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Cloning of rootstock selections and *Prunus* spp. cultivars by softwood cuttings

Newton Alex Mayer[a,*], Bernardo Ueno[a], Tamara Böhrer Rickes[b], Marcus Vinícius Lima Andrade de Resende[c]

[a] Embrapa Clima Temperado, BR 392, km 78, CEP 96010-971, Pelotas, Rio Grande do Sul State, Brazil
[b] IFSul Environmental Management Course, Campus CAVG, Embrapa Clima Temperado, Brazil
[c] Instituto Federal de Educação, Ciência e Tecnologia de Minas Gerais - Campus Bambuí, Minas Gerais State, Brazil

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ABSTRACT

The goal of this research was to evaluate adventitious rooting capacity and root quality on softwood cuttings of 30 peach rootstock selections potentially tolerant to the Peach Tree Short Life syndrome (PTSL) from 2009/2010 selection cycle. Two trials were conducted with 15 clonal peach (*Prunus persica*) rootstock selections each, and three reference cultivars: 'Capdeboscq', 'Okinawa' (*P. persica*) and 'Sharpe' [Chickasaw (*P. angustifolia* Marsh.) x *Prunus* spp.]. We concluded that propagation of peach rootstock selections by softwood cuttings is technically feasible, with rooting percentages ranging from 54.17 to 90%. The rootstock selections tested differ for most of analyzed variables, which allow distinguishing superior genotypes, but there is no difference among selections as the percentage of living rooted cuttings. Some selections (DB-SEN-09-23, SS-CHI-09-39 and SS-CHI-09-40) showed root formation and root quality similar to 'Capdeboscq', similar (IR-ESM-09-01 and JB-ESM-09-13) to 'Okinawa', similar (VEH-GRA-09-57) to both or even better (GL-ERA-09-33) than both reference cultivars. However, the selection FB-ESM-09-44 presented the worst root quality, with zero percentage of suitable rooted cuttings for transplanting.

1. Introduction

Obtaining rootstocks from pits of several peach scion cultivars [*Prunus persica* (L.) Batsch.], available in the peach processing industries in Pelotas area (Rio Grande do Sul State, Brazil), is a traditional practice and still performed in several nurseries in Southern Brazil. The abundance of peach pits (processing residue) and the lack of more consistent information on the use of rootstock cultivars selected and adapted to the edaphoclimatic conditions of different micro-regions of peach cultivation area are factors that favor the maintenance of this tradition (Mayer et al., 2014a). As a consequence, the use of seeds with a high degree of heterozygosity for rootstock production will give rise to trees different among them, notably in the root system, which will be reflected in tree size, production, longevity and reaction to the Peach Tree Short Life syndrome (PTSL), especially in areas with some physical-chemical soil restriction (Mayer et al., 2009; Mayer and Ueno, 2012).

In the Rio Grande do Sul State, one of the main agronomic problems that peach faces is the PTSL syndrome, whose causes involve several biotic and abiotic factors (Mayer and Ueno, 2012; Campos et al., 2014). One of the obstacles to investigate and deepen researches on PTSL has been the lack of knowledge about the genetic material used to produce rootstocks, due to the use of mixtures of pits from different scion peach cultivars for canning and their sexual propagation (Mayer et al., 2009). In the Southeastern of the United States, after several decades of researches on this syndrome (Brittain and Miller, 1978), its losses are being drastically reduced with the release and commercial use of 'Guardian®' (Okie et al., 1994), 'Sharpe' (Beckman et al., 2008) and 'MP-29®' rootstocks (Beckman et al., 2012).

Genetic improvement depends on genetic variability. According to Janick (2011), selection in seedling populations, followed by fixing desirable characteristics using vegetative propagation methods, is the

Abbreviations: DC%, dead cutting percentage; DRC%, dead rooted cutting percentage; LRC%, live rooted cutting percentage; SRC%, suitable rooted cuttings percentage for transplanting; URS%, unsuitable rooted cuttings percentage for transplanting; RNC, root number per cutting; RL, root length; COL%, cutting percentage with original leaves; SC%, sprouted cutting percentage; PTSL, Peach Tree Short Life; RH, air relative humidity (%); T, air temperature (°C)

* Corresponding author.
E-mail addresses: alex.mayer@embrapa.br (N.A. Mayer), bernardo.ueno@embrapa.br (B. Ueno), tamararickes@hotmail.com (T.B. Rickes), marcusvlar@gmail.com (M.V.L.A. de Resende).

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oldest known way of genetic improvement. Considering the reality of nursery tree peach production system prevalent in the Southern of Brazil and advances obtained with researches in the United States, Embrapa Clima Temperado started in 2007 a study of clonal selection *in situ* of rootstocks potentially tolerant to the PTSL, based on the considerable genetic variability of rootstocks and on selection pressure existing in the orchards affected by the syndrome (Mayer et al., 2009). After seven years of selection, 148 accessions of interest were rescued and cloned (Mayer et al., 2018), using the new methodology of cut off below the grafting point to stimulate the new sprouting of rootstock, which is physiologically juvenile (Davies, 2018), followed by softwood stem rescue and rooting by cuttings (Mayer et al., 2009). Mother trees of selected clones are being maintained in the "*Prunus* rootstock collection" to continue the selection process, aiming at the future release a PTSL tolerant rootstock cultivar. Characteristics also desired in a good rootstock are: the easiness of vegetative propagation; the production of a satisfactory and vigorous root system; absence of root suckers; tolerance to biotic and abiotic stresses; high efficiency in absorbing water and nutrients; grafting compatibility with scion cultivars and their ability to positively affect these phenotypes (Nečas and Krška, 2013; Mayer et al., 2014a.; Jalil et al., 2016; Warschefsky et al., 2016; Mayer et al., 2018; Oliveira et al., 2018), characteristics that need to be known in the selected rootstocks.

Adventitious rooting of stem cuttings can be affected by several factors, such as genetics, management of mother tree (nutrition, age, pruning, plant health status, physiological stage and cultivation conditions), preparation of cuttings (stem diameter, cutting type, quality and leaf hydration), growth regulators (source, dose and immersion time) and environmental conditions (air and substrate temperature, air relative humidity, wind, characteristic of containers, substrate, time and frequency of intermittent mist system) (Hartmann et al., 2002; Ruter, 2015; da Rosa et al., 2017a, 2017b; Oliveira et al., 2018). As a general rule for *Prunus* spp., the best results have been obtained with softwood cuttings under intermittent mist system and use of indolbutyric acid (between 2000 and 6000 mg.L^{-1}), but with significant differences between genotypes (Nečas and Krška, 2013; Mayer et al., 2014b; Mayer et al., 2017; da Rosa et al., 2017a, 2017b; Mayer et al., 2018; Oliveira et al., 2018).

The objective was to evaluate the adventitious rooting capacity and root quality in softwood cuttings from 30 rootstock selections potentially tolerant to PTSL syndrome, from the 2009/2010 selection cycle of the Embrapa Clima Temperado, taking as reference cultivars such as 'Capdeboscq', 'Okinawa' (*P. persica*) and 'Sharpe' ['Chickasaw' (*P. angustifolia* Marsh.) x *Prunus* spp.].

2. Material and methods

2.1. Mother trees and germplasm

Six-year-old own-rooted mother trees from 30 rootstock selections [*Prunus persica* (L.) Batsch.] selected as potentially tolerant to PTSL syndrome (Mayer et al., 2009) and kept in the "*Prunus* rootstock collection" (Fig. 1, Phases 1 and 2) of Embrapa Clima Temperado (Pelotas, Rio Grande do Sul State, Brazil), were used as a source of propagating material for this research (Fig. 1, Phase 3) (Table 1).

