Performance of Resistant Varieties (PIWI) at two different altitudes in Southern Brazil

André Luiz Kulkamp de Souza[1], Alberto Fonatanella Brighenti[2], Emilio Brighenti[2], Vinícius Caliari[1], Marco Stefanini[3], Oliver Trapp[4], João Peterson Pereira Gardin[1], Marco Antônio Dalbó[1], Leocir José Welter[5] and Samila Silva Camargo[6]

[1]Santa Catarina State Agricultural Research and Rural Extension Agency (EPAGRI), Videira Experimental Station, 1660 João Zardo St., Zip Code 89560-000, Videira, SC, Brazil. E-mail: andresouza@epagri.sc.gov.br; caliari@epagri.sc.gov.br; joaogardin@epagri.sc.gov.br; dalbo@epagri.sc.gov.br; samilasc@yahoo.com.br
[2]Santa Catarina State Agricultural Research and Rural Extension Agency (EPAGRI), São Joaquim Experimental Station, 102 João Araújo Lima St., Zip Code 88600-000, São Joaquim/SC, Brazil. E-mail: brighent@epagri.sc.gov.br; albertobrighenti@epagri.sc.gov.br
[3]Edmund Mach Foundation, 1 E. Mach St., Zip Code 38010, San Michele all'Adige, TN, Italy. E-mail: marco.stefanini@fmach.it
[4]Julius Kühn-Institut, Geilweilerhof, Zip Code: 76833, Siebeldingen, Germany. E-mail: oliver.trapp@julius-kuehn.de
[5]Santa Catarina Federal University (UFSC), 3000 Ulysses Gaboardi Rd., Zip-Code 89520-000, Curitibanos/SC, Brazil. E-mail: leocir.welter@ufsc.br
[6]Serviço Nacional de Aprendizagem Industrial (Senai), 85 Josefina Henn St., Zip Code 89560-000, Videira, SC, Brazil. E-mail: samilasc@yahoo.com.br

Abstract. In southern Brazil there is a predominance of labrusca and hybrid varieties for wine and juice production due to climatic conditions of high rainfall, temperature and relative humidity. Growing varieties that combine disease resistance and wine quality (PIWI) can be an alternative to improve wine quality. The objective of this work was to evaluate the performance of three PIWI varieties (Felicia, Calardis Blanc and Aromera) in two regions (Videira, 27°01'S and 51°08'W, altitude 830m; and São Joaquim, 28°13'S and 50°04'W, altitude 1100m) in the vintage 2018. The date of occurrence of main phenological stages, productiveindexes, clusters characteristics and grape qualitative indexes was evaluated. There was no difference for budbreak date, but flowering, veraison an maturity time varied between regions. The development of plants is slower when they are cultivated at a higher altitude. The number of clusters per plant and yield were higher at 830 m for all varieties. For productive indexes Felicia and Calardis Blanc varieties stood out in relation to Aromera in all parameters. Among the evaluated varieties, Felicia and Calardis Blanc were better adapted to the lower altitude region and had higher productivity and the same grape quality. On the other hand, Aromera presented higher productivity at 830m but higher soluble solids content at 1100m.

1 Introduction

In southern Brazil there is a predominance of labrusca and hybrid varieties for wine and juice production due to the climatic conditions of high rainfall, temperature and relative humidity [1]. One of the main constraints for the cultivation of European grapevine varieties is their high susceptibility to fungal diseases. Grapevine downy mildew, caused by the oomycete *Plasmopara viticola* [(Berkeley & M.A. Curtis) Berleses & De Toni], is the main grape disease in Southern Brazil [2].

The firsts fungus-resistant varieties, issued from traditional breeding, carried a significant percentage of non-*V. vinifera* species in their genetic and were therefore considered as "interspecific hybrids" [3]. Based only on phenotypic evaluation data, it is hardly feasible to track the accumulation of resistance genes in a new breeding line [4]. The use of molecular markers provides a new tool for breeders and may help to overcome this problem [5]. This tool allowed the development of fungus-resistant varieties carrying both disease-resistance genes and a significant percentage (more than 85%) of *V. vinifera* in their pedigree; those are generally referred to as "PIWI" (from German: Pilzwiderstandsfähige, "disease resistant") and are accepted as *V. vinifera* varieties in European catalogues [3].

The grapevine phenology, plant yield and grape quality have a strong relationship with environmental factors [6]. In Santa Catarina State, the two main production regions are those of Videira and São Joaquim, with different altitudes and edaphoclimatic characteristics. The climatic potential of these regions for grape production (*Vitis vinifera* L.) has been proven by several researches [7, 8]. These conditions provide distinctive climate compared to other grape-growing regions of Brazil, shifting the vine phenological cycle. Altitude can strongly affect the climatic conditions since it is directly associated to the resulting temperature, humidity and other environmental factors which will influence grape maturation [9]. Due to cooler air temperatures in such regions, the vegetative and reproductive cycle of vine is longer, resulting in slow and complete grape ripening, suitable for production of quality wine [7, 10].

