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Estimating genetic divergence between peach rootstock cultivars using multivariate techniques based on characteristics associated with seeds

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ABSTRACT. The production of peach rootstocks in Brazil is still performed mainly from seeds of different cultivars, whose endocarps are obtained in peach canning industries. This type of material is not ideal for use as rootstocks, since it is a varietal blend of genotypes with differing in physical and physiological characteristics which can include germination and growth of seedlings. We examined the genetic divergence of peach rootstock based on the relative contribution of 15 seed and endocarp characteristics, using multivariate procedures, in order to help select promising crosses for genetic improvement. Endocarp and seeds from eight rootstock cultivars of *Prunus persica* suggested as appropriate for cultivation in southern Brazil were evaluated for the biometric characteristics of length, width, thickness and fresh weight, and the seeds were submitted to a germination test. An analysis of variance of the data, principal component analysis and clustering using Tocher's optimization method were carried out. Genetic variability was found among the cultivars for all the characteristics. The characteristics with the greatest contribution to the genetic divergence between rootstocks were endocarp fresh weight, seed width and thickness, and germination percentage. On the basis of principal component analysis, using the variables with the greatest power of discrimination, the cultivars were divided into four groups. For breeding programs we suggest crosses between the cultivars Flordaguard χ Capdeboscq, Capdeboscq χ Tsukuba 1 and Capdeboscq χ Okinawa, aimed at obtaining improved peach rootstock with superior seed and seedling vigour, together with other characteristics of interest for farmers in southern Brazil.

Key words: Multivariate analysis; *Prunus persica*; Seed analysis

INTRODUCTION

With recent advances in fruit farming, the preference for rootstock cultivars with superior characteristics, which could result in better fruit quality, variability for vigour, resistance to soil pests, early seedling production and greater productive efficiency are of great interest to nurseries and rural producers (Mayer et al., 2015b; Souza et al., 2017). Among stone fruit, the peach *Prunus persica* is one of the most widely grown species in Brazil. The south and southeast of Brazil are the main peach-farming areas of the country. The state of Rio Grande do Sul stands out as the main producer, with 127 thousand tons a year, representing 60% of domestic production (IBGE, 2016).

In order to maintain the increases and expansion in the production of these regions, advances are necessary, especially in breeding programmes that have made scion cultivars available that have a low demand for cold and are resistant to conditions of stress and disease (Mayer and Antunes, 2010; Silva et al., 2014). However, genetic improvement of peach rootstock is still in the early stages in Brazil.

There is currently a range of potential peach rootstock cultivars to be used for the production of seedlings, replacing those obtained from stones obtained from the canning industry and/or used together with the Capdeboscq cultivar (Mayer et al., 2015a). Among the possible materials to be used as peach rootstock are 'Tsukuba 1, 2 and 3', 'Okinawa', 'Okinawa Roxo' and 'Flordaguard' (Mayer et al., 2015b; Souza et al., 2016; Souza et al., 2017; Souza et al., 2019). These materials differ in their demand for chill hours, vigor and resistance to soil phytonematodes, among others (Schmitz et al., 2014; Mayer et al., 2015b).

Even with the numerous materials available for the production of peach rootstock in the southern regions of the country, there are few studies that explore the genetic divergence between cultivars from easily measurable descriptors that are related to the physiological quality of the seeds, with a view to optimizing seedling production (Souza et al., 2015; Souza et al., 2016; Souza et al., 2018). Among the characteristics resulting from seed-analysis tests, those that express vigor are of great interest, as they are highly indicative of seedling performance, reflecting growth, longevity and even tolerance to adversity (Carvalho and Nakagawa, 2012). It is therefore necessary to concentrate efforts in evaluating these characteristics on the different available types of genetics, in order to suggest alternatives, not only for nurseries, but also for breeders to carry out controlled crosses and obtain new combinations of greater genetic potential.

