REVISTA BRASILEIRA DE
FRUTICULTURA
Published by the Brazilian Society of Fruit Crops
ISSN 0100-2945

Genetics and Plant Breeding - Original Article
Edited by: Ana Maria Costa/Alexandre Pio Viana

Peach cultivars and new IAC selections for mild winter

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Abstract: Traditional peach production regions provide adequate chill for satisfactorily bud's flower break dormancy, in cultivars there developed. However, considering the expansion of the orchards in mild winter areas and the expected global trends to warmer conditions, the local development of cultivars became relevant. Based on this background, this study proposed to evaluate the performance of 33 peach and nectarine cultivars and selections in mild winter climate. Features associated to the vegetative development, phenology, productivity and fruit characteristics were measured in nine seasons, and the data analyzed by multivariate analysis of variance. Significant correlations between features were remarked. The Pillai and F tests presented significant results, highlighting significant differences among cultivars for almost all features. Peach and nectarine genotypes showed genetic diversity that may be accessed for use as cultivars, or parental for crosses. 'IAC Aurora 1', 'IAC Aurora 2', 'IAC Centenário', 'IAC Douradão', 'IAC Jóia4', 'IAC Ouromel 3', 'IAC Régis', 'Diamante', 'Eldorado', 'FlordaPrince', 'Premier' and 'Tropic Beauty' were the cultivars with the best results. A large number of selections showed promising results, emphasizing, the 'IAC 680-177', 'IAC 1085-27', 'IAC 785-9', 'IAC 2982-31', 'IAC 4682-45'and 'IAC 6882-84'.

Index terms: multivariate analysis, principal component analysis, Southeast Brazil, *Prunus persica*.

Cultivares e novas seleções IAC de pêssego para regiões de inverno ameno

Resumo: As regiões tradicionais de produção de pêssego apresentam frio adequado para a quebra de dormência das gemas de forma satisfatória, nas cultivares localmente desenvolvidas. No entanto, considerando a expansão dos pomares em áreas

Rev. Bras. Frutic., v.46, e-025 DOI: *https://dx.doi.org/10.1590/0100-29452024025*
Received 02 Mar, 2023 • Accepted 21 Jul, 2023 • Published Jan/Feb, 2024. Jaboticabal - SP - Brazil.

de inverno ameno e as tendências globais esperadas para condições mais quentes, o desenvolvimento local de cultivares tornou-se relevante. Com base nisso, este estudo propôs-se a avaliar o desempenho de 33 cultivares e seleções de pessegueiro e nectarineira em clima de inverno ameno. Características associadas ao desenvolvimento vegetativo, fenologia, produtividade e características dos frutos foram medidas em nove safras; e os dados, analisados por análise de variância multivariada. Foram observadas correlações significativas entre as características. Os testes de Pillai e F apresentaram resultados significativos, destacando a presença de diferenças entre cultivares para quase todas as características. Os genótipos de pessegueiro e de nectarineira apresentaram diversidade genética que pode ser acessada para uso como cultivares, ou parentais para cruzamentos. As cultivares 'IAC Aurora 1', 'IAC Aurora 2', 'IAC Centenário', 'IAC Douradão', 'IAC Jóia4', 'IAC Ouromel 3', 'IAC Régis', 'Diamante', 'Eldorado', 'FlordaPrince', 'Premier' e 'Tropic Beauty' apresentaram os melhores resultados. Um grande número de seleções apresentou resultados promissores, destacando-se 'IAC 680-177', 'IAC 1085-27', 'IAC 785-9', 'IAC 2982-31', 'IAC 4682-45' e 'IAC 6882-84'.

Termos para indexação: análise multivariada, análise de componentes principais, sudeste do Brasil, *Prunus persica*.

Introduction

The Rosaceae botanical family has many fruit species suitable for human consumption, e.g., *Prunus persica* (peach) and *P. persica* var. *nucipersica* (nectarine). In 2020, while China ranked as the top 1 world producer with 15.016.103 ton., Brazil ranked in 14th, with 201.880 ton. (FAO STAT, 2022). The Brazilian production is distributed between *in natura* consumption (57%) and industrialization (43%) destinations (SOBIERAJSKI et al., 2019). Brazil imported 13,239 ton. of peaches and nectarines in 2020 (FAO STAT, 2022), reflecting a great opportunity for Brazilian's producers (FERNANDES et al., 2022).

The commercial peach orchards are situated in Southern and Southeastern Brazil (SOBIERAJSKI et al., 2019; FERNANDES et al., 2022). These states show regions suitable for stone fruits production, however, present a mild winter and not always provide the chill requirement of cultivars developed in traditional areas in United States, Europe or Asia. In addition, climate changes may lead to warmer conditions in several regions (BLAIN, 2011; IPCC, 2018), affecting the performance of elite cultivars currently used (GRADZIEL, 2022; MILECH et al., 2022). These aspects highlight the need for local development of peach and nectarines cultivars (SOBIERAJSKI et al., 2016). Since 1950 the Agronomic Institute (IAC) of São Paulo State has develop low chill cultivars (RASEIRA and FRANZON, 2014; THUROW et al., 2017; SOBIERAJSKI and BLAIN, 2022) based on the IAC-Prunus germplasm genetic variability.

The State of São Paulo is recurrently the second Brazilian peach producer, and its production is predominantly for fresh market consumption (SOBIERAJSKI et al., 2019; DINI et al., 2021). As mentioned above, frequently the ideal chill accumulation is not provided in Brazil, when compared with tradition peach cultivation regions around the world. This occurs in the location of Capão Bonito, situated in the south region of the State of São Paulo. Despite the lack of chilling required to breaking the dormancy for many peach and nectarines cultivars, this region is recognized for its stone fruits cultivation. On this background, we infer that the genetic plasticity of some cultivars and selections enables the adaptation of these genotypes to mild winter conditions. The present study aims to evaluate the vegetative development, the phenology, the productivity and the pomological characteristics of 33 peaches and nectarines cultivars and selections under Capão Bonito environment conditions.

Material and Methods

The trial was installed in 2007 at the Research and Development Unit of Capão Bonito (24° 02' 23" S; 48° 23' 03" W; 740 m a.s.l.) of Agronomic Institute (IAC), in state of São Paulo, Brazil. The experimental data were collected from 2009 to 2017. According to Köppen's classification system the climate is "Cfa". The average of rainfall, minimum and maximum temperature for this period is depicted in Figure 1. The experiment was compounded by 33 peach and nectarines cultivars and selection, trained by open-vase system (5 x 4 m) in a randomized blocks design, with four replications and three plant by plot.

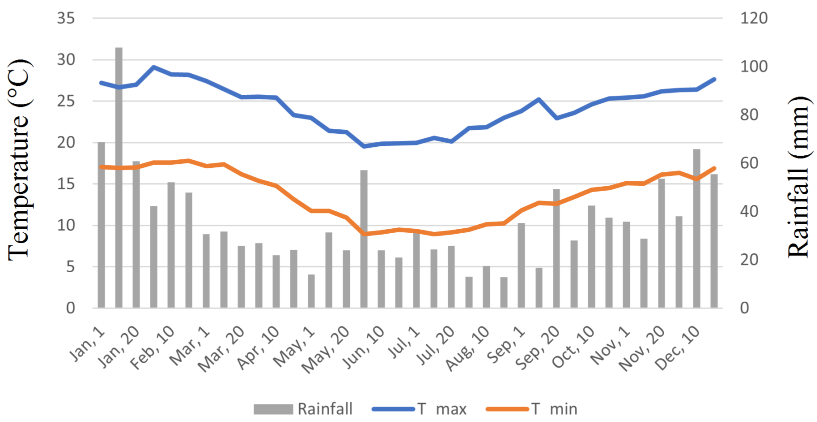

Figure 1. Average of rainfall (mm), minimum (T min, °C) and maximum (T max, °C) temperatures. Capão Bonito, SP, Brazil, 2009 – 2017.