In addition to these selections, eight-year-old budded mother trees of 'Capdeboscq' and 'Okinawa' (*P. persica*), and three-year-old own-rooted mother trees of 'Sharpe' ['Chickasaw' (*P. angustifolia* Marsh.) x *Prunus* spp.] were also used to supply softwood shoots, and used as a reference cultivars. The 'Capdeboscq' peach was used because it was a reference, until the 1980s, for the rootstocks production in the Rio Grande do Sul State (Brazil) (Mayer et al., 2014a.); the 'Okinawa' peach for being the main rootstock used in the São Paulo State (Brazil) (Mayer et al., 2014a.). In sites with PTSL history of Pelotas, Rio Grande do Sul State, both cultivars ('Capdeboscq' and 'Okinawa') seems to be some PTSL tolerance when used as a peach rootstock, due greater tree survival than those budded on no-identified rootstocks (mix of peach pits from several scion cultivars obtained in canning industry) (Mayer et al., 2019). 'Sharpe' rootstock was used for being tolerant to PTSL in the Southeast US (Beckman et al., 2008; Mayer et al., 2014a; Mayer and Ueno, 2015).

In the first half of August 2016, drastic pruning of all mother trees was carried out to stimulate new and intense sprouting (Davies, 2018). Drastic pruning consisted of cutting all scaffolds with pneumatic scissors at 1–1.2 m above soil level (Fig. 1, Phase 3), with shortening of all remaining shoots (Mayer et al., 2018). For trials setup of this research (Fig. 1, Phase 3B), softwood shoots of each selection or cultivar were collected early morning, identified and immediately transported to the intermittent mist system of Embrapa Clima Temperado, keeping them always moist.

2.2. Trials and experimental design

Due to the several rootstock selections (30 in total) and available facilities, two trials were carried out (Fig. 1, Phase 3B). The criterion to share rootstock selections for trials 1 and 2 was the increasing order of selection codes from the 2009/2010 selection cycle.

Trial 1: conducted between November 30th 2016, and January 30th 2017. Fifteen clonal peach rootstock selections potentially tolerant to PTSL syndrome were tested (Table 1), including three reference cultivars ('Capdeboscq', 'Okinawa' and 'Sharpe'), totaling 18 treatments.

Trial 2: conducted between January 9th and March 9th 2017. Another 15 clonal peach rootstock selections were tested (Table 1) and the same three reference cultivars were included, totaling 18 treatments.

Each trial was installed in a completely randomized design with 18 treatments, with four replications of 15 cuttings, totaling 72 plots or 1080 cuttings. Each plastic box contained two random plots.

Softwood cuttings were prepared with 15 cm-long and diameter between 8 and 12 mm (peach) and between 5 and 8 mm ('Sharpe'). A cross section was made at cutting base and in bevel at cutting distal end, keeping three distal nodes with all their leaves cut in half, to reduce leaf area. The cutting base (3 cm) was treated with a hydroalcoholic solution of indolbutyric acid at 3000 mg.L^{-1} for five seconds. Plastic boxes (46 × 30 × 10 cm), with a perforated bottom (32 holes per box, 11 mm in diameter), were filled with medium vermiculite and used as containers. Cuttings were placed at seven-centimeters-depth, in vermiculite previously moistened. Boxes were kept on galvanized iron benches, 1 m high, under an intermittent mist system (Fig. 1, Phase 3B), installed inside an agricultural arch-type greenhouse (24 × 8 m, with 3 m-height) with a transparent polyethylene roof and side panels with anti-insect screen, without air temperature or air relative humidity control. The intermittent mist system (line of Tietze® violet-type misting nozzles, equidistant 1 m from each other), placed 70 cm above the plastic boxes, which was programmed to be activated for 12 s every 4.5 min, allowing constant moisture maintenance on leaf surface. A 50 % Lumineti® reflective screen was placed 1.2 m above the misting nozzles line, to reduce incident solar radiation.

2.3. Air relative humidity and air temperature data recording

Air temperature (°C) and air relative humidity (%) were recorded every 30 min with a Datalogger, Model AK172-V2 AKSO, kept in shade 1 m above the misting nozzles line. Recorded data are presented in Figs. 2–4 (trial 1) and in Figs. 5–7 (trial 2).

2.4. Variables and statistical analysis

Sixty days after each trial setup, the following variables were evaluated: 1) percentage of dead cuttings (DC): all dead cuttings without any root formation were considered; 2) percentage of dead rooted cuttings (DRC): all rooted cuttings that were dead were

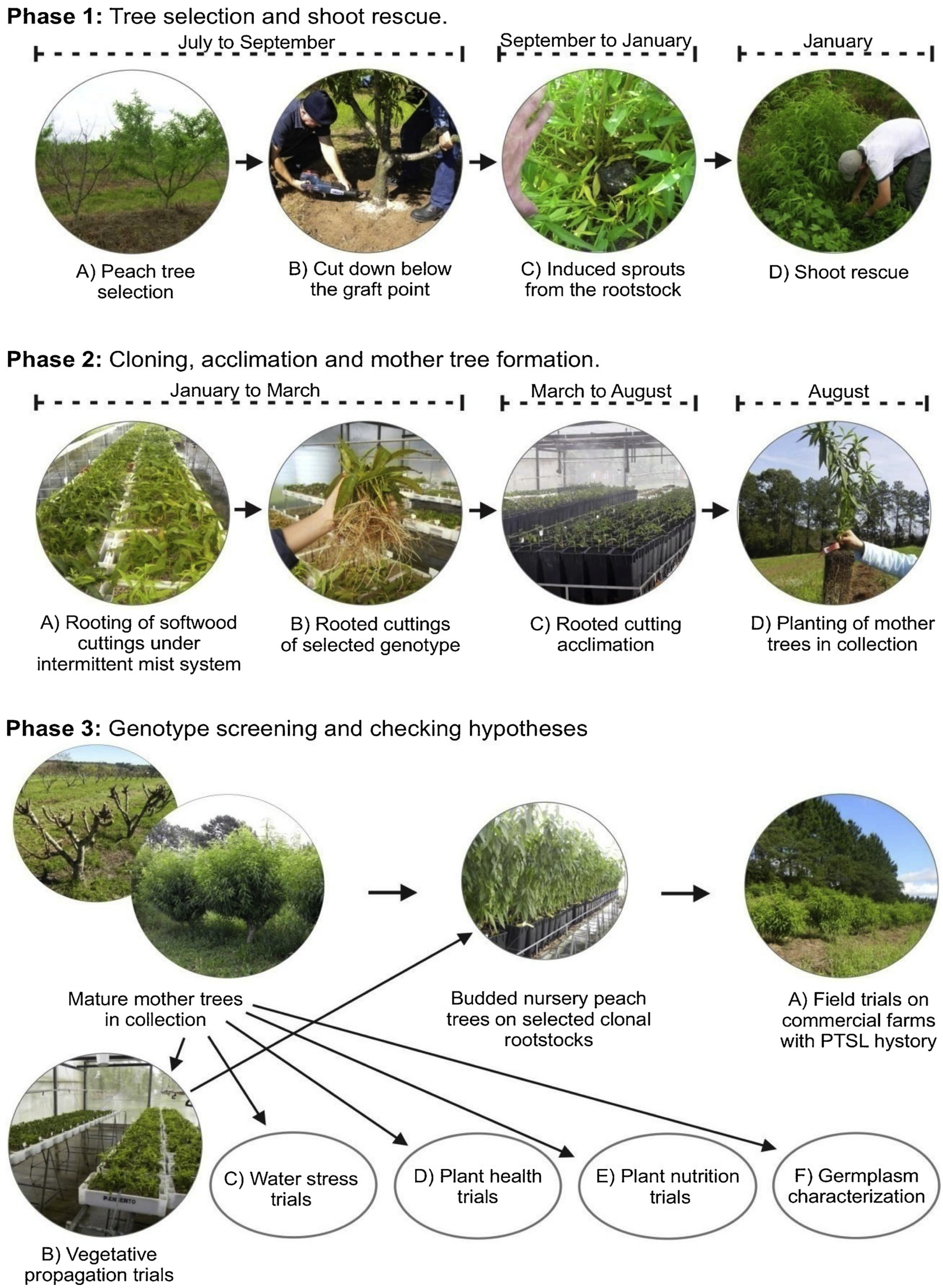

Fig. 1. Sequence diagram of peach rootstock selection and screening of genotypes potentially tolerant to PTSL syndrome developed by Embrapa Clima Temperado in Pelotas, Rio Grande do Sul State, Brazil. The present research is illustrated by Phase 3B.