Till now in Brazil, genetic improvement of *Prunus* has mainly focused on the production of new scion cultivars of the peach, nectarine and plum (Silva et al., 2014; Silva et al., 2016; Matias et al., 2016); however, in view of the importance and influence of rootstock to the longevity and productivity of the orchard, studies that seek to understand the variability of the available rootstock cultivars are essential, both in relation to the individual performance of the cultivar, and to the genetic variability of existing genotypes, with the aim of supporting the development of rootstock with superior characteristics of interest than those that already exist.

To analyze the contribution of quantitative descriptors in determining genetic divergence among cultivars of any one species, the use of multivariate analysis is suggested, since this allows several characteristics to be evaluated simultaneously (Cruz et al., 2012). According to Wagner Júnior (2011), the use of multivariate procedures, such as the principal component and clustering methods to analyze genetic divergence, may help the breeder concentrate his efforts on the most promising combinations, provided a new intraspecific cross is first suggested, thereby increasing the efficiency of breeding programs.

Multivariate techniques were employed by Silva et al. (2014) to analyze genetic divergence among 15 scion cultivars of the peach based on characteristics of the plant and fruit. Of the 15 cultivars evaluated, 12 formed a single group due to low variability of the measured characteristics, thereby demonstrating the limited possibilities of obtaining superior genotypes using such a set of cultivars.

The genetic variability between 28 peach scion cultivars and two nectarine cultivars was evaluated by Matias et al. (2016) using multivariate procedures. Using 14 fruit quality characteristics, they were successful in determining the relative contribution of each characteristic to the variability between cultivars, separating them into different groups, favouring selection of the materials to obtain new hybrids based on the characteristics of greater value.

Along this line, we applied multivariate analysis to determine which quantitative descriptors associated with the endocarp, seeds and plantlets significantly contribute to the genetic divergence of eight peach rootstock cultivars, so that we could suggest promising crosses for breeding programs.

MATERIAL AND METHODS

The study was conducted using ripe peach fruit harvested between December 2016 and January 2017, of the peach rootstock germplasm collection at the Federal University of Pelotas (UFPel) located in the municipality of Capão do Leão, state of Rio Grande do Sul. Were using propagation material from peach rootstock of the cultivars: Aldrighi, Capdeboscq, Flordaguard, Okinawa, Okinawa Roxo, and Tsukuba 1, 2 and 3. After the fruit were harvested, the endocarps were processed following a biometric evaluation was carried out, recording the following characteristics: length, width and thickness (using a digital caliper with a precision of 0.01 mm). The unit fresh weight was recorded on scales with a precision of 0.01 g. For this stage of the analysis a completely randomized experimental design was used, with four replications of 50 seeds each.

To obtain the seeds, the endocarps were flamed with 70% alcohol for eight seconds, and then broken with the aid of a manual lathe. Seeds with an intact external appearance were then measured for the following biometric variables: length, width and thickness (using a digital caliper with a precision of 0.01 mm). The unit fresh weight was recorded on scales with a precision of 0.01 g. For this stage of the analysis a completely randomized experimental design was used, with four replications of 50 seeds each.

The seeds were immediately disinfested with 2% hypochlorite solution for 10 min and then washed three times in distilled water. For the germination test, 25 seeds were placed in a petri dish (90 x 15 mm), containing filter paper moistened with 4 mL of fungicidal solution (Orthocid® 500-12 mg.L^{-1}). The germination test was also carried out in a completely randomized experimental design, with four replications of 50 seeds. The Petri dishes were sealed with parafilm and placed in a Biochemical Oxygen Demand (BOD) chamber at a temperature of 7 ± 0.5^{o}C in the absence of light, where they remained for 24 days, as recommended by Souza et al. (2017).

The germinated seeds were evaluated every two days, with a protrusion of the radicle of around 2 cm in length being adopted as the germination criterion (Brasil, 1992). Once the number of seeds germinated daily was known, the following characteristics were evaluated: germination speed index - determined as per Brasil (1992); germination percentage – carried out according to the total percentage of normal plantlets (those showing perfect essential structures) 24 days after the start of the test.

