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Morphological traits of 'Granada' peach nursery trees from rootstocks of two production systems

Abstract – The objective of this work was to evaluate the effect of the use of rootstocks from clonal and seed production systems on the morphology of nursery peach trees of cultivar Granada. The experiment was carried out in a completely randomized design with five treatments ('Granada' scion grafted onto five rootstocks) and five replicates. The rootstocks from clonal production were the 'Okinawa' peach plant and the GKM-ELD-10-70, EF-SAU-10-78, and EF-SAU-10-87 peach genotypes kept in pots. The rootstocks from the seed production system came from peach seed of some scion varieties (mixed pits) used for canning production and propagated in a nursery field system. Shoot and root morphological variables were evaluated. The rootstock production system did not affect root volume. However, the nursery trees of the clonal rootstocks system kept in pots showed a higher percentage of water in the roots. The clonal rootstocks in the potted system do not affect most of the morphological traits of 'Granada' peach nursery trees; however, they induce a homogeneous root system and delay leaf abscission, besides not requiring root pruning.

Index terms: *Prunus persica*, propagation method, rootstock, stone fruit.

Morfologia de mudas de pessegueiro 'Granada' com porta-enxertos de dois sistemas de produção

Resumo – O objetivo deste trabalho foi avaliar o efeito do uso de porta-enxertos provenientes dos sistemas de produção clonal e por sementes sobre as características morfológicas de mudas de pessegueiro da cultivar Granada. O experimento foi realizado em delineamento inteiramente casualizado, com cinco tratamentos (copa 'Granada' enxertada em cinco porta-enxertos) e cinco repetições. Os porta-enxertos da produção clonal foram o pessegueiro 'Okinawa' e os genótipos de pessegueiro GKM-ELD-10-70, EF-SAU-10-78 e EF-SAU-10-87 mantidos em vasos. Os porta-enxertos do sistema por sementes provieram de sementes de pêssego de algumas variedades copa (mistura de sementes), utilizadas para a fabricação de conserva e propagados em sistema de viveiro de campo. Foram avaliadas as variáveis morfológicas da parte aérea e das raízes. O sistema de produção dos porta-enxertos não afetou o volume de raízes. No entanto, as mudas do sistema de porta-enxertos clonais em vasos apresentaram maior percentagem de água nas raízes. Os porta-enxertos clonais em sistema de vasos não afetam a maioria das características morfológicas de mudas de pessegueiro 'Granada'; no entanto, induzem um sistema radicular homogêneo e retardam a abscisão foliar, além de não necessitarem de poda radicular.

Termos para indexação: *Prunus persica*, método de propagação, porta-enxerto, frutífera de caroço.

Guilherme Nicolao[1 ✉],
Newton Alex Mayer[2],
Bernardo Ueno[2] and
Valmor João Bianchi[3]

[1] Universidade Federal de Pelotas, Faculdade de Agronomia Eliseu Maciel, Avenida Eliseu Maciel, s/nº, CEP 96160-000 Capão do Leão, RS, Brazil.
E-mail: guilherme.nicolao@ufpel.edu.br

[2] Embrapa Clima Temperado, BR-392, Km 78, 9.° Distrito, Monte Bonito, Caixa Postal 403, CEP 96010-971 Pelotas, RS, Brazil.
E-mail: alex.mayer@embrapa.br, bernardo.ueno@embrapa.br

[3] Universidade Federal de Pelotas, Departamento de Botânica, Instituto de Biologia, Avenida Eliseu Maciel, s/nº, CEP 96001-970 Capão do Leão, RS, Brazil.
E-mail: valmor.bianchi@ufpel.edu.br

✉ Corresponding author

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Introduction

The quality of a nursery tree is defined by genetic, sanitary, and morphophysiological traits, and it is an efficient propagation method and production system that could improve orchard productivity and longevity. The vegetative propagation of rootstock and scion allows to choose tolerant genotypes to pests, diseases, drought, and waterlogging, in addition to stimulate the vigor of trees and peach yield (Paula et al., 2011; Klumb et al., 2017; Yordanov et al., 2018; Beckman et al., 2019; Hayat et al., 2020; Mayer et al., 2021a). In the Rosaceae family, the effects of rootstock on tree vigor are more notable on apple (Biasuz & Kalcsits, 2022), plum (Wolf et al., 2019), and apricot (Yordanov et al., 2018) than on peach (Zhivondov et al., 2017; Szymajda et al., 2020). This way, identifying peach rootstock genotypes with different levels of vigor can be useful for different tree densities and training systems.

