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ORIGINAL ARTICLE

Screening for adventitious rooting in clonal selections of peach rootstocks

Screening para enraizamento adventício em seleções clonais de porta-enxertos para pessegueiro

Karen Pinheiro Lackman[1]*
Newton Alex Mayer[2]
Guilherme Nicolao[3]
Bernardo Ueno[4]

[1,2,3,4] Empresa Brasileira de Pesquisa Agropecuária (Embrapa) Clima Temperado, Rodovia BR-392, Km 78, 9º Distrito, 96010-971, Pelotas-RS, Brasil.

*** Corresponding Author:**
E-mail: lackman64@gmail.com

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ABSTRACT: The peach tree (*Prunus persica*) is one of the main fruit specie in temperate climate in the world, and its fruits are appreciated for fresh consumption or processed. The use of clonal rootstocks for peach trees is being promoted in the main producing countries, aiming at the preservation of genetic characteristics in selected genotypes. In the present research, the objective was to carry out a screening in 12 clonal selections of rootstocks (*Prunus persica*) to evaluate adventitious rooting capacity of softwood cuttings under intermittent mist system, comparing them with three reference cultivars. After fifty-three days of cutting set, determinations of nine variables were carried out, and in all of them there were significant differences among treatments. The screening allowed identification of rootstock selections that showed adventitious rooting capacity similar or even superior to the reference cultivars Capdeboscq, Okinawa and Sharpe, indicating advances in the selection process. Cutting mortality, in general, was high and occurred mainly before rooting initiation, indicating early leaf fall. Among tested selections, VEH-AGA-12-06, RB-MAC-12-08 and RB-MAC-12-09 stood out with the highest percentages of live rooted cuttings, and VEH-AGA-12-04 as to root number and root length.

RESUMO: *O pessegueiro (Prunus persica) é uma das principais frutíferas de clima temperado cultivadas no mundo, sendo seus frutos apreciados para consumo in natura ou processado. O uso de porta-enxertos clonais para pessegueiro está sendo fomentado nos principais países produtores, visando a preservação de características genéticas em genótipos selecionados. No presente trabalho, teve-se por objetivo realizar um screening em 12 seleções clonais de porta-enxertos (Prunus persica) para avaliar a capacidade de enraizamento adventício de estacas herbáceas em câmara de nebulização intermitente, comparando-as com três cultivares de referência. Após cinquenta e três dias da estaquia, realizaram-se as determinações de nove variáveis, sendo que em todas elas foram constatadas diferenças significativas entre os tratamentos. O screening permitiu identificar seleções de porta-enxerto que apresentaram capacidade de enraizamento adventício similar ou até superior às cultivares de referência Capdeboscq, Okinawa e Sharpe, indicando avanços no processo de seleção. A mortalidade de estacas, em geral, foi elevada e ocorreu principalmente antes da iniciação da formação das raízes, indicando queda precoce das folhas. Dentre as seleções testadas, se destacaram VEH-AGA-12-06, RB-MAC-12-08 e RB-MAC-12-09 com as maiores porcentagens de estacas enraizadas vivas, e VEH-AGA-12-04, quanto ao número e comprimento de raízes.*

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1 Introduction

Climatic conditions of the Southern Brazil favor the commercial peach, nectarine and plum orchards, all belonging to the genus *Prunus*. The region of Pelotas, Rio Grande do Sul State, has the largest peach growing area in the country, as it is an important stone nursery tree production pole, has the largest industrial park processing peaches, in addition to favorable climatic conditions and genetic improvement of adapted scion cultivars. For the nursery tree production, grafting is traditionally carried out in "inverted T-method" on peach rootstocks, which are predominantly produced through the seed germination, often obtained from the scion peach varieties for processing (Mayer *et al.*, 2014).

The peach tree can be propagated sexually or asexually. Sexual form (seeds) being indicated only at the beginning of genetic improvement programs or for the rootstock production, since they have been selected for this purpose and taken to homozygosis. In the asexual form or clonal propagation, softwood cuttings under a intermittent mist system have shown interesting results (Mayer *et al.*, 2020). A 12-15cm-long cuttings from softwood shoots are used, which perpetuate all the characteristics of the mother tree genotype, ensuring that the descendants remain genetically identical.

In Brazil, stone fruit nursery trees are predominantly produced in nurseries maintained under field conditions (bare root type), where active bud grafting onto *P. Persica* seed propagated rootstocks is adopted (Schmitz *et al.*, 2012; Mayer *et al.*, 2014). However, in nurseries that do not have their own mother tree rootstock blocks, seeds from the peach canning industries are used, which constitute mixtures of several scion cultivars with heterozygous characteristics that, later in the orchards, translate into non- uniformity among trees and different reactions to biotic and abiotic soil conditions, especially for Peach Tree Short Live (PTSL) (Rocha *et al.*, 2007; Mayer & Ueno, 2012; Schimitz *et al.*, 2012; Mayer *et al.*, 2014).

The Peach Tree Short Life (PTSL) syndrome is caused by a complex of biotic and abiotic factors, seen in clusters or isolated trees, where isolated or interacting factors, such as the ring nematode *Mesocriconema xenoplax*, pruning time (Nyczepir *et al.*, 1985; Nyczepir, 1990), root-knot nematodes (*Meloidogyne* spp.) (Reighard *et al.*, 2019), infection by *Pseudomonas siringae* (Lownsbery *et al.*, 1977) can cause symptoms at different levels, since bud drop to total scion death (Mayer & Ueno, 2012; Campos *et al.*, 2014). Trees of the same orchard grafted onto different rootstocks, or onto rootstocks with no known genetic identity (mixtures of canning seeds), show great variability of response in orchards in areas with a PTSL history, revealing the existence of more tolerant rootstock to this syndrome (Beckman *et al.*, 1993; Mayer & Ueno, 2012).