To perform this work, a collaboration project was developed between Santa Catarina State Agricultural Research and Rural Extension Agency (Brazil), Santa Catarina Federal University (Brazil), Julius Kuhn Institute (Germany) and Edmund Mach Foundation (Italy) in order to test the adaptation of resistant varieties (PIWI) in different wine producing areas of Santa Catarina State. The objective of this work was to evaluate the performance of three PIWI varieties in two regions in the vintage 2018.

2 Material and Methods

The vineyards were settled in traditional grape growing zone (Videira, 27°01'S and 51°08'W, altitude 830m) and in the highlands (São Joaquim, 28°13'S and 50°04'W, altitude 1100m) of Santa Catarina State – Brazil, during the season 2017/2018. The climate of these regions are characterized as humid subtropical, without dry season, and according to the Köppen classification, the climate is Cfb [11].

The white PIWI varieties evaluated were Felicia, Calardis Blanc and Aromera, grafted on 1103 Paulsen. The vineyard was planted in September 2015, they were spacing 3.0 x 1.2m. They were trained in vertical shooting positioning trellis, with double spur pruning. It was used the randomized block design with five replicates of ten plants of each variety, which totaled 150 plants. In field conditions, low rates of mancozeb and thiophanate-methyl combined with others fungicides were applied to maintain low levels of downy mildew and others foliar diseases, yet still allow sufficient disease to evaluate the different genotypes.

The phenological scale and the date of occurrence of each phenological event was recorded between pruning and maturity. The four main phenological events were budbreak, full bloom, *véraison* (change in berry skin color) and maturity [12].

Climatic data, such as precipitation (mm), relative humidity (%), maximum, minimum and mean air temperature (°C) were measured on site with an automatic weather station from CIRAM (Center of Environmental Resources Information and Hydrometeorology of Santa Catarina).

Table 1. Climatic parameters obtained with meteorological station, from budbreak to full bloom (B – FB), full bloom to *véraison* (FB – V) *véraison* to maturity (V – M), during the growing season 2017/2018, in two different altitudes of Santa Catarina State, Brazil.

Climatic Parameters	**B - FB**		**FB - V**		**V - M**	
	830	**1100**	**830**	**1100**	**830**	**1100**
Minimum Temp. (°C)	13,6	12,5	14,4	12,5	18,0	14,7
Maximum Temp. (°C)	26,7	23,6	27,0	24,3	27,6	25,9
Mean Temp. (°C)	19,4	17,3	19,7	17,7	21,7	19,2
Amplitude (°C)	13,0	10,9	12,4	11,8	10,2	11,3
Precipitation (mm)	217	164	327	320	114	202
Relative Humidity (%)	77,5	74,6	78,2	75,7	88,0	81,9

The productive parameters evaluated were number of clusters, fertility index, productivity per vine (kg), estimated yield (Ton/ha), cluster weight (g), number of berries and cluster compactness index (cluster weight/cluster length²).

Technological maturity analyses were performed at the Laboratories of Epagri. Analyzes of soluble solids (°Brix) and total acidity (Meq/L), were performed on grape must, according to the methodology proposed by OIV [13]. Soluble solids (°Brix) were measured using an optical refractometer (model Instrutherm- RTD -45) with temperature correction. Total acidity was measured by titration method with a 10 mL aliquot of juice with standardized 0.1 N NaOH.

Phenology data were analyzed using descriptive statistics (mean and standard deviation). The other data were analyzed for statistical significance by means of F test. Tukey test ($p \leq 0.05$) was performed to compare varieties when analysis of variance showed significant differences among means.

3 Results and Discussion

The dates of occurrence of main phenological stages can be observed in Table 2. The earliest variety is Felicia, where the budbreak occurred on August 29 and 30. The variety Calardis Blanc has an intermediate budbreak in the first week of September. Aromera is the latest variety; its budbreak occurred on September 10 and September 12. This feature is favorable to prevent damage by late frosts that are common in the region [14]. Long maturation periods increase the likelihood of damage due to grape bunch rot. The very early ripening is a factor that can be highly advantageous under tropical and subtropical conditions [15]. Short cycle varieties like Felicia or Calardis Blanc could be chosen to avoid the rainy periods of Brazilian summer and still ensuring excellent yields and high quality grapes.