The genetic quality (rootstock cultivar) of tree propagative material has been associated with peach tree short life (PTSL) (Beckman et al., 2019), a devastating syndrome caused by biotic and abiotic factors, firstly identified in the United States of America and similarly observed in the south of Brazil (Mayer & Ueno, 2021). This syndrome happens in the early years of the orchard, causing a sudden collapse of plants in late winter or early spring, and the plants show symptoms like bud fall and necrosis on one-year-shoots and scaffolds, wilting of sprouts, and death of some branches or of the entire scion in more severe cases (Beckman et al., 2019; Mayer & Ueno, 2021). This syndrome is mainly attributed to the use of segregating seed from different scion cultivar, obtained from peach canning industries for rootstock production, which reduces the morphological and physiological quality of the nursery trees. Consequently, this kind of rootstock has poor adaptability to soil conditions at orchards, such as drought, waterlogging, PTSL, and to the high temperature amplitude in the fall and winter (Mayer & Ueno, 2021).

The absence of a well-recommended rootstock for PTSL sites in Brazil has led researchers to start selecting, rescuing, and cloning potentially tolerant rootstocks (Mayer & Ueno, 2021). These genotypes are vegetatively propagated under intermittent mist system and growing in potted system with fertigation, in greenhouse conditions (Mayer & Ueno, 2021; Nicolao et al., 2021). The morphology of these potted trees with clonal rootstocks should be compared with bare-root seedling rootstocks from conventional nursery tree production system, for a better understanding in field orchard performances.

The state of Rio Grande do Sul, Brazil, has laid down some standards for stone fruit nursery trees, like the identification of rootstock and scion, minimum diameter of 1 cm at 5 cm above the grafting point, main stem with at least 50 cm height between the collar and the apex, with lateral shoots of at most 25 cm, and height of the graft between 10 and 20 cm above the collar (Rio Grande do Sul, 1998). In the USA, the quality of nursery trees is standard by a series of aspects, aiming to guarantee a minimum quality, according to the needs of each crop (American National Standards, 2014).

Furthermore, the traditional system of nursery trees production in the south of Brazil does not guarantee the rootstock identity because the mix of scion cultivars used to produce rootstock were not selected for nematode tolerance, such as *Mesocriconema xenoplax*, *Meloidogyne* spp. and *Pratylenchus* spp., which can be present on many Brazilian nursery fields and orchard areas. However, these nematodes cannot be controlled by pesticides because there are no registered nematicides for peach trees in Brazil (Agrofit..., 2022).

In order to avoid diseases and improve the conditions for growing trees, other fruit crops demand the cultivation in greenhouse, in nursery tree production, such as those for sour passion fruit free of virus (Petry et al., 2019), guava free of *Meloidogyne* spp. (Pereira et al., 2017); and *Citrus* free of greening (Bové et al., 2015).

The objective of this work was to evaluate the effect of the use of rootstocks from clonal and seed production systems on the morphology of nursery peach trees of cultivar Granada.

Materials and Methods

The experiment was carried out at the greenhouse of Embrapa Clima Temperado, an Emprapa's agricultural research center for temperate climate, located in the municipality of Pelotas, in the state of Rio Grande do Sul (RS), Brazil (31°40'46"S, 52°26'23"W) from December, 2019 to June, 2021.

The trial was carried out in a completely randomized design, with five treatments and five replicates, with one nursery tree per plot, totaling 25 plots. The treatments consisted of the combination of the scion 'Granada' grafted on five rootstocks from clonal and seed production systems. The rootstocks from the clonal production system were 'Okinawa' peach, and the peach genotypes GKM-ELD-10-70, EF-SAU-10-78 and EF-SAU-10-87 maintained in pots. The rootstocks from the seed production system came from peach seed of some scion varieties (mixed pits) used for canning manufacturing and propagated in a nursery field system.

For the production of nursery trees on rootstocks from the clonal production, softwood leafy cuttings were prepared from shoots collected from mother trees of the *Prunus* rootstock germplasm bank of Embrapa Clima Temperado. Cuttings were left under intermittent mist system for adventitious rooting (Nicolao et al., 2021). After the rooting period, the rooted suitable cuttings were transplanted to pots developed for citrus nursery trees (*citro*-pots of 3.78 L), filled with Turfa Fértil (SSP Hortaliça CA) substrate. The substrate consisted of peat (70% v/v) and charred rice husk (30% v/v), with the addition of N (0.04%), P_2O_5 (0.04%), K_2O (0.05%), and calcitic limestone (1.5%). Rooted cuttings were kept by 30 days on acclimation, and then they were transferred to a greenhouse for growing in 44.4 *citro*-pots per m² arranged on benches. The rootstocks were grafted with 'Granada' peach (Raseira et al., 2014) by inverted T-method. Nursery trees were fertigated by two min, twice a day, with nutrient solution (Mayer et al., 2021b).