As an alternative to overcome problems arising from the traditional system of rootstock production in Southern Brazil, including losses due to PTSL, vegetative propagation through cuttings presents good prospects, as it allows nursery trees production in large quantities for commercial purposes (Mayer *et al.*, 2020).

Considering the effect of the genotype on rooting cuttings of *Prunus* spp. and the importance of ease propagation for peach rootstocks and commercial use (Mayer *et al.*, 2020) the present reserach sought to perform screenning to assess the adventitious rooting potential in softwood cuttings in twelve peach selections potentially tolerant to the PTSL, including the reference cultivars Capdeboscq, Okinawa and Sharpe.

2 Material and methods

The Cuttings were prepared from softwood shoots, collected from mother trees of cultivars and rootstock peach selections, kept in field conditions, at Embrapa Clima Temperado, Pelotas, Rio Grande do Sul State, Brazil. The preparation of the mother trees consisted of drastic pruning of all scaffolds at 1 to 1.2 m above ground level, with the aid of two-handed scissors or a saw, in early August 2020. Drastic pruning (Figure 1.a) aims to stimulate vigorous and uniform new shoots, with a favorable hormonal balance for rooting.

On January 7th, 2021, softwood shoots were collected and immediately disposed under intermittent mist system to avoid leaf dehydration (Figure 1. B). Then, 12cm-long cuttings were prepared, leaving two or three apical nodes with the leaves cut in half. The cutting base (3cm) was treated with 3,000 mg.L^{-1} of indolebutyric acid in liquid solution, for five seconds.

Cuttings were placed in perforated plastic boxes (46 x 30 x 10 cm), containing a ratio of 1:1 (v:v) of fine vermiculite and raw rice husks (Figures 1.c and 1.d). Boxes were placed on iron benches, inside an agricultural greenhouse equipped with an intermittent mist system which was programmed to be activated for 15sec at 5min intervals, allowing the leaf surface to remain constantly moist. From the beginning of February, the system was programmed to be turned off during the night.

Treatments consisted of twelve peach rootstocks selections of Embrapa Clima Temperado, from the 2012/2013 selection cycle aiming tolerance to the PTSL, in addition to three reference cultivars (Capdeboscq, Okinawa and Sharpe), totaling 15 treatments, as listed in Tables 1 and 2. Three replicates of fifteen cuttings were used, totaling forty-five cuttings per treatment, which were arranged in a completely randomized design.

Fifty-three days after cutting set, the following variables were evaluated: percentage of live rooted cuttings; percentage of callused cuttings; percentage of dead cuttings; percentage of dead rooted cuttings. The live rooted cuttings were visually classified as suitable or unsuitable for transplanting, considering a minimum of four roots and their adequate distribution around cutting base. In live rooted cuttings, root number per cutting was also counted and root length of the three largest roots per cutting was measured, with a ruler. The percentage of cuttings with original leaves and percentage of sprouted cuttings were also determined. Data of variables expressed as percentages were transformed into arc sen$\sqrt{x/100}$, being analyzed by F test and means compared by Scott-knott test. The other variables did not undergo transformation.

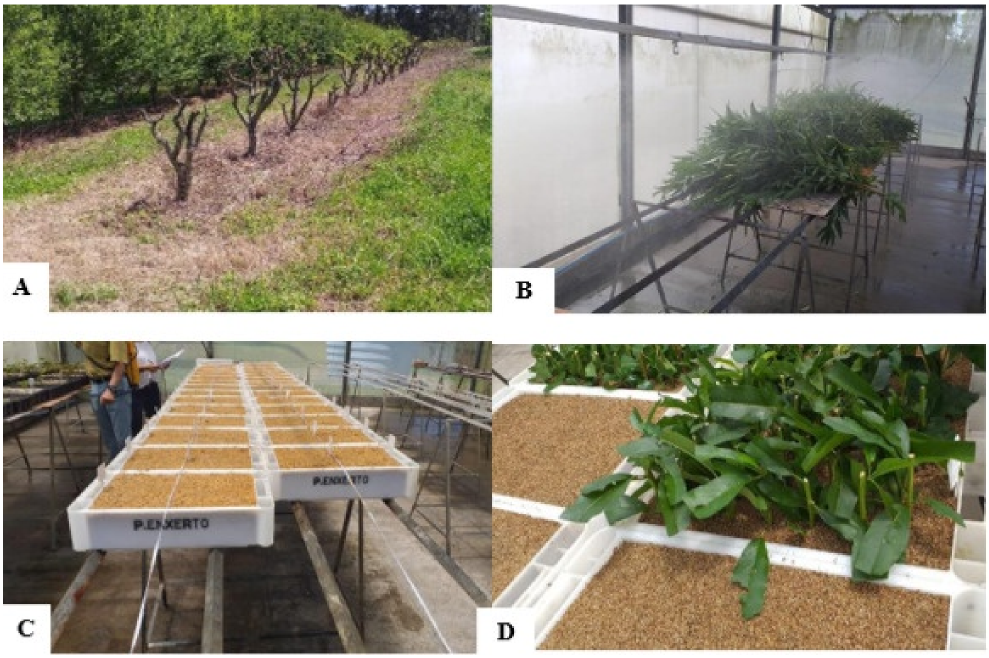

Figure 1. A) Drastic prunning on mother trees. B) Softwood shoots under intermittent mist, for moisture maintenance. C) Perforated plastic boxes containing a mixture of fine vermiculite and raw rice husks. D) 12cm-long cuttings in substrate for rooting. Source: Own authorship.