After a period of cold stratification, the seeds were planted at a depth of 1 cm in polystyrene trays of 72 cells (114 cm^3 per cell) containing as substrate a mixture composed of soil + vermiculite + medium sand + Plantmax®commercial substrate (1:1:1:1) and kept in a greenhouse. When the height of the plantlets was 2 cm above the substrate, irrigation was begun with a nutrient solution, as per Souza et al. (2011), watering three times weekly to field capacity of the substrate.

The height of the plantlets was recorded at 22 days after sowing (DAS), the period for which at least 75% of the plantlets reached the transplanting stage (15 cm in height between the collar region and the apex under greenhouse conditions), as recommended by Souza et al. (2011). At 22 DAS, the collar diameter was also evaluated two cm above the level of the substrate (mm), together with the dry weight of the plantlets, which was separated into roots and shoots. The roots were washed in running water, and the shoots and roots then placed in a paper bag, remaining in a drying oven at 70°C with circulating air to constant weight (72 h). The material was then weighed (on scales with a precision of 0.01 g) to determine the shoot dry weight, root system dry weight, and from the sum of these, the total dry weight of the plant.

Fifteen variables related to seed analysis were collected, among them biometric measurements of the length (EL), width (EW), thickness (ET) and fresh weight (EFW) of the endocarps, the length (SL), width (SW), thickness (ST) and fresh weight (SFW) of the seeds, and variables related to the germination test: germination percentage (GER), germination speed index (GSI), plantlet height (HGT), shoot dry weight (SDW) and total dry weight (TDW) of the plantlets, in addition to the Dickson quality index (DQI) (Dickson, Lead, and Osmer, 1960).

All the data were tested for homogeneity (Bartlett) and normality (Shapiro-Wilk), and the mean values of the variables under evaluation were submitted to analysis of variance (ANOVA); the mean values of the remaining variables were compared by Scott-Knott test at 5% probability of error. The ANOVA was carried out simply to verify variation between the cultivars, in a completely randomized design, adopting four replications of 50 seeds per treatment.

All the characteristics were then submitted to principal component analysis, estimating the relative contribution of each variable to discriminating the cultivars, eliminating variables with less explanatory power, following the method used by Lazarotto et al. (2013), where components able to synthesize an accumulated variance of around 70% were used.

With the most important variables chosen, cluster analysis was carried out using the Tocher optimization method, with the aid of the Statistica v 8.0 software (Statsoft, 2007).

RESULTS AND DISCUSSION

The analysis of variance and grouping of the mean values by the Scott-Knott test (Table 1) showed that there were significant differences between each cultivar in relation to the quantitative characteristics under evaluation, indicating the possibility of discriminating the cultivars based on these descriptors, and suggesting that the different genotypes available for the production of peach rootstock are agronomically different.

Table 1. Summary of the analysis of variance and mean-value comparison test of 15 quantitative descriptors from the analysis of the seed and plantlets of eight peach rootstocks.

