Development, yield potential and nutritional aspects of resistant grapevine varieties in Trentino Alto Adige

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Abstract. The reduction of the environmental impact of agricultural activity has stimulated the evaluation of new cultivars tolerant/resistant to fungal diseases within the context of Trentino viticulture. In an alluvial soil, 15 varieties of resistant vines were planted: *Aromera*, *Baron*, *Bronner*, *Cabernet Cantor*, *Cabernet Cortis*, *Cabernet Carbon*, *Cabino*, *Helios*, *Johanniter*, *Monarch*, *Muscaris*, *Prior*, *Regent*, *Solaris*, and *Souvignier gris*. Since 2015 they have been evaluated for nutritional aspects, vegetative-productive balance, quantitative-qualitative parameters of musts and health status. Some cultivars (*Cabernet Cortis, Cabino, Helios, and Prior*) had an insufficient vegetative development, whilst other varieties presented a balanced or excessive behaviour. Regarding magnesium (Mg), some of these cultivars presented deficiencies, often confirmed by visual analysis, but not always highlighted by leaf analyses (*Cabernet Cantor*, *Cabernet Cortis*, and *Monarch*). For such varieties, Mg supply is recommended. Nonetheless, with the aim of new plantings, the choice of more suitable rootstock combinations should be done. *Cabino* always showed very highly susceptibility to *Plasmopara viticola* attack, with an ineffective resistance.

1 Introduction

In the last few years, one of the goals of agricultural production processes is the reduction of environmental impact. Both consumers and producers are seeking out solutions with lower impact, allowing for enhanced value of the final product [1, 2, 3].
In Italy, the application phase of Directive 2009/128 EC on the sustainable use of pesticides - National Action Plans (NAPs) - often more stringent in their local application, is also aimed at finding solutions that are less impactful from an environmental point of view [4].
In grapevines, recently, the search for valid alternatives to the typically cultivated varieties of *Vitis vinifera* has identified new resistant and/or tolerant genotypes to the main cryptogams (in particular downy and powdery mildew). These cultivars represent the result of interspecific crossings, obtained from some important European research centers in viticulture, using cultivars of *Vitis vinifera* and other *Vitis* of American and Asian origins. They can be used by grapevine producers as a relevant solution for less intensive and more environment friendly viticulture.
Currently, only about twenty of these cultivars are registered in the Italian catalog, half of them obtained from State Viticultural Institute of Freiburg (D) and another half from the Institute of Applied Genomics of Udine (I).
Their registration is often restricted to specific geographical areas of cultivation and, in any case, they cannot be used for wines with a designation of origin (due to the article 6 of Legislative Decree 2010/61).
The production of wines from these resistant/tolerant varieties, although still very limited from the point of view of the areas invested, is assuming its relevance and visibility in Germany, Austria, and South Tirol, thanks to an association of viticulturists named PIWI, German acronym of *pilzwiderstandsfähig* that means fungus resistant [5].
Alternatively, these cultivars may represent a solution for growing plants in those farm portions where the phytosanitary treatment conflicts with sensitive areas protected by the NAPs, in which carrying out several fungicide treatments represents an objective difficulty for the grapevine producers.

2 Materials and methods

2.1 Collections description

In 2013, a Pergola trained varietal collection was created in Trentino at Vallagarina (Rovereto, lat.: 46 ° 52'37.96 "N, long.: 11 ° 01'14.03" E, 220 m a.s.l. – at a vine spacing of a 3.00 m between-row x 0.77 m in-row). The following 11 registered varieties were planted: *Bronner* (W = white berry), *Cabernet Cantor* (B = black berry), *Cabernet Carbon* (B), *Cabernet Cortis* (B), *Helios* (W), *Johanniter* (W), *Monarch* (B), *Muscaris* (W), *Prior* (B), *Solaris* (W), and *Souvignier gris* (W). In addition to these *Aromera* (W, unregistered prototype of Innovitis of

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Bolzano), *Baron* (B, Institute of Freiburg), *Cabino* (B, breeder: George Weiss, Austria), and *Regent* (W, Julius Kühn- Institute of Geilweirhof) were also present.
The soil of cultivation is a typical alluvial of the Adige plain, sandy, sub-alkaline, extremely calcareous (420 g/kg), with good content of active limestone (38 g/kg), organic matter (2.3%), very rich in phosphorus (52 mg/kg) and magnesium (330 mg/kg) and with medium potassium content (84 mg/kg) and a high Mg/K ratio.

