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Evaluation of mechanical properties of berries on resistant or tolerant varieties of grapevine

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Abstract. An experimental site located in Trentino (North-Eastern Italy), characterized by considerable rainfall that normally requires several plant protection treatments, was used to assess the behavior of 15 grape varieties resistant to the main fungal diseases from an agronomic, quantitative, qualitative, nutritional, and physiological point of view, since 2015. At the 4th year of planting (2016), mechanical properties (berry firmness, berry skin hardness, and thickness) of berries were evaluated using a TAxT2i Texture Analyzer in order to get information about parameters useful for wine process. The varieties showed significant differences in the studied parameters. *Regent* had the highest values of berry firmness, whilst *Johanniter* and *Cabino* the lowest. *Cabernet Cantor* and *Cabernet Cortis* generally presented higher values of berry skin hardness than the other varieties. Conversely, the lowest values of skin hardness were recorded in *Johanniter*, followed by both *Solaris* and *Cabino*. *Souvignier gris*, *Prior*, and *Bronner* had significantly higher values of berry skin thickness than *Cabino,* which, in turn, did not differ from the levels found in *Helios*, *Muscaris*, *Aromera*, and *Regent* berries, with values above 175 μm, range largely found in grapevine cultivars normally grown. The association between mechanical properties of berries and qualitative data could be used as an aid in decision-making about wine processes.

1 Introduction

In the last few years, one of the most important goals of viticulture has been the selection grapevine cultivars less demanding in terms of pest protection, to be used as a valid alternative to the main cultivated varieties of *Vitis vinifera*. In fact, the main cultivars normally require a large number of treatments to fight both downy mildew (*Plasmopara viticola*) and powdery mildew (*Uncinula necator* and *Oidium tuckeri)* during the growing season.
The meteorological conditions in Trentino are characterized by rainfall that exceeds an average of 800 mm per year, requiring several treatments aimed at providing phytosanitary defense.
For this reason, therefore, the identification of more resistant and/or tolerant cultivars, mainly to downy mildew, can be an interesting strategy for a more sustainable viticulture.
Some resistant and/or tolerant varieties recently identified— resulting from interspecific cross between cultivars of *Vitis vinifera* and other *Vitis* of American and Asian origin—have been under observation for some years in the Trentino viticultural area. The main agronomic, physiological, and nutritional aspects of these genotypes were evaluated [1, 2].
Of these aspects, some data are available, but they need to be validated with greater repeatability in the coming years. The evaluation of these varieties for a better placement at an enological and market level, however, is currently still lacking and requires further trials aimed to refine the techniques of production of specific wines.
This preliminary work has been carried out in order to obtain information on this topic, in particular analyzing the appearance of the mechanical properties of berries (berry firmness, skin hardness and skin thickness), referring to qualitative parameters too. This was done to support decision-making for the identification of optimal technological solutions for wine processes able to enhance the grapes coming from these resistant and/or tolerant varieties.

2 Materials and methods

In 2013, fifteen different genotypes of grapevine resistant/tolerant to the main fungal diseases, such as downy mildew and powdery mildew, were planted in Vallagarina (Trentino, North-Eastern Italy). The experimental site is located in Rovereto-Navicello (lat.: 46 ° 52'37.96 "N, long.: 11 ° 01'14.03" E), with an altitude of 220 m above sea level, on a sandy, sub-alkaline, extremely calcareous soil, characterized by good level of active limestone (3.8%) and organic matter (2.3%). The soil presents a high availability of phosphorus and magnesium, a medium content in potassium, and a high Mg/K ratio.

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The resistant cultivars tested - *Aromera*, *Baron*, *Bronner*, *Cabernet Cantor*, *Cabernet Carbon*, *Cabernet Cortis*, *Cabino*, *Helios*, *Johanniter*, *Monarch*, *Muscaris*, *Prior*, *Regent*, *Solaris*, and *Souvignier gris* – are present in a varietal collection composed of about 100 plants of each genotype, trained to pergola Trentina system with a plant density of 4329 vines/hectare (3 m x 0.77 m). No antifungal treatments were performed during each growing season.
Starting from the third year, nutritional aspects were monitored at the phenological phase of fruit set by using leaf analyses, as well as physiological aspects by detecting the intensity of leaf greenness (SPAD values) and the photosynthetically active biomass (NDVI index).
Every year, at harvest time, quantitative (yield) and qualitative (°Brix, titratable acidity -TA, pH, malic acid, tartaric acid, potassium) parameters of musts were collected. Nevertheless, in order to obtain different wines, grapes were harvested annually and processed into microvinifications. The obtained wines were then tasted during the springtime of each following year. With regard to these data, it should be noted that in the present work they are not reported, as they are partially present in another work [2].
In 2016, four years after planting, from each cultivar under observation, mechanical properties of the berries (berry firmness, skin hardness and skin thickness), also called rheological parameters, were evaluated by puncture and compression test [3, 4], using a Universal Testing Machine TAxT2i Texture Analyzer (Stable Micro System, Godalming, Surrey, UK). For the evaluation of berry skin thickness, before Texture Analyzer measurements, samples of berries were frozen with liquid nitrogen [5]. For each mechanical parameter, a sample of 30 berries was used.
Quantitative (average yield/hectare) and qualitative (°Brix, pH and TA) data of each cultivar recorded in 2016 and obtained from the average of 14 plants per genotype, are used in this work to highlight potential enological products.
All data were statistically processed using Systat software package (Systat Software Inc., USA), separating the averages by Tukey test. In the text, the values statistically different are indicated by different letters. The levels of significance reported and indicated with n.s., *, **, ***, represent respectively not significant, significance for values of $P \leq 0.05$ and $P \geq 0.01$, $P < 0.01$ and $P \geq 0.001$, $P < 0.001$. The multivariate procedure of *Cluster Analysis* was applied to the mean values of parameters related to mechanical properties of the berries. Normalized Euclidean distances (root mean-squared distances) were used.