Cultivar	Variable														
	EL	**EW**	**ET**	**EFW**	**SL**	**SW**	**ST**	**SFW**	**GER**	**GSI**	**RDW**	**SDW**	**TDW**	**HGT**	**DQI**
Aldrighi	25.50 b	16.88 b	15.66 c	3.23 b	14.39 c	7.97 c	4.76 c	0.27 c	93 b	5.44 c	0.16 e	0.34 g	0.50 g	15.02 c	0.06 d
Capdeboscq	26.91 a	17.43 a	15.09 b	4.18 a	16.37 a	7.79 d	5.36 a	0.37 a	100 a	8.93 b	0.19 c	0.58 b	0.77 b	18.62 b	0.08 b
Flordaguard	27.27 a	16.78 b	14.54 c	3.91 a	15.03 b	8.82 a	3.66 d	0.23 d	100 a	11.58 a	0.29 a	0.61 a	0.90 a	23.70 a	0.09 a
Okinawa	27.29 a	16.62 b	13.49 d	2.62 d	14.41 c	6.52 f	3.49 d	0.15 f	100 a	6.86 c	0.13 f	0.32 h	0.46 h	14.07 c	0.05 e
Okinawa Roxo	23.56 d	17.21 b	15.07 b	2.93 c	11.79 d	7.29 e	4.60 c	0.18 e	100 a	6.23 c	0.18 d	0.47 e	0.65 e	18.15 b	0.06 d
Tsukuba1	24.27 c	17. 99 a	15.88 a	3.21 b	14.12 c	8.25 b	5.40 a	0.31 b	100 a	6.63 c	0.21 b	0.54 c	0.75 c	15.07 c	0.08 b
Tsukuba2	25.06 b	16.80 b	14.54 c	2.98 c	14.00 c	8.08 b	5.25 b	0.31 b	92 b	5.50 c	0.19 c	0.51 d	0.70 d	15.50 c	0.07 c
Tsukuba3	25.54 b	16.85 b	14.45 c	2.96 c	13.98 c	8.12 b	5.11 b	0.28 c	93 b	5.49 c	0.18 d	0.39 f	0.57 f	15.13 c	0.06 d
Mean	25.67	17.07	14.72	3.25	14.26	7.84	4.70	0.261	97.4	7.08	0.19	0.47	0.66	16.91	0.07
SR Trtmt	7.75**	0.82**	1.85**	1.12**	6.46**	1.96**	2.26**	0.02**	51.57*	18.54**	0.01**	0.048**	0.09**	40.40**	0.01**
CV (%)	1.89	2.68	2.25	5.78	2.37	1.49	2.85	5.82	4.43	14.4	1.37	0.37	0.52	7.6	5.2

Mean values followed by the same lowercase letter in the columns belong to the same group by Scott-Knott test at 5%. EL: endocarp length, in mm; EW: endocarp width, in mm; ET: endocarp thickness, in mm; EFW: endocarp fresh weight, in g/unit; SL: seed length, in mm; SW: seed width, in mm; ST: seed thickness, in mm; SFW: seed fresh weight, in g/unit; GER: germination percentage; GSI: germination speed index; RDW: root dry weight, in g/plantlet; SDW: shoot dry weight, in g/plantlet; TDW: total dry weight, in g; HGT: plantlet height, in cm; DQI: Dickson quality index. MS Trtmt.: mean square of the treatments in the analysis of variance for the characteristic. *Significant values at 5% by F-test.

All the peach rootstock cultivars showed excellent seed germination capacity, which was determined by germination test and expressed as a mean germination percentage (97.4%) and germination speed index (7.8), which was considered satisfactory based on results obtained by Souza et al. (2016). The greatest proportion of germinated seeds (±70%) occurred between 9 and 16 days of incubation, which shows a high germination synchrony between the seeds of the different cultivars under evaluation.

It is important to highlight the superior performance of the Flordaguard cultivar, evidenced by the higher mean value for each of the quantitative descriptors from the germination test. Cultivars with a superior germination rate, GSI, total dry weight, height and DQI are recommended for use in the production of peach rootstock (Souza et al., 2015), since these characteristics have a positive influence in reducing the time to obtain rootstocks suitable for grafting.

The time required for the rootstock to reach the grafting stage and/or for the seedlings to meet the minimum standards for marketing is one of the main obstacles in the present production system for peach seedlings in southern Brazil. As such, the use of cultivars that have seeds of superior vigor, such as, for example, the Flordaguard cultivar, can ensure optimization and anticipation of the seed germination process, and maximization of the initial growth of the plants (Fischer et al., 2016), which may encourage nurseries to utilize little-used material.

It should be emphasised that the Flordaguard cultivar is genetic material which is immune to *Meloidogyne incognita* (Paula et al., 2011). This phytonematode has a high incidence in the orchards of southern Brazil (Mayer et al., 2017), and is described as phytoparasitic and of agricultural interest due to a high potential for damaging the production and quality of stone fruit (Claverie et al., 2011). Another relevant characteristic of this cultivar is that the stone does not adhere to the fruit pulp, which facilitates post-harvest handling of the endocarp and consequently of the seeds, in relation to maintaining physiological and phytosanitary quality, so that later the propagative material can express its maximum vigor.