Table 1
Identification of rootstocks, selection location or origin of propagules of *Prunus* cultivars ([x]) used to produce mother trees, which were used as donors of softwood shoots for trials 1 and 2. Embrapa Clima Temperado, Pelotas-RS, 2018.

Rootstock	Trial 1	
	Species	Selection location or origin of propagules
IR-ESM-09-01	*P. persica*	Rincão da Caneleira, 8th Pelotas district-RS
IR-ESM-09-02	*P. persica*	Rincão da Caneleira, 8th Pelotas district-RS
IR-GRA-09-07	*P. persica*	Rincão da Caneleira, 8th Pelotas district-RS
JB-ESM-09-13	*P. persica*	Colônia Maciel, 8th Pelotas district-RS
JB-ESM-09-15	*P. persica*	Colônia Maciel, 8th Pelotas district-RS
DB-SEN-09-22	*P. persica*	Colônia Santa Áurea, 8th Pelotas district-RS
DB-SEN-09-23	*P. persica*	Colônia Santa Áurea, 8th Pelotas district-RS
DLS-ERA-09-25	*P. persica*	Capela Santa Ana, São Marcos-RS
DLS-ERA-09-27	*P. persica*	Capela Santa Ana, São Marcos-RS
GL-ERA-09-31	*P. persica*	Fazenda Souza, Caxias do Sul-RS
GL-ERA-09-32	*P. persica*	Fazenda Souza, Caxias do Sul-RS
GL-ERA-09-33	*P. persica*	Fazenda Souza, Caxias do Sul-RS
WAO-CHI-09-36	*P. persica*	Forqueta Baixa, Vale Real-RS
SS-CHI-09-39	*P. persica*	Pinto Bandeira-RS
SS-CHI-09-40	*P. persica*	Pinto Bandeira-RS
Capdeboscq	*P. persica*	Embrapa Clima Temperado, Pelotas-RS
Okinawa	*P. persica*	"Irmãos Kagi" Nursery, Atibaia-SP
Sharpe	['Chickasaw' (*P. angustifolia* Marsh.) x *Prunus* spp.]	University of Florida, Gainesville-FL, USA
Rootstock	**Trial 2**	
	Species	Selection location or origin of propagules
SS-CHI-09-41	*P. persica*	Pinto Bandeira-RS
FB-ESM-09-43	*P. persica*	Vila Nova, 7th Pelotas district-RS
FB-ESM-09-44	*P. persica*	Vila Nova, 7th Pelotas district-RS
FB-ESM-09-45	*P. persica*	Vila Nova, 7th Pelotas district-RS
FB-ESM-09-46	*P. persica*	Vila Nova, 7th Pelotas district-RS
FB-ESM-09-47	*P. persica*	Vila Nova, 7th Pelotas district-RS
VEH-GRA-09-54	*P. persica*	Espigão, 1st Canguçu district -RS
VEH-GRA-09-55	*P. persica*	Espigão, 1st Canguçu district -RS
VEH-GRA-09-57	*P. persica*	Espigão, 1st Canguçu district -RS
VEH-GRA-09-58	*P. persica*	Espigão, 1st Canguçu district -RS
PRBO-SAU-09-62	*P. persica*	Coxilha dos Campos 1st Canguçu district -RS
VR-PRE-09-65	*P. persica*	Colônia São Manoel, 8th Pelotas district-RS
SAS-SAU-09-71	*P. persica*	Colônia São Manoel, 8th Pelotas district-RS
SAS-SAU-09-73	*P. persica*	Colônia São Manoel, 8th Pelotas district-RS
JAH-MAC-09-77	*P. persica*	Olhos d'Água, Bagé-RS
Capdeboscq	*P. persica*	Embrapa Clima Temperado, Pelotas-RS
Okinawa	*P. persica*	"Irmãos Kagi" Nursery, Atibaia-SP
Sharpe	['Chickasaw' (*P. angustifolia* Marsh.) x *Prunus* spp.]	University of Florida, Gainesville-FL, USA

[(x)] References: Mayer et al. (2009), 2014a; Mayer and Ueno (2015).

considered; 3) percentage of live rooted cuttings (LRC): all rooted cuttings that were alive; 4) percentage of suitable rooted cuttings for transplanting (SRC): those rooted cuttings alive and which, according to a visual classification carried out by one person, were classified as suitable for transplanting, taking into account the satisfactory root quality and their adequate distribution around the cutting base (Mayer et al., 2014b; Mayer et al., 2018); 5) percentage of unsuitable rooted cuttings for transplanting (URC): those live rooted cuttings that,

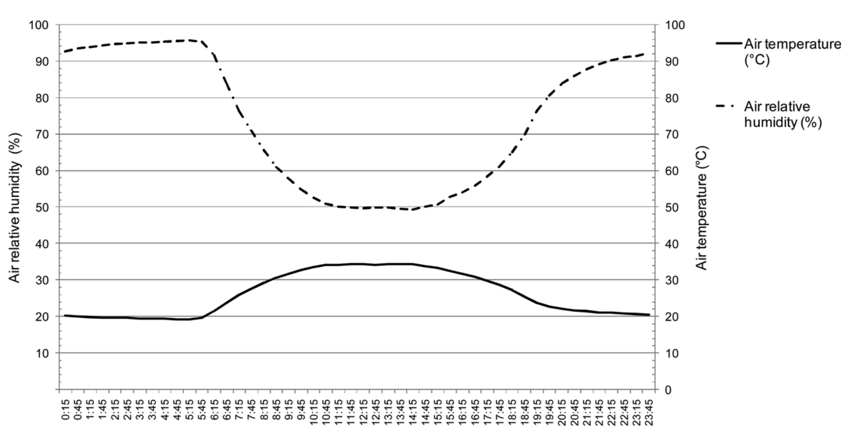

Fig. 2. Air relative humidity (%) and air temperature (°C) inside greenhouse during trial 1. Graph containing the averages per 24 h period, based on data recorded every 30 min, between Nov/30/2016 and Jan/30/2017.

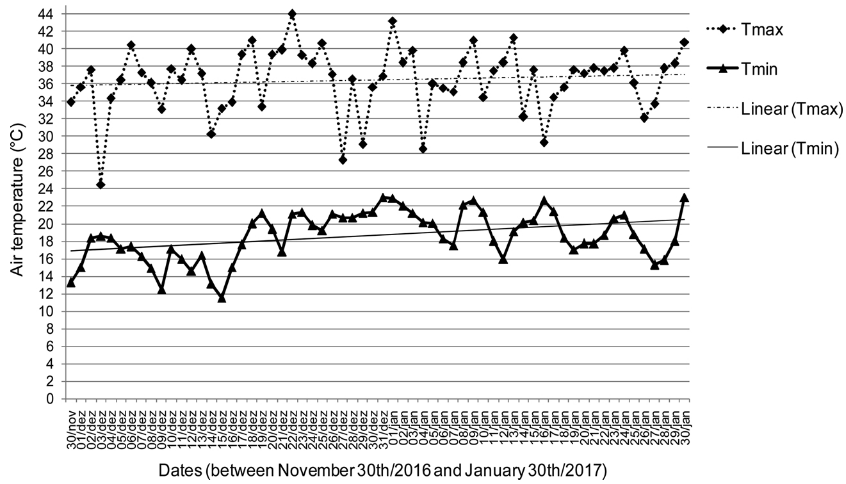

Fig. 3. Maximum and minimum daily air temperatures (°C) recorded inside greenhouse during trial 1, between Nov/30/2016 and Jan/30/2017.

according to visual classification carried out by one person, were classified as unsuitable for transplanting, that is, with unsatisfactory root quality and/or inadequate root distribution around the cutting base (Mayer et al., 2014b; Mayer et al., 2018); 6) root number per cutting (RNC): the root number per cutting of those classified as live rooted cuttings was counted; 7) root length of the three largest roots of each cutting (RL): the length of the three largest roots of live rooted cuttings was measured with a ruler (expressed in cm); 8) cuttings with original leaves (COL): the percentages of cuttings that remained with their original leaves adhered to the cutting at the trial end were counted; 9) sprouted cuttings (SC): the percentages of cuttings with new sprouting were counted at the trial end. Eventually, in some plots, there were also cuttings that formed only callus. As the callus percentage were zero or very low (less than 6.67 %), no statistical analysis of this variable was performed and data will not be presented.

