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Containers and doses of controlled release fertilizer in the production of radish in a protected environment

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Abstract

The cultivation of radish has aroused interest on the part of agricultural producers, but it is still necessary to develop and improve management practices that allow greater production and quality of tubers. In this sense, the objective of this work was to evaluate the growth and production of radishes cultivated in containers of different volumes, filled with substrate enriched with increasing doses of controlled release fertilizer (CRF), in a protected environment of the screened type. The research was carried out in the Didactic Garden of the Federal University of Ceará. The experimental design used was in randomized blocks, in a split-plot scheme, with three replicates. The plots were constituted by the volumes of containers (31 and 100 cm^3 $cell^{-1}$) and the subplots by the fertilization doses (0, 4, 8, 12 kg m^{-3} or g l^{-1}). The number of leaves, plant height, fresh and dry mass of the shoot, leaf area, chlorophyll 'a' and 'b', tuber length and diameter, fresh and dry mass of the tuber and yield were evaluated. Plants cultivated in a 100 cm^3 container showed the highest values for all variables and increasing doses of CRF resulted in an increase in radish growth and production. It's concluded that is possible to produce radish in containers filled with substrate enriched with CRF under protected cultivation conditions of the screened type.

Keywords: *Raphanus sativus L.*, substrates, tuberous root, tray

Introduction

The radish (*Raphanus sativus* L.) is a tuberous root vegetable belonging to the Brassicaceae family. Its tuber is consumed worldwide and can be enjoyed in cooked form, raw in salads and juices, and also processed into pickles, dried or canned (Garcia et al., 2022; Manivannan et al., 2019).

Radish has also attracted the attention of consumers and researchers due to its nutritional and phytochemical composition, being rich in vitamins (folic acid), minerals (potassium, calcium, copper, iron, phosphorus and zinc), fiber and antioxidant components (El-Beltagi et al., 2022; Gamba et al., 2021).

This vegetable is grown in countries in Africa, Asia, Europe, North America and South America (Arro; Labate, 2022). In Brazil, its production is estimated at 10.5 thousand tons (IBGE, 2017). Most of it comes from small farms, and about 90% of the production is recorded in the Southeast and South regions (Bonfim-Silva et al., 2020). The Brazilian states of Rio Grande do Sul and São Paulo are its largest consumers (Moreira et al., 2022).

This crop is an interesting production option for the producer, given its short cycle and rusticity (Moreira et al., 2019). One way to increase productivity and contribute to the increase in the quality of vegetables is through the use of protected cultivation that helps in the management of climatic factors, maintaining the most suitable conditions for the full growth and development of crops (Pachiyappan et al., 2022; Silva; Silva; Paguiuca, 2014; Purquerio; Tivelli, 2006). For the small producer it can also be a viable alternative, because it can be designed according to the financial and climatic conditions of the region and the crop of interest, and besides the return in quality and production in adverse climatic conditions (Liao et al., 2020), the investment brings returns in protection against pests, weeds and diseases, more

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efficient use of production resources, improved quantity and increased income for farmers (Ummyiah et al., 2017).

The use of the protected environment can be combined with container filled with substrate (Guimarães et al., 2015; Lemos Neto et al., 2016). However, this form of production is still little explored when thinking about its use for conducting the plant during the entire production cycle.

To overcome this limitation, the choice of the size of the container to be used can be combined with the fertilization of the substrate to be used for the filling. Controlled release fertilizers (CRF), can be recommended, since they can satisfy the nutritional needs of the plants during their entire production cycle, as they gradually release nutrients that can be used for the nutritional demand of the plants (Vejam et al., 2021).

Within this context, the choice of containers filled with substrates combined with different doses of CRF can be considered a first step towards improving this new form of cultivation for radish. In this sense, the objective of this work was to evaluate the growth and production of radish, cultivated in containers of different volumes and filled with substrate enriched with increasing doses of CRF, in a protected environment.