The vegetative development was measured by tree height, treetop width and diameters of the rootstock and scion, once a year before the pruning. The phenology data was considered at the full blooming (50% of flowers in full bloom). The harvest was considered by the beginning and ending dates. The dates were transformed accord to Julian date calendar. The productivity was evaluated measuring the total fruit weight by tree obtained by digital balance. The fruit weight was estimated by sampling 20 fruits per tree. The fruit characterization included fruit height and width measured from 20 sampled fruits. The soluble solids of the sampled fruits were measured by a portable digital refractometer (Pal-1, Atago).

The multivariate analysis of variance was applied, and its significance was evaluated by the Pillai Test (SILVA, 2016). The data were standardized to eliminate the units of the characteristics effects ($Z = (x - \mu)/\sigma$), where: Z = transformed value; x = original value; μ = mean; and σ = standard deviation. The analysis of variance was used to evaluate the differences among cultivars (means over the years), for each feature. Additionally, for those features presenting significant F Test, the Scott-Knott Test was applied to classify the cultivars and selections. All hypothesis tests were calculated at 5% significance level. The Pearson's coefficient was used to estimate the correlation among characteristics. The Principal Component Analysis (PCA) was applied to highlight the mains factors, which explain the total variance (SILVA, 2016). The number of Principal Component (PC) was established by the Kaiser's criterion (BRAEKEN and VANASSEN, 2017). The statistical tests were calculated using the R-software (R CORE TEAM, 2019) with 'biotools' (SILVA, 2022), and 'agricolae' (DEMENDIBURU, 2022). The results were plotted using the 'ggplot2' (WICKHAM et al., 2019) and 'scatterplot3d' (LIGGES et al., 2022).

Results and Discussion

The Pearson's correlations coefficients among the characteristic ranged from weak (e.g., -0.02 between scion diameter and blooming season) to high (e.g., 0.90 between rootstock and scion diameters; Figure 2). Significant correlations between features are a required condition for application of multivariate analysis of variance (SILVA, 2016), so these results allow its use. Matias et al. (2014) observed high correlation between fruit weight and equatorial diameter (0.97), and fruit weight and polar diameter (0.92), which are higher than those presented in this study (0.57 and 0.79, respectively). However, the correlation coefficient found in this study are significant ($p < 0.05$). Regarding the correlation between fruit weight and soluble solids, the studies of Matias et al. (2014; r: -0.11) and Sobierajski and Blain (2022; r: from -0.24 to 0.15) are in line with that observed in this study (r: -0.16; $p \geq 0.05$).

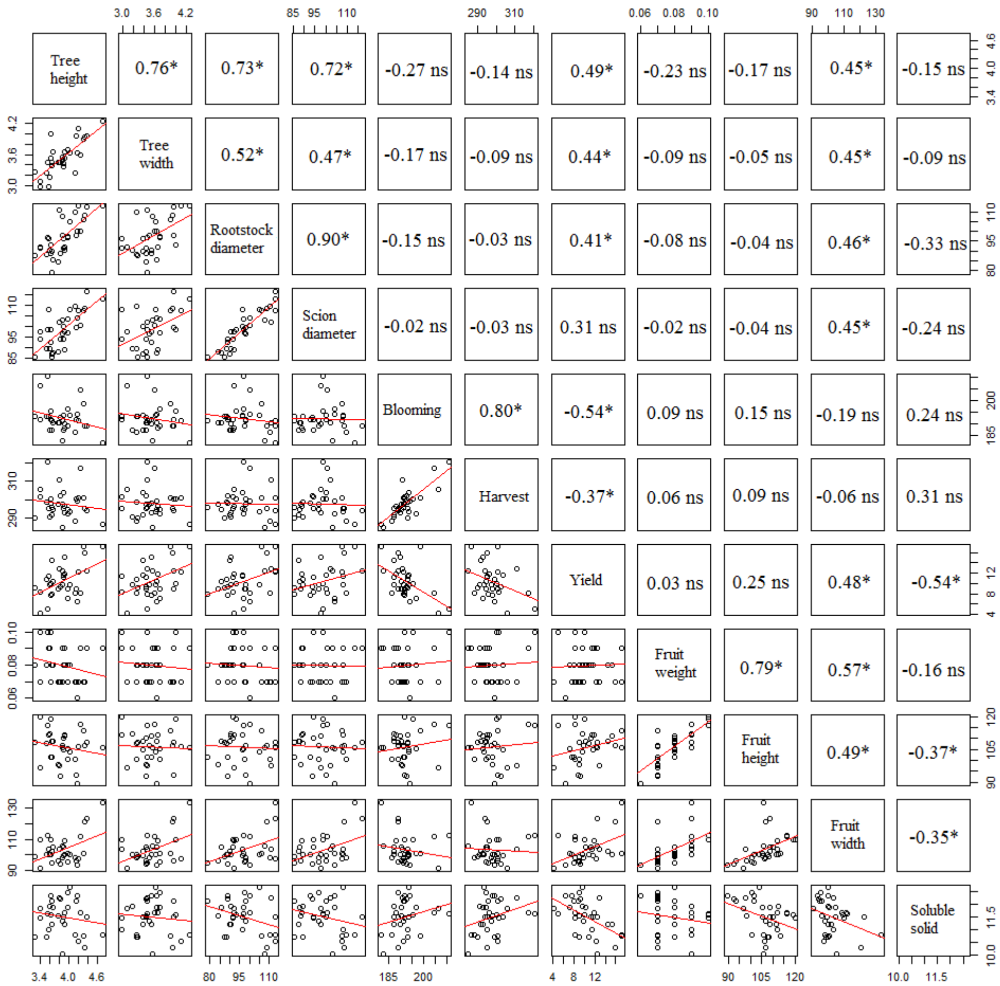

Figure 2. Scatter plot matrix and Pearson's correlation coefficient between pairs of traits (Tree height, Treetop width, Rootstock diameter, Scion diameter, Blooming, Harvest, Yield, Fruit weight, Fruit height, Fruit width and Soluble solid) of 33 peaches (*Prunus persica*) and nectarines (*P. persica* var. *nuscipersica*) cultivars and selections. Capão Bonito, SP, Brazil, 2009 – 2017. *: $p < 0.05$; ns: $p \geq 0.05$.

The Pillai test presented significant results ($p < 0.05$) in all years, suggesting differences among cultivars at least one characteristic by year (Table 1). The analysis of variance showed significant differences among cultivars for almost all features (Table 2), except for fruit weight (2015 and 2017) and soluble solid (2017).

Table 1. Multivariate analysis of variance of 33 peaches (*Prunus persica*) and nectarines (*P. persica* var. *nuscipersica*) cultivars and selections. Capão Bonito, SP, Brazil, 2009 – 2017.