The variables expressed as percentage were transformed to arc sen $\sqrt{x/100}$ and the others were not transformed. The results were subjected to analysis of variance by the F test and the means compared by the Scott-Knott test, at 99 % confidence, using the SASM - Agri software. A multivariate analysis was performed for each trial, using Minitab 14 software, where the agglomerative hierarchical cluster analysis took place by average linkage method, with standardized Euclidean distance as a basic measure of similarity. Only four variables were considered: percentage of live rooted cuttings (LRC%), percentage of suitable rooted cuttings (SRC%), root number (RNC) and root length (RL), for being the most important (Hartmann et al., 2002; Beyl et al., 1995; Mayer et al., 2014b; Mayer et al., 2018), in addition to having a better correlation among them.

3. Results

Trial 1. According to the data (Tables 2 and 3), significant statistical differences were observed in all nine variables evaluated. Considering only the 15 rootstock selections tested, the only variable in which no significant difference was detected between them was the percentage of live rooted cuttings. For all other variables, there are also statistical differences among the 15 selections, which allows to distinguish those with greater and lesser potential for vegetative propagation by softwood cuttings. For percentages of dead cuttings (DC%) and dead rooted cuttings (DRC%), the statistical analysis formed two groups in each variable, which allowed identifying more vulnerable and mortality-prone selections, in these environmental conditions (Table 2). The percentages of dead rooted cuttings (DRC%) were, in most cases, higher than the percentages of dead cuttings (DC%) (without roots), with average values of 21.39 and 11.25 %, respectively. The total mortality of cuttings (DC% + DRC%, data not shown) among selections varied between 16.67 % (IR-ESM-09-01) and 40.0 % (SS-CHI-09-40). However, the three reference cultivars showed total mortality percentages close to this upper limit or even higher (‘Capdeboscq’ = 38.33 %; ‘Okinawa’ = 28.34 %; ‘Sharpe’ = 75.01 %).

The percentages of live rooted cuttings (LRC%), observed in the 15 selections tested, were considered satisfactory and varied between 54.17 % (IR-GRA-09-07) and 76.67 % (JB-ESM-09-15), but without significant statistical differences among themselves. This group of 15

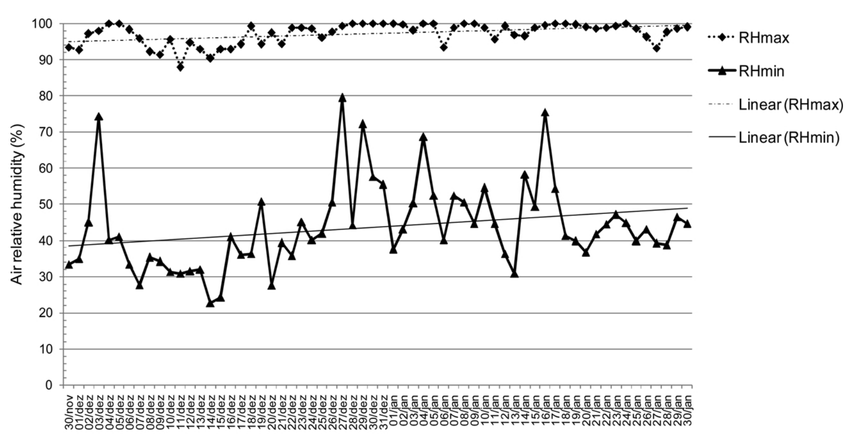

Fig. 4. Maximum and minimum daily air relative humidity (%) recorded inside greenhouse during trial 1, between Nov/30/2016 and Jan/30/2017.

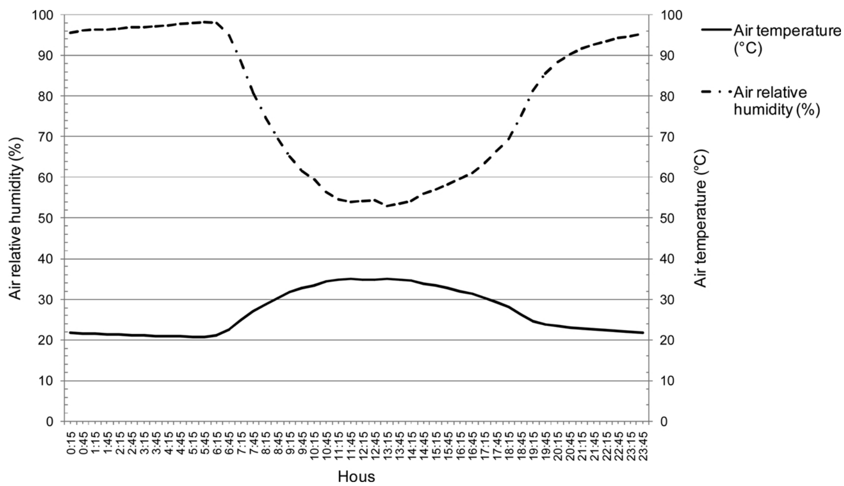

Fig. 5. Air relative humidity (%) and air temperature (°C) inside greenhouse during trial 2. Graph containing the averages per 24 h period, from data recorded every 30 min, between Jan/09/2017 and Mar/09/2017.

selections also did not differ statistically from 'Capdeboscq' (60.0 %) and 'Okinawa' (71.67 %), but all were significantly superior to 'Sharpe' (23.33 %) (Table 2). The percentages of suitable rooted cuttings (SRC%) and unsuitable (URC%) to transplant also showed statistically significant differences between treatments, forming two groups in each variable. Of the 15 rootstock selections tested in trial 1, eight (IR-ESM-09-01; IR-ESM-09-02; IR-GRA-09-07; JB-ESM-09-13; DB-SEN-09-23; GL-ERA-09-32; GL-ERA-09-33; SS-CHI-09-40) showed statistical similarity regarding to 'Capdeboscq' and 'Okinawa', for both variables (SRC% and URC%). Again 'Sharpe' stood out negatively, with 20.38 % of suitable (SRC%) and 79.62 % of unsuitable rooted cuttings (URC%) (Table 2).

The statistical analysis of root number per cutting (RNC) formed two distinct groups between treatments, whereas, for root length (RL), five groups were formed (Table 3). Although seven rootstock selections (IR-ESM-09-01; JB-ESM-09-13; DB-SEN-09-23; GL-ERA-09-32; GL-ERA-09-33; SS-CHI-09-39 and SS-CHI-09-40) did not differ statistically from the three reference cultivars as to the root number per cutting, one of these selections (GL-ERA-09-33) stood out regarding to all the others and presented greater average of root length (12.84 cm). Statistical differences between treatments were also observed for cuttings with original leaves (COL%) (which formed two groups) and sprouted cuttings (SC%) (three groups) (Table 3). Four selections (IR-ESM-09-02, DB-SEN-09-23, SS-CHI-09-39 and SS-CHI-09-40) stood out for presenting the highest percentages of cuttings with original leaves (COL%) and sprouted cuttings (SC%), simultaneously. It is also possible to verify that, under the environmental conditions offered, the selections and cultivars tested presented percentages of sprouted cuttings (SC%) always higher than percentages of cuttings with original leaves (COL%) (except for JB-ESM-09-15) (Table 3).

Cluster analysis was applied to share the 15 peach rootstock selections and three peach cultivars according to their ability to root and root development (Fig. 8). Considering the acceptable level of 70 % similarity, nine groups were formed. Selections IR-ESM-09-01 and JB-ESM-09-13 were in the 'Okinawa' group, while selections DB-SEN-09-23, SS-CHI-09-39 and SS-CHI-09-40 were in the 'Capdeboscq' group. 'Sharpe' rootstock was alone in its group, differing from all the other eight groups due to lowest rooting percentages and poor root quality.