Materials and methods

The experiment was conducted in a shaded protected environment located in the Teaching Garden of the Department of Plant Science of the Federal University of Ceará, in the municipality of Fortaleza-CE (3° 44' 22'' S and 38° 34' 35'' W, altitude of 21 m), during the period from September 15 to October 23, 2017. The climate of the region, according to the Köppen classification, is tropical 'As' with dry summer, with an average annual temperature greater than 26 °C and average annual precipitation of approximately 1,450 mm (Alvares et al., 2014).

During the study, a thermohygrometer was placed inside the greenhouse to measure temperature and relative humidity. Temperatures ranged between 36.0 °C (maximum) and 23.3 °C (minimum) and relative humidity between 76% (maximum) and 24% (minimum) (**Figure 1**).

The experimental design was randomized blocks in a subdivided plot scheme, with three replicates. In the plots were tested two volumes of containers, 31 and 100 cm^3 $cell^{-1}$, corresponding to polyethylene trays of 162 cells (most used in vegetable crops) and 60 cells (can provide more space for the production of larger size tubers). In the subplots, four doses of controlled release fertilizer (CRF) were evaluated (0, 4, 8 and 12 kg m^{-3} or grams l^{-1}).

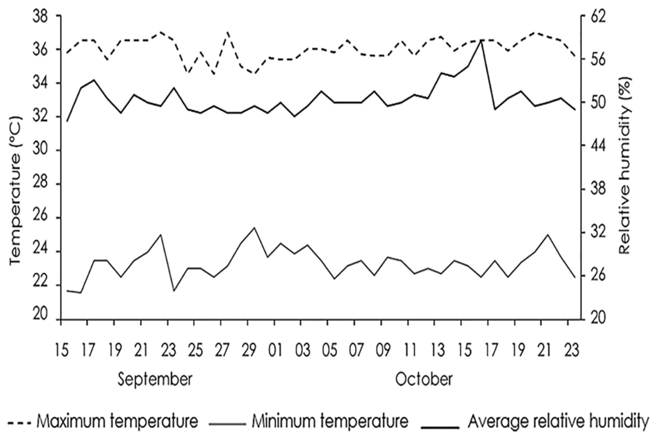

Figure 1- Temperatures (maximum and minimum) and average relative humidity inside the protected environment during the period of the work. Fortaleza, 2017.

The experimental plots were composed of 15 plants in the case of containers, considering as useful plot, the 10 central plants. The containers were filled with a substrate formulated from a mixture of worm humus and vermiculite (in a 3:2 v:v ratio). The chemical characteristics of the substrate used before incorporation of vermiculite and different doses of CRF were pH (water)= 6.7; P= 331.8 mg dm^{-3}; P-rem= 57.9 mg l^{-1}; K= 1700.0 mg dm^{-3}; Ca^{2+}= 16.5 cmolc dm^{-3}; Mg^{2+}= 12.7 cmolc dm^{-3}; Al= 0.0 cmolc dm^{-3}; H+Al= 3.80 cmolc dm^{-3}; SB= 33.6 cmolc dm^{-3}; CTC (t)= 33.6 cmolc dm^{-3}; CTC (T)= 34.7 cmolc dm^{-3}; V= 90% and MO = 18,32 g kg^{-1}. The micronutrients presented values of Zn= 54.4 mg dm^{-3}; Fe= 14.2 mg dm^{-3}; Mn= 76.4 mg dm^{-3}; Cu= 0.5 mg dm^{-3}; B= 3.4 mg dm^{-3}. The substrate had the following mineral composition 11% clay, 12% silt and 77% sand.

After substrate formulation, the CRF (Forth Cote mini 3M®, NPK formula, 14-14-14) was added. Sowing was performed on September 15, 2017, sowing three seeds of radish ‘Zapp’ per cell. The containers were placed under a protected environment of screened type, built with a wooden structure, measuring 6 m long, 4 m wide and 2.40 m high; and, with coverage and lateral closing of black monofilament shading. At eight days after sowing (DAS), thinning was performed, leaving only one seedling per container cell. During the experiment, daily irrigations were done manually with the help of a sieve-type watering can, always trying to keep the humidity close to the cell capacity.

