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Propagation

Influence of grafting production method on agronomic performance of wine grape varieties

André Luiz Kulkamp de Souza[1], Samila Silva Camargo[2], Edson Luiz de Souza[3], Nelson Pires Feldberg[4], Angelica Bender[5]

Abstract – Agronomic performance of different types of Chardonnay, Malbec, Merlot and Sauvignon Blanc vines grafted on '1103 Paulsen' rootstock were evaluated after planting in Videira-SC. The treatment factors tested were the variety scions and grafted plants: RN – year-old bare root produced by omega grafting, EV – year-old bare root rootstock grafted in the summer, EI – rootstock cuttings rooted first in pots and then planted in the field at the end of spring and grafted in the following winter, FE - rootstock cuttings incubated for callusing and grafted just after the emission of first roots and then planted in the field, BI – year-old bare root rootstocks planted in the field in the winter and then grafted in the following winter, BE –year-old bare root rootstocks grafted and planted in the field after the scion buds started sprouting. The study was carried out as a randomized block experimental design. The 'Chardonnay' variety showed slower growth compared to the others, regardless of the grafted plant used. It is possible to implement commercial vineyards using all the types of grafted plants evaluated. The vines produced by BE, RN and FE presented a higher survival rate after being planted in the field.
Index terms: *Vitis vinifera*, development, vigor, yield, rootstock.

Influência do método de produção de mudas de videira no desempenho agronômico de variedades de uvas para vinho

Resumo – Avaliou-se o desempenho agronômico após o plantio de diferentes tipos de mudas das variedades 'Chardonnay', 'Malbec', 'Merlot' e 'Sauvignon Blanc' enxertadas em 'Paulsen 1.103'. Os fatores testados foram as variedades copa e tipos de mudas (RN- raiz nua enxertado à máquina; EV- porta-enxerto de raiz nua com enxertia verde no verão; EI- porta-enxerto enraizado com substrato comercial plantados na primavera e enxertados no campo no inverno; FE-porta-enxerto mantido em forçagem e enxertia após a emissão de raízes; BI-porta-enxerto de raiz nua e enxertia a campo no inverno; BE-enxertia de porta-enxertos de raiz nua levados ao campo após o inchamento das gemas da variedade copa). O delineamento experimental utilizado foi o de blocos ao acaso. A variedade 'Chardonnay' apresentou desenvolvimento mais lento em relação às demais, independentemente do tipo de muda utilizado. É possível a implantação de vinhedos comerciais com todos os tipos de mudas avaliados. As mudas produzidas por BE, RN e FE proporcionam maior taxa de sobrevivência das mudas após o plantio em campo.
Termos para indexação: *Vitis vinifera*, desenvolvimento, vigor, produtividade, porta-enxerto.

Corresponding author:
andresouza@epagri.sc.gov.br

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[1]Dr. Researcher, Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina, Videira, Santa Catarina State, Brazil. E-mail: andresouza@epagri.sc.gov.br (ORCID 0000-0003-4889-6291)

[2]Dra. Prof., Serviço Nacional de Aprendizagem Industrial (SENAI), Videira, Santa Catarina State, Brazil. E-mail: samilasc@yahoo.com.br (ORCID 0000-0002-0659-1361)

[3]Dr. Professor, Universidade do Oeste de Santa Catarina (UNOESC), Videira, Santa Catarina State, Brazil. E-mail: edsonluizdesouza@gmail.com (ORCID 0000-0001-8238-1529)

[4]Me., Analyst, Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Canoinhas, Santa Catarina State, Brazil. E-mail: nelson.feldberg@embrapa.br (ORCID 0000-0002-5626-2427)

[5]Oenologist, PhD student, Universidade Federal de Pelotas, Pelotas, Rio Grande do Sul Stat, Brazil. E-mail: bender.angelica.fruti@gmail.com (ORCID 0000-0002-1141-6090)

Introduction

Brazilian viticulture presents great diversity, since grape production is widespread from Rio Grande do Sul to Rio Grande do Norte and Ceará states (CAMARGO et al., 2011). In the southern region of the country there is a greater predominance of the cultivation of American and hybrid grapes for winemaking and juice production, while in other Brazilian regions, the cultivation of American and European table grapes stands out, both for the domestic market, as well as for export (LEÃO, 2010), having, therefore, a differentiation in the use of varieties regarding the place of cultivation.

The selection of varieties and the quality of propagation material are extremely important, since the implanting of the vineyard is one of the main factors responsible for the success of viticulture. Therefore, the use of quality grafted plants plays an important role in reducing planting failures and providing satisfactory canopy growth.

