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Different environments and doses of controlled-release fertilizer in peach rootstocks production

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Key words: fertilization, plant nutrition, *Prunus persica*.

Abstract: The objective of this study was to evaluate the effects of different environments and doses of controlled-release fertilizer (CRF) on the initial growth of peach rootstocks [*Prunus persica* L. (Batsch)] cv. Capdeboscq. The experimental design was completely randomized, in a 2 x 4 factorial design, four replications and five plants per plot. The treatments were the combination of two cultivation environments (on open-air benches and greenhouse benches) and four doses of CRF (0, 2, 4 and 8 g L^{-1} of substrate), in the 19-06-10 NPK formulation. Ninety days after their transplanting, the variables plant height, stem diameter, number of leaves per plant, shoot dry matter, root dry matter, total dry matter, plant height and stem diameter ratio were evaluated in addition to the Dickson Quality Index. All morphological variables evaluated presented a quadratic positive response to the increase of the applied fertilizer until the dosage of maximum technical efficiency (around 6.2 g L^{-1}). The maintenance of the plants in greenhouse benches and the incorporation of 4 g L^{-1} CRF to the substrate ensures greater efficiency in the input use, reducing the amount of time necessary for peach trees cv. Capdeboscq to achieve their grafting point and to be used as rootstocks.

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All relevant data are within the paper and its Supporting Information files.

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The authors declare no competing interests.

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1. Introduction

Southern Brazil is the greatest national peach producer and this region is recognized as one of the main production centers of stone fruit trees in the country, especially peach trees. However, the traditional production system of these species is mostly performed in the field (Bianchi *et al.,* 2014; IBGE, 2018), strongly influenced by climatic conditions.

The use of protected environments is an alternative for the production of stone fruit trees, which can ensure the survival of the plants during the most critical phase of the tree production chain. Especially in rootstock production by seeds, the seedlings emergence stage and initial growth require environment control, as well as optimal nutrition and irrigation, and protection against pests and diseases in order to assure the fast growth and development of the plants (Souza *et al.,* 2017).

The production of fruit plants in protected environments, such as greenhouses, allows the maintenance of optimum conditions for cultivation throughout the year, anticipating and extending the grafting period, reducing production costs and increasing the plants quality standard for sale (Oliveira *et al.,* 2017).

In Brazil, the traditional production system of stone fruit trees requires 360-540 days to grow a plant that is suitable for trading (Mayer *et al.,* 2015). In this system, the necessary time for rootstocks to reach the grafting point is of approximately 240 days (Fischer *et al.,* 2016). In part, this long period is due to the slow growth of plants in the field during the winter and early spring.

In order to reduce the time between seed germination and the production of rootstocks suitable for grafting, the cultivation in a protected environment, as well as the use of appropriate substrates and fertilizers in the proper doses for the crop are alternatives to optimize the initial phase of the plants growth (Bianchi *et al.,* 2014; Jamal *et al.,* 2017; Menegatti *et al*., 2019 b).

The environmental conditions of the plant production system directly influence the plants physiological processes and can directly affect plants growth (Souza *et al.,* 2017). Protected environments can promote greater uniformity for the plants growth in comparison with plants produced in the field or in an unprotected environment (Reis *et al.,* 2010; Fischer *et al.,* 2016; Oliveira *et al.,* 2017). Different environments can also affect the germination of seeds, and the growth and quality of the seedlings produced. The interaction between environmental conditions with the application of fertilizers may contribute to optimize the space for plant production in nursery and to reduce the plant production systems impact on the environment.

In addition to the use of commercial substrates, the increase of the nutrient supply is recommended because the substrate alone does not provide enough nutrients for the complete development of the plants (Dutra *et al.,* 2016). Among the many types of fertilizers available, the controlled-release fertilizer (CRF) is the most efficient. CRF promotes the slow release of nutrients and the absorption of the ideal amount throughout the plants' growth period, allowing them to achieve maximum strength (Zamunér Filho *et al.,* 2012; Menegatti *et al.,* 2017 a).

The concomitant use of fertilizers with the substrate favors the formation of more vigorous plants in shorter time, which reduces the period in which they stay in the nursery and, consequently, the production costs (Muniz *et al.,* 2013; Menegatti *et al.,* 2017 b). However, few are the researches that report the use of fertilization as an additional factor to the production of stone fruit trees (Zhang *et al.,* 2014; Jamal *et al.,* 2017; Menegatti and Bianchi, 2019). Even scarcer are the studies that consider plant propagation in a protected environment, such as a greenhouse in comparison with open environments (Picolotto *et al.,* 2007; Reis *et al.,* 2010).