The production of nursery trees on rootstock from seed (mixed pits) was done in the field system, carried out in a commercial nursery located in the municipality of Pelotas, RS, Brazil. Nonidentified scion peach pits were dried under shade and sown in the nursery field at 1.2×0.1 m spacing (8.33 nursery trees per m²). The grafting of scion peach 'Granada' was made by the inverted-T method. These nursery trees were routinely managed, including drip irrigation. Five samples of nursery trees were randomly collected, and their whole root system protected by wet soil to avoid dehydration.

The nursery trees morphology were determined for the variables and tools described as follows: collar stem diameter and stem diameter, at 5 cm above and below grafting point (mm), calculated through the average of two measured cross-sections, with a digital caliper; grafting point height from the collar line, with a measuring tape; tree height from the collar line to the top of the stem (cm), with measuring tape; first lateral shoot height, from the grafting point to the insertion one of the lateral shoot, with a measuring tape; average length of lateral shoots (cm), measuring the total length of shoots (with a measuring tape) by plant, divided by the total number of shoots. Additionally, the average leaf number and lateral shoot number per tree were counted, and leaf fresh matter (g) was obtained in an analytical balance.

Tree root systems were carefully washed in tap water, and the root volume (cm³) was determined by submerging the root system in a graduate test tube (1 L) with water, until the collar line. Root volume was estimated by water displacement (1 mL = 1 cm³).

The nursery trees were pruned at 50 cm height (from the collar), and the fresh matter of pruned shoots (g) was weighed. At the collar line, shoot and root system were separated. Fresh matter of remaining shoot (g) was determined with analytical balance.

Traditionally, bare-root nursery peach trees from field nurseries should have the root pruned for sale. Thus, bare-root nursery tree samples had their roots pruned, leaving all roots with 15 cm length. Fresh pruned roots (g) were measured with analytical balance. Nursery tree samples from the potted system were not tangled, therefore, the root pruning was not necessary. Total fresh matter (g) was obtained by the sum of pruned and remaining fresh matter of the roots and shoots.

All shoot and root samples were conditioned in paper bags and dried in oven at 65°C until constant matter was attained, and dry matter (g) of each part was determined. Shoot/root dry matter ratio was also determined. Root and shoot water percentage was obtained by fresh/dry matter ratio. Due to the absence of leaves in the mixed pits rootstocks, the variables leaf fresh matter, leaf dry matter and leaf water (%) were compared just among the treatments of potted trees of the clonal system ('Okinawa' and GKM-ELD-10-70, EF-SAU-10-78, EF-SAU-10-87). Finally, the Dickson quality index was determined according to Dickson et al. (1960).

The variables were expressed as percentages and transformed into arc sen $\sqrt{x/100}$. The data were subjected to analyses of variance, and the means were compared by Tukey's test, at 5% probability, using the SASM-Agri software.

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Results and Discussion

There were no differences among rootstock treatments for the stem collar diameter, stem diameter below the grafting point, and lateral shoot length (Table 1). The stem diameter above grafting point was larger in mixed pit trees than on EF-SAU-10-78. This trait is related to the spacing between nursery trees that is more favorable for plants grown in the field, since they receive more solar radiation, which results in higher accumulation of biomass than plants growing closer in the greenhouse. Similar response was obtained in apple nursery trees, as apple plants have a larger leaf area and diameter of main stem, and a larger spacing is used among the plants (Zhang et al., 2015).

Nursery trees on mixed pit rootstocks had the grafting point height (8.3 cm) out of the standard that is between 10 and 20 cm established in the rules of Rio Grande do Sul state (Rio Grande do Sul, 1998). However, this is a variable that can be easily adjusted by instructions to the grafters.

Nursery trees grafted on EF-SAU-10-78 had their aerial part smaller than those on 'Okinawa', a vigorous rootstock (Table 1). The influence of the rootstock on the trees is well documented for several fruit trees specie, as follows: apple (Zhang et al., 2015; Biasuz & Kalcsits, 2022); plum (Wolf et al., 2019); and for peach trees, in which Zhivondov et al. (2017) also observed a lower vigor of the scion cultivar Baby Gold 9, grafted on n.° 9-205 (clonal rootstock) than on 'Elberta' (seedlings). Differences in vigor (also expressed by collar stem diameter) among rootstocks are related to water and nutrient use efficiency, which results in differences for the synthesis of carbohydrates (Klumb et al., 2017).