With the intensification of winegrowing, there is a growing demand for vine grafting with high agronomic performance, either to compose new vineyards or to replace existing ones (RIBEIRO et al., 2017). Currently, there are several forms of production and sale of vine grafts, whether by nurserymen or by the growers themselves. In the South and Southeast regions of Brazil, the most traditional system for obtaining vine grafts is the direct field grafting on rootstocks rooted in nurseries or planted in the definitive location in the previous year, a process that takes about two years for the formation of the grapevine (BOTELHO et al., 2006; JESUS et al., 2018).

However, in recent years, other systems for obtaining vine grafts have been used in the country, such as the bench grafting technique that is used in the main wine-growing countries worldwide. This propagation system has been used commercially since 2000 in the South and Southeast regions of Brazil (REGINA et al., 2012). Rezende and Pereira (2001) highlight some advantages of bench grafting, such as large-scale production of vineyard grafts at a low cost, obtaining vigorous plants, selection of grafted plants and more uniform formation of the vineyard, reduction of labor, in addition to reducing the time to obtain the first harvest. Roberto et al. (2004a; 2004b) studied the anticipation of seedling production, using green grafting and herbaceous cuttings in a mist chamber of the 'Italia' and 'Rubi' varieties on 'IAC-572 Jales' and 'IAC-766 Campinas' rootstocks, obtaining high vine graft survival rates.

Regardless of the methodology used in the grafting, it is necessary that the resulting vine have an adequate morphological standard, as this plays an important role in the grapes production process and, as a result, scientific studies are needed to demonstrate which of the options provides the best response in the first years of planting and later, in the productive period for a given grape variety and planting location.

Consequently, the constant search for innovations with the purpose of obtaining quality grafted vines, in a shorter period, justifies the study and use of new technologies in the production system (REZENDE; PEREIRA, 2001). Thus, the aim of this work was to define which type of grafted plant provides the best agronomic performance in a vineyard of Chardonnay', 'Malbec', 'Merlot' and 'Sauvignon Blanc' wine varieties.

Material and methods

The experiment was carried out in an area of the Epagri Experimental Station in Videira/SC (latitude 27º00'S, longitude 51º09'W, altitude 779 m). According to the Köppen classification system, the region is characterized as humid mesothermal and mild summer (Cfb). Different types of *Vitis vinifera* varieties were implanted, produced on the '1103 Paulsen' rootstock, and planted in 2010, with a spacing of 1.2 x 3.0 m between plants and rows, respectively, in an area previously prepared through deep tillage, followed by plowing, harrowing and ridge construction. The fertilization for correction and maintenance was carried out as recommended for the crop (SOCIEDADE BRASILEIRA DE CIÊNCIA DO SOLO, 2004). In subsequent years, the area was mowed in the rows and between the rows, and pruning was carried out in spurs of up to three buds at the beginning of September. The training system adopted was a bilateral cordon, supported in the form of an espalier band, with the first wire at a height of 1.10 m.

The randomized block experimental design was used, in a 4 x 6 factorial scheme and five replications, totaling 24 treatments with plots consisting of five plants for the grafting evaluations and three plants for all other evaluations. The two factors studied were: four varieties ('Chardonnay', 'Malbec', 'Merlot' and 'Sauvignon Blanc') and six different types of grafted plants: RN - bare root rootstock produced in a nursery by grafting with an Omega Uno machine (Fornasier Cesare & C.), aged 8 to 10 months; EV - planting of bare root rootstocks, 8 to 10 months old and subsequent green grafting carried out in the subsequent summer; EI - rootstock cuttings rooted in containers with commercial substrate in a greenhouse and planted in the vineyard in late spring with subsequent grafting in the field in the subsequent winter; FE - rootstock cuttings forced in a greenhouse and grafted soon after the first roots were emitted; BI - planting of bare root rootstock, with 8 to 10 months of age and subsequent grafting in the field in the subsequent winter; BE - grafting of 8 to 10 month old bare root rootstocks (bearded), previously rooted in a nursery and taken to the field soon after the onset of bud swelling of the canopy

variety, about 10 to 20 days after grafting, depending on each variety. The combinations were produced from genetic material of the same origin and with genetic and sanitary guarantees.

Harvest was determined with weekly monitoring of the maturation curve, based on seed maturity, soluble solids content, total acidity, and pH, in addition to good sanitary conditions. Additionally, we tried to wait for the total acidity to drop from 100 meq L^{-1}.