Figura 1. A) Plantas matrizes manejadas com poda drástica. B) Ramos herbáceos sob nebulização intermitente, para manutenção da hidratação. C) Caixas plásticas perfuradas contendo mistura de vermiculita fina e casca de arroz crua. D) Estacas com 12 cm acondicionadas em substrato para enraizamento. Fonte: autoria própria.

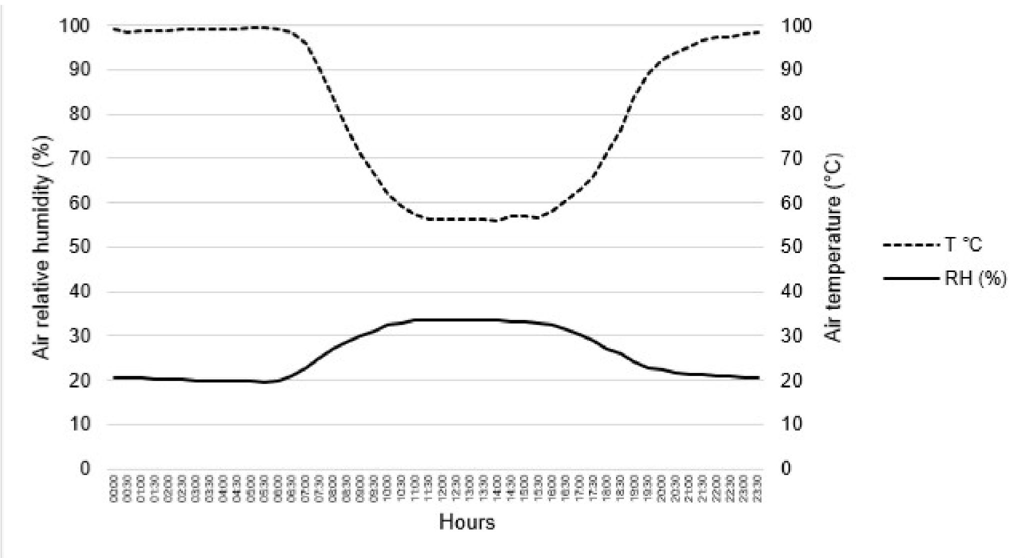

Figure 2. Air relative humidity (%) and air temperature (°C) inside greenhouse during trial time. The graph shows the averages for a 24-hour period, with records obtained every 30 minutes, between Jan/07/2021 and Mar/05/2021. Source: own authorship.

Figura 2. Umidade relativa do ar (%) e temperatura do ar (°C) no interior da estufa agrícola durante o período de condução do experimento. O gráfico apresenta as médias por período de 24h, com registros obtidos a cada 30 min, entre 07/jan/2021 e 05/mar/2021. Fonte: autoria própria.

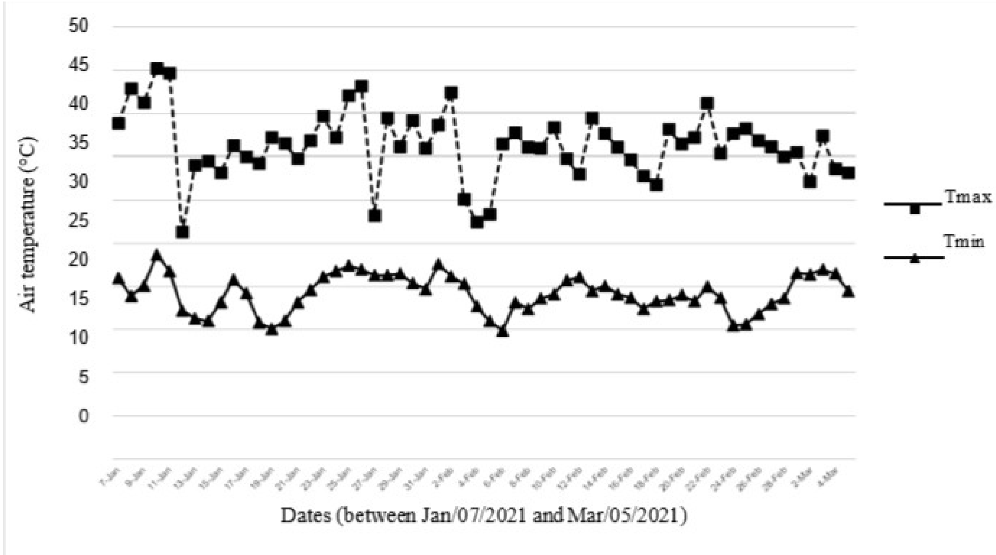

Figure 3. Maximum and minimum air temperatures (°C) recorded inside greenhouse during trial, between Jan/07/2021 and Mar/05/2021. Source: own authorship.
Figura 3: Temperaturas (°C) máximas e mínimas registradas no interior da estufa agrícola durante a condução do experimento, entre 07/Jan/2021 e 05/Mar/2021. Fonte: autoria própria.