Table 2. Date of occurrence of main phenological events of varieties Felicia, Calardis Blanc and Aromera cultivated in two altitude ranges of Santa Catarina State – Brazil.

Phenological Stage	Felicia		Calardis Blanc		Aromera	
	830	**1100**	**830**	**1100**	**1100**	**830**
Budbreak	08/29	08/30	09/06	09/04	09/12	09/10
Full Bloom	10/09	10/10	10/09	10/14	11/02	10/23
Véraison	11/27	12/10	12/30	01/02	01/15	12/30
Maturity	01/09	01/16	01/23	01/30	03/07	02/01

There was no difference for budbreak date between regions, but full bloom, *veraison* and maturity time varied between regions (Figure 1). At 830 m altitude the average growth cycle length was 139 days, while at 1100 m altitude it was 154 days. For Felicia, the earliest cultivar, the cycle was six days shorter, being the cycle reduced between full bloom and veraison. For Aromera the cycle was 32 days longer at 1100 m, being the cycle reduced from budbreak to maturity. This shows that longer is the cycle, longer is the delay until harvest. Calardis Blanc presents the longest period between full bloom and véraison, approximately 80 days, but the period between véraison and maturity is the lowest of the three varieties studied.

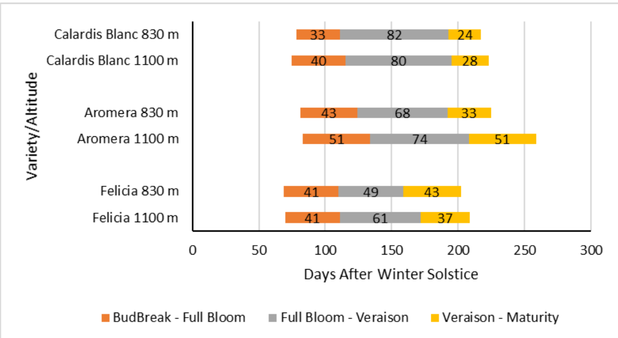

Figure 1. Chronological durations (days) of each phenological stages of varieties Felicia, Calardis Blanc and Aromera cultivated in two altitude ranges of Santa Catarina State – Brazil.

Differences in the extent of the cycles can be explained by temperatures. When a region has higher average temperatures than other, the vine growth cycle is accelerated due to higher heat accumulation and starting ripening in advance [16]. This result is explained by the low temperatures observed in the region of highest altitude (Table 1), resulting in a prolongation of early development stages of the vine.

The productive indexes of white PIWI varieties can be observed is Table 3. For productivity and estimated yield Felicia and Calardis Blanc varieties stood out in relation to Aromera. The highest productivity was from Felicia at the lowest altitude with 20 tons/ha, followed by Calardis Blanc with 14.8 tons/ha. The lowest productivity was from Aromera produced at 1100 m. Productivity is one of the most important parameters to be considered in variety selection, mainly in white varieties, that does not need to reach high levels of soluble solids and need to maintain the acidity for elaboration of white wines and sparkling wines [17]. These values are much higher than those found in Brazil in vines trained in VSP [18][19][20], which shows the differentiated productive potential of Felicia and Calardis Blanc. In the same way, Aromera also presents satisfactory productivities.

Table 3. Productivity per vine, estimated yield and fertility index of varieties Felicia, Calardis Blanc and Aromera cultivated in two altitude ranges of Santa Catarina State – Brazil.

Variety	Productivity per vine (kg)		Estimated yield (Ton/ha)		Fertility index	
	830	**1100**	**830**	**1100**	**830**	**1100**
Felicia	9.0 aA	2.0 bA	20 aA	6 bA	3.5 aA	1.4 bA
Calardis Blanc	6.7 aB	2.1 bA	15 aB	6 bB	2.6 aB	1.9 bA
Aromera	2.6 aC	1.1 bA	7 aC	3 bA	1.8 aC	1.4 aA
Average	6.1 a	1.7 b	14 a	5 b	2.6 a	1.5 b

*Means followed by different capital letters in the column differ by Tukey test ($p < 0.05$). Means followed by different minuscule letters in the row differ by Tukey test ($p < 0.05$).

For bud fertility index, higher values were found at 830 m for Felicia and Calardis Blanc; for Aromera there were no differences. Felicia produced at 830 m is the most fertile and the most heavily cluster. In previous works the values of fertility index were on average 0.85 for different Italian varieties, 1.00 for Cabernet Sauvignon and 1.12 for Sauvignon Blanc grown in highlands of Santa Catarina State [18][19][20].

The number of clusters was higher at 830 meters for all varieties and in average; they produced 40.5 clusters per plant versus 15.5 at 1100 m (Table 4). The varieties that produced the greatest number of clusters were Felicia and Calardis Blanc at 830m.