The scarce information about the use of controlled-release fertilizers in the production of peach rootstocks in protected environments encouraged the accomplishment of this study, whose objective was to verify the effect of different environments and doses of CRF on the initial growth of peach trees cv. Capdeboscq for rootstock purposes.

2. Materials and Methods

Ripe peach fruits of cv. Capdeboscq were harvested in January 2017 from clonal mother plants kept in the Germplasm Collection of peach rootstocks at the Federal University of Pelotas (UFPel), Brazil. The experiment was conducted between October (2017) and January (2018), at the Department of Botany-UFPel, Capão do Leão, RS, Brazil, at 21° 48' south latitude, 41° 20' west longitude and an altitude of 11 m.

After the harvest of the fruits, the post-harvest management of the pits was carried out according to Picolotto *et al.* (2007). Then the seeds were stratified, as described by Souza *et al.* (2017). After the stratification period (35 days at 7°C), the seeds were sown, 1.0 cm deep, in 72-cell polystyrene trays (114 cm^3 per cell) containing a mixture of orchard soil + vermiculite + medium sand + commercial substrate Plantmax® (1:1:1:1) as substrate, and kept in a greenhouse.

When the seedlings, hereinafter referred as "plants", reached the transplant point (15 cm between collar and apex), they were transplanted into 1-liter plastic bags containing washed sand, which was used as substrate (Table 1) and whose CRF (Osmocote®) doses had the N-P-K formulation of 19-06-10 (4-6 months), which were previously incorporated into the sand.

The experimental design was completely randomized, in a 2 x 4 factorial design, with two environments (on open air benches and on benches inside the greenhouse) and four doses of Osmocote® (0, 2, 4 and 8 g L^{-1} substrate), with four replications and five plants per replication.

"Protected environment" refers to the Arco

Table 1 - Average chemical composition of the sand substrates used in the production of peach tree rootstocks

Substrates	OM** %	V %	H+Al mg dm^{-3}	SB mg dm^{-3}	CEC mg dm^{-3}	P mg dm^{-3}	K µg dm^{-3}	Ca µg dm^{-3}	Mg µg dm^{-3}	Zn µg dm^{-3}	Fe µg dm^{-3}	Mn µg dm^{-3}
Sand*	0.00	67.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00

*sand; **OM= Organic Matter; V= Base saturation; SB= Sum of Bases; CEC= Cation Exchange Capacity (CEC).

Pampeana metallic structure greenhouse model, covered with a 150-millimeter thick, low-density polyethylene plastic film, arranged at the north-south direction and with the following dimensions: 10.0 m x 21.0 m and with the maximum height of 5.0 m. The benches used in the two environments were 1-meter high metallic structures, positioned at ground level. The environmental open air conditions and the ones in the greenhouse during the period of the experiment are described in Table 2.

Table 2 - Environmental conditions: temperature (T°C), relative humidity (RH%) and global radiation (W m-²) in the two cultivation environments (in open-air benches and greenhouse benches) during the cultivation period of peach trees cv. Capdeboscq

Environment	Temperature (°C)	RH (%)	Global radiation (W m-²)
Greenhouse	23.42	66.81	348.50
Open air	21.15	78.62	477.17

Ninety days after transplantation, when 75% of the plants of one of the treatments reached the grafting point (at least 5 mm of stem diameter and 10 cm above the soil), the plants were evaluated for the variables stem diameter (SD), plant height (H) and number of leaves (NL). Based on these data, it was possible to calculate the plant height and stem diameter (H/SD) ratio. The height of the rootstocks was measured using a graduated ruler, and the stem diameter was measured with a digital caliper.

The plants were dried in a forced air circulation oven at 70°C for 72 hours to obtain the shoot dry matter (SDM), root dry matter (RDM) and total dry matter (TDM) per plant. The Dickson quality index (DQI) was obtained by the formula: DQI = TDM/[(H/SD) + (SDM/RDM)], according to Gomes and Paiva (2011).

The stem diameter increase (ΔSD) was obtained through the data collected every 15 days until the end of the experiment (90 days after transplantation).