	Source of Variation	DF	Pillai	Approx. F	Num DF	Den DF
2009	Cultivar	32	2.90	10.43**	192	2136
	Residual	256				
2010	Cultivar	31	3.64	8.64**	248	2568
	Residual	321				
2011	Cultivar	32	1.99	5.20**	160	1255
	Residual	251				
2012	Cultivar	28	2.96	7.34**	168	1266
	Residual	211				
2013	Cultivar	31	3.55	7.06**	217	1484
	Residual	212				
2014	Cultivar	32	3.24	8.07**	224	2093
	Residual	299				
2015	Cultivar	32	1.90	3.96**	160	1030
	Residual	206				
2016	Cultivar	32	2.69	3.16**	160	435
	Residual	87				
2017	Cultivar	32	1.96	1.73**	160	430
	Residual	86				

** $p < 0.01$.

Table 2. Analysis of variance (F_{test} and Mean Square Error - MS_{res}) of features associated to the vegetative development, phenology, productivity and fruit characteristics of 33 peaches (*Prunus persica*) and nectarines (*P. persica* var. *nuscipersica*) cultivars and selections. Capão Bonito, SP, Brazil, 2009 – 2017.

		2009	2010	2011	2012	2013	2014	2015	2016	2017
Tree height (m)	*F test*	4.98**	8.46**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	MS_{res}	0.24	0.21							
Treetop width (m)	*F test*	4.10**	5.63**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	MS_{res}	0.37	0.21							
Rootstock diameter (mm)	*F test*	5.71**	4.20**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	MS_{res}	135.95	385.99							
Scion diameter (mm)	*F test*	5.02**	4.77**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	MS_{res}	149.35	221.39							
Blooming (Julian days)	*F test*	1,437**	70.25**	n.a.	n.a.	45.25**	45.24**	4.72**	2.46**	2.70**
	MS_{res}	0.92	14.36			13.96	20.51	64.82	11.60	33.58
Harvest (Julian days)	*F test*	4,869**	54.72**	13.45**	44.40**	18.37**	17.02**	12.90**	4.58**	2.72**
	MS_{res}	0.25	65.60	47.62	17.49	49.31	46.47	33.84	79.54	33.78
Yield (kg.tree-1)	*F test*	n.a.	7.55**	2.88**	2.45**	3.04**	4.72**	7.44**	3.68**	2.24**
	MS_{res}		17.24	30.37	69.98	14.30	39.96	24.78	28.32	68.27
Fruit weight (g)	*F test*	n.a.	26.74**	16.48**	4.78**	5.27**	4.62**	0.95ns	3.09**	1.31^{ns}
	MS_{res}		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fruit height (mm)	*F test*	n.a.	n.a.	10.77**	10.67**	5.09**	9.34**	n.a.	n.a.	n.a.
	MS_{res}			48.98	31.17	138.05	56.44			
Fruit width (mm)	*F test*	n.a.	n.a.	5.96**	6.62**	4.97**	6.43**	n.a.	n.a.	n.a.
	MS_{res}			58.09	26.87	80.87	34.14			
Soluble solid (°Brix)	*F test*	n.a.	n.a.	n.a.	109.47**	119.85**	82.69**	5.43**	3.87**	1.25^{ns}
	MS_{res}				0.21	0.27	0.11	1.28	0.85	0.71

n.a. – not evaluated; ** – $p < 0.01$; ^{ns} – $p \geq 0.05$.

The average value for each cultivar's features were used to rank the best cultivars and selections (Tables 3 to 5). Regarding the features associated to vegetative development, the 'IAC Régis' ranked among the best cultivars, for all features associated with vegetative development (Table 3). In addition, the 'IAC Aurora 1', 'IAC Aurora 2', 'IAC Centenário', and 'IAC Jóia 4' also showed high values for vegetative development (tree width, and rootstock and scion diameters). The selection 'IAC 680-177' showed no statistical difference with the 'IAC Régis' for tree width. Regarding the other features associated to vegetative development, no selection was grouped with the best cultivars.

Table 3. Mean, standard deviation (SD) and Scott-Knott (SK) test of 33 peaches (*Prunus persica*) and nectarines (*P. persica* var. *nuscipersica*) cultivars and selections, for features associated to the vegetative development: tree height (m), tree width (m), scion (mm) and rootstock (mm) diameters. Capão Bonito, SP, Brazil, 2009 – 2017.

Cultivar	Tree Height			Tree Width			Scion Diameter			Rootstock Diameter		
	Mean	SD	SK	Mean	SD	SK	Mean	SD	SK	Mean	SD	SK
Diamante	4.22	0.79	c	3.60	0.53	c	100.23	11.77	b	99.92	10.84	a
Eldorado	3.56	0.65	e	3.46	0.69	c	98.38	10.54	c	96.27	11.12	b
Fla 84-16N	3.98	0.45	c	3.71	0.54	b	103.73	8.63	b	96.89	7.32	b
FlordaPrince	3.97	0.58	c	3.61	0.51	c	105.67	12.78	a	102.58	11.26	a
IAC 1085-26	3.52	0.65	e	3.24	0.40	d	89.24	9.80	d	87.76	11.53	b
IAC 1085-27	3.81	0.52	d	3.44	0.32	c	93.76	8.94	c	88.42	10.40	b
IAC 1880-62	3.90	0.48	d	3.67	0.46	b	89.03	8.47	d	91.81	10.25	b
IAC 2680-91	3.68	0.42	e	3.70	0.60	b	87.81	9.72	d	85.06	8.44	b
IAC 2982-24	3.78	0.52	d	3.44	0.49	c	87.77	12.83	d	83.65	11.44	b
IAC 2982-31	3.91	0.46	d	3.53	0.39	c	97.38	8.93	c	90.29	9.35	b
IAC 2982-32	3.61	0.42	e	3.18	0.54	d	89.25	8.72	d	90.02	11.73	b
IAC 4682-45	3.66	0.55	e	3.44	1.05	c	85.72	11.93	d	79.12	10.93	b
IAC 5480-19	3.31	0.64	e	3.28	0.66	d	85.34	8.10	d	86.86	10.98	b
IAC 680-177	4.15	0.33	c	3.96	0.45	a	99.84	7.92	b	97.69	9.63	b
IAC 6882-37	3.90	0.30	d	3.44	0.46	c	94.06	5.90	c	91.33	9.53	b
IAC 6882-84	3.62	0.56	e	3.52	0.62	c	92.70	9.76	c	88.66	8.08	b
IAC 6982-2	3.86	0.41	d	3.49	0.33	c	96.69	8.84	c	97.64	10.80	b
IAC 785-9	3.63	0.87	e	3.37	0.89	c	86.67	11.51	d	89.28	11.91	b
IAC Aurora-1	4.18	0.41	c	4.10	0.27	a	107.40	10.93	a	112.36	10.12	a
IAC Aurora-2	4.32	0.38	b	3.94	0.38	a	108.48	10.66	a	108.26	8.20	a
IAC Big Aurora	3.97	0.53	c	3.69	0.46	b	96.82	9.45	c	97.04	8.20	b
IAC Centenária	4.18	0.26	c	3.65	0.34	b	103.65	9.81	b	99.88	10.24	a
IAC Centenário	4.36	0.49	b	3.98	0.44	a	116.38	10.53	a	112.24	11.01	a
IAC Douradão	3.41	0.44	e	2.98	0.48	d	94.17	12.76	c	91.01	11.72	b
IAC Jóia-2	3.57	0.14	e	2.97	0.26	d	106.75	4.50	a	96.54	6.97	b
IAC Jóia-4	4.29	0.75	b	3.92	0.81	a	107.28	12.23	a	105.72	11.44	a
IAC Ouromel-3	3.83	0.45	d	3.43	0.41	c	101.21	9.72	b	108.59	5.21	a
IAC Ouromel-4	3.87	0.58	d	3.38	0.61	c	100.06	8.63	b	96.08	10.49	b
IAC Régis	4.69	0.42	a	4.27	0.47	a	112.93	9.52	a	112.68	11.61	a
IAC Tropical-2	4.13	0.45	c	3.25	0.50	d	109.21	9.66	a	109.36	10.95	a
Premier	3.64	0.22	e	3.98	0.49	a	98.93	8.52	b	92.44	8.26	b
Sunripe	3.40	0.58	e	3.07	0.68	d	97.52	11.66	c	91.42	10.25	b
Tropic Beauty	3.86	0.41	d	3.56	0.45	c	103.02	9.43	b	107.05	11.41	a
All	3.87	0.60		3.55	0.62		98.40	12.12		96.48	12.09	

Cultivars with the same letter in column are not significantly different by Scott-Knott test ($p \geq 0.05$).