Trial 2. Data from this trial (Tables 4 and 5) revealed statistical differences between treatments for six of the nine variables evaluated. In the percentage of dead cuttings (DC%), two distinct groups were formed. In the group of those with the highest percentages (between 11.67 and 36.67 %), there are eight selections, together with three reference cultivars. The percentage of dead rooted cuttings (DRC%) showed no statistically significant difference. Regarding the total mortality of cuttings (DC% + DRC%, data not shown), the VEH-GRA-09-55 and FB-ESM-09-43 selections stand out positively, with the lowest percentages (10 and 13.34 %, respectively). However, as a negative highlight, 'Sharpe' rootstock presented the highest percentage of total mortality (53.34 %).

The percentage of live rooted cuttings (LRC%) did not show any significant difference between the tested selections and results were considered satisfactory or even excellent, since values ranged between 55 % (SAS-SAU-09-73) and 90 % (VEH-GRA-09-55) (Table 4).

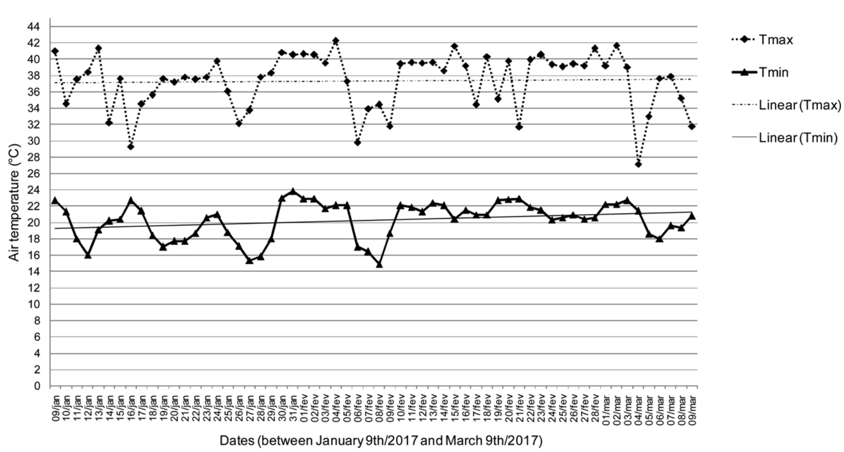

Fig. 6. Maximum and minimum daily air temperatures (°C) recorded inside greenhouse during trial 2, between Jan/09/2017–Mar/09/2017.

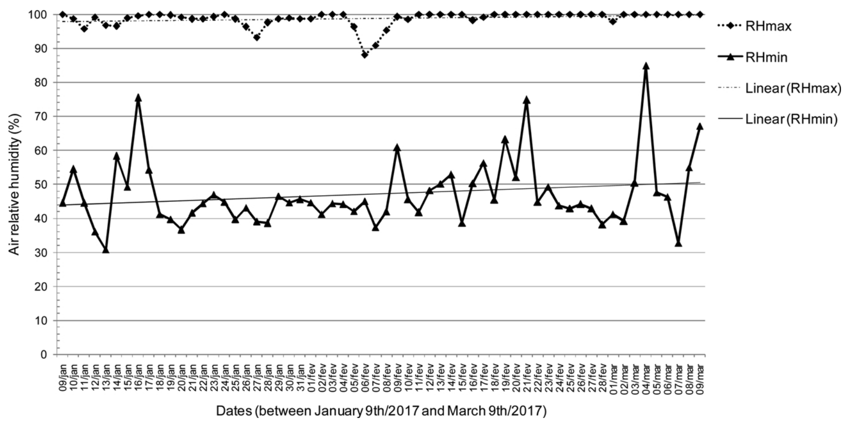

Fig. 7. Maximum and minimum daily air relative humidity (%) recorded inside greenhouse during trial 2, between Jan/09/2017–Mar/09/2017.

Table 2
Percentages of dead cuttings (DC), of dead rooted cuttings (DRC), of live rooted cuttings (LRC), of suitable rooted cuttings (SRC) and unsuitable (URC) to transplant, 60 days after cutting setting (trial 1) of three cultivars and 15 rootstock selections potentially tolerant to PTSL syndrome. Embrapa Clima Temperado, Pelotas-RS, Brazil.

Rootstock	DC (%)	DRC (%)	LRC (%)	SRC (%)	URC (%)
IR-ESM-09-01	3.34 b	13.33 b	69.17 a	79.35 a	20.65 b
IR-ESM-09-02	5.00 b	16.67 b	65.83 a	57.45 a	42.55 b
IR-GRA-09-07	20.00 a	11.67 b	54.17 a	46.75 a	53.25 b
JB-ESM-09-13	6.67 b	23.33 a	70.00 a	68.75 a	31.25 b
JB-ESM-09-15	6.67 b	13.33 b	76.67 a	40.01 b	59.99 a
DB-SEN-09-22	7.50 b	23.34 a	58.34 a	29.72 b	70.28 a
DB-SEN-09-23	3.34 b	28.34 a	68.33 a	52.78 a	47.22 b
DLS-ERA-09-25	16.67 a	6.67 b	73.33 a	30.11 b	69.89 a
DLS-ERA-09-27	11.67 b	13.33 b	70.00 a	35.63 b	64.37 a
GL-ERA-09-31	26.67 a	10.00 b	63.33 a	28.73 b	71.27 a
GL-ERA-09-32	18.33 a	18.34 b	63.33 a	47.92 a	52.08 b
GL-ERA-09-33	5.00 b	25.00 a	70.00 a	48.50 a	51.50 b
WAO-CHI-09-36	15.00 a	23.34 a	60.00 a	28.57 b	71.43 a
SS-CHI-09-39	6.67 b	26.67 a	66.67 a	38.46 b	61.54 a
SS-CHI-09-40	1.67 b	38.33 a	58.34 a	48.01 a	51.99 b
Capdeboscq	13.33 a	25.00 a	60.00 a	55.02 a	44.98 b
Okinawa	6.67 b	21.67 a	71.67 a	67.35 a	32.65 b
Sharpe	28.34 a	46.67 a	23.33 b	20.38 b	79.62 a
$F_{Rootstock}$	2.34**	2.47**	1.86*	2.95**	1.82**
CV (%)	63.82	38.72	19.84	32.33	27.88

Means followed by different letters in the column differ from each other by the Scott-knott test. ** significant at 1 % error probability. * significant at 5 % error probability.

Table 3
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), 60 days after cutting setting (trial 1) of three cultivars and 15 rootstock selections potentially tolerant to PTSL syndrome. Embrapa Clima Temperado, Pelotas-RS, Brazil.

Rootstock	RNC	RL (cm)	COL (%)	SC (%)
IR-ESM-09-01	14.22 a	9.66 c	56.67 a	71.67 b
IR-ESM-09-02	9.34 b	6.03 e	51.67 a	80.00 a
IR-GRA-09-07	7.94 b	8.03 d	41.67 a	73.33 b
JB-ESM-09-13	16.54 a	8.36 d	43.34 a	73.33 b
JB-ESM-09-15	7.16 b	10.73 b	68.34 a	36.67 c
DB-SEN-09-22	6.01 b	11.18 b	61.67 a	73.33 b
DB-SEN-09-23	15.43 a	8.95 c	41.67 a	90.00 a
DLS-ERA-09-25	5.33 b	6.61 e	35.00 b	63.33 b
DLS-ERA-09-27	8.36 b	8.80 c	43.33 a	75.00 b
GL-ERA-09-31	8.21 b	7.24 d	33.34 b	80.00 a
GL-ERA-09-32	13.12 a	6.25 e	18.33 b	86.67 a
GL-ERA-09-33	14.13 a	12.84 a	66.67 a	73.33 b
WAO-CHI-09-36	8.19 b	5.45 e	20.00 b	91.67 a
SS-CHI-09-39	16.98 a	7.61 d	51.67 a	81.67 a
SS-CHI-09-40	19.69 a	9.77 c	55.00 a	90.00 a
Capdeboscq	14.90 a	10.08 c	48.34 a	76.67 b
Okinawa	17.79 a	10.13 c	31.67 b	86.67 a
Sharpe	16.16 a	8.95 c	25.00 b	80.00 a
$F_{Rootstock}$	6.43**	11.66**	4.18**	3.12**
CV (%)	29.56	13.21	22.72	16.59

Means followed by different letters in the column differ from each other by the Scott-knott test. ** significant at 1 % error probability.