The agronomic performance of the grape varieties under the different types of grafted plants was determined through evaluations of vigor, yield, and fruit quality, which began two years after the implantation of the vine grafting, in the 2012, 2013 and 2014 harvests, and by the vegetative variables, which were obtained from the mass of branches from winter pruning material (g) and number of branches per plant. Yield was estimated considering bunch mass (g), number of bunches and production per plant (kg) at harvest time. The Ravaz index was determined from the relationship between the mass of fruits per plant (kg) and the mass of pruned material from the same plant (kg) obtained during the pruning of the crop (CUS, 2004). Fruit quality was determined by physicochemical analyses of pH, soluble solids (ºBrix) and total acidity (meq L^{-1}). The soluble solids content was determined in a benchtop digital refractometer with automatic temperature compensation. The pH was evaluated in a pHmeter and the total acidity determinations were made by titration of the sample, with a standardized solution of 0.1 N NaOH, adopting pH 8.2 as the final point of the titration. Yield indices were not evaluated in the first year (2012 crop) for 'Chardonnay', only the mass of branches from winter pruning material was statistically compared, as this variety showed slower growth and development when compared to the others.

The data obtained were analyzed for normality using the Shapiro Wilk test, homoscedasticity using the Hartley test and the independence of the residues using graphical analysis. For the variable mortality percentage, it was necessary to transform the data $\sqrt{(x+1)}$. Subsequently, the data were submitted to analysis of variance using the F test ($p \leq 0.05$). After verifying statistical significance, the effects of treatments (varieties x grafted plants) were compared by Tukey's test at 5% probability ($p<0.05$).

Results and discussion

The four varieties studied were analyzed separately in the 2012, 2013 and 2014 harvests for the variables pH, soluble solids, total acidity, bunch mass and mass of branches from pruning, as they did not show statistical interaction with the grafted plants (Table 1).

Table 1. pH Values, soluble solids (ºBrix) and total acidity (meq L^{-1}) of grapes and bunch mass (g) and mass of branches from winter pruning (g) of 'Chardonnay', 'Malbec', 'Merlot' and 'Sauvignon Blanc', in the 2012, 2013 and 2014 harvests in Videira/SC.

Variety	pH	Soluble solids (°Brix)	Total Acidity (meq L^{-1})	Bunch Mass(g)	Mass of branches (g)
			2012		
'Chardonnay'	-	-	-	-	87.0 c
'Malbec'	3.8 b	18.3 ns	100.7 b	114.8 a	543.0 a
'Merlot'	3.8 a	18.8	94.6 c	123.3 a	460.8 b
'Sauvignon Blanc'	3.6 c	18.6	108.0 a	99.3 b	447.3 b
CV (%)	1.5	4.6	8.1	19.5	30.7
			2013		
'Chardonnay'	3.7 d	18.5 c	94.7 c	66.8 c	289.5 d
'Malbec'	3.8 c	20.2 a	118.1 a	153.1a	762.4 b
'Merlot'	3.8 a	19.4 b	93.9 c	134.4 b	657.3 c
'Sauvignon Blanc'	3.8 b	18.9 bc	107.2 b	79.4 c	900.8 a
CV (%)	1.0	5.2	9.5	23.0	23.4
			2014		
'Chardonnay'	3.1 c	19.5 ns	97.8 b	64.6 c	513.0 c
'Malbec'	3.4 a	19.7	83.2 c	176.3 a	1081.0 a
'Merlot'	3.3 b	19.4	85.9 c	185.3 a	684.6 bc
'Sauvignon Blanc'	3.1 c	19.3	106.9 a	109.2 b	915.8 ab
CV (%)	1.4	3.9	7.0	21.0	20.9

*Means followed by the same lowercase letter in the column do not differ statistically by Tukey's test at 5% probability of error. ns: not significant by Tukey test at 5% probability of error.

The results presented in Table 1 varied according to the year of assessment. For the pH of the grapes, in the first two harvests (2012 and 2013), the 'Merlot' vine had the highest average (3.8), different from 2013, where 'Malbec' had an average value of 3.4, showing that the pH indices of the different varieties decreased in the last year. In the same region, the different production cycles are strongly influenced by microclimatic changes, which favors the maturation of the grapes at different stages. In similar studies, several authors found changes between two cycles, when comparing the 'Merlot', 'Sauvignon Blanc' and 'Cabernet Sauvignon' varieties (Borghezan et al., 2011a).

For the soluble solids content, statistical difference was only observed in the 2013 season for the varieties. The 'Malbec' variety had a higher soluble solids content compared to the others. It is worth emphasizing the importance of analyzing this variable, as it is used as an index of maturity for some fruits and indicates the quantity of dissolved substances, mostly sugars (CHAVES, 2013). On the other hand, the total acidity was higher in 2012 and 2014 for 'Sauvignon Blanc', with an average of 107.46 meq L^{-1} while in the 2013 harvest, 'Malbec' had an average value of 118.14 meq L^{-1}.