Possible differences between treatments were verified by analysis of variance (ANOVA). The variables that exhibited significant differences were submitted to regression analysis in order to verify the plants growth response in proportion to the CRF increasing doses in both growing environments. The data analysis was performed in the statistical package Sisvar (Ferreira, 2011).

3. Results and Discussion

At the end of the experiment (90 days after transplantation), the survival rate of the peach rootstock plants was of 100% for all treatments. All variables exhibited interaction (p <0.05) between the environment factors and the CRF (Osmocote®) doses (Table 3), indicating that the study of factor interaction is important to define the best condition to stimulate plant growth and development.

Table 3 - Summary of the variance analysis for contrasts between the environmental factors of cultivation and CRF (Osmocote®) doses for the variables stem diameter (SD), plant height (H), number of leaves per plant (NL), shoot dry matter (SDM), root dry matter (RDM), total dry matter (TDM), plant height and stem diameter (H/SD) ratio, and the Dickson Quality Index (DQI) of peach trees cv. Capdeboscq 90 days after transplantation

Source of variation	df	Mean square							
		SD (mm)	H (cm)	NL	SDM (g)	RDM (g)	TDM (g)	H/SD	DQI
Environment (E)	1	128.2 **	1897.8 **	56.2 **	603.8 **	96.9 **	216.2 **	474.4 **	42.0 **
Dose of CRF (D)	3	137.7 **	549.8 **	109.8 **	233.8 **	37.9 **	84.1 **	103.0 **	60.7 **
E x D	3	8.0 **	162.9 **	11.6 **	70.1 **	12.6 **	26.9 **	31.4 **	3.9 *
Mean		4.3	60.8	55.0	5.9	9.6	15.5	13.4	1.7
CV (%)		4.0	4.3	11.9	10.1	25.5	17.0	6.4	9.7
Mean Greenhouse		4.6	80.9	64.0	8.48	13.8	22.3	16.7	1.8
Mean Open air		3.9	40.7	46.0	3.3	5.3	8.6	10.0	1.5

* Significant at the probability level (p<0.01) and ** significant at the probability level (p<0.05) by the F test.

All morphological variables exhibited a quadratic behavior in the adjustment of the regression equations (Figs. 1, 2, 3 and 4), proving that the highest dose test results decreases the variables values, that is, increasing the fertilizer dosage allows the increase of the plants growth up to the maximum technical efficiency dose (MTED).

The MTED for plant height in the protected environment was of 6.43 g L^{-1}, corresponding to the height of 113.8 cm, which was three times higher than the control treatment (substrate without the addition of Osmocote®) in the same environment, 90 days after transplantation (Fig. 1). The MTED for plant height in the external environment was of 5.09 g L^{-1}, whose plants reached the height of 52.1 cm, in contrast to the 23.9 cm high of the treatment without the addition of CRF (Fig. 1).

Similar height growth was also observed with the application of Osmocote® in the studies performed by Silva *et al.* (2011) in the production of Rangpur lime rootstock [*Citrus limonia* L. (Osbeck)] and by Dutra *et al.* (2016) in the growth of Canafistula [*Peltophorum dubium* (Spreng.) Taub.]. However, the environments and doses tested in their studies were different of this one.

The positive effects of CRF application on plant growth in different species reinforce the necessity of specific studies to enable the definition of the MTED for each species and cultivar, which may provide superior growth and efficiency in the use and exploitation of fertilizers by the plants.

The estimated MTED for the SD variable of the plants cultivated in greenhouse was of 7.29 g L^{-1}, corresponding to a diameter of 5.51 mm (Fig. 2). According to the current legislation of the Secretary of Agriculture and Food of Rio Grande do Sul (Ordinance 302/98), the grafting must be performed when the rootstocks reach a SD over 5 mm and a height of 10 cm from the ground. Thus, the MTED estimated for plant grown in greenhouse allows the rootstocks to reach the minimum diameter for grafting at 90 days after transplantation.