3 Results and discussion

The investigated varieties showed significant differences for the rheological parameters studied (table 1).
Regent had significantly higher values of berry firmness than all the other cultivars. The lowest values of this rheological parameter were found in *Johanniter* and *Cabino*.
The skin hardness test showed that both *Cabernet Carbon* and *Cabernet Cortis* cultivars generally had higher values than the other varieties. The lower values of this parameter, however, were recorded on the berries of *Johanniter*, followed by those of *Solaris* and *Cabino*.
Regarding skin thickness, *Souvignier gris*, *Prior*, and *Bronner* showed the highest values, whilst *Cabino* the lowest ones, although this cultivar did not statistically differ from *Helios*, *Muscaris*, *Aromera*, *Johanniter*, and *Regent*.

Table 1: mean values of parameters related to mechanical properties of berries (berry firmness, skin hardness, and skin thickness) in relation to cultivar. For each parameter, 450 cases

Variety	Parameter		
	Berry firmness (g)	Skin hardness (Newton)	Skin thickness (μm)
Aromera	622 de	0.406 def	165 fg
Baron	597 def	0.451 bcde	187 bcde
Bronner	572 ef	0.423 cdef	204 ab
C. Cantor	917 b	0.519 ab	181 cdef
C. Carbon	765 bcd	0.591 a	189 bcde
C. Cortis	836 bc	0.596 a	192 bcd
Cabino	423 f	0.366 fg	157 g
Helios	681 cde	0.429 cdef	165 fg
Johanniter	413 f	0.320 g	173 defg
Monarch	704 cde	0.381 efg	189 bcde
Muscaris	739 bcde	0.473 bcd	161 fg
Prior	733 bcde	0.425 cdef	202 abc
Regent	1217 a	0.494 bc	167 efg
Solaris	702 cde	0.367 fg	193 bcd
Souvignier g.	756 bcde	0.484 bcd	216 a
Significance	***	***	***

It is interesting to remark that these latter varieties presented lower levels than the average normally recorded for cultivated grapevine of *Vitis vinifera*, which generally ranged around values of 175 μm [6].
The average values of berry firmness, skin hardness and skin thickness of *Pinot gris* and *Cabernet franc* (data not shown in table 1), varieties particularly widespread at international level and taken as a reference, were recorded in the same year of the trial. The values were respectively 530 g, 0.580 Newton and 172.5 μm in the white berry cultivar and 1047 g, 0.733 Newton and 143.6 μm in the red berry cultivar.
It should be noted that *Cabernet franc* has been chosen because it represents one of the cultivars characterized by the lowest skin thickness values (below 150 μm) compared to those of the main cultivated grapevines [7].
The comparison of the three rheological parameters of the studied cultivars with these reference varieties was made using the *Cluster Analysis.* The results reported in figure 1 allow identification of the positioning of

resistant and/or tolerant genotypes tested with respect to those identified as an international reference. From a technological point of view, these results may be used as an aid in decision-making about wine processes.

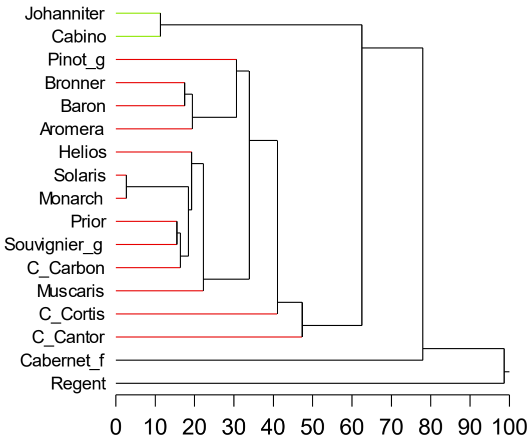

Fig. 1: grouping of the cultivars in relation to the three mechanical properties of the berries through Cluster Analysis. Normalized Euclidean distances are reported.