Statistical differences were also observed in percentages of suitable (SRC%) and unsuitable rooted cuttings (URC%) to transplant, both variables forming three groups. In these two variables, the VEH-GRA-09-55 selection stands out again, which, together with 'Capdeboscq' and 'Okinawa', integrated the group of those with the highest percentages of suitable rooted cuttings (SRC%) for transplanting. 'Sharpe' was in the group of intermediate treatments, in both variables, and selection FB-ESM-09-44 stood out negatively, with 0 % of suitable rooted cuttings (SRC%) for transplanting (Table 4).

The root number per cutting (RNC) was, in general, quite satisfactory and showed a significant difference between treatments, forming five distinct groups (Table 5), with emphasis on the selection VEH-GRA-09-57 (22.98 roots per cutting), 'Okinawa' (20.99) and 'Sharpe' (18.61). For the average root length (RL) of the three largest roots, another variable that also defines quality, three distinct groups were formed. In this variable, selections VEH-GRA-09-58 (11.39 cm) and PRBO-SAU-09-62 (12.72 cm) stood out. The percentages of cuttings with original leaves (COL%) were, in general, low (less than 46.67 %), whose statistical analysis was significant and formed two groups. However, for sprouted cuttings (SC%), there was no significant difference between treatments (Table 5). As observed in trial 1, the percentage of sprouted cuttings in trial 2 was also higher than percentage of cuttings with original leaves (COL%), with the exception of only one selection (VEH-GRA-09-54).

Considering the acceptable level of 70 % similarity by cluster analysis, nine groups were formed (Fig. 9). In this trial, 'Capdeboscq' and 'Okinawa' stayed in the same group, together with VEH-GRA-09-57 selection. Five groups were composed of a single selection or cultivar (FB-ESM-09-43, FB-ESM-09-44, VEH-GRA-09-55, SAS-SAU-09-73 and 'Sharpe'), for presenting characteristics totally different from the other groups.

4. Discussion

The percentages of dead cuttings (DC%), that is, those that died early without having started adventitious root formation, were, in general, high in both experiments, with values of up to 28.34 % (trial 1) and 36.67 % (trial 2) verified in 'Sharpe' rootstock. One factor that contributed to cutting mortality before the beginning of root formation

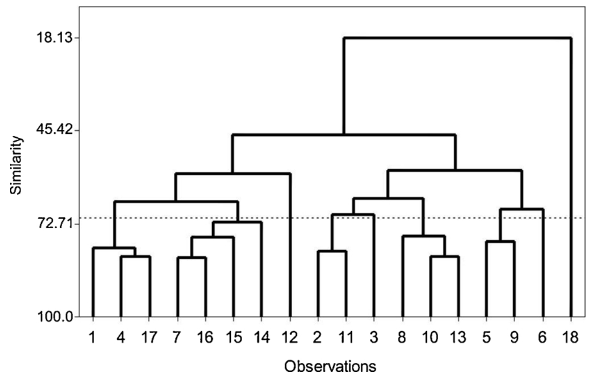

Fig. 8. Dendrogram with Average Linkage Method and Euclidian Distance (Cophenetic correlation coefficient = 0.8642582) illustrating the relationship among peach rootstocks selections and cultivars tested for rooting performance (trial 1) (dashed line = 72.07 %), where: 1 = IR-ESM-09-01; 2 = IR-ESM-09-02; 3 = IR-GRA-09-07; 4 = JB-ESM-09-13; 5 = JB-ESM-09-15; 6 = DB-SEN-09-22; 7 = DB-SEN-09-23; 8 = DLS-ERA-09-25; 9 = DLS-ERA-09-27; 10 = GL-ERA-09-31; 11 = GL-ERA-09-32; 12 = GL-ERA-09-33; 13 = WAO-CHI-09-36; 14 = SS-CHI-09-39; 15 = SS-CHI-09-40; 16 = 'Capdeboscq'; 17 = 'Okinawa'; 18 = 'Sharpe'.

Table 4

Percentages of dead cuttings (DC), of dead rooted cuttings (DRC), of live rooted cuttings (LRC), of suitable rooted cuttings (SRC) and unsuitable (URC) to transplant, 60 days after cutting setting (trial 2) of three cultivars and 15 rootstock selections potentially tolerant to PTSL syndrome. Embrapa Clima Temperado, Pelotas-RS, Brazil.

Rootstock	DC (%)	DRC (%)	LRC (%)	SRC (%)	URC (%)
SS-CHI-09-41	18.33 a	13.34 a	68.33 a	37.15 b	62.85 b
FB-ESM-09-43	6.67 b	6.67 a	85.00 a	33.17 b	66.83 b
FB-ESM-09-44	11.67 a	20.00 a	63.33 a	0.00 c	100.00 a
FB-ESM-09-45	6.67 b	15.00 a	78.33 a	25.11 b	74.89 b
FB-ESM-09-46	6.67 b	15.00 a	76.67 a	15.93 b	84.07 b
FB-ESM-09-47	13.33 a	10.00 a	76.67 a	30.53 b	69.47 b
VEH-GRA-09-54	8.33 b	11.67 a	75.00 a	35.50 b	64.50 b
VEH-GRA-09-55	0.00 b	10.00 a	90.00 a	55.77 a	44.23 c
VEH-GRA-09-57	13.34 a	16.67 a	70.00 a	31.68 b	68.32 b
VEH-GRA-09-58	18.34 a	18.34 a	63.33 a	29.76 b	70.24 b
PRBO-SAU-09-62	16.67 a	16.67 a	63.34 a	32.62 b	67.38 b
VR-PRE-09-65	18.33 a	11.67 a	63.33 a	24.38 b	75.62 b
SAS-SAU-09-71	5.00 b	18.34 a	76.67 a	31.67 b	68.33 b
SAS-SAU-09-73	16.67 a	25.00 a	55.00 a	30.28 b	69.72 b
JAH-MAC-09-77	8.33 b	13.33 a	78.34 a	31.42 b	68.58 b
Capdeboscq	15.00 a	13.33 a	66.67 a	52.92 a	47.08 c
Okinawa	15.00 a	20.00 a	65.00 a	48.66 a	51.34 c
Sharpe	36.67 a	16.67 a	46.67 a	33.63 b	66.37 b
$F_{Rootstock}$	3.22**	0.43^{NS}	1.64^{NS}	5.18**	5.23**
CV (%)	50.69	53.81	20.38	28.66	15.81

Means followed by different letters in the column differ from each other by the Scott-knott test. ^{NS} not significant; ** significant at 1 % error probability.

Table 5

Root number per cutting (RNC), root length of three largest roots (RL), percentage of cuttings with original leaves (COL) and percentage of sprouted cuttings (SC), 60 days after cutting setting (trial 2) of three cultivars and 15 rootstock selections potentially tolerant to PTSL syndrome. Embrapa Clima Temperado, Pelotas-RS, Brazil.

Rootstock	RNC	RL (cm)	COL (%)	SC (%)
SS-CHI-09-41	8.56 c	9.46 b	21.67 b	58.34 a
FB-ESM-09-43	9.44 c	7.78 c	20.00 b	68.33 a
FB-ESM-09-44	4.72 e	7.55 c	26.67 a	58.34 a
FB-ESM-09-45	8.25 c	9.54 b	23.33 b	55.00 a
FB-ESM-09-46	7.33 d	9.41 b	6.67 b	71.67 a
FB-ESM-09-47	13.73 b	10.27 b	8.33 b	80.00 a
VEH-GRA-09-54	15.18 b	8.59 c	38.33 a	33.33 a
VEH-GRA-09-55	16.92 b	9.12 b	21.67 a	60.00 a
VEH-GRA-09-57	22.98 a	8.52 c	46.67 a	50.00 a
VEH-GRA-09-58	12.99 b	11.39 a	3.33 b	53.33 a
PRBO-SAU-09-62	13.08 b	12.72 a	31.67 a	50.00 a
VR-PRE-09-65	9.11 c	8.66 c	15.00 b	58.33 a
SAS-SAU-09-71	16.11 b	8.23 c	40.00 a	46.67 a
SAS-SAU-09-73	11.75 c	6.82 c	20.00 b	56.67 a
JAH-MAC-09-77	11.92 c	9.67 b	35.00 a	68.33 a
Capdeboscq	15.74 b	9.36 b	35.00 a	68.33 a
Okinawa	20.99 a	10.11 b	30.00 a	65.00 a
Sharpe	18.61 a	9.70 b	13.33 b	56.67 a
$F_{Rootstock}$	14.47**	3.39**	3.40**	1.65^{NS}
CV (%)	19.47	16.13	41.33	22.08

Means followed by different letters in the column differ from each other by the Scott-knott test. ^{NS} not significant; ** significant at 1 % error probability.