2.2 Assessments and analyses

Starting from 2015, the experimental protocol provided for the analyses of the leaf nutritional status and musts for technological ripening parameters (the latter were made only on 14 varieties). In the three-year period between 2015 and2017, fifteen plants for each cultivar were evaluated at fruit set (BBCH 71-73 [6]), with regard to nutritional aspects through leaf analyses and SPAD indexes (Konica Minolta). On leaf samples, nitrogen (N) was determined by the Dumas total combustion method, whilst for other elements concentration - phosphorus (P), potassium (K), Calcium (Ca), Mg, iron (Fe), manganese (Mn), boron (B), copper (Cu), zinc (Zn), and sulfur (S) - the ICP-OES plasma emission spectrometry analysis was used. Readings related to SPAD measurements were done on two leaves/plant (30 cases/cultivar) .
On the same vines, the photosynthetically active biomass (NDVI index) was measured using the Spectrosense 2+ instrument (*Skye Instruments Ltd*).
Yield components (i.e. cluster and shoot number, yield per vine and other derived parameters) from each monitored plant were measured, while the qualitative parameters of the must (°Brix, titratable acidity - TA, pH, malic acid, tartaric acid, potassium, and yeast assimilable nitrogen - YAN) were determined by FT-IR spectrophotometer (FOSS Analytical) on a sample averaged by all the collected plants with a weight of 1.5 kg.
Due to the growth habit of these cultivars, which was not homogeneous, further data were collected in order to acquire more precise information regarding their vegetative-productive expression. With this aim, classical agronomic indexes were measured: length and number of shoots, and number of secondary shoots. Only in 2017, the *Point quadrat* method [7,8] was applied at veraison, supplemented by the estimation of growth development using point cards [7,8].
In each growing season, the appearance of symptoms related to the main fungal diseases was monitored. No antifungal treatments were carried out to protect the vines, regardless of the fact that normal management recommends at least 1-3 treatments.
The frost event that hit northern Italy between 19 and 21 April 2017 caused serious damage to the already developing buds and shoots, stimulating the plants to sprout from latent or secondary buds, which are usually less fruitful than the primary buds. Therefore, yield data will be limited to 2015-16 seasons.

All data were statistically processed using STATISTICA statistical packages (version 13.0), separating the averages by Tukey test. In the text, the values that are statistically different to this test are indicated by different letters. The levels of significance reported and indicated with n.s., *, **, ***, representing not significant, significance for values of $P \leq 0.05$ and $P \geq 0.01$, $P < 0.01$ and $P \geq 0.001$, $P < 0.001$, respectively.