Second in importance for the characteristics under evaluation was the Capdeboscq cultivar, which showed higher values for the biometric characteristics of the endocarp and seeds. This cultivar was used for a long time as rootstock in the production of peach seedlings in southern Brazil, due to the ease of obtaining stones from the canning industries of the region (Mayer et al., 2017) and the high germination potential of the seeds.

One advantage of the Capdeboscq cultivar, which maintains high germination rates in the presence of the endocarp, is to dispense with the use of pre-germination procedures, such as breaking the stone, suggested for the majority of *Prunus* species of commercial interest as a way of obtaining a high percentage of germination (Souza et al., 2017). The endocarp acts as a physical barrier in most peach rootstock cultivars, since it is a highly lignified structure that surrounds the seed, offering high resistance, and significantly compromising seed germination due to the difficulty of the embryo to break through the barrier during the germination process (Souza et al., 2016; Fischer et al., 2016; Souza et al., 2017).

Another factor that historically has promoted widespread use of the Capdeboscq cultivar, is the superior vigor of the plantlets, a result of late seed maturation and good adaptation to the climate of southern Brazil (Souza et al., 2016; Mayer et al., 2017;, Souza et al., 2018), in addition to being compatible with almost all peach, nectarine and plum cultivars (Mayer et al., 2017).

Disadvantages of using the Capdeboscq cultivar include a high susceptibility to different species of the genus *Meloidogyne* (Fachinello et al., 2000; Souza et al., 2014) and the characteristic of the pulp adhering to the stone, making it difficult to clean and to maintain post-harvest integrity of the endocarp and seeds.

In southern Brazil, layering the stones in the shade of trees in the field still predominates. Under this management system, pulp adhering to the stone causes rotting and/or drying of the pulp residue near the stone, resulting in low yield for plantlet production, possibly due to the phytosanitary conditions, which result in a higher incidence of phytopathogens and seed rot.

As such, important among the characteristics desired in peach rootstock for southern Brazil, is the use of cultivars with endocarps that do not adhere to the pulp, to facilitate post-harvest management; seeds with high germination potential and vigor for initial plantlet growth (Souza et al., 2016); resistance and/or immunity to phytonematodes (Paula et al., 2011); a low demand for chill hours; and a potential for vegetative propagation (Mayer et al., 2015), among others. The desire for cultivars with these characteristics reinforces the need for developing genotypes that have the highest number of such characteristics and would be considered ideal for the production of peach rootstock (Mayer et al., 2017).

Principal component analysis revealed that the first two components were enough to explain 73% of the observed variation (Table 2), the first being the most important, accounting for 48.2% and the second, for 24.9%. As such the first two components were used to identify the most important characteristics.

Table 2. Eigenvalues and eigenvectors for the multivariate analysis by principal components, obtained from fifteen characteristics of the seed analysis of eight cultivars.

FACTOR	Eigenvalue	Total Variance (%)	Accumulated Eigenvalue	Accumulated Total Variance
1	4.82	48.20	4.82	48.20
2	2.49	24.90	7.31	73.10
3	0.513	5.13	7.823	78.23
4	0.655	6.55	8.478	84.78
5	0.412	4.12	8.89	88.90
6	0.405	4.05	9.295	92.95
7	0.199	1.99	9.494	94.94
8	0.162	1.62	9.656	96.56
9	0.159	1.59	9.815	98.15
10	0.088	0.88	9.903	99.03
11	0.084	0.84	9.987	99.87
12	0.004	0.04	9.991	99.91
13	0.003	0.03	9.994	99.94
14	0.003	0.03	9.997	99.97
15	0.003	0.03	10	100.00

The relative importance of the descriptors for genetic divergence obtained with the principal component analysis can be seen from the weight of each characteristic in the first two components (Table 3). The quantitative descriptors that contributed most to the divergence between cultivars in the first component were the Dickson quality index (34.4%), followed by seed thickness (19.8%) and finally seed length (8.51%). Together, these descriptors accounted for approximately 62% of the divergence between cultivars.