At 35 DAS, measurements were taken to determine chlorophyll "a" and "b" using a chlorophyllometer and, at 38 DAS, the harvest was performed and the following variables were analyzed average number of leaves (NL), plant height (PH, cm), fresh (FMS, g) and dry (DMS, g) mass of the shoot, leaf area (LA, cm^2), tuber diameter (largest transverse measurement of the tuber) (TD, cm), tuber length (largest longitudinal measurement of the tuber) (TL, cm), fresh mass of the tuber (FMT, g), dry mass of the tuber (DMT, g) and yield (Y, kg m^{-2}).

After the harvest of plants, the PH and TD were measured using a pachymeter. The plants were separated in shoot and root parts, and their fresh masses were determined using a digital precision balance. The determination of leaf area was performed with the help of a LI-COR LI-3100C bench-top leaf area meter.

Subsequently, the fresh shoot and root materials (the latter cut into four parts in their transversal and longitudinal axes) were placed in paper bags and dried in a forced air circulation oven at 65 °C for 72 hours, when they reached a constant weight. The dry mass was determined on analytical balance (Analytical Balance Bel M214-AIH/4 houses). The yield was calculated from the root fresh mass data, adjusted to the total number of plants as a function of area.

The data obtained were submitted to analysis of variance, and the means were compared by the Tukey test at 5% probability. The effect of CRF doses and the interaction between factors, when significant, were interpreted by regression analysis. The analyses were performed using the statistical computer program Sisvar (Ferreira, 2011).

Results And Discussion

For the fresh mass of the shoot and fresh and dry mass of tuber interaction ($p < 0.05$) of the evaluated factors, container volumes and doses of controlled release fertilizer (CRF) was observed. However, there was no interaction between these factors for the other characters: number of leaves, plant height, dry mass, length, diameter and yield, but there was isolated effect of both ($p < 0.05$).

For the number of leaves (NL), leaf area (LA), plant height (PH) and fresh mass of the shoot (FMS) a linear increasing behavior was observed as the CRF doses increased (**Figure 2**). In general, the doses of CRF provided better plant performance when compared to those grown in the control.

Positive effects of increasing doses of CRF were indicated by other researchers to have contributed to greater height in eggplant (Moreira et al., 2010). For 'cravo' lemon tree (SERRANO et al., 2006) and *Dianthus caryophyllus* (Oliveira, 2006) increasing doses of CRF also contributed to higher fresh mass accumulation. In general, researchers relate the higher concentrations of nutrients made available as the factor responsible for greater plant growth.

This is because by promoting adequate fertilization there is an increase in growth efficiency, such as greater leaf area, which contributes to light interception, resulting in increased biomass production of the plants (Mahakosee et al., 2022). In relation to the containers, the larger volume made possible to obtain plants with a greater number of leaves, leaf area, plant height and accumulation of fresh mass of the shoot (Figure 2). Other research has also shown a tendency for greater growth in plants grown in larger containers, for example, greater number of leaves in *Solanum sessiliflorum* and *Solanum paniculatum* (Guimarães et al., 2012); greater leaf area in melon (Maynard: Vavrina; Scott, 1996), watermelon (Liu; Latimer, 1995), okra (Modolo, 1998) and lettuce (Silva et al, 2000); greater plant height of beet (Echer, et al., 2007), eggplant (Costa et al., 2011), tomato (Oliveira et al., 2011), *Brassica pekinensis* L. (Lemos Neto et al., 2016) and cabbage (Nava; Marreiros, 2021) and higher values of fresh mass of the shoot in lettuce (Marques et al., 2003) and cauliflower (Godoy; Cardoso, 2005). According to the researchers, the greater availability of water and nutrients for the plants submitted in larger containers contributed to a greater development of the plants.

For the variables dry mas of the shoot (DMS), tuber length (TL), tuber diameter (TD) and fresh mass of the tuber (FMT) it was observed that the adjustment of regression by the linear model was the one that presented the greatest reliability for the representation of the results. There were increasing responses for the variables as the CRF application increased (Figure 3). The length and diameter of the tuber reached 3.30 and 2.28 cm, respectively for the dose of 12 kg m^{-3}.