For the bunch mass variable, the 'Malbec' and 'Merlot' varieties resulted in greater bunch mass in the 2012 and 2014 harvests, while in 2013 this occurred only for 'Malbec', a behavior that makes it stand out in different seasons compared with the other varieties.

Still referring to Table 1, the mass of branches removed in the winter pruning was higher for 'Malbec' (2012 crop) and 'Sauvignon Blanc' (2013 crop), while in 2014, both did not differ statistically, with an average 998 g of removed branches, which shows a greater vegetative growth and vigor of these, in relation to 'Merlot' and 'Chardonnay'. It is notable that a vigorous branch has very high respiratory activity, thus energy consumption is greater than in branches of medium to low vigor, in which there is greater balance between photosynthesis and respiration (BRIGHENTI et al., 2010).

The same variables shown in Table 1 are repeated in Table 2, however, in this case, they are correlated to the different grafted plants in the 2012, 2013 and 2014 harvests. It is observed that in the first year, there were no statistical differences for the four variables. In 2013, there were differences between the grafted plants for the sugar content in the grapes (soluble solids). The treatment with the highest soluble solids content was BI, differing from FE, which had the lowest value for soluble solids, with an average of 18.65 ºBrix.

Table 2. pH Values, soluble solids (ºBrix), total acidity (meq L^{-1}) and bunch mass (g) of grapes and mass of branches from winter pruning (g) from different grafted plants, in the 2012, 2013 and 2014 harvests in Videira/SC.

Grafted plant	pH		Soluble solids (°Brix)		Total Acidity (meq L^{-1})		Bunch Mass (g)		Mass of branches (g)	
					2012					
RN	3.77	ns	18.86	ns	98.72	ns	115.03	ns	400.25	ns
EV	3.73		18.24		99.93		101.88		323.82	
EI	3.75		18.75		101.96		120.01		412.77	
FE	3.75		18.81		98.63		119.98		387.50	
BI	3.73		18.34		103.24		107.62		409.12	
BE	3.73		18.24		104.21		110.41		373.76	
CV (%)	1.51		4.65		8.08		19.47		30.69	
					2013					
RN	3.79	ns	19.32	ab	103.46	ns	100.66	ns	658.08	ns
EV	3.78		19.32	ab	102.65		109.71		594.02	
EI	3.78		19.34	ab	103.28		107.21		681.21	
FE	3.77		18.65	b	106.91		108.28		669.83	
BI	3.80		19.57	a	101.79		122.91		689.56	
BE	3.79		19.17	ab	102.85		101.80		622.42	
CV (%)	1.05		5.23		9.49		23.01		23.43	
					2014					
RN	3.25	ns	19.65	ns	93.35	ns	118.70	b	852.29	ns
EV	3.26		19.70		92.27		142.86	ab	747.00	
EI	3.22		19.50		93.72		141.28	ab	777.45	
FE	3.24		19.30		91.52		126.25	ab	905.23	
BI	3.24		19.50		94.29		147.01	a	735.54	
BE	3.24		19.26		95.65		127.02	ab	774.24	
CV (%)	1.41		3.87		7.04		20.99		20.86	

*Means followed by the same lowercase letter in the column in each year do not differ statistically by Tukey's test at 5% probability of error. ns: not significant by Tukey test at 5% probability of error. RN - bare root graft produced by machine grafting; EV – planting of bare root rootstocks and subsequent green grafting; EI - rootstock cuttings rooted in containers, planted in the vineyard in late spring and grafted in the field in the subsequent winter; FE – forced rootstock cuttings, grafted after the first roots were emitted; BI – planting of bare root rootstocks and subsequent grafting in the field in the subsequent winter; BE - grafting of rootstocks previously rooted in a nursery and taken to the field after bud swelling of the canopy variety.

Treatment BI stands out in the 2014 harvest for the variable bunch mass (147.01 g), without statistically differing from EV, EI, FE and BE, with RN being the grafted plant that characterized the lowest bunch mass of the different varieties, with an average value of 118.70 g.

The Ravaz index variable showed interaction between the treatment factors evaluated (Table 3). In the 2012 harvest, no significant differences were obtained for cultivars regarding the EV and the highest results were verified for 'Sauvignon Blanc' in the BI (4.50), FE (4.32) and BE (4.14) treatments, differing from the other varieties. In 2013 and 2014, the red varieties 'Malbec' and 'Merlot' presented higher values compared to 'Chardonnay' and 'Sauvignon Blanc' for all the evaluated grafted plant. The Ravaz index indicates the balance between yield and vigor of the vines. According to different authors, the Ravaz index should be between 5 and 10 (KLIEWER & DOKOOZLIAN, 2005; SANTOS et al., 2006; BORGHEZAN et al., 2011b). Only 'Malbec' reached the range indicated in the literature when produced as EI (5.22) in 2013 and EV (5.74) in 2014. These results demonstrate that this variable had little influence on the grafted plant used, with the main determinant being vigor and fertility of each variety.