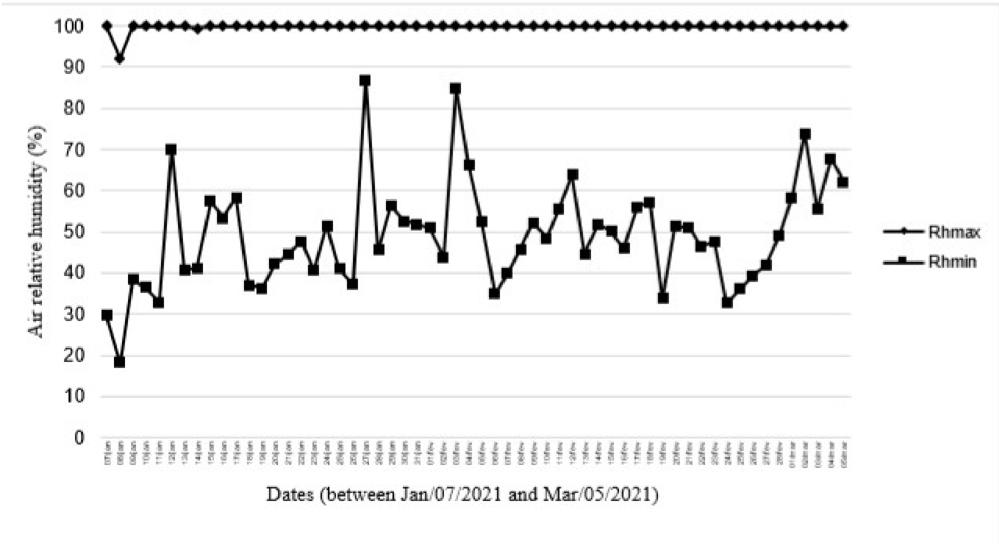

Figure 4. Maximum and minimum air relative humidity (%) recorded inside greenhouse during trial, between Jan/07/2021 and Mar/05/2021. Source: own authorship.
Figura 4: Umidades relativas (%) do ar máximas e mínimas registradas no interior da estufa agrícola durante a condução do experimento, entre 07/Jan/2021 e 05/Mar/2021. Fonte: autoria própria.

3 Results and Discussion

Cumulative Percentages of dead cuttings and dead rooted cuttings

There were significant differences among selected rootstocks in relation to dead cuttings, that is, cuttings that died without having formed any roots, whose values vary between 2.22% (Sharpe) and 71.11% (VEH-AGA-12-05) (Table 1). It was also verified that percentage of dead cuttings was always higher than percentage of dead rooted cuttings, for all tested genotypes, indicating early leaf fall, probably due the lack of leaf moisture uniformity between day and night.

A factor that contributes to cutting mortality is early leaf fall (Mayer *et al*., 2020), being the site of synthesis of endogenous auxins, responsible for adventitious rooting (Bona & Biasi, 2015). Genetic factors and growth habits also influence hormonal balance, reflecting in differentiated rooting potential. Two selections (VEH-AGA-12-03 and VEH-AGA-12-05) had the highest percentages of dead cuttings, with 52.22% and 71.11%, respectively. Data also show that none of the selections had the lowest percentage of dead cuttings compared to the reference cultivars, with ‘Okinawa’ and ‘Sharpe’ showing the lowest percentages (8.89 and 2.22%, respectively).

Five selections, in addition to the cultivars Capdeboscq and Okinawa, presented the highest percentages of dead rooted cuttings, whose values varied between 6.67% and 20.0%. Mortality of rooted cuttings under intermittent mist system is usually caused by oxygen deficiency at the cuttings base due to saturation of substrate pores with water (Pimentel *et al*., 2014). In this case, ‘Sharpe’ rootstock, due to its genetic inheritance from plum trees (Mayer & Ueno, 2015) may have presented tolerance to this situation of moisture in substrate. Two selections (RB-MAC-12-08 and RB-MAC-12-09), which were originally selected from the same commercial orchard, also had 0% of dead rooted cuttings. Tolerance to substrate saturated with moisture is related to oxygen consumption during respiration, which varies according to genotype (Toro *et al*., 2018). The ratio of 1:1 for the mixture of fine vermiculite and raw rice husk used as substrate may have contributed to poor drainage and even though the initial rooting process was formed, there was necrosis at the cuttings base (Mayer *et al*., 2020).

Percentages of live rooted cuttings

Cultivar Sharpe had the highest percentage of live rooted cuttings (97.78%) (Table 1). In the second group, with the highest percentages, are the cultivars Capdeboscq and Okinawa, in addition to the selections VEH-AGA-12-06, RB-MAC- 12-08 and RB-MAC-12-09, whose percentage of live rooted cuttings were between 71.11 and 84.44%.

Appropriate cuttings preparation, combined with a favorable environment for adventitious rooting, are the main factors for obtaining high percentages of live rooted cuttings. Survival of rooted cuttings is also related to the period necessary for root formation, which varies according to amount of reserves (starch and sucrose) present in cuttings (Tsipouridis et al., 2006) and the intrinsic characteristics of species and genotype (Hartmann *et al*., 2011). After root initiation, new root system must be able to absorb enough water for leaf transpiration demand, which must remain photosynthetically active, providing energy for root system and new shoots (Ruter, 2015; Da Rosa *et al*., 2017; Oliveira *et al*., 2018).

Percentages of suitable rooted cuttings

The variable cuttings suitable for transplanting reveals the root quality formed and indicates the yield that each genotype presented in rooting phase and will effectively be used in the subsequent phase, that is, the rooted cuttings acclimatization (Mayer *et al*., 2018). In this variable, two selections stood out (VEH-AGA-12-05 and VEH-AGA-12- 01), with percentages of cuttings suitable for transplanting (100.0% and 96.97%) significantly higher in relation to the other treatments. In the second group formed, percentages varied between 37.78% and 82.93%, with no statistical difference among treatments.