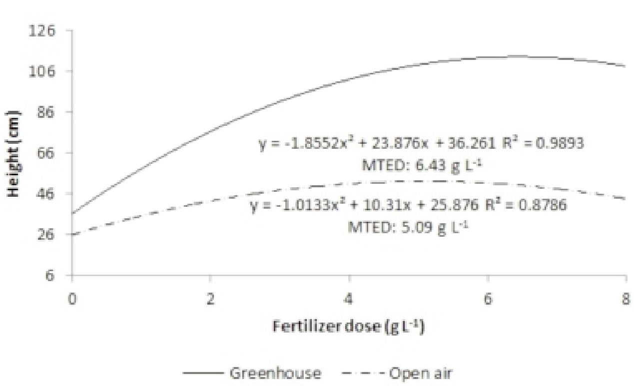

Fig. 1 - Plant height (cm) of the peach plants cv. Capdeboscq, in relation to the dosage of the controlled-release fertilizer (CRF) and two cultivation environments, 90 days after transplanting.

On the other hand, in the external environment, the plants have not reach the minimum stem diameter required for grafting during the experiment, even at the highest CRF dose (Fig. 2).

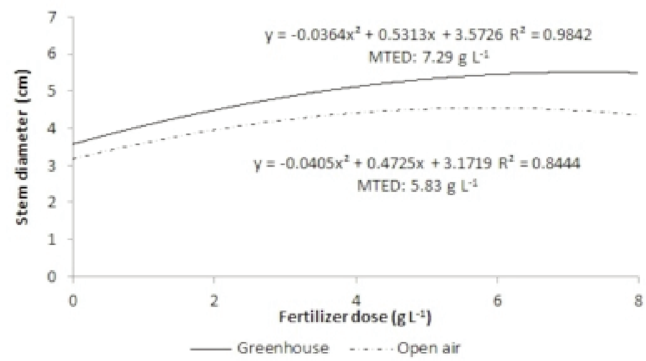

Fig. 2 - Stem diameter (mm) of peach plants cv. Capdeboscq, in relation to the dosage of the controlled-release fertilizer (CRF) and two cultivation environments, 90 days after transplanting.

In peach rootstock production, it is extremely important to define the environment and the fertilizer MTED to obtain the ideal SD for grafting in a shorter period. The minimum diameter of 5 mm is used to make sure that the rootstocks phloem and xylem have greater competence to perform rapid vascular connection between the scion/rootstock (Santarosa *et al.,* 2016), which will allow the effective translocation of the nutrients absorbed by the roots (rootstock) to the aerial part (scion cultivar). This condition will result in a higher percentage of graft-take and growth of the grafted plants, and it will reduce the period to obtain commercial plants.

Souza *et al.* (2013) stress the influence of the rootstock diameter to reduce the time to develop grafted plants of "Ponkan" tangerine. The plants rapid growth was obtained with the use of rootstocks with larger diameter in the appropriate cultivation conditions in the greenhouse.

The best plant growth in both height and stem diameter was obtained in plants grown in a greenhouse with the MTED. This suggests that the greenhouse environment provided better conditions of temperature, humidity and luminosity for the plant growth. Associated with the MTED, these conditions allowed the plants to reach the ideal point for rapid grafting, which is a desired aspect in the production system of peach tree rootstocks.

Paricá seedlings [*Schizolobium amazonicum* Huber ex Ducke] grown in a protected environment also exhibited superior performance for plant height and stem diameter (Frigotto *et al.,* 2015). These authors concluded that greenhouse cultivation significantly increases the growth variable values in comparison with external environment cultivation.

The highest mean number of leaves per plant (97) was obtained with the estimated MTED (4.69 g L^{-1}) for the plants grown in the greenhouse (Fig. 3A).

As for the variable number of leaves, it was found that the plants of cv. Capdeboscq cultivated in an open sky achieved DMET higher than plants kept in a greenhouse (Fig. 3), a fact that may be related to phytosanitary problems, such as, for example, small leaf spots and necroses detected in the leaves of this treatment, during the conduction of the plant experiment. These leaf damage possibly induced damage to the leaf photosynthetic apparatus, however, this damage may have been efficiently reversed through the emission and growth of new leaves.

This hypothesis can be supported by the fact that, at this moment, the plant enhances the production of photoassimilates and destines most of it, the maintenance and maximization of the aerial part, making this organ the drain of greater energy demand, both to stimulate the leaf growth maximizing the capture of light, as well as to boost the thickening of the stem diameter ensuring the robustness of the rootstock.

It should also be noted, according to the results obtained in this work, that plants grown in the open suggest that they have prioritized the increase in the diameter of the stem at the expense of growth in height, as shown in Table 4, a strategy that can increase the robustness of the plants and decrease the exposure of the aerial part, guaranteeing their survival for a longer period, as well as the maintenance of the physiological processes in this cultivation environment, which expose the plants to sudden environmental variations.