Table 3. Ravaz index (fruit yield per plant/mass of pruned branches per plant) of the 'Chardonnay', 'Malbec', 'Merlot' and 'Sauvignon Blanc' varieties in vineyards established with different grafted plants, in the 2012, 2013 and 2014 seasons in Videira/SC.

Grafted plant	Varieties in 2012			
	'Chardonnay'	'Malbec'	'Merlot'	'Sauvignon Blanc'
RN	-	2.22Bab	2.80ABab	3.42Aab
EV	-	1.47Ab	1.64Ab	1.60Ac
EI	-	1.90Bab	3.05Aa	3.20Ab
FE	-	1.70Bb	1.95Bab	4.32Aab
BI	-	2.97Ba	2.94Ba	4.50Aa
BE	-	2.07Bab	2.91Ba	4.14Aab
CV (%)	24.68			
	Varieties in 2013			
	'Chardonnay'	'Malbec'	'Merlot'	'Sauvignon Blanc'
RN	1.55Ba	3.78Aca	3.87Aa	1.88Ba
EV	1.58Ba	4.40Aabc	3.61Aa	1.12Ba
EI	0.82Da	5.22Aa	3.61Ba	2.12Ca
FE	1.47Ba	3.95Abc	3.78Aa	1.70Ba
BI	1.38Ca	4.98Aab	3.73Ba	2.15Ca
BE	0.94Ba	3.69Ac	3.73Aa	1.63Ba
CV (%)	20.66			
	Varieties in 2014			
	'Chardonnay'	'Malbec'	'Merlot'	'Sauvignon Blanc'
RN	0.65Ca	3.54Bbc	5.24Abc	2.50Ba
EV	1.02Da	5.74Ba	7.43Aa	3.25Ca
EI	0.63Da	4.34Babc	6.11Aab	2.82Ca
FE	1.13Ba	4.86Aab	6.20Aab	2.36Ba
BI	0.59Ca	3.63Bbc	5.84Aab	3.06Ba
BE	0.67Ca	2.81ABc	3.88Ac	2.26Ba
CV (%)	26.36			

**Means followed by the same lowercase letter in the column and uppercase in the row in each year do not differ statistically by Tukey test at 5% probability of error. ns: not significant by Tukey test at 5% probability of error. RN - bare root graft produced by machine grafting; RN - bare root graft produced by machine grafting; EV – planting of bare root rootstocks and subsequent green grafting; EI - rootstock cuttings rooted in containers, planted in the vineyard in late spring and grafted in the field in the subsequent winter; FE – forced rootstock cuttings, grafted after the first roots were emitted; BI – planting of bare root rootstocks and subsequent grafting in the field in the subsequent winter; BE - grafting of rootstocks previously rooted in a nursery and taken to the field after bud swelling of the canopy variety.

The Ravaz index values in the present study were between 0.59 for 'Chardonnay' in 2014 for BI and 7.43 for 'Merlot' in 2014 for EV. Values below 4 indicate that the plants, regardless of the grafted plant used, showed greater vegetative development at the expense of production. Zalamela et al. (2013) explain that values lower than 4 characterize excess vigor in the vines and/or low grape production. Borghezan et al. (2011b) found values ranging between 1.4 and 2.1 for the 'Cabernet Sauvignon', 'Merlot' and 'Sauvignon Blanc' varieties in the Serra Catarinense region, justifying these results by the imbalance of photoassimilates, since a greater vegetative growth due to reduced production per plant indicates an imbalance in the source-sink relationship. Zalamena et al. (2013) evaluated the 'Cabernet Sauvignon' variety cultivated with cover crops in the Planalto Sul region of Santa Catarina for the Ravaz index and the values observed in the vines in all treatments were less than 4, due to a higher dry matter production of the pruned branches. According to these authors, this is due to local edaphoclimatic conditions, consisting of fertile soils, high temperatures and precipitation, in addition to the use of a vigorous rootstock ('1103 Paulsen').

In 2012, the factors studied were analyzed independently for the number of bunches variable since there was no interaction between the grafted plants and the varieties (Table 4). As mentioned above, the 'Chardonnay' variety was not evaluated because there was no production in the first year. On the other hand, 'Sauvignon Blanc' produced a greater number of bunches (14.43), being higher than the 'Malbec' and 'Merlot' varieties, which produced an average of 8.35 and 8.71 bunches, respectively. Significant differences were found between the different grafted plants used (Table 4). The treatments with the highest bunch production were RN and FE, however, they did not differ from BE, with an average of more than 12 bunches of grapes per plant, with the lowest number of bunches being observed for BI. This variable is of great importance, as the size or mass of bunches is directly related to the yield of the vine, and a high yield is considered a fundamental condition for the viability of production (HERNANDES et al., 2010). The precocity of production, that is, the occurrence of the first harvest, is of great importance for the economic viability of a vineyard, since the initial investment in viticulture is always concentrated in the first years, during the implantation and establishment of the plants.