As for the influence of the volume of containers, the responses were similar to those observed for the other variables already analyzed, that is, the container with a volume of 100 cm^3 enabled the production of plants with greater accumulation of dry mass of the shoot and tuber growth (**Figure 3**).

Higher contents of dry mass in containers with higher volume were also obtained for eggplant (Costa et al., 2011), pepper (Miqueloni; Negreiros; Azevedo, 2013) and in *Acmella oleracea* (L.) R. K. Jansen (Sampaio et al., 2019). In general, the higher values of masses obtained in the various works carried out with containers, indicate that those of larger volume, by allowing more space for the growth of the root system, as well as having a greater cell capacity and, thus, concentration of nutrients, enable better conditions for the development of the plants for a longer time, which contributes to the greater accumulation of masses.

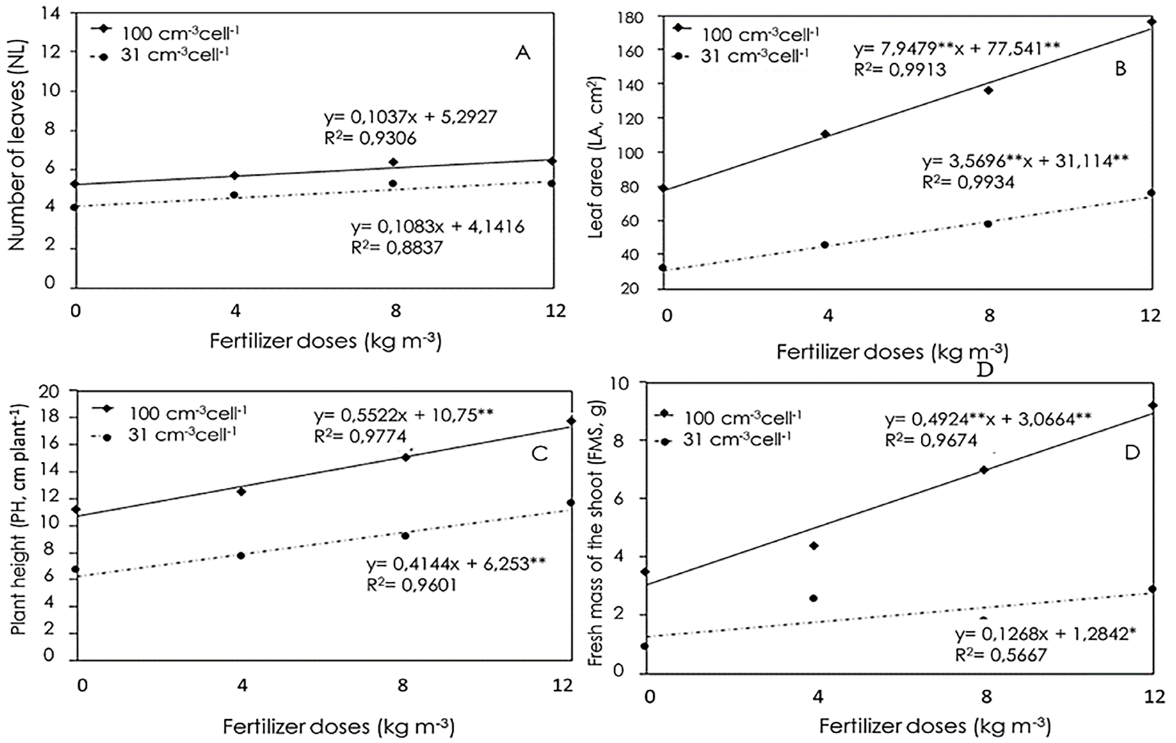

Figure 2- Number of leaves (NL; A), leaf area (LA; B), plant height (PH; C) and fresh mass of the shoot (FMS; D) of radish plants grown in containers of two volumes combined with different doses of controlled release fertilizer. Fortaleza, 2017.