3 Results and discussion

For the sake of brevity, complete nutritional data are not reported, only those that are significant from a statistical point of view will be discussed. All annual analytical data related to the leaf mineral elements concentration was used as a replicate due to the fact that only single values are available for each combination.
Regarding macroelements, only N, K and Mg showed significant differences among the cultivars, whereas Fe and B were the microelements displaying differences.
Regent proved to be the variety with the highest N level (3.1% d.w.) compared to *Cabino* (2.14%), *Solaris* (1.98%), *Muscaris* (2.29%), and *Cabernet Cortis* (2.26%), which showed the lowest levels (values of $P \leq 0.05$). *Solaris* shows N at deficient levels compared to the reference standards [9], suggesting that this cultivar requires higher levels of N fertilization than the other varieties. Some of these genotypes, such as *Solaris* and *Cabernet Cortis*, characterized by low N levels, also have low SPAD values and pale green colorations detectable by eye.
The leaf Mg levels were lower than the standard minimum threshold [9] for four cultivars: *Bronner* (0.16%), *Helios* (0.20%), *Souvignier gris* (0.19%), and *Johanniter* (0.19%); the first three also showed visual Mg deficiency symptoms.
A special notice should be made for both *Cabernet Cantor* and *Monarch*, which have shown, in all years, visual Mg deficiencies, although leaf concentrations were above the limit (0.20-0.39%), with values respectively equal to 0.28 % and 0.22%.
No cultivar showed average leaf Fe levels below the limit reference range (60-130 mg/kg). Although limits of the foliar diagnosis of iron are known, *Johanniter* (92 mg/kg) and *Regent* (94 mg/kg) were characterized by the highest values of this ion, much higher (P values ≤ 0.05) compared to *Souvignier gris*, which always had lower concentrations throughout the three-year period (65 mg/kg).This result is partially confirmed by the visual assessment, which highlighted the unequivocal Fe deficiency in this cultivar. *Cabernet Cortis* (76 mg/kg), *Cabino* (70 mg/kg), and *Prior* (78 mg/kg) also showed visual symptoms of light chlorosis attributable to Fe deficiency. No variety had any B deficiency, although *Baron* (21 mg/kg), *Regent* (20 mg/kg), *Prior* (24 mg/kg), and *Cabino* (27 mg/kg) showed significantly lower values ($P \leq 0.05$) compared to those found in both *Cabernet Carbon* (47 mg/kg) and *Cabernet Cortis* (56 mg/kg), which instead showed, on average, high levels.
The exploratory analysis (EFA, Exploratory Factor Analysis made by using Principal Component Analysis –

PCA) of NDVI and SPAD and of the nutritional data related to them in the correlation matrix, extracts two factors able to explain 64.5% of the cumulative variance (figure 1).
Factor 1 is negatively correlated with SPAD, N, Ca, Fe, and S, while factor 2 positively with NDVI and Mg.

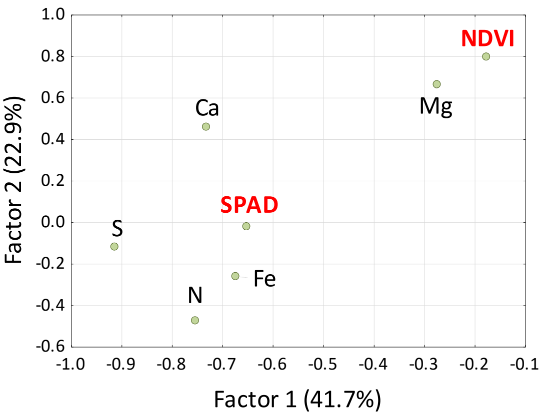

Fig. 1: Exploratory Factor Analysis (PCA)

This graphic outlay shows that NDVI values are more discriminated by Mg content, while SPAD index is coherently influenced by the values of N, Fe, and S.
The three-year average relative to NDVI index (figure 2) allows a sorting of the cultivars according to the photosynthetically active biomass values, even if the high variability of the weaker cultivars offsets the statistical significance.

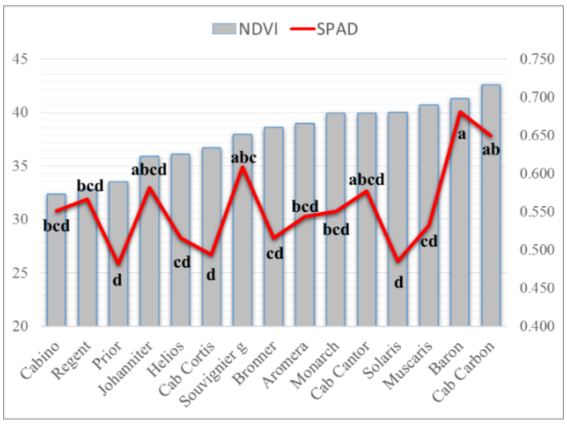

Fig. 2: mean values of NDVI and SPAD indices (2015-2017)

The data deriving from the *Point Quadrat* method (table 1) are shown by averaging the three insertion canopy zones: basal, median and apical. This reading is appropriate for those cultivars that are able to fill all the space available on the pergola. Otherwise, the interpretation of the disaggregated data by distinguishing different area may be more illuminating.
Cabino, *Prior* and, partially, *Helios*, show an insufficient development of the shoots, a reduced number of leaf layers and leaves with clear symptoms of nutritional deficiencies.