Unlike the first crop, in 2013 and 2014 there was an interaction for the number of bunches (Table 4), verifying the inferiority of 'Chardonnay' in this production variable when compared to 'Malbec', 'Merlot' and 'Sauvignon Blanc'. According to other authors working with vines, and corroborating these results, the number of bunches and, consequently, the yield, are directly related to the genetic characteristics of each variety, however, climate interference may also occur (NORBERTO et al., 2008; MOTA et al., 2010).

In 2013, 'Malbec' and 'Merlot' had similar behavior regarding the number of bunches, with emphasis on the grafted plants produced by the RN, EV, FE and BE treatments. However, in 2014, 'Malbec' produced more only when the grafted plants were produced by the BI method (Table 4). The 'Sauvignon Blanc' variety produced a greater number of bunches with EI and FE in 2013, with an average of more than 24 bunches per plant. In the following harvest, in addition to the two treatments already mentioned, the RN also resulted in a favorable production, with 22.7 bunches per plant.

During the first crop of the plant evaluation, there was an interaction between both factors studied for the number of branches per plant variable (Table 5). It is observed that the 'Malbec' and 'Sauvignon Blanc' varieties were superior to 'Merlot'. The 'Malbec' with BI and BE, and the 'Sauvignon Blanc' produced by EI and FE presented a greater number of branches per plant, which characterizes a greater vegetative growth from these treatments for both varieties. However, according to Borghezan et al. (2011b), a balance between vegetation and production should always be prioritized, as it is important to obtain suitable grapes for winemaking. Regarding the relation between the number of branches and grafted plant, the values were different in 2013 and 2014, where in this last year the data did not differ. In 2013, the treatment EV provided plants with a smaller number of branches, indicating plants that were still deficient in formation.

Table 4. Number of bunches per plant of the 'Chardonnay', Malbec', Merlot' and 'Sauvignon Blanc' varieties in vineyards established with different grafted plants, in the 2012, 2013 and 2014 crops in Videira/SC.

Variety	2012
'Chardonnay'	-
'Malbec'	8.35B*
'Merlot'	8.71B
'Sauvignon Blanc'	14.43A
Grafted plant	**2012**
RN	12.44A
EV	7.71BC
EI	11.04ABC
FE	12.41A
BI	7.26C
BE	12.14AB
CV (%)	29.89

Grafted plant	2013							
	'Chardonnay'		'Malbec'		'Merlot'		'Sauvignon Blanc'	
RN	3.83	Ba**	19.97	Aa	18.47	Aa	21.17	Aab
EV	5.17	Ba#	17.37	Aa	14.30	Aa	14.73	Ab
EI	3.40	Ca	20.03	Aba	17.07	Ba	24.97	Aa
FE	4.90	Ba	24.67	Aa	19.63	Aa	23.40	Aa
BI	5.87	Ca	25.23	Aa	14.00	Ba	13.46	Bb
BE	5.87	Ba	20.77	Aa	16.67	Aa	20.63	Aab
CV (%)					15.65			

Grafted plant	2014							
	Chardonnay		Malbec		Merlot		Sauvignon Blanc	
RN	4.00	Ba	20.64	Aab	20.44	Aa	22.70	Aa
EV	7.58	Ca	19.36	ABab	21.36	Aa	13.94	BCb
EI	4.08	Ba	20.72	Aab	19.30	Aa	25.20	Aa
FE	4.75	Ba	17.24	Ab	21.44	Aa	24.26	Aa
BI	7.20	Ca	27.04	Aa	21.04	ABa	18.20	Bab
BE	6.20	Ba	22.60	Aab	19.30	Aa	20.56	Aab
CV (%)					25.97			

*Means followed by the same uppercase letter in the column do not differ statistically by Tukey's test at 5% probability of error for variety and grafted plant. ** Means followed by the same uppercase letter in the row do not differ statistically by Tukey test at 5% probability of error for grafted plant within variety. #Means followed by the same lowercase letter in the column do not differ statistically by Tukey's test at 5% error probability for variety within grafted plant. RN - bare root graft produced by machine grafting; EV – planting of bare root rootstocks and subsequent green grafting; EI - rootstock cuttings rooted in containers, planted in the vineyard in late spring and grafted in the field in the subsequent winter; FE – forced rootstock cuttings, grafted after the first roots were emitted; BI – planting of bare root rootstocks and subsequent grafting in the field in the subsequent winter; BE - grafting of rootstocks previously rooted in a nursery and taken to the field after bud swelling of the canopy variety.