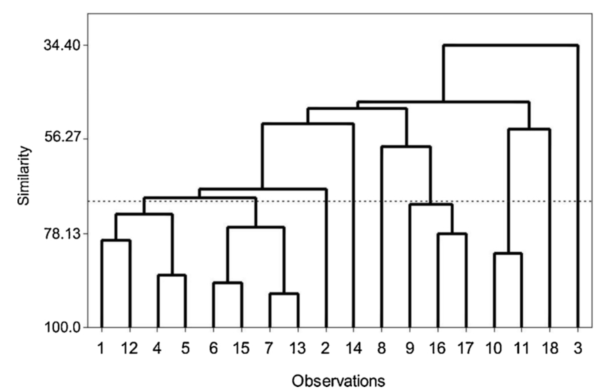

Fig. 9. Dendrogram with Average Linkage Method and Euclidian Distance (Cophenetic correlation coefficient = 0.749757) illustrating the relationship among peach rootstocks selections and cultivars tested for rooting performance (trial 2) (dashed line = 71.30 %), where: 1 = SS-CHI-09-41; 2 = FB-ESM-09-43; 3 = FB-ESM-09-44; 4 = FB-ESM-09-45; 5 = FB-ESM-09-46; 6 = FB-ESM-09-47; 7 = VEH-GRA-09-54; 8 = VEH-GRA-09-55; 9 = VEH-GRA-09-57; 10 = VEH-GRA-09-58; 11 = PRBO-SAU-09-62; 12 = VR-PRE-09-65; 13 = SAS-SAU-09-71; 14 = SAS-SAU-09-73; 15 = JAH-MAC-09-77; 16 = 'Capdeboscq'; 17 = 'Okinawa'; 18 = 'Sharpe'.

was the early fall of original leaves of the cuttings. Herbaceous cuttings without their original leaves, in the initial rooting stage, do not perform photosynthesis and, without new roots or sprouts, die quickly (Hartmann et al., 2002; Ruter, 2015; Fragoso et al., 2015; Mayer et al., 2018). The photosynthetic process is responsible for the production of carbohydrates and natural hormones, such as endogenous auxins and rooting cofactors, which are transferred to the cuttings base by polar transport, increasing auxin concentrations and providing better conditions for root induction (Hartmann et al., 2002). Factors such as poor nutrition of mother tree, endogenous hormonal balance favorable to the senescence of leaves, phytosanitary problems, water and thermal stresses, inadequate regulation of periods of activation and shutdown of mist system, as well as the use of substrates or containers unsuitable that raise the moisture saturation zone at the cuttings base, can contribute to the fall of leaves during the adventitious rooting period, and in most cases, difficult to diagnose the main cause (Hartmann et al., 2002; Ruter, 2015). In softwood cuttings, the leaf wetting system (time, frequency, droplet size and amount of water) also affects rooting, as it interferes with water and physiological status of the cuttings, maintains the photochemical efficiency, in addition to influencing the temperature around the cuttings (Tetsumura et al., 2017). It is also noteworthy that, in both trials of the present study, disinfection of mother trees and cuttings was not performed, which may have contributed to emergence of fungal diseases. In both trials, the fungus *Phomopsis* spp. was identified, which is quite common genus in peach trees in Southern Brazil.

The percentages of dead rooted cuttings (DRC%) were also high, in both trials, reaching a maximum of 46.67 % in 'Sharpe' (Table 2) and 25.0 % in the selection SAS-SAU-09-73 (Table 4). It was also observed that, in most of tested selections and reference cultivars used, the highest percentages of mortality occurred after the beginning of rooting, which reveals environmental conditions with some deficiency and that did not favor the preservation of live cuttings. In this aspect, it is likely that the substrate (medium vermiculite) has retained too much water, since the most common symptoms of mortality in rooted cuttings were upward.

The percentages of live rooted cuttings (LRC%), obtained in both experiments, were considered satisfactory, despite the occurrence of high percentages of total mortality. Among the 15 selections tested in each trial, it was observed that there were no statistically significant differences between them, which compared to the cultivars 'Okinawa' and 'Capdeboscq'. The percentage of live rooting cutting (LRC%) is the most important variable in experiments of vegetative propagation by cuttings and the statistical equality observed in selections compared to 'Okinawa' and 'Capdeboscq' reveals another important feature of the accessions selected: the technical viability of cloning by softwood cuttings. The ability to form adventitious roots varies between selections or cultivars of the genus *Prunus* (Nečas and Krška, 2013; Mayer et al., 2014b.; Mayer et al., 2015, 2017; da Rosa et al., 2017a, 2017b.; Mayer et al., 2018; Oliveira et al., 2018), which can be attributed to the differences in the endogenous levels of auxins and rooting cofactors, age or phenological stage of the mother tree, nutrient contents, phenolic and/or biochemical components, lignin and adaptation of cuttings to the environmental conditions offered during the rooting period (Hartmann et al., 2002; Ruter, 2015; Tetsumura et al., 2017). Once the grafting compatibility is verified, the easiness of vegetative propagation has been pointed out as the main criterion for rootstock selection for perennial fruit species (Warschefsky et al., 2016; Oliveira et al., 2018; Mayer et al., 2018).

Regarding 'Sharpe', the percentages of live rooted cuttings (LRC%) were low (only 23.33 % in trial 1 and 46.67 % in trial 2), which is also attributed to the low percentages of cuttings with original leaves (COL %) (25.0 and 13.33 %, respectively). Another aspect refers to the morphological characteristics of 'Sharpe' softwood shoots, which are usually smaller in diameter (≈5 to 8 mm) than that of the peach tree (≈8 to 12 mm). Low live rooted cutting percentages (LRC%) (21.67 %) in 'Sharpe' softwood cuttings, also treated with 3000 mg L^{-1} of indolbutyric acid, have already been observed (Mayer et al., 2018). However, in hardwood cuttings of 'Sharpe' without leaves, treated with the same phytoregulator and dose and kept under intermittent mist to preserve it moist, cuttings showed 85 % rooting and a satisfactory root quality and root number per cutting (Mayer and Ueno, 2015). Therefore, considering cutting types (softwood and woody) and recent studies with propagation by cutting in *Prunus* spp. (Mayer et al., 2014b; da Rosa et al., 2017a, 2017b; Mayer et al., 2018; Oliveira et al., 2018), it turns out that 'Sharpe' is the only exception (Mayer and Ueno, 2015), as the general rule in *Prunus* spp. is that the adventitious rooting of softwood cuttings is always more effective.

The percentages of suitable rooted cuttings (SRC%) and unsuitable rooted cuttings (USR%) for transplant are complementary variables, which sum results in the percentage of live rooted cuttings (LRC%). The percentage of suitable rooted cuttings (SRC%) for transplanting is related to root system quality and translates, in practice, the transplanting yield that a selection or rootstock cultivar can provide, concerned to the total live rooted cuttings (LRC%). In trial 1, the selections IR-ESM-09-01, IR-ESM-09-02, IR-GRA-09-07, JB-ESM-09-13, DB-SEN-09-23, GL-ERA-09-32, GL-ERA-09-33 and SS-CHI-09-40 stood out in this variable (SRC%), comparing to 'Capdeboscq' and 'Okinawa', whereas in trial 2 only one selection (VEH-GRA-09-55) showed statistical similarity with 'Capdeboscq' and 'Okinawa'. As a negative highlight, the selection FB-ESM-09-44 presented 100% of unsuitable rooted cuttings (URC%) for transplanting (Table 4), that is, although it presented 63.33 % of live rooted cuttings (LRC%), the root quality was too poor, with inadequate root distribution around cutting base. This poor root quality in the selection FB-ESM-09-44 was also verified with the lowest value (4.72) for root number per cutting (RNC) and one of the smallest averages for root length (RL) (7.55 cm).