The cutting ability to emit roots is linked to genetic characteristics, environmental conditions, endogenous cutting factors, shoot age, amount of carbohydrates, hormones and other fundamental metabolic compounds, in such a way that mother tree nutrition and rooting cutting potential are closely linked (Hartmann *et al*., 2011; Oliveira *et al*., 2012). Some endogenous factors such as enzymatic inactivation or oxidation limit the action of auxins, while phenolic compounds and antioxidants favor action of hormones responsible for inducing rhizogenesis (Geiss *et al*., 2009). However, the environmental conditions in greenhouse should be optimal for production of transplantable peach cuttings (Figure 5.b).

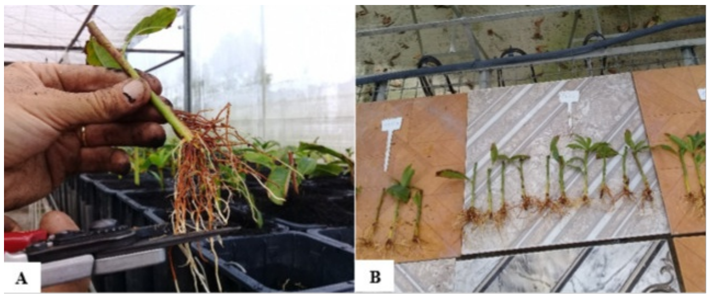

Figure 5. A) Rooted softwood cutting being prepared for transplanting in growth pot. B) Assessment and classification of rooted cuttings as suitable for transplanting. Source: own authorship.

Figura 5. A) Estaca herbácea enraizada sendo preparada para o transplantio em embalagem de crescimento. B) Avaliações e classificação das estacas enraizadas em aptas para o transplantio. Fonte: autoria própria.

Percentages of unsuitable rooted cuttings

As observed in previous variable, there was also a statistically significant difference for the percentage of rooted cuttings unsuitable for transplanting, as both are interdependent variables. Most treatments showed high percentages of unsuitable rooted cuttings, which varied between 17.07% and 62.22%, with no statistical difference between them. Therefore, selections VEH-AGA-12-05 (0.00%) and VEH-AGA-12-01 (3.03%) stood out positively with the lowest rates of discarded rooted cuttings.

Therefore, this variable translates percentage of rooted cuttings that must be discarded, due to the unsatisfactory root quality for the subsequent phase (acclimatization in potted system). Cuttings with unsatisfactory rooting (classified as unsuitable for transplanting) should be discarded, as they compromise survival after transplanting, resulting in unnecessary expenses with substrate, time for filling packages and rootstocks with poor quality of roots.

Table 1. Percentages of dead cuttings (%DC), of dead rooted cuttings (%DRC), of living rooted cuttings (%LRC), of rooted cuttings suitable (%SRC) and unsuitable (%URC) for transplant, at 53 days after softwood cutting setting of cultivars and rootstock selections of potentially tolerant to PTSL. Embrapa Temperate Climate, Pelotas-RS. Source: own authorship.

Tabela 1. Porcentagens de estacas mortas, de estacas enraizadas mortas, de estacas enraizadas vivas, de estacas enraizadas aptas e inaptas ao transplante, aos 53 dias após a estaquia herbácea de cultivares e seleções de porta-enxertos potencialmente tolerantes à morte-precoce. Embrapa Clima Temperado, Pelotas-RS. Fonte: autoria própria.

Rootstock	%DC	%DRC	%LRC	%SRC	%URC
VEH-AGA-12-01	22.22 c	20.00 a	57.78 c	96.97 a	3.03 b
VEH-AGA-12-02	37.78 b	4.45 b	57.78 c	82.93 b	17.07 a
VEH-AGA-12-03	52.22 a	6.82 a	38.73 d	70.83 b	29.17 a
VEH-AGA-12-04	31.11 b	8.89 a	60.00 c	81.44 b	18.56 a
VEH-AGA-12-05	71.11 a	2.22 b	26.67 d	100.00 a	0.00 b
VEH-AGA-12-06	24.44 c	2.22 b	71.11 b	66.16 b	33.84 a
VEH-AGA-12-07	35.55 b	2.22 b	62.22 c	60.83 b	39.17 a
RB-MAC-12-08	24.44 c	0.00 b	75.56 b	57.16 b	42.84 a
RB-MAC-12-09	24.92 c	0.00 b	75.08 b	60.50 b	39.50 a
RB-MAC-12-10	42.22 b	2.22 b	55.56 c	37.78 b	62.22 a
RB-MAC-12-11	26.66 c	8.89 a	64.45 c	39.81 b	60.19 a
RB-MAC-12-12	33.33 b	20.00 a	46.67 d	52.38 b	47.62 a
CAPDEBOSCQ	17.78 c	8.89 a	73.33 b	75.05 b	24.95 a
OKINAWA	8.89 d	6.67 a	84.44 b	63.10 b	36.90 a
SHARPE	2.22 d	0.00 b	97.78 a	79.68 b	20.32 a
F	7.2215**	3.2830**	7.7859**	5.5887**	5.5887**
C.V. %	24.45	80.70	14.60	18.26	33.29

Means followed by distinct letters in the column differ from each other by the Scott-knott test. ** Significant at 1% error probability. Source: Own authorship.

Médias seguidas por letras distintas na coluna diferem umas das outras pelo teste de Scott-knott. ** Significativo a 1% de probabilidade de erro. Fonte: Autoria própria.

