a
DMS	10.23	1.92	0.29	31.49

*T1 – 37 g cattle manure per pot (15 t ha^{-1}), T2 – 75 g cattle manure per m² (30 t ha^{-1}) recommended; T3 – 150 g cattle manure per m² (60 t ha^{-1})); T4 – 5% of the biofertilizer at the concentration of 50 mL L^{-1}; T5 – 10% of the biofertilizer at the concentration of 100 mL L^{-1}; T6 –15% of the biofertilizer at the concentration of 150 mL L^{-1}; T7 – control (mineral fertilization). Means with different letters differ from each other by the test of Tukey at 5% probability.

CONCLUSIONS

The doses of 75 g of bovine manure and 10% of the biofertilizer obtained the highest averages of the diameter of the tuberous root and fresh matter of the tuberous root.

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