Table 5. Average number of branches per plant of the 'Chardonnay', Malbec', 'Merlot' and 'Sauvignon Blanc' varieties, from plants established with different grafted plants, in the seasons 2012, 2013 and 2014 in Videira/SC.

Grafted plants	2012			
	Chardonnay	Malbec	Merlot	Sauvignon Blanc
RN	-	8.10Bab	8.87Ba**	11.90Aab#
EV	-	6.17ABb	4.17Bb	8.96Ab
EI	-	8.40Bab	6.58Bab	13.54Aa
FE	-	9.17Bab	6.63Bab	13.07Aa
BI	-	9.87Aa	3.92Bb	9.25Ab
BE	-	10.6Aa	6.75Bab	11.87Aab
CV (%)	8.77			

Variety	2013	2014
Chardonnay	4.14C*	7.55C
Malbec	11.11B	13.94B
Merlot	10.99B	14.19B
Sauvignon Blanc	14.77A	16.73A
CV (%)	21.28	15.52

Grafted plants	2013	2014
RN	10.9A	13.7ns
EV	8.6B	12.7
EI	10.3AB	12.6
FE	11.1A	13.3
BI	9.7AB	13.0
BE	11.0A	13.3
CV (%)	21.28	15.52

*Means followed by the same uppercase letter in the row do not differ statistically by Tukey test at 5% probability of error for grafted plant within variety. ** Means followed by the same lowercase letter in the column do not differ statistically by Tukey test at 5% probability of error for variety within grafted plant. #Means followed by the same lowercase letter on the row do not differ statistically by Tukey test at 5% probability of error for grafted plant and variety. ns-not significant by Tukey test at 5% probability of error. RN - bare root graft produced by machine grafting; EV – planting of bare root rootstocks and subsequent green grafting; EI - rootstock cuttings rooted in containers, planted in the vineyard in late spring and grafted in the field in the subsequent winter; FE – forced rootstock cuttings, grafted after the first roots were emitted; BI – planting of bare root rootstocks and subsequent grafting in the field in the subsequent winter; BE - grafting of rootstocks previously rooted in a nursery and taken to the field after bud swelling of the canopy variety.

Table 6 shows the data on yield per plant (kg) for the different varieties in the 2012 and 2013 crops, where there was no interaction between the two factors studied. The yield in 2012 was higher in 'Merlot' and 'Sauvignon Blanc' while in 2013, the highlight was 'Malbec'. Regarding the number of branches in the last two years of evaluation, a greater vegetative growth occurred in 'Sauvignon Blanc', with an average of 15 branches per plant. In the first two years of evaluation, production per plant was higher in treatments RN and FE in 2012 and FE in 2013, while the less productive plants came from BI and EV, in 2012 and 2013, respectively. It is notable that from the first to the second year of evaluation, there was an increase in production per plant of 594.5 g of grapes, a value that demonstrates the greater development of the plants and, consequently, a greater growth-yield balance.

The data obtained for yield per plant in 2014 showed interaction between the variety and grafted plant factors (Table 6). Once again, the 'Chardonnay' vine was inferior to the others, regardless of the technique used for obtaining the vine graft, with an average production of around 383 g/plant, followed by 'Sauvignon Blanc' (2.2 kg/plant), 'Malbec' (3.7 kg/plant) and 'Merlot' (3.8 kg/plant). For the other varieties, different behaviors were observed according to the grafting method. The highest production per plant in 2014 occurred in the BI treatment for 'Malbec', in RN and EI for 'Sauvignon Blanc' and RN, EV, EI, FE and BI for Merlot. The method with the lowest production occurred in BE for 'Merlot', while the others had similar averages, all proving favorable in this characteristic of such importance and interest to the producer.

Table 6. Production per plant (kg) of 'Chardonnay', 'Malbec', 'Merlot' and 'Sauvignon Blanc' varieties in vineyards established with different grafted plants, in the 2012, 2013 and 2014 crops in Videira/SC.