The root number per cutting (RNC) and root length (RL) are also variables that reflect the quality and propagation potential of a genotype. Although significant statistical differences between treatments were detected in these variables, in both trials, the results are considered excellent. When observing the two variables together, it appears that the selection GL-ERA-09-33 (Table 3) was the only treatment that remained in the groups with the highest averages, that is, it has the largest root number and longest average length. It was also found that five selections (JB-ESM-09-15, DB-SEN-09-22 and GL-ERA-09-33, in trial 1; VEH-GRA-09-58 and PRBO-SAU-09-62, in trial 2) showed greater root length than that obtained in the three reference cultivars. Auxins promote an increase in root number and root length in softwood cuttings of *Prunus* spp. (Hartmann et al., 2002; Kebede et al., 2013), and indolbutyric acid is usually the most used, in doses between 2000 and 6000 mg L^{-1}. The number of primary roots the tree will have is defined during the short period of adventitious rooting (usually within 60 days) (Hartmann et al., 2002; Mayer et al., 2014b; da Rosa et al., 2017a, 2017b; Mayer et al., 2018) and that will be reflected in the field performance, because with a vigorous, wide root system and with a large number of primary roots the tree tends to be more adapted to stony soils and with water deficit, which may induce greater growth and productivity (Jalil et al., 2016).

The permanence of original leaves on cutting and/or the beginning of sprouting during rooting phase are fundamental factors to enable propagation of softwood cuttings in an intermittent mist system (Hartmann et al., 2002; Ruter, 2015; Fragoso et al., 2015). As shown in results, the percentages of cuttings with original leaves (COL%) were, in general, low, however this negative factor was compensated by the fast sprouting of cuttings (SC%) during both trials (Tables 3 and 5). With original leaves adhered to the cutting and/or the emission of new sprouts, the photosynthetic process and elaboration of prohormones is continued, which is fundamental for rooting on leafy cuttings (Fragoso et al., 2015; Mayer et al., 2018). Growing apexes, young leaves and buds are sites of indole-acetic acid synthesis, an endogenous auxin that contributes to root formation (Hartmann et al., 2002). The ability of vegetative buds on cutting to initiate emission of new shoots during rooting period under intermittent mist system varies between cultivars and selections and is a desirable genetic trait, although not essential for peach (Mayer et al., 2018). Vegetative buds in 'Lovell' softwood cuttings or 'Guardian®' semi-hardwood cuttings (both *P. persica*) did not sprout under a mist system, however, excellent rooting percentages (> 85 %) were obtained, if treated with indolbutyric acid at 3000 mg.L^{-1} (Mayer et al., 2015).

The most important variables in vegetative propagation trials by cuttings are the percentage of live rooted cuttings (LRC%), percentage of suitable rooted cuttings for transplanting (SRC%) or rooting grade, root number per cutting (RN) and root length (RL) (Hartmann et al., 2002; Beyl et al., 1995; Mayer et al., 2014b; Mayer et al., 2018; Oliveira et al., 2018). For both trials, cluster analysis was efficient and allowed separation of treatments in nine groups. In trial 1, some selections were similar to 'Capdeboscq', like DB-SEN-09-23, SS-CHI-09-39 and SS-CHI-09-40; others were similar to 'Okinawa', like IR-ESM-09-01 and JB-ESM-09-13; but GL-ERA-09-33 was the best among all 18 treatments tested (Fig. 8). For trial 2, only VEH-GRA-09-57 was similar to both reference cultivars ('Okinawa' and 'Capdeboscq') (Fig. 9). Thus, cluster analysis permitted classification of peach rootstocks selections using main four variables analyzed, and helped to indicate the most promising selections with these combined characteristics. This kind of analisys was also successful used for hardwood cuttings of kiwifruit (Beyl et al., 1995).

Another important factor that interferes on adventitious rooting and root quality of leafy cuttings is the environment temperature and its fluctuations over the period (Tetsumura et al., 2017). When air temperature rises, metabolism of cuttings increases. Photosynthesis and respiration are temperature sensitive so, as the temperature increases, the respiration rate tends to increase more rapidly than photosynthesis, which can result in weight loss and possibly death of cuttings (Hartmann et al., 2002; Ruter, 2015). It is important to highlight that the ideal temperature during adventitious rooting of cuttings will depend on cutting type (softwood, semi-hardwood or hardwood) and, consequently, the time of year and the environment necessary to make rooting feasible. Thus, the ideal air temperature range is also related to the environment: full sun, partial or total shade, agricultural greenhouse, misting, fogging or closed and humidity-saturated environment (Ruter, 2015).

No information was found in literature on the ideal temperature range for rooting softwood cuttings of peach in an intermittent mist system. However, as a general rule for temperate species, Hartmann et al. (2002) cite that daytime air temperatures, between 21 and 27 °C, and nighttime temperatures, around 15 °C, are ideal for rooting. Thus, considering the average temperatures recorded every 30 min (Figs. 2 and 5), it appears that average temperatures greater than 27 °C occurred between 07:45 and 18:15 h, that is, during practically all daytime. Air relative humidity (RH) showed an inversely proportional behavior to the air temperature (Figs. 2 and 5) and the minimum daily RH values fluctuated considerably, while the maximum daily RH values were predominantly between 95 and 100% (Figs. 4 and 7). Air temperatures > 27 °C represented 41.2 and 41.0 % of total time of trials 1 and 2, respectively, while air temperatures < 15.0 °C represented only 1.95 and 0.07 %, respectively (Figs. 3 and 6). Also noted are the maximum temperatures recorded (44.0 and 42.3 °C, respectively), as well as the thermal fluctuations recorded in a single day, which reached 25.4 °C on Dez/12/16, of trial 1 (Fig. 3), and 22.4 °C on Dez/01/17, of trial 2 (Fig. 6). These data show that the high temperatures that occurred during both trials, as well as temperature fluctuations in periods of 24 h, were not the most suitable for cutting adventitious rooting and impaired the results. For future studies, it is suggested that measures should be taken to mitigate these adverse factors.

The present study confirms the considerable genetic variability that exists and used to produce peach rootstocks in Rio Grande do Sul State, normally found in orchards affected by the Peach Tree Short Life syndrome. In addition to influencing tree vigor, fruit production, tree longevity and tree reaction to different biotic and abiotic factors in the soil (Mayer et al., 2009; Mayer and Ueno, 2012; Mayer et al., 2014a.), this rootstock genetic variability can also be reflected in rooting potential and root quality, even in selections originally from the same commercial orchard (Mayer et al., 2018), which again was proved in the present study.

5. Conclusions

In the adopted experimental conditions, it was possible to conclude that:

a) The propagation of rootstock selections potentially tolerant to the Peach Tree Short Life syndrome by softwood cuttings is technically feasible, with rooting percentages ranging from 54.17 to 90 %.
b) The tested rootstock selections differ from each other for most of variables analyzed, which allows distinguishing superior genotypes. However, there is no difference between selections regarding the percentage of live rooted cuttings.
c) Among three reference cultivars used, 'Sharpe' rootstock stood out negatively, with the highest percentages of total mortality, lowest percentages of live rooted cuttings and suitable rooted cuttings for transplanting.
d) Some selections (DB-SEN-09-23, SS-CHI-09-39 and SS-CHI-09-40) showed root formation and root quality similar to 'Capdeboscq', similar (IR-ESM-09-01 and JB-ESM-09-13) to 'Okinawa', similar (VEH-GRA-09-57) to both or even better (GL-ERA-09-33) than both reference cultivars. However, the selection FB-ESM-09-44 presented the worst root quality, with zero percentage of suitable rooted cuttings for transplanting.

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CRediT authorship contribution statement

Newton Alex Mayer: Funding acquisition, Conceptualization, Methodology, Formal analysis, Writing - original draft, Project administration. **Bernardo Ueno:** Conceptualization, Data curation, Validation, Writing - review & editing. **Tamara Böhrer Rickes:** Data curation, Investigation. **Marcus Vinícius Lima Andrade de Resende:** Investigation, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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