Root number per cutting

The root number per cutting (RNC) (Table 2) was also significantly influenced by treatments tested, whose statistical analysis formed two distinct groups. In addition to the three reference cultivars, six other rootstock selections were part of the group with the highest root number per cutting. Although a statistical difference was detected, in general it is observed that means for this variable were quite satisfactory, since 12.56 roots per cutting was the lowest mean, observed in the VEH-AGA-12-03 selection.

The root number per cutting presents a positive correlation with tree survival of genus *Populus* spp. (Branislav *et al.*, 2009), as also observed in *Prunus* spp., as cutting survival is related to its root number (Mayer *et al.*, 2014). For Mindêllo *et al.*, (2008), it is more important for a cutting to have several roots with good growth to a few long roots, because after transplanting, it allows for greater chances of survival.

Length of the three largest roots

The statistical analysis of this variable revealed significant differences among treatments, separating into three distinct groups. The VEH-AGA-12-04 selection had the highest mean (13.22cm), being statistically superior compared to the other genotypes. Selections VEH-AGA-12-05, VEH-AGA-12-07 and RB-MAC-12-10 were statistically similar to Okinawa and Sharpe cultivars. The other rootstock selections and the cultivar Capdeboscq formed group with the lowest root number per cutting, with a lower average of 5.26 cm (RB-MAC-12-11). The length of the three largest roots is one of the variables that reveals quality of adventitious root system (Mayer *et al.*, 2020).

Root length is affected by application of putrescine under cutting base, and synergy was observed between this molecule and exogenous auxin, significantly increasing the root length of 'GF 677' rootstock (*P. amygdalus* x *P. persica*) (Zikah *et al.*, 2006; Kordzadeh & Sarikhani, 2021). However, a higher content of endogenous putrescine was found in 'GF 677' rootstock, which is difficult to root, when compared to 'Myrobalan 29C' rootstock, which is easy to root (Tsafouros & Roussos, 2019).

Therefore, the ideal condition and endogenous hormonal balance for adventitious rooting and adventitious root quality varies among species and also among cultivars. In general, it has been observed that, in Southern Brazil, root quality in Prunus spp. is influenced by the genotype, good quality of softwood cuttings (obtained by drastic pruning of mother tree), exogenous treatment with indolebutyric acid and a rooting period around 60 days should be used (Mayer *et al.*, 2018; Mayer *et al.*, 2020).

Root number per cutting and length of the three largest roots express quality of adventitious roots in cuttings, whose adequate architecture and distribution is expressed by the percentage of cuttings suitable for transplanting. Abundant and vigorous roots are important characteristics in a good rootstock, which will manifest in the future orchard in greater efficiency in absorption of water and nutrients (Solari *et al.*, 2006). The root system biomass, root distribution in depth and in horizontal direction is affected by the genetic characteristics of the rootstock.

Percentages of cuttings with original leaves

This variable was also statistically influenced by tested treatments (Table 2), with cultivars Sharpe and Okinawa showing the highest percentages of leaf retention. Two other groups were formed by statistical analysis, with most selections showing low retention capacity of the original cuttings leaves. It is observed that percentage of cuttings with original leaves was always equal to or greater than the percentage of sprouted cuttings, indicating the importance of a good adjustment of intermittent mist system as a way to preserve original leaves in favor of adventitious rooting.

Leaf abscission is caused, among other factors, by water deficit (Rouhi *et al.*, 2007). Considering that Sharpe cultivar is an interspecific plum hybrid (Beckman *et al.*, 2008), leaf morphology may have favored good moisture on leaf surface and the high percentage of original leaves in the cutting (88.89%).

The percentage of cuttings with original leaves is an indication of quality of prepared cuttings and favorable environment for the cuttings during rooting period, considering that leaf is a energy source, from which it exports this energy in form of sugars to the plant's drains, such as roots. These, use energy to meet the respiratory demand of aerial tree part, in addition to absorbing mineral nutrients necessary for tree growth and development (Toro *et al.*, 2018).

Percentages of sprouted cuttings

The percentage of sprouted cuttings was also significantly influenced by tested treatments (Table 2). Once again, cultivar Sharpe stood out positively, with the highest percentage of sprouted cuttings (80.00%). Statistical analysis also formed another two groups, with seven treatments forming the intermediate group and another seven treatments forming group with the lowest percentages of sprouted cuttings. The new shoots contribute to continuity of photosynthetic process during rooting phase and, consequently, to the rooting and root quality, that is, when the original leaves fall, these new shoots can make up for the lack of these during adventitious rooting (Mayer *et al.*, 2018).

Table 2. Root number per cutting (RNC), root length of the three largest roots (RL), percentage of cuttings with original leaves (%COL) and percentage of sprouted cuttings (%SC), at 53 days after cutting setting of cultivars and rootstock selections potentially tolerant to PTSL. Embrapa Temperate Climate, Pelotas-RS.

Table 2. Número de raízes por estaca, comprimento das três maiores raízes, porcentagem de estacas com folhas originais e porcentagem de estacas brotadas, aos 53 dias após a estaquia de cultivares e seleções de porta-enxertos potencialmente tolerantes à morte-precoce. Embrapa Clima Temperado, Pelotas-RS.