Table 1: *Point Quadrat* analysis (2017)

Variety	Mean number of leaf layers	Vegetation gaps (%)	Internal leaves (%)
Aromera	1. 96 abcde	15.69 bc	24.51 ab
Baron	2.55 abcd	13.73 bc	43.50 a
Bronner	1.67 bcde	17.65 bc	23.08 ab
Cab. Cantor	1.25 abc	29.41 bc	21.16 ab
Cab. Carbon	2.61 bcde	3.92 abc	39.41 ab
Cab. Cortis	1.59 bcde	25.49 abc	22.41 ab
Cabino	0.78 de	49.02 bc	6.30 b
Helios	0.96 cde	49.02 ab	14.55 ab
Johanniter	2.88 ab	9.80 bc	43.48 a
Monarch	1.61 bcde	13.73 bc	13.60 ab
Muscaris	3.57 a	0.00 c	48.20 a
Prior	0.69 e	70.59 a	14.40 ab
Regent	2.27 abcde	11.76 bc	35.73 ab
Solaris	2.90 abcde	3.92 bc	39.31 ab
Souvignier g.	2.10 abcde	13.73 bc	29.66 ab
Significance	***	***	**

The analysis of data distinguished by the different areas of the canopy wall highlights for *Cabino* 41.2%, 35.3% and 70.6% of gaps respectively for basal, median and apical zones; for *Prior*, 41.2%, 70.6% and 100%; for *Helios* 17.6%, 52.9%, and 76.5%. A group of varieties composed by *Aromera*, *Bronner*, *Cabernet Carbon*, *Cabernet Cortis*, *Monarch*, and *Souvignier gris* was found to have an average number of leaf layers between 1.25 and 2.10. In any case, it should be pointed out that in varieties such as *Cabernet Cantor,* the value of the average number of leaf layers (1.25) is likely too low as it also associates to excessive vegetation gaps. Finally, the group consisting of *Baron*, *Cabernet Carbon*, *Johanniter*, *Muscaris*, *Regent*, and *Solaris* have a high number of leaf layers. Among these cultivars, *Muscaris* and *Baron* have a vegetative excess, well evidenced by the high number of layers, low values of the vegetation gaps and high number of internal leaves. These foliar densities on the pergola can clearly reduce the canopy efficiency, given the high percentage of internal leaves that receives low levels of photosynthetically active radiation, resulting mainly from diffused light.
From the analysis of vegetative and productive data (table 2) a different behavior is observed: *Regent* is characterized by extreme vigor and low productivity, *Baron* also shows a low Ravaz index due, in this case, to a reduced fruit load.
Some varieties - *Johanniter*, *Bronner*, *Cabernet Cortis*, *Monarch*, *Solaris* and *Souvignier gris* – still present in their third year satisfying yield levels per hectare, whereas *Baron*, *Cabino*, *Helios*, *Prior*, and *Regent* show very low values of this parameter. Must composition reported in table 3 points out the possibility to reach, in a large majority of cultivars, a sufficient level of soluble solids.

Table 2: Vegetative and productive data (2015-2016)