The early fruit ripening is an important commercial characteristic in peach production, particularly in State of São Paulo. This fact provides advantage for the producers, who may offer fruits of high quality before the harvest season of South of Brazil and other countries in South America (NAVA et al., 2020). The cultivars 'IAC Régis' and 'Tropic Beauty' showed the shortest period for blooming season (Table 4). Concerning the IAC selections, most of them were classified as early blooming and harvest seasons (Figure 3). This occurs due to the IAC Breeding Program selects genotypes for *in natura* consumption (DINI et al., 2021), that requires low chilling accumulation, well adapted to State of São Paulo mild winter climate. Milech et al. (2022) emphasize the importance of the breeding programs to develop low chilling cultivars in subtropical and high-altitude tropical regions, mainly considering the global warming.

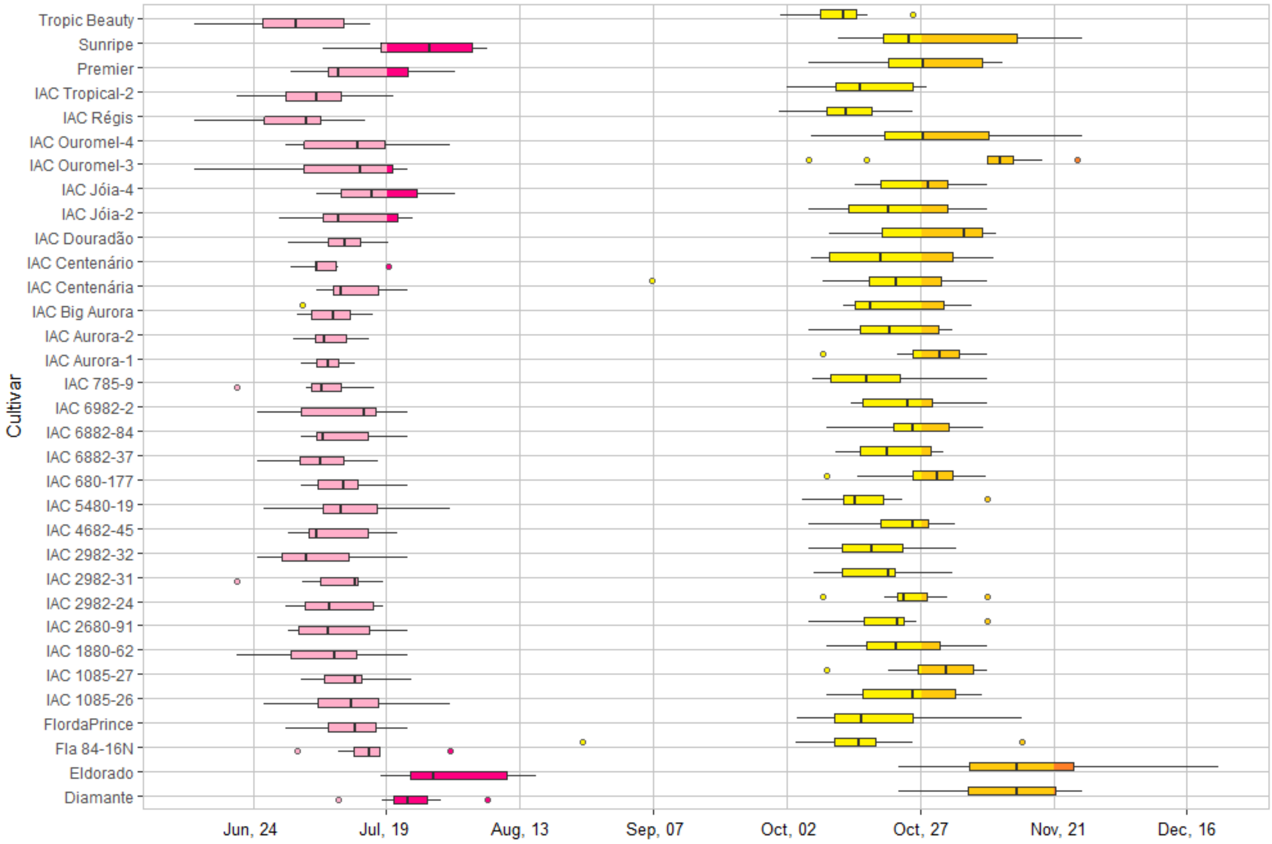

Figure 3. Boxplot (median, quartiles and outliers' points) presenting the nine years average of blooming (pink) and harvest (yellow) seasons of 33 peaches (*Prunus persica*) and nectarines (*P. persica* var. *nuscipersica*) cultivars and selections. Color gradient: light – early season; and dark – late season. Capão Bonito, SP, Brazil, 2009 – 2017.

The cultivars ranked as the best cultivar for yield by tree (kg.tree^{-1}; Table 4) were: 'IAC Aurora1', 'IAC Aurora2', 'IAC Centenário', 'IAC Jóia 4', 'IAC Ouromel 3', 'IAC Régis' and 'Tropic Beauty'. Regarding the selections, the 'IAC 2982-31' and 'IAC 785-9' showed no statistical differences with the group that presented the best results for yield by tree. Regards to fruit weight, cultivar 'Eldorado' presented the best result, followed by 'Diamante', 'IAC Douradão' and 'Premier'. Nava et al. (2020) presented fruit weight means values for 'IAC Douradão' of 101.50g (2016) and 59.60g (2017), similar those measured in the present study (98.36g). Sobierajski and Blain (2022) evaluated the IAC-Prunus germplasm among 2012 and 2014 and the 'IAC Douradão' showed fruit weight means values of 126.35, 112.51 and 106.31g, respectively.

Table 4. Mean, standard deviation (SD) and Scott-Knott (SK) test of 33 peaches (*Prunus persica*) and nectarines (*P. persica* var. *nuscipersica*) cultivars and selections, for features associated to the phenological development and productivity: blooming and harvest season (Julian's day), yield (kg. tree^{-1}) and fruit weight (g). Capão Bonito, SP, Brazil, 2009 – 2017.