The first lateral shoot height was affected by the rootstocks (Table 1). 'Granada' scions grafted onto 'Okinawa' and GKM-ELD-10-70 were taller than on EF-SAU-10-78, EF-SAU-10-87 and mixed pits rootstock. 'Okinawa' and GKM-ELD-10-70 reduced the scion branching. Szymajda et al. (2020) also observed a larger number of lateral shoots on less vigorous rootstocks, showing the inverse relationship between vigor and branching on 'Redhaven' peach nursery trees .

The lateral shoot number was affected by the rootstocks, in which bare-root nursery trees from the conventional system had an average of 14.8 lateral shoots, which is greater than the average on clonal rootstocks of the alternative system (Table 1). Nursery environmental conditions, like tree density, sun radiation, and genetic combination (scion/rootstock) can affect the balance of plant growth regulators and scion branching (Figure 1), differently from the conditions imposed in greenhouse, where plants are closer and more shaded, which modifies the plant growth pattern (Zhang et al., 2015).

The root volume, total fresh matter, total dry matter, total fresh matter of shoots, shoot water content, and shoot/root ratio were not affected by the treatments (Table 2). The transplant of suitable rooted cuttings of rootstocks and fertigation contribute to the uniformity of nursery trees from the potted alternative system.

Table 1. Morphological characterization of shoots of 'Granada' peach (*Prunus persica*) nursery trees grafted on four clonal rootstocks, and produced in potted system in a greenhouse, and grafted on rootstocks from seed production system (mixed pits) propagated in nursery field(1).

Rootstock	Stem collar diameter (mm)	Stem diameter below the grafting point (mm)	Stem diameter above the grafting point (mm)	Grafting point height (cm)	Aerial tree height (cm)	First lateral shoot height (cm)	Number of lateral shoots	Average length of lateral shoots
Okinawa(2)	14.12a	11.85a	8.28ab	13.90a	85.00a	39.70a	6.00b	12.30a
GKM-ELD-10-70(2)	12.80a	11.16a	8.61ab	11.60b	80.40ab	26.70a	4.20b	17.60a
EF-SAU-10-78(2)	12.96a	11.82a	7.44b	12.60b	54.20b	13.90b	3.40b	13.10a
EF-SAU-10-87(2)	13.27a	12.50a	8.12ab	11.80b	70.40ab	14.90b	4.60b	13.40a
Mixed pits	13.96a	13.18a	10.92a	8.30c	69.00ab	13.80b	14.80a	15.60a
$F_{rootstock}$	0.4848^{ns}	0.9610^{ns}	3.8290*	46.7717**	3.1006*	1.9820^{ns}	11.4062**	0.3878^{ns}
CV (%)	14.17	14.64	17.49	5.83	21.07	82.95	46.95	53.36

(1)Means followed by equal letters in the columns do not differ from each other, by Tukey's test, at 5% probability. ^{ns}Nonsignificant. * and **Significant at 5% and 1% probability, respectively. (2)Clonal rootstocks.

Rootstock propagation by seed from plants not selected to be used for such purpose can promote heterogeneity among nursery trees (Menegatti et al., 2022), since the variability of seed size and starch reserve, among rootstocks cultivars, may result in differences among nursery trees for tree growth and vigor.

Root water content was lower in mixed pit rootstocks (47.0%) than in clonal rootstocks that had no difference among them (Table 2). Values between 55.0 and 55.3% of water in the root tissue were reported for 'Miyabi Fuji' apple nursery trees on 'Marubakaido' and 'M.9' rootstocks produced in field system (Botirov & Arakawa, 2021). Bare-root nursery trees showed a lower root water content due to leaf fall, which resulted in stopping transpiration and in translocation of soluble sugars, consequently reducing water and nutrient uptake in the winter (June to September).

Figure 1. 'Granada' peach (*Prunus persica*) nursery trees produced by two systems: A, alternative potted system subjected to fertigation inside a greenhouse, showing healthy leaf retention (bar = 10 cm); B, conventional bare-root system under field conditions, showing no leaf retention (bar = 10 cm); C, fasciculate root system with several fine roots, from a nursery tree budded on GKM-ELD-10-70 clonal rootstock selection after root washing; and D, a heterogeneous root system and poor fine roots of a bare-root tree after root pruning. Photos by Newton Alex Mayer.

Total dry matter of shoots was greater in mixed pit rootstocks than on EF-SAU-10-78 (Table 2). Dry matter of shoots is related to spacing among nursery trees, which is intrinsic to each system of production. Vigor is affected by rootstock, which induces growth differences before budding (Oliveira et al., 2020) and can change the biomass allocation between root and shoot, after budding (Menegatti et al., 2022). Larger differences were reported for shoot dry matter of 'Esmeralda' peach nursery trees budded on mixed pits rootstocks than this species budded on the selection VHS-SEN-10-07 (Mayer et al., 2021b).