Rootstock	RNC	RL (cm)	%COL	%SC
VEH-AGA-12-01	26.13 a	6.67 c	35.55 c	35.55 b
VEH-AGA-12-02	26.84 a	7.48 c	48.89 c	42.22 b
VEH-AGA-12-03	12.56 b	7.42 c	34.29 c	9.21 c
VEH-AGA-12-04	27.44 a	13.22 a	57.78 c	2.22 c
VEH-AGA-12-05	26.17 a	10.09 b	17.78 c	13.33 c
VEH-AGA-12-06	22.48 a	8.17 c	66.67 b	33.33 b
VEH-AGA-12-07	21.38 a	9.10 b	62.22 b	6.67 c
RB-MAC-12-08	20.08 b	6.92 c	48.89 c	8.89 c
RB-MAC-12-09	15.98 b	7.53 c	54.76 c	36.67 b
RB-MAC-12-10	16.54 b	9.32 b	51.11 c	2.22 c
RB-MAC-12-11	20.14 b	5.26 c	40.00 c	33.33 b
RB-MAC-12-12	15.43 b	7.25 c	44.45 c	2.22 c
CAPDEBOSCQ	27.80 a	7.97 c	73.33 b	33.33 b
OKINAWA	21.88 a	10.23 b	82.22 a	26.67 b
SHARPE	27.50 a	9.69 b	88.89 a	80.00 a
F	2.8598**	10.9603**	5.4819**	9.0026**
C.V.%	23.64	11.92	19.21	37.72

Means followed by distinct letters in the column differ from each other by the Scott-knott test. ** significant at 1% probability of error. Source: Own authorship.

Médias seguidas por letras distintas na coluna diferem umas das outras pelo teste de Scott-knott. ** significativo a 1% de probabilidade de erro. Fonte: Autoria própria.

4 Conclusion

The screening allowed the identification of rootstock selections that showed adventitious rooting capacity similar or even superior to the reference cultivars Capdeboscq, Okinawa and Sharpe, indicating advances in the rootstock selection process.

Cutting mortality, in general, was high and occurred mainly before root initiation, indicating early leaf fall.

Among selections tested, VEH-AGA-12-06, RB-MAC-12-08 and RB-MAC-12- 09 stood out with the highest percentages of live rooted cuttings, and VEH-AGA-12-04, as to root number and root length.

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References

BECKMAN, T. G.; CHAPARRO, J. X.; SHERMAN, W. R. ‘Sharpe’, a clonal plum rootstock for peach. **HortScience**, Alexandria, v. 43, n. 7, p. 2236-2237, 2008. DOI: 10.21273/HORTSCI.43.7.2236.

BECKMAN, T. G.; OKIE, W. R.; NYCZEPIR, A. P. Use of clonally replicated seedlings in field screening for resistance to peach tree short life. **Journal of the American Society for Horticultural Science**, v. 118, p. 115-118, 1993. DOI: 10.21273/JASHS.118.1.115

BONA, C.M.D. and L.A. BIASI.Influence of leaf retention on cutting propagation of Lavandula dentata L. **Revista Ceres**. 57(4), 526-529, 2015. DOI: 10.1590/S0034-737X2010000400014.

BRANISLAV, K.; SAVO, R.; DRAGANA, M.; PETAR, I.; MARINA, K. Early shot and root growth dynamics as indicators for the survival of black poplar cuttings. **New Forests**, v. 38, p. 177-185, 2009. DOI: 10.1007/s11056-009-9138-7.

CAMPOS, A.D.; CARNEIRO, R. M. D. G.; GOMES, C. B.; MAYER, N.A. In: do RASEIRA, M.C.B., PEREIRA, J.F.M., CARVALHO, F.L.C. (Eds.). **Morte precoce de plantas**. Embrapa, Pessegueiro. Brasília-DF, 2014. pp. 509–530.

DA ROSA, G.G.; ZANANDREA, I.; MAYER, N. A.; BIANCHI, V.J. Propagação de porta-enxerto de *Prunus* spp. por estaquia: efeito do genótipo, do estádio de desenvolvimento do ramo e tipo de estaca. **Revista Ceres**, 64, 90–97, 2017. DOI: 10.1590/0034-737X201764010013.

GEISS, G.; GUTIERREZ, L.; BELLINI, C. Adventitious root formation: new insights and perspectives. In: ROBERTS, J. A.; EVAN, D.; MCNAUS, M. T.; ROSE, J. K. C. **Annual Plant Reviews**. 1 Ed, Wiley, cap. 5, p. 127-156, 2009. DOI: 10.1002 / 9781444310023.ch5.

HARTMANN, H. T.; KESTER, D. E.; DAVIES JUNIOR, F. T.; GENEVE, R. L. **Plant propagation: principles and practices**. 8th ed. Boston: Prentice Hall, 928 p, 2011.

KORDZADEH, S.; SARIKHANI, H. Effect of different concentrations of indole butyric acid, putrescine and hydrogen peroxide on stem cuttings of the rootstock GF677 (*Prunus amygdalus* x *Prunus persica*) according to the cutting season. **Revista Facultad Nacional de Agronomía**, Medellín, v. 74, n. 2, p. 9571-9582, 2021. DOI: 10.15446/rfnam.v74n2.92414.

LOWNSBERY, B. F.; ENGLISH, H.; NOEL, G. R.; SCHICK, F. J. Influence of Nemaguard and Lovell rootstocks and Macroposthonia xenoplax on bacterial canker of peach. **Journal of nematology**, v. 9, n. 3, p. 221-224, 1977.

MAYER, N.A.; BIANCHI, V. J.; CASTRO, L. A. S. Porta-enxertos. In: CARVALHO, F. L. C.; RASEIRA, M. C. B.; PEREIRA, J. F. M. **Pessegueiro**. Brasília, DF: Embrapa. p.173-223, 2014.

MAYER, N.A.; UENO, B. **A morte-precoce do pessegueiro e suas relações com porta-enxertos (Documentos, 359)**. Embrapa Clima Temperado, Pelotas, 2012. 42p.