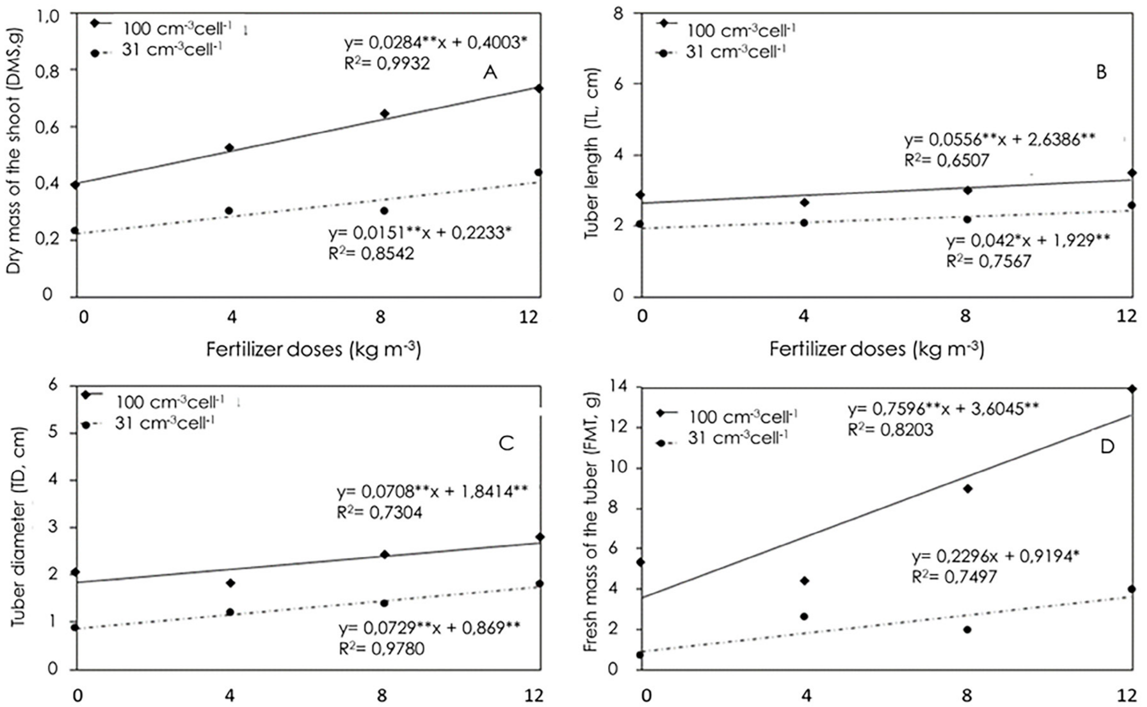

Figure 3- Dry mass of the shoot (DMS; A), tuber length (TL; B), tuber diameter (TD; C) and fresh mass of the tuber (TFM; D) of radish plants grown in containers of two volumes combined with different doses of controlled release fertilizer. Fortaleza, 2017.

The values of dry mass of tuber (DMT) and yield (Y) also showed a linear upward behavior when the CRF dosage was increased and the container used was larger (**Figure 4**). According to Medeiros et al. (2019) the mass of tuber is the variable of greatest importance in determining the effect of fertilization (Medeiros et al., 2019).