There were no differences among rootstocks for pruned and remaining shoot fresh matter (Table 3). The pruning removed 34% of root fresh matter of trees on mixed pit rootstocks, which resulted on less root fresh matter than that from trees on GKM-ELD-10-70, while trees from the alternative system did not differ among them. Root pruning of bare-root nursery trees implies a significant reduction of the matter of adventitious roots, eliminating an important reserve of carbohydrates that is necessary for the resumption of growth of a new adventitious root system and subsequent sprouting. The negative impact of root pruning was described by Symeonidou & Buckley (1999), when the root pruning in nursery trees of *Prunus avium* and *P. cerasifera* caused the shoot growth decreasing after the field transplant.

The remaining root fresh matter was affected by rootstocks, and it was lower for plants on mixed pit rootstocks than for those on GKM-ELD-10-70 (Table 3). Larger fresh matter of remaining roots on GKM-ELD-10-70 can be an advantage for establishment in the field, due to the larger contact of roots with the soil surface. According to Tworkoski et al. (2016), a larger root matter increases the tolerance to drought in apple trees, resulting on the faster recovery of the photosynthetic activity after a drought period. In the Rosaceae family, the rootstock affects the fresh matter of scion, which is related to strength and capacity to explore the soil resources (Hayat et al., 2020).

Leaf number, leaf fresh matter, leaf dry matter, and leaf water content were affected by the treatments, and their values were higher in trees from the alternative system than those from the mixed pit rootstocks (Table 3). These traits may be related to the growing in greenhouse, as it allows to the plants a better control on pests and diseases, temperature, and incidence of strong wind, which can affect the photosynthetic efficiency. In addition, the individual fertigation system allows of a better substrate moisture to meet the transpiration demand of scions, resulting in a higher translocation of sugars and mineral nutrients to be stored in roots and branches (Lawrance & Melgar, 2018).

There was no effect of treatments on the remaining root dry matter, pruned shoot dry matter, and remaining shoot dry matter. However, the pruned root dry matter was affected by the treatments (Table 4). The pruning of roots requires extra energy from the plant to form new adventitious roots soon after transplanting. However, the absence of root pruning in the alternative system makes it possible to use the carbohydrate stored for growth, which can result in a large growth differential. The pruning of 50 and 75% of length of taproot resulted in a lower shoot number in the first two years in the field in nursery trees of *Carya illinoinensis* 'Kanza' (Oueodraogo et al., 2020).

The Dickson quality index exhibited no variation among the different rootstocks (Table 4). According to Binotto et al. (2010), the stem base diameter, root dry matter, and shoot dry matter are the variables most strongly correlated with the Dickson quality index. However, the stem base diameter and root dry matter did not differ among the tested rootstocks, which did not result in differences for this index.

Table 2. Morphological characterization for water content, fresh (FM) and dry (DM) matter of roots and shoots of 'Granada' peach (*Prunus persica*) nursery trees grafted on four clonal rootstocks and produced in potted system in a greenhouse, and on rootstocks from seed production system (mixed pits) propagated in nursery field[(1)].

Rootstock	Root volume	Root			Shoot			Shoot/root dry
	(cm^3)	Total FM (g)	Total DM (g)	Water (%)	Total FM (g)	Total DM (g)	Water (%)	matter ratio
Okinawa[(2)]	99.20a	108.20a	25.90a	68.90a	62.00a	29.10ab	53.10a	1.37a
GKM-ELD 10-70[(2)]	134.00a	122.20a	30.80a	74.80a	66.80a	24.90ab	62.70a	0.79a
EF-SAU-10-78[(2)]	102.00a	101.40a	24.20a	69.60a	41.60a	15.10b	63.70a	1.58a
EF-SAU-10-87[(2)]	108.00a	109.40a	33.60a	77.90a	57.60a	23.30ab	59.50a	0.70a
Mixed pits	79.60a	79.60a	41.90a	47.00b	81.40a	38.70a	52.50a	0.93a
$F_{rootstock}$	0.7379^{ns}	2.8660^{ns}	1.1206^{ns}	14.5226**	1.2075^{ns}	2.7752*	0.8736^{ns}	0.8340^{ns}
CV (%)	48.83	45.34	47.35	12.98	46.84	44.81	27.95	86.47

[(1)]Means followed by equal letters in the columns, do not differ from each other by Tukey's test, at 5% probability. ^{ns}Nonsignificant. ** and *Significant at 1% and 5% probability, respectively. [(2)]Clonal rootstocks.