The cultivation environment has a strong influence on environmental conditions, such as temperature and global radiation, parameters that are indirectly related to the efficiency of plants in terms of light absorption capacity, and later conversion to energy, as well as in the absorption and use of nutrients.

A gradual production increase of shoot dry matter, root dry matter and total dry matter up to the CRF MTED was registered (Fig. 3B, 3C and 3D), regardless of the cultivation environment. However, the plants grown in greenhouse presented higher values for total dry matter. These results corroborate the effects of Osmocote® in the growth of Rangpur lime rootstocks, as reported by Scivittaro *et al.*

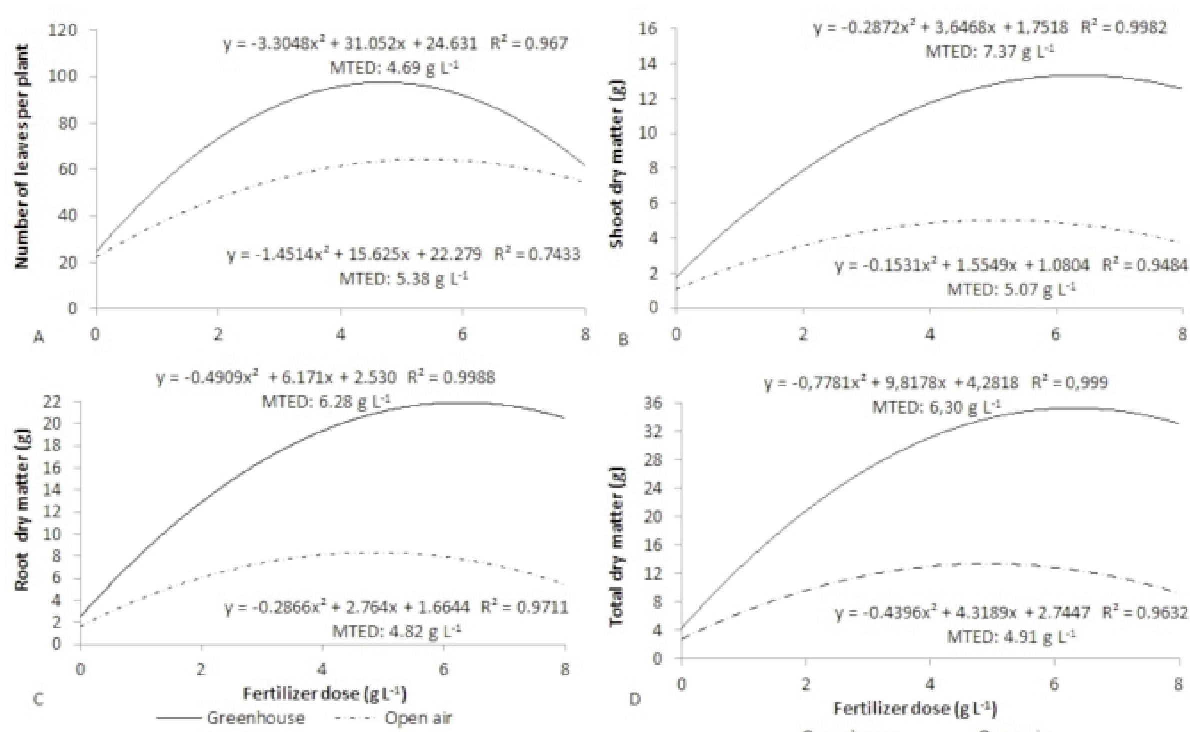

Fig. 3 - Number of leaves per plant (3A), shoot dry mass (3B), root dry mass (3C) and total dry mass (3D) of peach plants cv. Capdeboscq, in relation to the dosage of CRF and two cultivation environments.

Table 4 - Mean values of the differences between greenhouse and open air for the variables stem diameter (SD), plant height (H), number of leaves per plant (NL), shoot dry matter (SDM), root dry matter (RDM), total dry matter (TDM), plant height and stem diameter (H/SD) ratio, and Dickson quality index (DQI) of peach plants cv. Capdeboscq 90 days after transplantation

Dose	SD (mm)	H (cm)	NL	SDM (g)	RDM (g)	TDM (g)	H/SD	DQI
0	0.47	10.6	4.6	0.7	1.2	1.9	1.9	0.1
2	0.35	33.4	19.8	4.1	5.8	9.9	6.3	0.2
4	0.84	51.6	38.9	7.0	11.9	19.0	8.4	0.5
8	1.11	64.9	6.4	8.7	14.9	23.7	9.7	0.5

(2004). They found that as controlled-released fertilizer doses increased, the dry matter production of the Rangpur lime rootstocks increased as well.