Table 3. Contribution of the 15 characteristics associated with seeds and plantlets of eight peach cultivars in each of the principal components.

Characteristic	Weight Factor 1	Contribution Factor 1 (%)	Weight Factor 2	Contribution Factor 2 (%)
EL	-0.04	0.03	0.19	1.18
EW	-0.02	0.12	0.65	8.14
ET	0.19	1.20	-0.05	0.03
EFW	0.24	1.99	-0.94*	8.6
SL	0.97*	13.7	0.74	9.19
SW	0.6	8.51	0.99*	7.3
ST	0.88*	19.8	0.55	7.58
SFW	0.47	3.48	0.61	8.15
GER	0.55	6.75	0.96*	12.1
GSI	0.25	2.02	0.22	2.16
RDW	0.24	2.35	0.54	6.43
SDW	0.32	2.05	0.47	5.18
TDW	0.14	1.25	0.55	7.42
HGT	0.37	2.45	0.25	3.00
DQI	0.99*	34.3	0.77	13.54

*Variables with a significant contribution to the factors: %. EL: endocarp length, in mm; EW: endocarp width, in mm; ET: endocarp thickness, in mm; EFW: endocarp fresh weight, in g/unit; SL: seed length, in mm; SW: seed width, in mm; ST: seed thickness, in mm; SFW: seed fresh weight, in g/unit; GER: germination percentage; GSI: germination speed index; RDW: root dry weight, in g/plantlet; SDW: shoot dry weight, in g/plantlet; TDW: total dry weight, in g; HGT: plantlet height, in mm; DQI: Dickson quality index.

The characteristics of germination percentage, endocarp fresh weight and seed width were considered descriptors of secondary importance, individually contributing 12.1%, 8.6% and 7.3% respectively, and together, 28% of the divergence found between cultivars in the second component. Rodrigues et al. (2017) also suggested analysis of the germination speed index between the variables derived from a seed analysis to discriminate ten progenies of the passion fruit, due to the relative contribution of this characteristic to genetic divergence between the evaluated genotypes.

The remaining characteristics played a small part in discriminating the cultivars, so it is suggested that the quantitative descriptors that contributed little to discriminating the genotypes be discarded, since including some of them may cause changes in the composition of the groups.

With the most important variables selected, cluster analysis was carried out using the Tocher optimisation method, which allowed the peach rootstock cultivars to be grouped into four distinct groups (Figure 1). Only one group was formed from more than one cultivar, called group 1, containing Aldrighi, Tsukuba 2 and 3, and Okinawa Roxo, suggesting low variability of the characteristics evaluated between these cultivars.

As shown in tabela 2, all the cultivars that make up group 1 had lower values for the variables from the germination test and those that express vigor, for example, GER, GSI, HGT and DQI. However, a common characteristic among the cultivars that comprise this group, except for the Aldrigui cultivar, is resistance to *Meloidogyne javanica* (Fachinello et al., 2000), an attribute of great relevance to future breeding programs.