Table 3. Morphological characterization for root fresh matter, shoot fresh matter, leaf number, leaf fresh and dry matter, and leaf water content of 'Granada' peach (*Prunus persica*) nursery trees grafted on four clonal rootstocks and produced in potted system in a greenhouse, and grafted on rootstocks from a seed production system (mixed pits) propagated in a nursery field[(1)].

Rootstock	Root fresh matter (g)		Shoot fresh matter (g)		Leaf number	Leaf fresh matter (g)	Leaf dry matter (g)	Leaf water (%)
	Pruned	Remaining	Pruned	Remaining				
Okinawa[(2)]	0.00b	108.20ab	15.60a	46.40a	64.40a	39.00a	11.40a	70.80a
GKM-ELD-10-70[(2)]	0.00b	122.20a	18.80a	48.00a	84.80a	54.00a	13.10a	74.60a
EF-SAU-10-78[(2)]	0.00b	101.40ab	5.40a	36.20a	45.80a	33.40a	9.90a	70.00a
EF-SAU-10-87[(2)]	0.00b	109.40ab	14.00a	43.60a	69.40a	49.00a	13.90a	72.00a
Mixed pits	27.80a	51.80b	25.20a	56.20a	0.00b	-	-	-
$F_{rootstock}$	24.8981*	3.3350*	1.3156^{ns}	1.0082^{ns}	4.9300*	1.244^{ns}	0.51134^{ns}	0.5936^{ns}
CV (%)	100.20	47.94	89.95	35.01	62.23	42.74	46.10	8.14

[(1)]Means followed by equal letters in the columns, do not differ from each other by Tukey's test, at 5% probability. *Significant at 5% probability. ^{ns}Nonsignificant. [(2)]Clonal rootstocks.

Table 4. Morphological characterization for pruned and remaining roots and shoot dry matter of 'Granada' peach (*Prunus persica*) nursery trees grafted on four clonal rootstocks and produced in potted system in a greenhouse, and on rootstocks from seed production system (mixed pits) propagated in a nursery field(1).

Rootstock	Root dry matter (g)		Shoot dry matter (g)		DQI
	Pruned	Remaining	Pruned	Remaining	
Okinawa(2)	0.00b	25.90a	6.70a	22.40a	8.00a
GKM-ELD-10-70(2)	0.00b	30.80a	7.80a	17.10a	7.70a
EF-SAU-10-78(2)	0.00b	24.20a	2.50a	12.60a	8.20a
EF-SAU-10-87(2)	0.00b	33.60a	6.80a	16.50a	9.50a
Mixed pits	13.70a	28.20a	10.90a	27.80a	14.30a
$F_{rootstock}$	22.4040**	0.3494^{ns}	2.1900^{ns}	2.5722^{ns}	1.7998^{ns}
CV (%)	105.64	49.73	84.97	42.60	48.28

(1)Means followed by equal letters in the columns, do not differ from each other by Tukey's test, at 5% probability. **Significant at 1% probability. nsNonsignificant. DQI: Dickson quality index. (2)Clonal rootstocks.

In the present work, positive effects were verified for the morphology of peach nursery trees from the clonal rootstock system in the potted production subjected to fertigation, in the greenhouse. Peach nursery trees from clonal rootstocks with superior morphological patterns can contribute to a greater tree survival in the field, with increasing yield, and better tolerance to biotic and abiotic adversities of the environment. Clonal rootstock and potted peach nursery tree production in a greenhouse can reduce the need for many nursery procedures, which are normally observed in the bare-root seedling rootstock of the conventional field system, such as manual weeding, herbicide applications, nursery tree uprooting, difficulty with pest control and fertilization, area rotation, no environmental control, as well as hard cultural practices for workers, like grafting in the field. However, peach nursery trees on the clonal rootstock production requires technical knowledge, nursery employees training, and adequate nursery facilities. Peach nursery tree production costs can be changed and should be decisive in future research.

Conclusions

1. The clonal rootstock production in potted system, in greenhouse, does not affect most of the morphological traits of 'Granada' peach (*Prunus persica*) nursery trees; however, it induces a homogeneous root system, delayed leaf abscission, and exclude the need for root pruning.

2. The evaluated clonal rootstocks produce peach nursery trees with a better water status and minor shoot branching than the mixed pit rootstock propagated in nursery field system.

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References

AGROFIT: Sistema de Agrotóxicos Fitossanitários. Available at: https://agrofit.agricultura.gov.br/agrofit_cons/principal_agrofit_cons. Acessed on: Apr. 27 2022.