The leaf area has not been quantified in this study. However, there are previous studies that support the increase of the number of leaves per plant is directly proportional to the growth of the leaf area (Menegatti *et al.,* 2017 a). The greatest leaf area of plants grown in greenhouses provides greater efficiency in solar energy uptake for photosynthesis and photoassimilate production, which is directly related to the nutrient supply, including nitrogen (N), present in the CRF formulation used in this study.

The use of CRF in the MTED ensures the availability and efficient utilization of N by the plants because the leaching level of N is reduced in comparison with conventional fertilizers (Zamunér Filho *et al.,* 2012; Muniz *et al.,* 2013). N is an essential element to the components of the photosynthetic system, such as chlorophylls, carboxylase activity/oxygenase of ribulose 1.5-bisphosphate and carboxylase of phosphoenolpyruvate (Bassi *et al.,* 2018), thus maintaining satisfactory rates of carbon assimilation (Taiz and Zeiger, 2017) and consequently guaranteeing the production of photoassimilates that support plant growth.

The CRF effects on the production of Rangpur lime plants for use as rootstocks were registered by Serrano *et al.* (2006) and Silva *et al.* (2011). They concluded that the fertilizer MTED increases the variables shoot dry matter, root dry matter and total dry matter, stressing the importance of fertilization for the maintenance of the photosynthetic process in order to increase the total dry matter and consequently the plants growth.

The relation between plant height and stem diameter (Fig. 4A) presents a balanced growth of the plants raised in greenhouses.

The H/SD ratio is one of the parameters most used in the plant's quality evaluation. Moreover, it

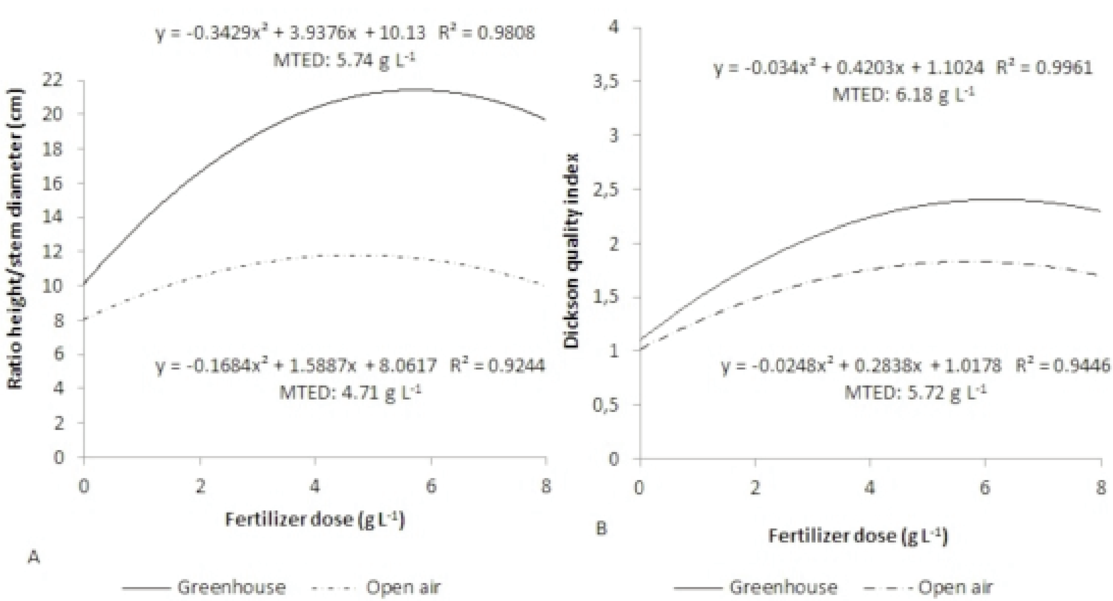

Fig. 4 - Ratio between height and stem diameter and Dickson quality index of peach plants cv. Capdeboscq, in relation to the dosage of controlled-release fertilizer and two cultivation environments.

reflects the accumulation of reserves and ensures greater resistance and adequate potential of the rootstock (Souza *et al.,* 2013). The index considers two parameters in a single indicator, and it can be used as a guide to determine the quality of the plants.