Cultivar	Blooming			Harvest			Yield			Fruit Weight		
	Mean	SD	SK	Mean	SD	SK	Mean	SD	SK	Mean	SD	SK
Diamante	206.24	10.9	b	319.44	12.0	b	7.99	2.37	c	94.31	19.44	b
Eldorado	212.45	10.9	a	326.06	19.9	a	5.20	1.84	d	114.05	33.03	a
Fla 84-16N	197.07	11.7	d	289.90	11.4	h	6.96	3.19	d	76.44	13.23	d
FlordaPrince	193.78	7.1	d	292.24	11.0	g	8.71	3.64	c	78.00	8.62	d
IAC 1085-26	194.54	12.4	d	299.37	12.3	f	11.10	3.94	b	74.06	12.05	d
IAC 1085-27	192.78	7.8	e	303.45	10.5	e	9.84	4.08	c	65.32	13.99	e
IAC 1880-62	187.45	11. 9	f	297.84	13.0	f	11.43	5.16	b	89.58	17.84	c
IAC 2680-91	192.25	10.0	e	296.35	10.5	f	10.84	4.29	b	79.50	13.46	d
IAC 2982-24	189.22	8.9	f	297.93	12.7	f	8.99	4.82	c	71.29	13.61	d
IAC 2982-31	189.05	9.5	f	293.97	8.9	g	14.08	5.49	a	75.07	11.98	d
IAC 2982-32	188.32	11.5	f	290.64	9. 6	h	10.32	3.39	b	89.26	12.49	c
IAC 4682-45	190.36	7.6	e	296.90	9.7	f	7.92	3.08	c	76.17	15.02	d
IAC 5480-19	194.75	11.9	d	291.97	12.3	g	8.89	3.51	c	72.22	16.11	d
IAC 680-177	190.82	6.7	e	301.56	10.5	e	8.85	3.34	c	65.40	14.68	e
IAC 6882-37	186.48	8.6	f	295.52	9.2	g	11.09	4.41	b	80.42	16.43	d
IAC 6882-84	190.61	7.0	e	297.42	11.2	f	7.92	3.39	c	72.41	15.02	d
IAC 6982-2	191.02	11.9	e	298.12	11.6	f	9.85	3.31	c	68.48	12.06	e
IAC 785-9	186.18	8.7	f	292.69	11.8	g	13.92	5.43	a	78.21	14.56	d
IAC Aurora-1	190.40	4.8	e	301.72	11.4	e	12.58	4.66	a	69.26	13.64	e
IAC Aurora-2	189.11	4.3	f	297.11	9.5	f	14.32	5.52	a	71.01	12.62	d
IAC Big Aurora	188.55	8.0	f	294.03	11.2	g	8.62	3.66	c	67.38	17.21	e
IAC Centenária	194.43	7.0	d	300.86	9.1	e	6.21	2.51	d	57.29	9.80	e
IAC Centenário	188.41	5.3	f	295.72	12.9	g	12.86	4.71	a	90.98	11.81	c
IAC Douradão	190.83	5.3	e	302.47	11.6	e	8.38	3.08	c	98.36	15.09	b
IAC Jóia-2	193.59	9.0	d	297.65	11.3	f	10.54	3.72	b	84.44	11.99	c
IAC Jóia-4	199.55	11.6	c	303.52	9.3	e	15.41	5.86	a	73.29	12.48	d
IAC Ouromel-3	190.59	15.2	e	312.89	13.4	c	12.81	5.61	a	71.67	10.43	d
IAC Ouromel-4	195.11	13.4	d	306.51	18.3	d	10.98	5.22	b	72.99	15.67	d
IAC Régis	180.76	10.0	h	287.09	8.2	i	15.05	5.57	a	86.03	14.47	c
IAC Tropical-2	184.78	9.4	g	288.67	12.6	h	7.96	3.93	c	70.16	15.54	e
Premier	196.52	11.1	d	303.33	11.0	e	9.11	2.92	c	96.92	23.59	b
Sunripe	208.18	12.6	b	306.36	17.5	d	4.28	2.47	d	72.60	18.50	d
Tropic Beauty	181.58	10.9	h	285.45	8.3	i	12.88	5.62	a	83.64	18.11	c
All	192.30	11.8		298.93	14.2		10.18	5.04		78.37	18.10	

Cultivars with the same letter in column are not significantly different by Scott-Knott test ($p \geq 0.05$).

The cultivars 'Diamante', 'Eldorado', 'IAC Douradão', 'IAC Régis' and 'Premier' showed the highest averages for characteristics associated with fruit size (Table 5). No selections were classified into the group with the best fruit width. Regarding the soluble solid contents, the cultivar with the highest value was 'IAC Centenária', along with 7 cultivars and selections. The 'IAC Douradão' presented average of 10.99 °Brix of soluble solid contents. This result is in line with those showed by Nava et al. (2020; °Brix: 10.0 and 13.3, respectively in 2016 and 2017).

Table 5. Mean, standard deviation (SD) and Scott-Knott (SK) test of 33 peaches (*Prunus persica*) and nectarines (*P. persica* var. *nuscipersica*) cultivars and selections, for features associated to the fruit quality: fruit height (mm), fruit width (mm) and soluble solid (ºBrix). Capão Bonito, SP, Brazil, 2009 – 2017.

Cultivar	Fruit Height			Fruit Width			Soluble Solid		
	Mean	SD	SK	Mean	SD	SK	Mean	SD	SK
Diamante	116.78	5.99	a	111.55	5.33	a	11.49	1.18	b
Eldorado	114.86	7.41	b	111.21	9.02	a	11.33	1.20	b
Fla 84-16N	105.47	4.24	d	100.82	5.59	c	11.21	1.82	b
FlordaPrince	105.90	7.67	d	102.35	4.26	c	12.07	2.20	a
IAC 1085-26	107.81	5.58	d	99.69	5.47	c	9.93	2.72	d
IAC 1085-27	92.50	7.25	f	94.35	5.72	d	11.90	1.72	a
IAC 1880-62	111.71	6.88	c	108.64	6.98	a	11.36	1.43	b
IAC 2680-91	107.46	9.11	d	103.65	7.31	b	11.52	1.20	b
IAC 2982-24	98.20	8.47	e	96.50	8.35	d	11.40	2.11	b
IAC 2982-31	111.18	6.07	c	100.16	5.93	c	10.58	1.26	c
IAC 2982-32	110.59	5.70	c	98.92	6.19	c	11.53	1.37	b
IAC 4682-45	100.21	17.17	e	94.38	9.62	d	11.99	1.26	a
IAC 5480-19	108.26	8.10	d	98.69	6.07	c	9.97	2.75	d
IAC 680-177	93.26	5.45	f	95.92	5.90	d	11.81	1.92	a
IAC 6882-37	109.98	6.74	c	104.94	6.10	b	11.11	1.23	b
IAC 6882-84	100.66	9.71	e	100.05	6.87	c	12.24	1.38	a
IAC 6982-2	106.83	8.64	d	98.22	5.58	c	10.80	1.86	c
IAC 785-9	108.32	5.97	d	101.55	5.75	c	10.66	1.45	c
IAC Aurora-1	105.69	5.89	d	97.06	5.86	d	10.06	1.88	d
IAC Aurora-2	106.60	6.55	d	98.79	6.42	c	9.82	1.17	d
IAC Big Aurora	99.04	12.99	e	95.46	6.54	d	12.43	1.58	a
IAC Centenária	89.49	6.11	f	93.59	5.01	d	12.55	2.98	a
IAC Centenário	108.20	6.72	d	103.66	7.04	b	11.05	1.14	b
IAC Douradão	119.77	6.47	a	109.81	6.38	a	10.99	1.67	b
IAC Jóia-2	111.14	5.57	c	102.73	6.01	b	10.33	1.87	c
IAC Jóia-4	113.39	5.73	b	101.04	5.41	c	10.44	1.02	c
IAC Ouromel-3	96.78	3.89	e	103.45	4.59	b	12.22	1.08	a
IAC Ouromel-4	104.94	9.14	d	99.70	9.97	c	11.22	1.42	b
IAC Régis	105.14	5.95	d	108.97	6.04	a	10.08	2.45	d
IAC Tropical-2	100.51	4.44	e	98.31	6.03	c	10.55	2.81	c
Premier	118.45	8.29	a	108.85	9.29	a	11.42	1.29	b
Sunripe	101.11	8.41	e	95.28	5.20	d	11.67	1.72	b
Tropic Beauty	104.91	6.46	d	104.99	6.56	b	9.12	2.24	d
All	105.91	10.10		101.31	8.05		11.12	1.97	

Cultivars with the same letter in column are not significantly different by Scott-Knott test ($p \geq 0.05$).