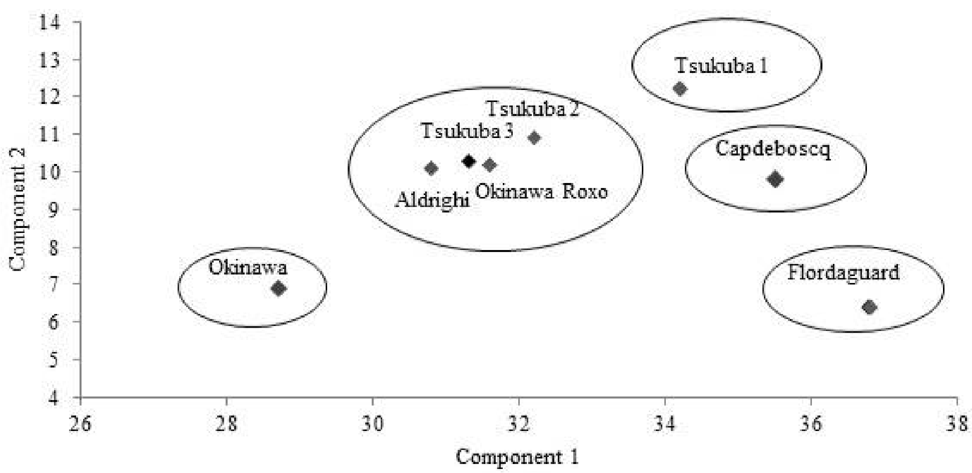

Figure 1. Grouping by the Tocher optimization method of eight peach rootstock cultivars, considering the first two principal components and the quantitative descriptors having the greatest contribution to the genetic divergence.

The remaining cultivars formed isolated groups; among them Capdeboscq and Flordaguard, earlier highlighted in this work due to the superiority obtained in the test for germination and plantlet emergence, in addition to isolated groups for the Tsukuba 1 and Okinawa cultivars. These last two have the common and advantageous characteristics of being resistant to *Meloidogyne javanica* (Paula et al., 2010) and the pulp not adhering to the stone. On the other hand, they require pre-germination treatment (removal of the endocarp) to obtain a high percentage of germination, which results in additional costs for the nursery, mainly due to the costly labor required for the procedure (Souza et al., 2015).

These same cultivars, although presenting high rates of germination in the absence of the endocarp, illustrated in the present work by GER, showed lower seed and plantlet vigor, confirmed by the values for GSI, total dry weight, height and DQI, characteristics which are relevant to obtaining rootstock suitable for grafting over a shorter period.

Discrimination of the cultivars into groups by similarity is of great importance for breeding, since, properly exploited, it can accelerate the genetic gain of joining certain characteristics in a single hybrid with each generation of crossing (Cruz et al., 2012). The more divergent the parents, the greater the resulting variability in the segregating population, and the greater the likelihood of regrouping the alleles into favorable new combinations.

The superior characteristics of seed and seedling vigor presented in this work for the Flordaguard, cultivar, together with resistance to *Meloidogyne incognita* (Paula et al., 2011) and the presence of a stone which does not adhere to the pulp, make this material attractive for use as a peach rootstock, as well as a promising choice for breeding programs.

Based on the results obtained in this work, a cross of the Flordguard χ Capdeboscq cultivars is suggested, since the latter also showed higher values for the characteristics that demonstrate seed and seedling vigor, as well as showing good adaptation to the climate in southern Brazil (Mayer et al., 2017) with high rates of seed germination in the presence of the endocarp (Fischer et al., 2013; Souza et al., 2015).

Another suggested alternative is based on crosses between the Capdeboscq χ Tsukuba 1 and Capdeboscq χ Okinawa cultivars, with the aim of combining the advantageous characteristics described above for the Capdeboscq cultivar with resistance to *Meloidogyne javanica* (Paula et al., 2010) and the characteristics of the pulp not adhering to the endocarp, resistance to *Meloidogyne spp.* and the differences in vigor shown by the Tsukuba 1 and Okinawa cultivars.

It is assumed that these combinations of crosses would be promising in generating segregating populations for selection, since they suggest the crossing of distant genetic material, i.e. belonging to different groups, and simultaneously favor the union of alleles responsible for characteristics of interest in creating peach rootstock to be used in orchards in the south of Rio Grande do Sul.

CONCLUSIONS

Each of the 15 characteristics obtained from the seed analysis of peach rootstock showed divergence between the eight cultivars that were evaluated. Of the 15 characteristics evaluated, only six made a large contribution to the total variation between the cultivars, particularly endocarp fresh weight, seed width and thickness, germination percentage and the Dickson quality index. For breeding programs aimed at obtaining materials of superior seed and seedling vigor, together with characteristics of interest in creating new peach rootstock for potential use in orchards in the southern state of Rio Grande do Sul, crosses between the Flordaguard χ Capdeboscq, Capdeboscq χ Tsukuba 1 and Capdeboscq χ Okinawa cultivars are recommended.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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