The balance of the plants growth confirmed by the H/SD ratio may have been favored by the use of CRF. The encapsulated fertilizers, such as CRF, allow the slow release of nutrients through a porous structure (Serrano *et al.,* 2006), becoming available to the plants root system over time and according to their nutritional need, avoiding the leach and loss observed in conventional fertilizers.

In addition to the H/SD ratio, the DQI is a good indicator of plant quality. For its calculation, it considers the plants robustness and biomass distribution balance. Therefore, the higher the value, the better the quality standard of the plants will be (Gomes and Paiva, 2011).

The ideal value considered for the DQI is approximately of 2.00 (Gomes and Paiva, 2011). In our study, the highest DQI was close to 2.2 for the estimated MTED of 6.18 g L^{-1} in plants grown in a greenhouse. However, for the plants kept in the external environment, the highest DQI value was of 1.83 with an MTED of 5.72 g L^{-1}, which is lower than the ideal value (Fig. 4B).

Previous research from Dutra *et al.* (2016) and Zamunér Filho *et al.* (2012), in addition to the results obtained in the present study, agree with the results for all morphological variables evaluated. A quadratic positive response was obtained proportionally to the increase of the CRF doses up to the MTED (of approximately 6.2 g L^{-1}). It proves that the plant will not have higher responses if a dose higher than the MTED is applied.

The ΔSD, evaluated every 15 days after the beginning the experiment, is presented in figure 5. For the plants cultivated in a greenhouse, the use of the doses of 4 and 8 g L^{-1} of Osmocote®, incorporated into the substrate, were proven efficient for the production of rootstocks suitable for grafting after 90 days because they presented a final SD mean of 5.1 mm and 5.5 mm, respectively.

Considering the aforementioned results and the relevance of the SD variable in the production of peach rootstocks, we suggest the incorporation of at least 4 g L^{-1} of Osmocote® into the commercial substrate and the cultivation of the plants in a greenhouse. Those conditions can increase the efficiency of the fertilizer use to obtain plants that can be grafted after 90 days.

The effects of different environments on the production of peach rootstocks cv. Okinawa were reported by Reis *et al.* (2010). They reached the ideal point for grafting after 179 days in a protected environment. Schmitz *et al.* (2014), evaluating the production of peach rootstocks cvs. Capdeboscq and Okinawa, in three production systems, reached the grafting point after 154 days.

Fischer *et al.* (2016), researching the influence of the stratification period on wet cold in the emergence and production of several peach rootstocks in the field, obtained materials suitable for grafting after 240 days. These results indicate that the use of CRF and a protected environment are promising in the shortening of the productive cycle, as the grafting

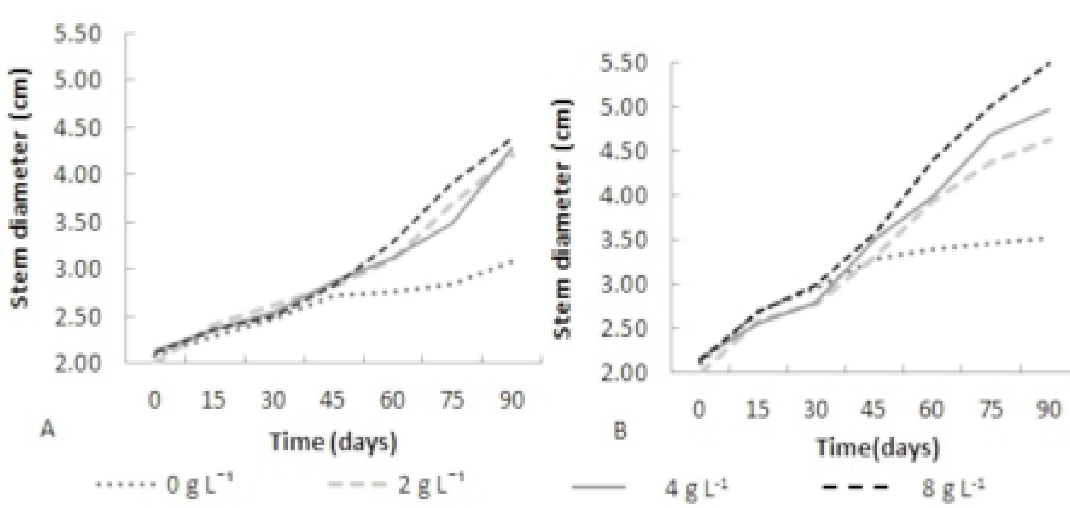

Fig. 5 - Increase of stem diameter, over time, of peach plants cv. Capdeboscq, in relation to the dose of the CRF and two cultivation environments (A) Open air and (B) Greenhouse.