The first two Principal Component's scores described how the rainfall, minimum and maximum air temperatures affected the cultivars harvest season, yield, fruit weight and soluble solids (Figure 4 A to D). The rainfall's vectors were higher than those of the minimum and maximum air temperatures. The cultivars 'IAC Jóia2', 'IAC Ouromel4' and 'Sunripe' had their harvest season increased as the rainfall increased (Figure 4A). However, the maximum temperature reduced the harvest season of 'IAC 4682-45' selection. The yield was an increasing function of the rainfall ('IAC 26-80-91', IAC 6882-84', 'IAC Aurora1' and 'IAC Big

Aurora'), the minimum temperature ('IAC 2982-24', 'IAC 2982-31', 'IAC 2982-32', 'IAC Aurora2', 'IAC Centenário', 'IAC Régis' and 'Sunripe'), and the maximum temperature ('IAC 2982-31', 'IAC 2982-32', 'IAC Centenário' and 'Sunripe'; Figure 4B).

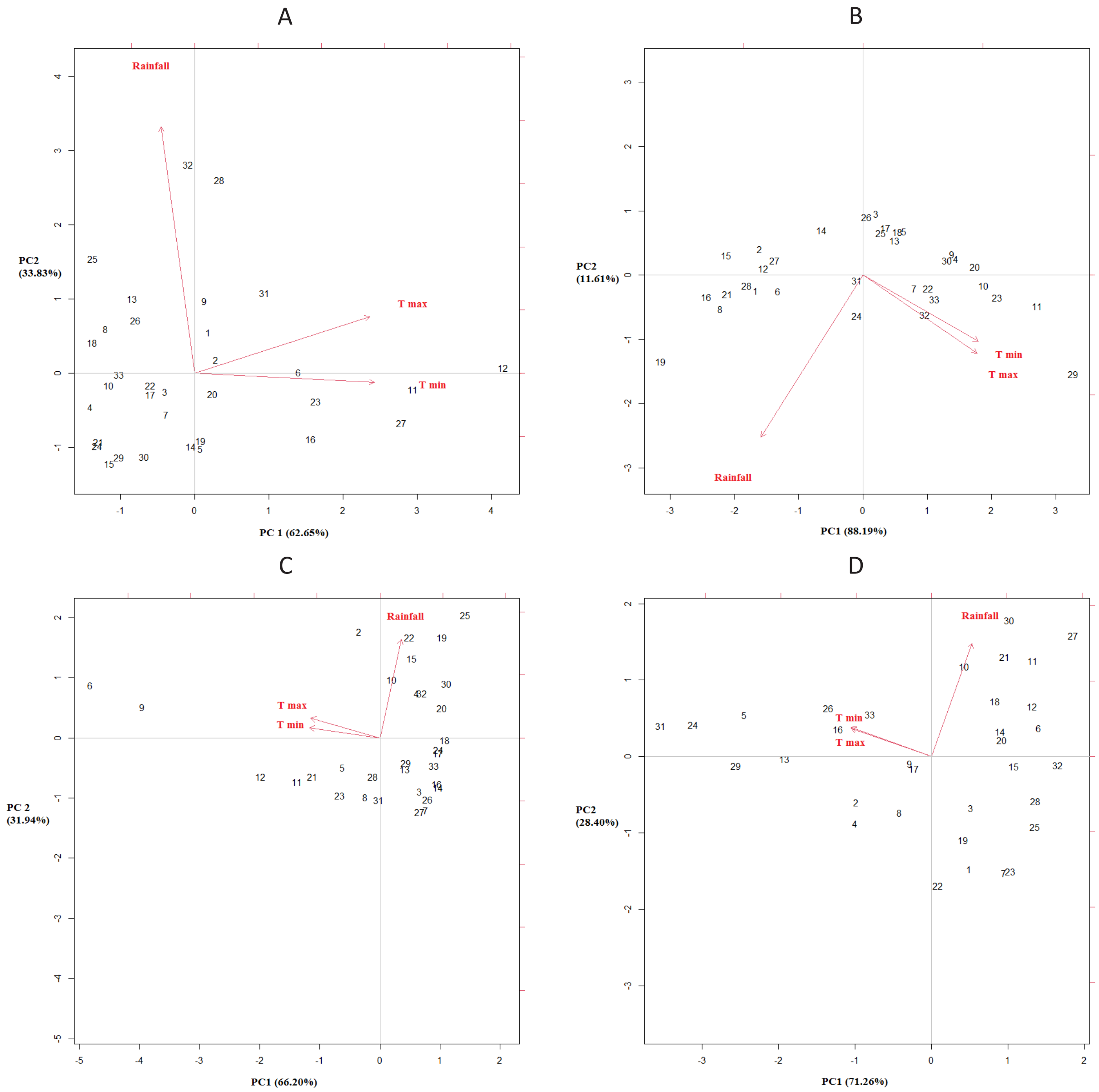

Figure 4. The first two Principal Component's scores describing the effect of the rainfall (mm), minimum and maximum air temperatures (°C) in to harvest season (A - Julian's day), yield (B - kg.tree^{-1}), fruit weight (C - g) and soluble solids (D - ^{o}Brix) of 33 peaches (*Prunus persica*) and nectarines (*P. persica* var. *nuscipersica*) cultivars and selections. Cultivar: 1. 'Diamante'; 2. 'Eldorado'; 3. 'Fla 84-16N'; 4. 'FlordaPrince'; 5. 'IAC 1085-26'; 6. 'IAC 1085-27'; 7. 'IAC 1880-62'; 8. 'IAC 2680-91'; 9. 'IAC 2982-24'; 10. 'IAC 2982-31'; 11. 'IAC 2982-32'; 12. 'IAC 4682-45'; 13. 'IAC 5480-19'; 14. 'IAC 680-177'; 15. 'IAC 6882-37'; 16. 'IAC 6882-84'; 17. 'IAC 6982-2'; 18. 'IAC 785-9'; 19. 'IAC Aurora 1'; 20. 'IAC Aurora 2'; 21. 'IAC Big Aurora'; 22. 'IAC Centenária'; 23. 'IAC Centenário'; 24. 'IAC Douradão'; 25. 'IAC Jóia 2'; 26. 'IAC Jóia 4'; 27. 'IAC Ouromel 3'; 28. 'IAC Ouromel 4'; 29. 'IAC Régis'; 30. 'IAC Tropical 2'; 31.'Premier'; 32. 'Sunripe'; 33. 'Tropic Beauty'. Capão Bonito, SP, Brazil, 2009 – 2017.