For weight of clusters, higher values were found at 830 m for Felicia and Calardis Blanc; for Aromera there were no differences. Felicia produced at 830 m is the most heavily cluster. The greater cluster weight at lower altitude can be explained by the smaller amount of berries in these clusters (Table 4). Temperature has marked and critical effects on both the duration and effectiveness of flowering and fruit set. Low temperatures slow anthesis, as well as pollen release, germination, and pollen-tube growth. If fertilization is delayed significantly, ovules abort. Cold temperatures slowly reduce pollen viability [21].

Table 4. Number of clusters, cluster weight and number of berries of varieties Felicia, Calardis Blanc and Aromera cultivated in two altitude ranges of Santa Catarina State – Brazil.

Variety	Number of clusters		Cluster weight (g)		Number of berries	
	830	1100	830	1100	830	1100
Felicia	50 aA	14 bB	177 aA	140 bA	127 aB	88 bB
Calardis Blanc	50 aA	23 bA	134 aB	93 bB	156 aA	129 bA
Aromera	22 aB	10 bB	117 aB	105 aB	81 aC	78 aB
Average	41 a	16 b	142.6 a	113 b	121 a	98 b

*Means followed by different capital letters in the column differ by Tukey test (p <0.05). Means followed by different minuscule letters in the row differ by Tukey test (p <0.05).

There was no difference for cluster compactness between the two regions (Table 5). Aromera presented the less compact cluster due to the smaller number of berries. The evaluation of cluster compactness index is important to prevent the occurrence of favorable microclimate for botrytis bunch rot. The ideal would be loose clusters, but with a good number of berries, which would not compromise productivity [22]. In this sense, the loosest cluster variety is Aromera and the more compact Calardis Blanc. Even though its compactness, the clusters of Calardis Blanc were not susceptible to botrytis bunch rot.

The physical-chemical indices of grapes can be observed is Table 5. In both evaluated sites, it was possible to produce grapes with adequate quality for wine production. For the elaboration of quality wines the levels of total soluble solids should be above 18 °Brix [21]. For the early varieties, Felicia and Calardis Blanc, the soluble solids contents were the same at both altitudes. In the vineyard at 1100 m altitude the highest soluble solids contents were observed for Aromera. The higher soluble solids content is a consequence of the local climatic conditions. This is related to a great availability of solar radiation, lower night-time temperatures and greater thermal amplitude in highlands condition. With longer ripening periods, vines produce grapes of higher enological quality [23].

Table 5. Cluster compactness index, soluble solids and total acidity of varieties Felicia, Calardis Blanc and Aromera cultivated in two altitude ranges of Santa Catarina State – Brazil.

Variety	Cluster compactness index		Soluble Solids (°Brix)		Total Acidity (mEq/L)	
	830	1100	830	1100	1100	1100
Felicia	0.55 aA	0.57 aB	20 aA	20 aB	81 aA	76 aA
Calardis Blanc	0.47 aB	0.52 aB	18 aB	19 aB	76 aA	115 bB
Aromera	0.68 aA	0.76 aA	19 bB	23 aA	109 aB	110 aB
Average	0.57 a	0.62 a	19 b	21 a	89 b	100 a

*Means followed by different capital letters in the column differ by Tukey test (p <0.05). Means followed by different minuscule letters in the row differ by Tukey test (p <0.05).

The total acidity of Calardis Blanc was higher at 1100 m while in the other varieties there were no differences. However, titratable acidity was higher in both cultivars grown at 1400 m. Higher temperatures at altitude of 830 m mainly influence these results. The increase in temperature causes an increase in plant respiratory activity, generating a decline in total acidity attributed to degradation of acidic compounds [25]. The lowest acidity was of Felicia and the largest of Aromera. White and sparkling wines are usually made with grapes with lower sugar content and acidity present [17].

Among the evaluated varieties, Felicia and Calardis Blanc seem to be better adapted to lower altitude region because they presented higher productivity and the same grape quality. However, Aromera presented higher productivity at 830m and higher soluble solids content at 1100m.

4 Conclusions

There was no difference for budbreak date, but the growth cycle of plants is longer when they are cultivated at a higher altitude.

The number of clusters per plant and yield were higher at 830 m for all varieties. For productive indexes Felicia and Calardis Blanc varieties stood out in relation to Aromera in all parameters.

Among the evaluated varieties, Felicia and Calardis Blanc were better adapted to the lower altitude region and had higher productivity and the same grape quality. But Aromera presented higher productivity at 830m and higher soluble solids content and 1100m.

5 Acknowledgments

To Research and Innovation Support Foundation of Santa Catarina State (FAPESC) for financial support os this project.

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