point can be reached after 90 days. This outcome is probably due to the ready availability of nutrients and the maintenance of the plants under favorable environmental conditions, although these results must be validated for other cultivars of [*Prunus persica* L. Batsch] rootstocks with potential use in Brazil, such as cvs. Flordaguard, Okinawa and the Tsukuba series (Menegatti *et al.,* 2019 a).

The greatest ΔSD occurred between 30 and 60 days after transplantation (Fig. 5), regardless of the dose employed, which may be due to the slow releasing of the nutrients, a main characteristic of the fertilizer used, which resulted in the greater amount of nutrients available to the plants during the experiment (Huett and Gogel, 2000). This result also suggests that it is necessary to replace the mineral elements around 60 days after the first application in order to maintain the plants optimal growth rate. Therefore, studies to elucidate the best CRF replacement period are necessary in order to ensure continued growth through the plants different development stages.

The CRF used in the production of peach rootstocks proved to be a promising alternative in comparison with conventional fertilizers. The CRF slowly and continuously releases nutrients to the plant, avoiding leach losses and volatilization. Furthermore, it ensures a better use of nutrients and reduces the environmental and economic impact (especially by the nitrogen economy, which is an expensive and easily leachable element that has a great potential to pollute the environment).

The negative aspect of using CRF is the higher cost in comparison with conventional fertilizers. However, the application of the MTED, with the purpose of maximizing the input use in the production of rootstocks, has been proving to be an economically viable alternative if we consider the price increase of basic inputs. Other characteristics to be considered are the conventional fertilizers high susceptibility of leaching due to the frequency of irrigation in the nursery and the need for parcelled applications, which are driven by higher production costs (Melo Júnior *et al.,* 2014).

The lowest ΔSD presented by plants that are grown in full sunlight (external environment) can be attributed to the restriction of the ideal microclimatic conditions for the plants growth, such as solar radiation, precipitation, wind and temperature. In our region, the high temperatures at full sun, which occur between October and January, may have caused thermal stress. Such conditions reduce transpiration, which consequently decreases the photosynthetic rates and accelerates the respiratory metabolism, reducing the growth rate not only for SD, but for all morphological variables (Afonso *et al.,* 2017; Bassi *et al.,* 2018).

Another factor that may have contributed to reduce the plants growth in external environment was the CRF formulation. The granules contain a homogeneous combination of nutrients and are covered by an organic resin that regulates the nutrients release proportionally to the substrates temperature and humidity (Melo Júnior *et al.,* 2014). In addition to the high temperatures, the heavy rainfall can contribute to accelerate the release of CRF nutrients, resulting in leaching losses.

According to the data provided by the Agroclimatology Station of Pelotas (EAPEL, 2017), between October 2016 and January 2017, the cumulative rainfall reached 549 mm, with a monthly average of approximately 137 mm, concentrated in three to four days of each month. The intense and concentrated precipitation in a short period of time may have caused greater leaching of the nutrients present in the soil solution that had the plants in external environment, reducing the efficiency of the fertilizer use and resulting in lower values for the evaluated variables in comparison with the plants grown in a greenhouse, which did not suffer the influence of the precipitation variable.

Considering the results obtained in this study, it was suggested that the control of the environment for plant cultivation provides greater efficiency in the use of productive resources (nutrients, water, temperature, light and others). In addition to these factors, the use of CRF incorporated into the substrate contributes to cause precocity in the production of peach rootstocks (reduction of the period to reach the grafting point) with a high-quality standard.

4. Conclusions

Considering the results obtained in this study, the cultivation of plants in a greenhouse is proposed, since it provides the best conditions for the use of CRF by the plants, and the concomitant use of the minimum dose of 4.0 g L^{-1} because it reduces the period to reach the grafting point to 90 days.

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