The fruit weight of 'IAC Jóia2' cultivar was negatively affected by the increase of rainfall, while the 'IAC 1085-27' and 'IAC 2982-24' selections were positively affected by the increase of air temperature values (Figure 4C). The soluble solids had their values decreased by the increase of rainfall for 'IAC 2982-32', 'IAC Big Aurora', 'IAC

Ouromel3' and 'IAC Tropical2' (Figure 4D). However, the soluble solids increased with the increase of air temperature values ('IAC 1085-26', 'IAC Douradão', 'IAC Régis' and 'Premier').

The Kaiser's criterion indicated that two (in 2009 to 2011, and 2013 to 2016) and three (in 2012 and 2017) principal components (PC) explain the most data variability (from 51 to 80%; Table 6). Considering all characteristics and years, the three first PCs explained, respectively, 37.11, 21.40 and 17.73% of the data variability, being the cumulative variance equal to 76.24% (Table 7 and Figure 5).

The PC1 can be understood as the contrast among the tree height, tree width, rootstock diameter, scion diameter, yield and fruit width versus soluble solid. The PC2 corresponded to the contrast among fruit weight, fruit height and fruit width versus tree height and soluble solid; and the PC3 among rootstock diameter, scion diameter, blooming, harvest and soluble solid versus yield.

Table 6. Cumulative Proportion and Kaiser's criterion values of the principal components (PC) of features associated to the vegetative development, phenology and fruit characteristics of 33 peaches (*Prunus persica*) and nectarines (*P. persica* var. *nucipersica*) cultivars and selections. Capão Bonito, SP, Brazil, 2009 – 2017.

	Importance of components	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
2009	Cum. Proportion	0.5147	0.7790	0.8746	0.9398	0.9912	1.0000		
	Kaiser's criterion	3.0880	1.5858	0.5735	0.3916	0.3085	0.0526		
2010	Cum. Proportion	0.3413	0.5979	0.7106	0.8062	0.8911	0.9448	0.9782	1.0000
	Kaiser's criterion	2.7305	2.0530	0.9013	0.7650	0.6822	0.4263	0.2674	0.1742
2011	Cum. Proportion	0.4930	0.6955	0.8826	0.9586	1.0000			
	Kaiser's criterion	2.4651	1.0126	0.9351	0.3802	0.2070			
2012	Cum. Proportion	0.3111	0.4841	0.6538	0.8063	0.9408	1.0000		
	Kaiser's criterion	1.8667	1.0380	1.0184	0.9148	0.8069	0.3554		
2013	Cum. Proportion	0.3655	0.5710	0.7069	0.8253	0.8959	0.9660	1.0000	
	Kaiser's criterion	2.5587	1.4387	0.9512	0.8283	0.4944	0.4909	0.2378	
2014	Cum. Proportion	0.2665	0.5116	0.6474	0.7640	0.8778	0.9512	1.0000	
	Kaiser's criterion	1.8655	1.7159	0.9502	0.8166	0.7968	0.5135	0.3416	
2015	Cum. Proportion	0.3773	0.6247	0.8132	0.9585	1.0000			
	Kaiser's criterion	1.8865	1.2369	0.9427	0.7262	0.2076			
2016	Cum. Proportion	0.2947	0.5432	0.7366	0.8884	1.0000			
	Kaiser's criterion	1.4732	1.2425	0.9673	0.7589	0.5580			
2017	Cum. Proportion	0.3626	0.5922	0.8020	0.9378	1.0000			
	Kaiser's criterion	1.8128	1.1480	1.0493	0.6788	0.3111			

Table 7. Characteristics and loadings of the three first principal components (PC) of features associated to the vegetative development (Tree height – TH; Tree width – TW; Rootstock diameter – RD; Scion diameter – SD), phenology (Blooming – B; Harvest – H), productivity (Yield – Y; Fruit weight – FW) and fruit characteristics (Fruit height – FH; Fruit width – FD; Soluble solid – SS), of 33 peaches (*Prunus persica*) and nectarines (*P. persica* var. *nuscipersica*) cultivars and selections. Capão Bonito, SP, Brazil, 2009 – 2017.

	Characteristics		Loadings										
	Cumulative proportion	Kaiser's criterion	TH	TW	RD	SD	B	H	Y	FW	FH	FD	SS
PC1	0.3711	4.0818	-0.4124	-0.3521	-0.4036	-0.3863	0.2218	0.1672	-0.3687	-0.0349	-0.0687	-0.3456	0.2508
PC2	0.5851	2.3541	0.2314	0.1357	0.1206	0.1095	-0.1031	-0.0761	-0.0854	-0.5896	-0.6011	-0.3377	0.2340
PC3	0.7624	1.9502	-0.1615	-0.1542	-0.2415	-0.3029	-0.5677	-0.5920	0.2535	-0.0565	-0.0349	-0.1051	-0.2182