Variety	2012	2013
'Chardonnay'	-	0.34D
'Malbec'	1.02B*	3.14A
'Merlot'	1.19AB	2.33B
'Sauvignon Blanc'	1.53A	1.54C
CV (%)	27.84	30.6
Grafted plant	2012	2013
RN	1.52A	1.70AB
EV	0.99AB	1.63B
EI	1.33AB	1.93AB
FE	1.54A	2.17A
BI	0.78B	1.81AB
BE	1.31AB	1.79AB
CV (%)	27.84	20.6

Grafted plant	2014			
	'Chardonnay'	'Malbec'	'Merlot'	'Sauvignon Blanc'
RN	0.24Ba	3.16Ab	3.39Aa	2.20Aa
EV	0.57Ba	3.57Ab	4.28Aa	1.64Ba
EI	0.27Ba	4.07Aab	3.65Aa	2.94Aa
FE	0.32Ca	2.73ABb	3.92Aa	2.38Ba
BI	0.55Ca	5.25Aa	4.09Aa	2.05Ba
BE	0.33Ca	3.64Ab	3.37ABa	2.28Ba
CV (%)	30.37			

*Means followed by the same uppercase letter in the column do not differ statistically by Tukey's test at 5% probability of error for variety and type of grafted plant. ** Means followed by the same uppercase letter in the row do not differ statistically by Tukey test at 5% probability of error for type of grafted plant within variety. #Means followed by the same lowercase letter in the column do not differ statistically by Tukey test at 5% probability of error of variety within grafted plant. RN - bare root graft produced by machine grafting; EV – planting of bare root rootstocks and subsequent green grafting; EI - rootstock cuttings rooted in containers, planted in the vineyard in late spring and grafted in the field in the subsequent winter; FE – forced rootstock cuttings, grafted after the first roots were emitted; BI – planting of bare root rootstocks and subsequent grafting in the field in the subsequent winter; BE - grafting of rootstocks previously rooted in a nursery and taken to the field after bud swelling of the canopy variety.

It is important to note that, currently, among the grafted plants evaluated in this experiment, only those with bare roots (RN) and grafted cuttings (FE) are available commercially. The other methods depend on grafting carried out by the growers themselves or by contracted grafters. Therefore, the evaluation of the plant mortality rate is necessary since the replacement of vine grafts above 5% is economically unfeasible as it directly affects the productivity and uniformity of the vineyard and increases the implantation cost. Maroli (2012) explains that grafting techniques in the field result in greater initial non-uniformity due to greater graft failures resulting in a delay in the formation of the vineyard, delaying the return on invested capital. This condition encourages the development of new grapevine propagation techniques, such as bench grafting, which is carried out in the nursery, and allows the selection of grafted plants that will form the vineyard, achieving greater homogeneity in the area.

Regarding the grafted plants, plant mortality of 0% (BE), 1% (RN), 7% (FE), 12% (EV), 13% (EI) and 21% (BI) was observed (Table 7). The establishment indices were quite different, with great influence of the type of vine grafting used in the implantation. The BE and RN treatments had the lowest mortality rate. Grafted plants that were grafted in the field in winter (EI and BI) had higher mortality, requiring a greater replacement of vine grafts. Field grafting in winter was subject to constant and drastic climate changes, common for this time of year in that region. Possibly, the higher mortality observed in the two treatments was due to these conditions. On the other hand, mortality was equivalent for the four varieties studied, suggesting that the grafted plant has greater importance for this variable.

Table 7. Percentage of plant mortality of the 'Chardonnay', 'Malbec', 'Merlot' and 'Sauvignon Blanc' varieties evaluated in 2011 in vineyards established with different grafted plants in Videira/SC.

Variety	Plant mortality (%)	
'Chardonnay'	15.00	ns
'Malbec'	7.00	
'Merlot'	6.00	
'Sauvignon Blanc'	8.00	
Grafted plants	Plant mortality (%)	
RN	1.00	cd
EV	14.00	abc
EI	13.00	ab
FE	7.00	bcd
BI	21.00	a
BE	0.00	d
CV (%)	20.59	

*Means followed by the same lowercase letter in the column do not differ statistically by Tukey's test at 5% probability of error. RN - bare root graft produced by machine grafting; EV – planting of bare root rootstocks and subsequent green grafting; EI - rootstock cuttings rooted in containers, planted in the vineyard in late spring and grafted in the field in the subsequent winter; FE – forced rootstock cuttings, grafted after the first roots were emitted; BI – planting of bare root rootstocks and subsequent grafting in the field in the subsequent winter; BE - grafting of rootstocks previously rooted in a nursery and taken to the field after bud swelling of the canopy variety.

Conclusions

The 'Chardonnay' variety showed slower development compared to the others, regardless of the type of grafted plant used.

It is possible to establish commercial vineyards of the 'Chardonnay', 'Sauvignon Blanc', 'Malbec' and 'Merlot' varieties with all evaluated grafted plants.

The grafted plants produced by grafting of rootstocks previously rooted in a nursery and taken to the field after the swelling of the buds of the crown variety (BE), the bare root vine grafts produced in a nursery by machine grafting (RN) with 8 to 10 months of age and forced rootstock grafted after root emission (FE) provide higher graft survival rate after planting in the field.

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