AMERICAN NATIONAL STANDARDS. **American standard for nursery stock**. 2nd ed. Columbus: American Hort, 2014. 97p. Available at: <https://www.americanhort.org/education/american-nursery-stock-standards/>. Acessed on: Apr. 5 2022.

BECKMAN, T.G.; ROLLINS, P.A.; PITTS, J.; CHAVEZ, D.J.; CHAPARRO, J.X. Disease resistance of 'MP-29', a clonal interspecific hybrid rootstock for peach, in post-release trials. **HortScience**, v.54, p.638-641, 2019. DOI: https://doi.org/10.21273/HORTSCI13592-18.

BIASUZ, E.C.; KALCSITS, L.A. Apple rootstocks affect functional leaf traits with consequential effects on carbon isotope composition and vegetative vigour. **AoB Plants**, v.14, p.1-11, 2022. DOI: https://doi.org/10.1093/aobpla/plac020.

BINOTTO, A.F.; LÚCIO, A.D.C.; LOPES, S.J. Correlations between growth variables and the Dickson quality index in forest seedlings. **Cerne**, v.16, p.457-464, 2010. DOI: https://doi.org/10.1590/S0104-77602010000400005.

BOTIROV, A.; ARAKAWA, O. Root growth changes in the winter planting of young 'Miyabi Fuji' apple trees. **International Journal of Horticultural Science and Technology**, v.8, p.227-233, 2021. DOI: https://doi.org/10.22059/IJHST.2021.315746.428.

BOVÉ, J.M.; ROGERS, M.E. Huanglongbing-control Worshop: Summary. **Acta Horticulturae**, v.1065, p.869-889, 2015. DOI: https://doi.org/10.17660/ActaHortic.2015.1065.109.

DICKSON, A.; LEAF, A.L.; HOSNER, J.F. Quality appraisal of white spruce and white pine seedling stock in nurseries. **Forestry Chronicle**, v.36, p.10-13, 1960. DOI: https://doi.org/10.5558/tfc36010-1.

HAYAT, F.; ASGHAR, S.; YANMIN, Z.; XUE, T.; NAWAZ, M.A.; XU, X., WANG, Y.; WU, T.; ZHANG, X.; QIU, C.; HAN, Z. Rootstock induced vigour is associated with physiological, biochemical and molecular changes in 'Red Fuji' apple. **International Journal of Agriculture & Biology**, v.24, p.1823-1834, 2020.

KLUMB, E.K.; RICKES, L.N.; BRAGA, E.J.B.; BIANCHI, V.J. Evaluation of gas exchanges in different *prunus* spp. rootstocks under drought and flooding stress. **Revista Brasileira de Fruticultura**, v.39, e899, 2017. DOI: https://doi.org/10.1590/0100-29452017899.

LAWRANCE, B.T.; MELGAR, J.C. Variable fall climate influences nutrient resorption and reserve storage in young peach trees. **Frontiers in Plant Science**, v.9, art.1819, 2018. DOI: https://doi.org/10.3389/fpls.2018.01819.

MAYER, N.A.; UENO, B. A morte precoce do pessegueiro no estado do Rio Grande do Sul, Brasil. **Agrociencia Uruguay**, v.25, art.395, 2021. DOI: https://doi.org/10.31285/AGRO.25.395.

MAYER, N.A.; UENO, B.; ANTUNES, L.E.C.; NAVA, G.; ROTH, F.M. Agronomic performance of 'BRS Kampai' peach on 15 clonal rootstocks and own-rooted trees in Pelotas-RS, Brazil. **Revista Brasileira de Fruticultura**, v.43, e-115, 2021a. DOI: https://doi.org/10.1590/0100-29452021115.

MAYER, N.A.; UENO, B.; NICOLAO, G. **Comportamento de seleções clonais de porta-enxertos para pessegueiro em áreas de replantio com histórico de morte precoce**. Pelotas: Embrapa Clima Temperado, 2021b. 19p. (Embrapa Clima Temperado. Boletim de pesquisa e desenvolvimento, 344).

MENEGATTI, R.D.; SOUZA, A. das G.; BIANCHI, V.J. Nutritional status of 'BRS Rubimel' peach plants in the nursery as a function of the rootstock. **Acta Scientiarum. Agronomy**, v.44, e54327, 2022. DOI: https://doi.org/10.4025/actasciagron.v44i1.54327.

NICOLAO, G.; MAYER, N.A.; MUNHOZ, P. de O.; UENO, B. Enraizamento adventício em estacas herbáceas de *Prunus* spp. **Agropecuária Técnica**, v.42, p.24-33, 2021. DOI: https://doi.org/agrotec.v42i1-4.56104.