Variety	Clusters /vine	Yield/vine (g)	Yield/ hectare (t)	Pruning wood (g)	Ravaz index	Single cane weight (g)
Aromera	21 abcd	1384 def	6	364.6 abc	3.8 c	42.6 b
Baron	15.7 bcde	439 g	2	361.4 abc	1.3 c	39.7 b
Bronner	23.9 ab	2494 ab	11	302.1 bc	9.6 bc	35.7 b
Cabernet Cantor	18.0 bcde	1867 bcde	8	311.3 bc	19.9 abc	34.7 b
Cabernet Carbon	18.9 abcde	1637 cde	7	265.4 bc	6.8 bc	26.8 bc
Cabernet Cortis	24.8 ab	2524 ab	11	243.9 cd	30.9 ab	26.1 bc
Cabino	14.6 cde	707 fg	3	126.1 de	6.8 bc	30.0 bc
Helios	12.6 de	657 fg	3	67.9 e	19.4 abc	10.7 c
Johanniter	24.1 abc	3143 a	14	311.4 bc	10.6 abc	38.4 b
Monarch	18.0 bcde	2636 ab	11	282.9 bc	10.4 bc	33.9 b
Muscaris	21.6 abc	1967 bcd	9	366.1 abc	5.8 bc	39.0 b
Prior	12.0 e	1262 defg	5	89.6 e	38.6 a	13.6 c
Regent	14.6 bcde	953 efg	4	518.6 a	2.0 c	92.8 a
Solaris	27.1 a	2411 ab	10	390 ab	7.8 bc	36.4 b
Souvignier gris	18.1 bcde	2291 abc	10	300 bc	9.0 bc	35.7 b
Significance	***	**	-	**	***	**

Monarch represents the only exception. In fact, this cultivar did not reach a satisfactory sugar content for an hypothetical red vinification during the trial's three year duration.

Table 3: main analytical data of musts (2015-17)

Variety	°Brix	pH	TA (g/l)	YAN (mg/l)
Aromera	22.1 ab	3.29 ab	5.35	57 b
Baron	21.9 ab	3.40 ab	5.30	109 ab
Bronner	20.4 ab	3.23 ab	6.33	67 b
Cab Cantor	23.6 a	3.20 ab	6.07	67 b
Cab Carbon	21.6 ab	3.24 ab	6.33	45 b
Cab Cortis	22.5 a	3.14 b	6.20	63 b
Cabino	21.9 ab	3.48 ab	5.90	102 ab
Helios	21.3 ab	3.30 ab	5.40	45 b
Johanniter	19.5 ab	3.44 ab	5.75	167 a
Monarch	17.8 b	3.18 ab	6.48	49 b
Muscaris	23.7 a	3.38 ab	6.53	81 b
Prior	20.6 ab	3.32 ab	6.09	39 b
Regent	21.3 ab	3.60 a	5.75	176 a
Solaris	23.8 a	3.22 ab	7.10	137 ab
Souvignier g.	21.4 ab	3.27 ab	6.97	57 b
Significance	**	*	ns	*

The monitoring of the vines' health status, with particular regard to fungal disease symptoms, has described, in 2016, damages on the leaves caused by downy mildew only on *Cabino* and *Regent*, with values accounting for a 5% of damage severity. In 2017, *Cabino* developed 90% damage to leaves, with significant damage also to clusters, likely greatly affecting the productivity.

4 Conclusions

In the pedoclimatic context of the Adige floodplain, the different cultivars have shown variable development. *Regent* and *Baron* have shown excessive vigor through a low Ravaz index and a high number of leaf layers; conversely, *Cabernet Cantor, Cabernet Cortis, Cabino, Helios,* and *Prior* have shown poor vigor. For some of these cultivars, a careful agronomic handling of fertilization and canopy management may reduce poor balance, especially in *Cabino*, *Helios,* and *Prior*, genotypes also showing high fractions of missing vines. *Baron*, *Cabino*, *Helios*, and *Regent* have shown low yield that compromises their economic sustainability. In addition, *Cabino* has revealed poor resistance to the fungal diseases and it cannot be recommended for cultivation.

The poor qualitative expression of the red berry *Monarch* is manifested: in fact, this variety failed to accumulate sufficient sugar content (18.3° Brix in 2015, 16.5° Brix in 2016, 18.6° Brix in 2017).

From the nutritional point of view, it is recommended to pay particular attention to Mg management as, despite the high soil availability of this ion at the specific site, deficiencies supported by leaf analyses showed up in *Bronner*, *Helios*, *Johanniter*, and *Souvignier gris*. In other cases, *Cabernet Cantor* and *Monarch* Mg deficiency was visible, although not confirmed by tissue analysis. . Consequently, Mg foliar treatments seem to be strongly recommended for such resistant cultivars.

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