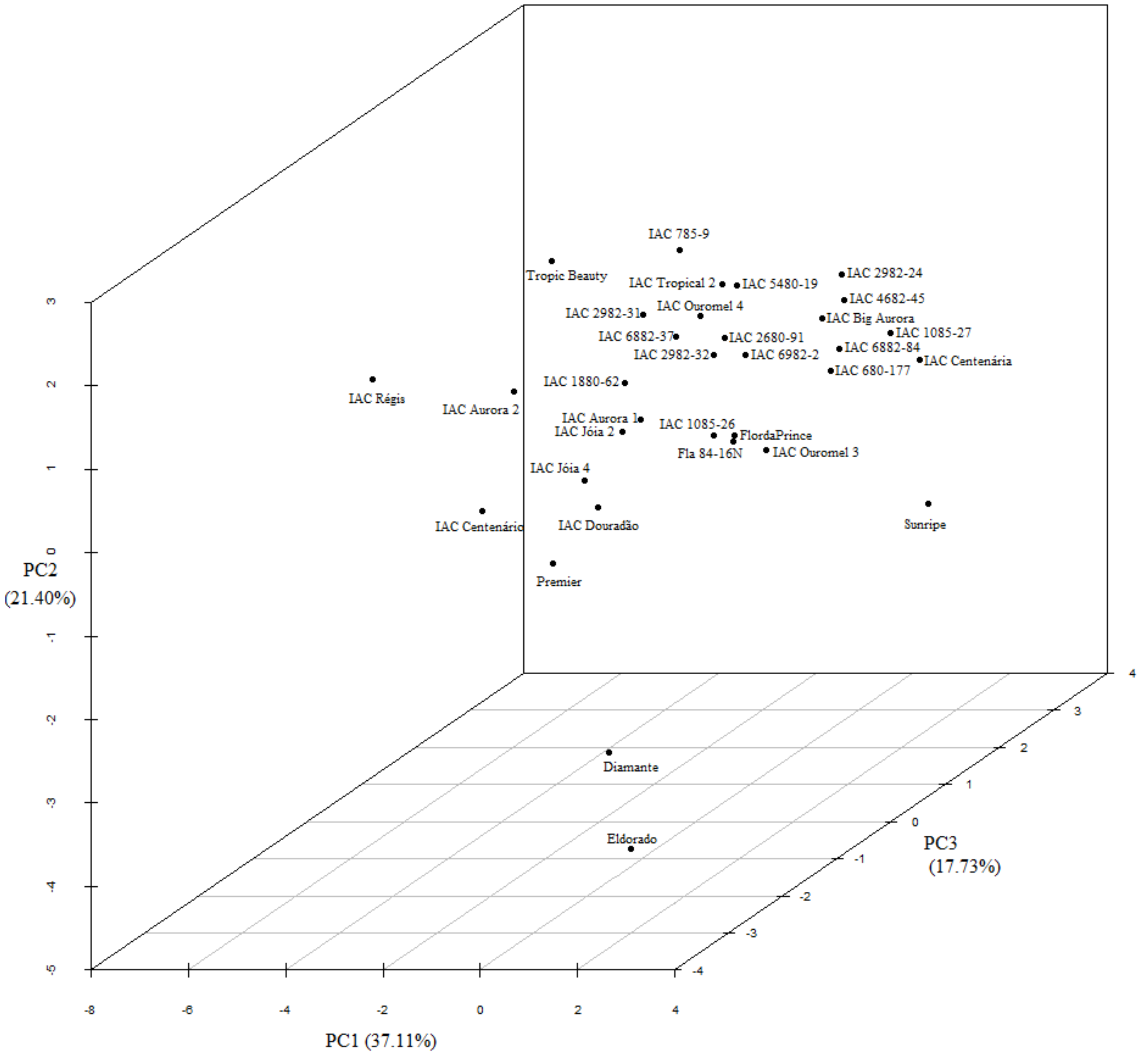

Figure 5. Cultivar's dispersals according the three first Principal Component's scores of 33 peaches (*Prunus persica*) and nectarines (*P. persica* var. *nuscipersica*) cultivars and selections. Capão Bonito, SP, Brazil, 2009 – 2017.

Cultivar's dispersal according to the three first principal components scores shows that the cultivars 'Diamante' and 'Eldorado' formed an external group, and the other cultivars and selection formed a single cloud of points (Figure 5). The formation of the external group was, probably, the result of features related to phenological development and productivity. The 'Diamante' and 'Eldorado' cultivars required long periods for flowering and harvesting seasons in contrast to the low productivity by tree.

Conclusion

'IAC Régis' is the best cultivar for vegetative development, followed by 'IAC Aurora 1', 'IAC Aurora 2', 'IAC Centenário' and 'IAC Jóia 4'. 'IAC Régis' and 'Tropic Beauty' show the earliest blooming and harvest seasons. 'IAC Jóia 4' present the best yield by tree, whiles 'Eldorado' presents the best fruit weight. 'Diamante' and 'Premier' are the most stable cultivar for fruit quality characteristics.

A large number of selections shows promising results. 'IAC 680-177' outstand for vegetative development; 'IAC 2982-31' for yield by tree, along with 'IAC 785-9'; and, 'IAC 1085-27', 'IAC4682-45', 'IAC 680-177' and 'IAC 6882-84' for fruit quality characteristics.

Acknowledgments

To National Council for Scientific and Technological Development (CNPq, Brazil, Process 304609/2022-6) for providing the grant for the fourth author.

References

BLAIN, G.C. Mudanças climáticas e a fruticultura. **Revista Brasileira de Fruticultura**, Jaboticabal, v.33, n.1, p.7–12, 2011. Número Especial

BRAEKEN, J.; VANASSEN, M.A.L.M. An empirical Kaiser criterion. **Psychological Methods**, Washington, v.22, p.450-66, 2017.

DEMENDIBURU, F. **Package agricolae**. Disponível em: *https://cran.r-project.org/web/packages/agricolae/agricolae.pdf*. Acesso em: 16 fev. 2022.

DINI, M.; RASEIRA, M.C.B.; VALENTINI, G.H.; ZOPPOLO, R. Duraznero: situación actual en Uruguay, Brasil y Argentina. **Agrociencia Uruguay**, Montevideo, v.25, p.e394, 2021.

FAOSTAT. Crops and livestock products. Roma, 2019. Disponível em: *https://www.fao.org/faostat. Acessoem*: 10 Mar. 2022.

FERNANDES, J.G.; SILVA, É.M.; RIBEIRO, T.D.; SILVA, E.M.; FERNANDES, T.J.; MUNIZ, J.A. Description of the peach fruit growth curve by diphasic sigmoidal nonlinear models. **Revista Brasileira de Fruticultura**, Jaboticabal, v.44, n.3, p.e875, 2022.

GRADZIEL, T.M. Exotic genes for solving emerging peach production challenges. **Scientia Horticulturae**, Amsterdam, v.295, p.110801, 2022.

IPCC - Intergovernmental Panel on Climate Change. The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change. Switzerland: Cambridge University Press, 2018. 26p.

LIGGES, U.; MAECHLER, M.; SCHNACKENBERG, S. **Package scatterplot3d**. Disponível em: *https://cran.r-project.org/web/packages/scatterplot3d/scatterplot3d.pdf*. Acesso em: 02 mar. 2022.

MATIAS, R.G.P.; BRUCKNER, C.H.; CARNEIRO, P.C.S.; SILVA, D.F.P.; SILVA, J.O.C.E. Repeatability, correlation and path analysis of physical and chemical characteristics of peach fruits. **Revista Brasileira de Fruticultura**, Jaboticabal, v.36, n.4, p.971-9, 2014.

MILECH, C.G.; DINI, M.; FRANZON, R.C.; RASEIRA, M.C.B. Chilling requirement of four peach cultivars estimated by changes in flower bud weights. **Revista Ceres**, Viçosa, MG, v.69, p.22–30, 2022.

NAVA, G.A.; KURSCHNER, E.O.; PAULUS, D. Harvest season, productivity and physicochemical quality of peach fruits grown in Dois Vizinhos, Paraná State, Brazil. **Semina: Ciências Agrárias**, Londrina, v.41, p.3011-22, 2020.

R CORE TEAM. **R**: a language and environment for statistical computing. Disponível em: *http://www.r-project.org*. Acesso em: 02 mar. 2019.

RASEIRA, M.C.B.; FRANZON, R.C. Melhoramento genético. *In*: RASEIRA, M.C.B.; PEREIRA, J.F.M.; CARVALHO, F.L.C. **Pessegueiro**. Brasília (DF): Embrapa, 2014. p.57–72.

SILVA, A.R. **Métodos de análise multivariada em R**. Piracicaba: FEALQ, 2016. 167p.

SILVA, A.R. **Package biotolls**. Disponível em: *https://cran.r-project.org/web/packages/biotools/biotools.pdf*. Acessoem:16 fev. 2022.

SOBIERAJSKI, G.R.; BLAIN, G.C. Peach germplasm: genetic diversity of low chill cultivars in Southeast Brazil. **Fruits**, Paris, v.77, n.2, p.1–10, 2022.

SOBIERAJSKI, G.R.; HARDER, I.C.F.; XAVIER, D.; ANONI, C.O. Breeding peaches for low-chill in São Paulo State, Brazil. **Acta Horticulturae**, The Hague, v.1127, p.35-9, 2016.

SOBIERAJSKI, G.R.; SILVA, T.S.; HERNANDES, J.L.; PEDRO JÚNIOR, M.J. Y-shaped and fruiting wall peach orchard training system in subtropical Brazil. **Bragantia**, Campinas, v.78, n.2, p.229-35, 2019.

THUROW, L.B.; RASEIRA, M.D.C.B.; BONOW, S.; ARGE, L.W.P.; CASTRO, C.M. Population genetic analysis of Brazilian peach breeding germplasm. **Revista Brasileira de Fruticultura**, Jaboticabal, v.39, n.5, p.e166, 2017.

WICKHAM, H.; CHANG, W.; HENRY, L.; PEDERSEN, T.L.; TAKAHASHI, K.; WILKE, K.; WOO, K. **Package ggplot2**. Disponível em: *https://cran.r-project.org/web/packages/ggplot2/ggplot2.pdf*. Acessoem:05 May. 2019.