The separation of the different groups of cultivars places to the extreme limits of the *Cluster*, *Johanniter*, and *Cabino* on one hand with low skin hardness values and medium-low thickness, and on the other hand *Regent* and *Cabernet franc*, with high levels of berry firmness and low skin thickness values.
The cultivars *Baron*, *Bronner*, and *Aromera* were found very close to *Pinot gris*; they were indeed characterized by medium-low values of both berry firmness and skin hardness, but with different thickness levels compared to those recorded in *Pinot gris*, with respectively low values in *Aromera*, medium-high in *Baron* and rather high in *Bronner*.
Solaris and *Monarch*, characterized by medium-low values of berry firmness and skin hardness, were grouped with *Helios*. The first two recorded an average level of skin thickness, different from the very low levels observed in the latter.
The group composed by *Muscaris*, *Cabernet Carbon*, *Souvignier gris*, and *Prior* has been unified for medium-high values of berry firmness and skin hardness, but with very different values of skin thickness, ranging from low levels (*Muscaris* and *Cabernet Carbon*) to very high ones (*Souvignier gris* and *Prior*).
Finally, *Cabernet Cantor* and *Cabernet Cortis* have been placed close to the varieties characterized by high levels of berry firmness and skin hardness, but with low skin thickness values.
Average values of quantitative (yield/hectare) and qualitative data of both resistant cultivars and varieties taken as a reference recorded in 2016 are reported in table 2. *Aromera*, *Bronner*, *Cabernet Cantor, Cabernet Cortis*, *Johanniter*, *Monarch*, *Muscaris*, *Solaris,* and *Souvignier gris* showed interesting production per hectare, ranging from 7.5 to 14 tonnes. Both *Pinot gris* and *Cabernet franc* presented yield around 15 tonnes. *Baron*, *Cabernet Carbon, Cabino*, *Helios*, *Prior*, and *Regent* had very low production.

Table 2: mean values of quantitative and qualitative parameters in relation to cultivar**.**

Variety	Parameter			
	Yield (t/hectare)	°Brix	pH	TA (g/L)
Aromera	9.5	18.59	3.29	5.4
Baron	1.9	21.99	3.54	4.2
Bronner	12.7	20.19	3.21	7.1
C. Cantor	7.8	25.43	3.19	6.9
C. Carbon	5.7	21.24	3.21	7.0
C. Cortis	8.0	23.45	3.08	6.5
Cabernet franc	15.0	23.16	3.49	3.2
Cabino	3.1	18.18	3.51	6.5
Helios	3.1	20.81	3.33	5.6
Johanniter	13.6	17.85	3.55	5.2
Monarch	13.2	16.51	3.11	8.0
Muscaris	12.1	24.17	3.35	7.3
Pinot gris	14.9	22.28	3.53	5.3
Prior	4.8	20.40	3.31	7.1
Regent	4.1	20.98	3.77	6.2
Solaris	13.7	25.10	3.24	7.2
Souvignier g.	9.3	23.49	3.39	7.4

Cabernet Cantor, *Cabernet Cortis*, *Muscaris*, *Solaris*, and *Souvignier gris* presented the highest sugar levels, whilst *Aromera*, *Cabino*, *Johanniter*, *Prior*, and *Monarch* the lowest ones. *Cabernet Cortis* and *Monarch* showed the lowest values of pH, conversely to *Regent* which had the highest. *Monarch* and *Baron* had respectively the highest and lowest levels of acidity.
The association of data on mechanical properties with those of production (yield) and quality of musts did not show any important correlations able to provide useful technological suggestions for the enhancement of the different resistant varieties from an enological point of view. However, although with low level of r square, values of skin hardness were positively correlated with sugar levels (r^2=0.21), as well as those of skin thickness with acidity (r^2=0.30).
Some rheological parameters, in particular, skin hardness and thickness, as recently reported [8], appear to be related to the quantity of extractable anthocyanins and to the amount of thiolic precursors, thus intervening both on the wine coloring and on the aromatic nature of the same. Due to these links, it clearly emerges that the evaluation of mechanical properties of berries and their association with qualitative and technological parameters need to be further investigated in order to finalize optimal winemaking processes specific for the resistant varieties. In fact, some of these cultivars characterized

by high levels of both skin thickness and hardness can be left for a long time in maceration in order to increase the concentration of thiol precursors [9]. In fact, as recently reported [10], some grape skin tannins were shown to contain very high amounts of 3-S-glutathionylhexan-1-ol and 3-S-cysteinylhexan-1-ol (polyfunctional thiol precursors), whose free forms are responsible for appreciated tropical-like flavours.

4 Conclusions

Data collected about rheological properties of the berries of resistant and/or tolerant cultivars, albeit limited to a single year, can undoubtedly constitute a source of fundamental information.

Similar measurements must be further validated by repeating them over several years and, moreover, by relating them to qualitative and productive data in order to properly finalize the winemaking processes.

If associated with the information deriving from the degree of fungal attack and/or entomological diseases, skin thickness data could be extremely important for a specifically targeted management of the different cultivars under observation.

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