OLIVEIRA, J.A.A.; SILVA, D.F.P. da; BRUCKNER, C.H.; GOMES, F.R.; RAGAGNIN, A.L.S.L.; ASSUNÇÃO, H.F. da. Initial development of peach rootstock genotypes propagated by herbaceous cuttings. **Revista Brasileira de Fruticultura**, v.42, e-626, 2020. DOI: https://doi.org/10.1590/0100-29452020626.

OUEODRAOGO, F.B.; BRORSEN, B.W.; BIERMACHER, J.T.; ROHLA, C.T. Effects of pruning at planting on pecan trunk development and total shoot growth. **HortTechnology**, v.30, p.248-250, 2020. DOI: https://doi.org/10.21273/HORTTECH04535-19.

PAULA, L.A. de; BIANCHI, V.J.; GOMES, C.B.; FACHINELLO, J.C. Reação de porta-enxertos de pessegueiro à *Meloidogyne incognita*. **Revista Brasileira de Fruticultura**, v.33, p.680-684, 2011. DOI: https://doi.org/10.1590/S0100-29452011000200043.

PEREIRA, F.M.; USMAN, M.; MAYER, N.A.; NACHTIGAL, J.C.; MAPHANGA, O.R.M., WILLEMSE, S. Advances in guava propagation. **Revista Brasileira de Fruticultura**, v.39, e-358, 2017.

PETRY, H.B.; MARCHESI, D.R.; BACK, M.M.; DELLA BRUNA, E.; SCHÄFER, G.; MELETTI, L.M.M. Produção de mudas de maracujazeiro-azedo em ambiente protegido: dimensionamento e manejo do ambiente de produção. **Agropecuária Catarinense**, v.32, p.37-39, 2019.

RASEIRA, M. do C.B.; PEREIRA, J.F.M.; CARVALHO, F.L.C. (Ed.). **Pessegueiro**. Brasília: Embrapa, 2014. 776p.

RIO GRANDE DO SUL. Secretaria da Agricultura e Abastecimento. **Normas e padrões de mudas de fruteiras para o estado do Rio Grande do Sul**. Porto Alegre, 1998. 100p.

SYMEONIDOU, M.V.; BUCKLEY, G.P. The effect of pre-planting desiccation stress and root pruning on the physiological condition and subsequent field performance of one year old *Prunus avium* and *P. cerasifera* seedlings. **Journal of Horticultural Science & Biotechnology**, v.74, p.386-394, 1999. DOI: https://doi.org/10.1080/14620316.1999.11511126.

SZYMAJDA, M.; PRUSKI, K.; ZURAWICZ, E.; SITAREK, M. The nursery value of new *Prunus persica* seedlings rootstocks for peach cultivars. **Scientia Horticulturae**, v.266, art.109282, 2020. DOI: https://doi.org/10.1016/j.scienta.2020.109282.

TWORKOSKI, T.; FAZIO, G.; GLENN, D.M. Apple rootstock resistance to drought. **Scientia Horticulturae**, v.204, p.70-78, 2016. DOI: https://doi.org/10.1016/j.scienta.2016.01.047.

WOLF, J.; ONDRÁŠEK, I.; NEČAS, T. Potential use of spring budding techniques in production of plum nursery trees. **Proceedings of the Latvian Academy of Sciences**, v.73, p.220-225, 2019. DOI: https://doi.org/10.2478/prolas-2019-0035.

YORDANOV, A.I.; TABAKOV, S.G.; KAYMAKANOV, P.V. Propagation of some apricot clonal rootstocks and their influence on growth of nursery trees. **Acta Horticulturae**, v.1214, p.83-88, 2018. DOI: https://doi.org/10.17660/ActaHortic.2018.1214.14.

ZHANG, Q.; HAN, M.; SONG, C.; SONG, X.; ZHAO, C.; LIU, H.; HIRST, P.M.; ZHANG, D. Optimizing planting density for production of high-quality apple nursery stock in China. **New Zealand Journal of Crop and Horticultural Science**, v.43, p.7-17, 2015. DOI: https://doi.org/10.1080/01140671.2014.900093.

ZHIVONDOV, A.; VASILEV, D.; MALCHEV, S.; NACHEVA, L.; GERCHEVA, P. Study on the red-leaf hybrid no. 9-205 as a rootstock for peach and nectarine cultivars. **Acta Agriculturae Serbica**, v.22, p.3-9, 2017. DOI: https://doi.org/10.5937/AASer1743003Z.