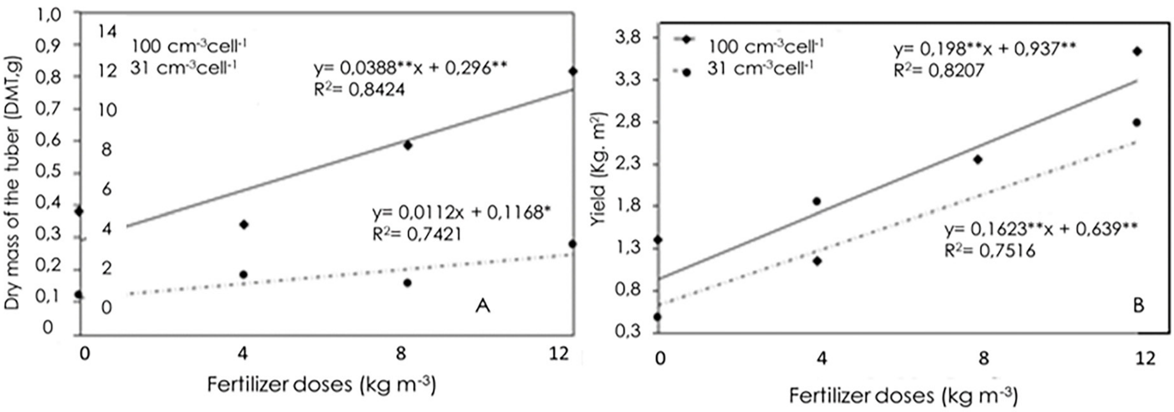

Figure 4 – Dry mass of the tuber (DMT; A) and yield (Y; B) of radish plants grown in containers of two volumes combined with different doses of controlled release fertilizer. Fortaleza, 2017.

For the 100 cm^3 container, the production per area had increases 134% when compared to the control treatment and 22.8% when compared to the 31 cm^3 container at the dose of 12 kg m^{-3}. In a study with containers of different volumes Guimarães et al. (2012) state that the relationship between the volume of the container filled with substrate and its productivity are directly proportional, which is in agreement with the present work.

For the variables chlorophyll 'a' and 'b', neither interaction nor effect was observed among the factors analyzed in isolation (**Table 1**).

In general, the responses observed for the characters evaluated show similar responses, being the container of larger volume (100 cm^3) and the increase in the doses of CRF, those that allowed obtaining plants with better performance. These results are similar to others obtained by researchers who focused their studies on the selection of containers and substrates for seedling production (Seabra Júnior; Gadun; Cardoso, 2004; Danner et al, 2007; Echer et al., 2007; Guimarães et al., 2012; Lemos Neto et al., 2016). In general, containers with larger volume, besides providing more space for root development, because they have a greater amount of substrate in their cells, end up providing the plants with a higher concentration of essential nutrients for their growth and development (Klein et al., 2012; Guimarães et al., 2012; Lemos Neto et al., 2016).

Table 1- Chlorophyll a (Chla) and Chlorophyll b (Chlb) of radish plants grown in containers of two volumes combined with different doses of controlled release fertilizer. Fortaleza, 2017

Container volume (cm^3 $cell^{-1}$)	Chla	Chlb
31	21.99^{ns}	3.84^{ns}
100	22.45	4.26
Fertilizer dose (kg m^{-3})		
0	22.06^{ns}	3.84^{ns}
4	22.18	4.11
8	22.47	4.16
12	22.17	4.10
average	22.22	4.05
CV 1(%)	10.97	14.10
CV 2 (%)	7.31	13.42

ns: effect not significant by F test at 5% probability level

In addition to the above, the larger volume of substrate also contributes to greater water retention (greater cell capacity), which is made available for a longer time to the plants (Schafer; Lerner, 2022; Fermino, 2003). This contributes not only to a reduction in the desiccation of the tubers, but also to a greater absorption of nutrients, since these tend to be absorbed more constantly by the root that is inserted in a substrate that remains wetter for longer (Schmitz; Souza; Kämpf, 2002).

As for the total observed production, three analyzed characters help to explain in a clearer way the high yield in the treatments with the largest doses of CRF combined with the largest volume of container (100 cm^3), they are: 1. number of leaves, 2. plant height and 3. leaf area, all directly or indirectly related to the photosynthesis of the plants.

The greater number of leaves and leaf area allow greater interception of light by the plants, and this interception is increased when the plant height is greater, since in this container there is greater spatial separation that reduces the occurrence of self-shadowing (Taiz; Zeiger, 2013). In this sense, by intercepting more light, if the other production factors (nutrients, water and space for growth) are not limiting, these plants will present higher rates of photosynthesis, that is, more photoassimilates will be produced and directed to the drain organs (Almeida et al, 2004; Chiewchankaset et al., 2022), in the case of radish, the tuber that presents large quantities of parenchyma cells where this synthesized material will be stored (Zierer et al., 2021).

Conclusion

It is concluded that the use of containers filled with substrate enriched with controlled release fertilizer (CRF) enables the growth and production of radish in a protected environment of screened type, being the containers of larger volume (100 cm^3) combined with the highest dose of CRF (12 kg m^{-3}), those that provided the highest values under the conditions of this study.

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