MAYER, N.A; UENO, B.; DAS NEVES, T. Propagação vegetativa de seleções de porta-enxertos potencialmente tolerantes à morte-precoce do pessegueiro. **Revista de Ciências Agroveterinárias**. Lages, SC, Brasil (ISSN 2238-1171), 2018. DOI: 10.5965/223811711732018300.

MAYER, N. A.; UENO, B. 'Sharpe': **Porta-enxerto para pessegueiro introduzido no Brasil pela Embrapa Clima Temperado**. Embrapa Clima Temperado, Pelotas, Documentos 392, 2015, 29p.

MAYER, N.A, UENO B.; RICKES T.B. RESENDE, M.V.L.A. Cloning of rootstock selections and *Prunus* spp. cultivars by softwood cuttings. **Scientia Horticulturae**, 273:109609, 2020. DOI: 10.1016/j.scienta.2020.109609.

MINDÊLLO, N. U.R. et al. Enraizamento adventício de estacas semilenhosas de cultivares de pessegueiro. **Scientia Agraria**, Curitiba, v.9, n.4, p.565- 568, out./dez. 2008. DOI: 10.5380/rsa.v9i4.12762.

NYCZEPIR, A. P.; BERTRAND, P. F.; MILLER, R. W.; MOTSINGER, R. E. Incidence of *Criconemella* spp. and peach orchard histories in short-life and non-short- life sites in Georgia and South Carolina. **Plant Disease**, v. 69, n. 10, p. 874-877, 1985.

NYCZEPIR, A. P. Influence of *Criconemella xenoplax* and prunning time on short life of peach trees. **Journal of Nematology**, v. 22, n. 1, p. 97-100, 1990.

OLIVEIRA, R. J. P.; BIANCHI, V. J.; AIRES, R.F.; Campos, A.D. Teores de em estacas lenhosas de mirtileiro. **Revista Brasileira de Fruticultura**, 34:1199-1207, 2012. DOI: 10.1590/S0100-29452012000400029.

PIMENTEL, P. et al. Physiological and morphological responses of *Prunus* species with different degree of tolerance to long-term root hypoxia. **Scientia horticulturae**, v. 180, p. 14-23, 2014. DOI: 10.1016/j.scienta.2014.09.055.

REIGHARD, G. L.; HENDERSON, W. G.; SCOTT, S. O.; SUBBOTIN, S. A. First report of the root-knot nematode, *Meloidogyne floridensis* infecting Guardian® peach rootstock in South Carolina, USA. **The journal of nematology**, v. 51, p. 1-3, 2019. DOI: 10.21307/jofnem-2019-061.

ROCHA, M.D.S.; BIANCHI, V.J.; FACHINELLO, J.C.; SCHMITZ, J.D.; PASA, M.S.; SILVA, J.B. Comportamento agronômico inicial da cv. chimarrita enxertada em cinco porta-enxertos de pessegueiro. **Revista Brasileira de Fruticultura**, Jaboticabal, v.29, p.583-588, 2007. DOI: 10.1590/S0100-29452007000300032.

ROUHI, V.; SAMSON, R.; LEMEUR, R.; VAN DAMME, P. Photosymthetic gas exchange characteristics in three different almond species during drought stress and subsequent recovery. **Environmental and experimental botany**, v. 59, p. 117-129, 2007. DOI: 10.1016/j.envexpbot.2005.10.001.

RUTER, J.M.Cloning plants by rooting stem cuttings. In: BEYL, C.A., TRIGIANO, R.N. (Eds.). **Plant Propagation Concepts and Laboratory Exercises**. Taylor & Francis Group, Boca Raton, pp. 217–229, 2015.

SOLARI, L. I.; PERNICE, F.; DEJONG, T. M. The relation ship of hidraulic conductance to root system characteristics of peach (*Prunus persica*) rootstocks. **Physiologia Plantarum**, v. 128, p. 324-333, 2006. DOI: 10.1111 / j.1399-3054.2006.00747.x.

SCHIMITZ, J.D.; BIANCHI, V.J.; PASA, M.S.; KULKAMP, A.L. e FACHINELLO, J.C. Vigor e produtividade do pessegueiro 'Chimarrita' sobre diferentes porta-enxertos. **Revista Brasileira de Agrociência**, Pelotas, v.18, p.01-10, 2012.

TORO, G.; PINTO, M.; PIMENTEL, P. Root respiratory components of Prunus spp. rootstocks under low oxygen: regulation of growth, maintenance, and ion uptake respiration. **Scientia horticulturae**, v. 239, p. 259-268, 2018. DOI: 10.1016/j.scienta.2018.05.040.

TSIPOURIDIS, C.; THOMIDIS, T.; BLADENOPOULOU, S. Rhizogenesis of GF677, early crest, may crest and arm king stem cuttings during the year in relation to carbohydrate and natural hormone content. **Scientia Horticulturae**, Amsterdam, v. 108, n. 1, p. 200-204, 2006. DOI: 10.1016/j.scienta.2006.01.014.

TSAFOUROS, A.; ROUSSOS, P. A. The possible bottleneck effect of polyamines catabolic enzimes in efficient adventitious rooting of two stone fruit rootstocks with different rooting capacity even under high endogenous polyamine titers. **Journal of plant physiology,** v. 244,2019. DOI:10.1016/j.jplph.2019.152999.

ZIKAH, S.; ZAMIRI, N.; ZIV, M. Putrescine and hydrogen peroxide improve the rooting of ‘GF-677’ rootstock in woody cuttings and tissue culture shots. **Acta horticulturae**, v. 713, 2006.