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Effects of defoliation on quality attributes of Nero di Troia (*Vitis vinifera* L.) grape and wine

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Malic acid (PubChem CID: 525)
Citric acid (PubChem CID: 311)
D-Gluconic acid (PubChem CID: 10690)
Malvidin-3-glucoside (PubChem CID: 443652)
(+)-Catechin (PubChem CID: 9064)
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A B S T R A C T

Field studies were conducted in Puglia (Italy) to evaluate the influence of defoliation around cluster zones on grape and wine quality. Nero di Troia grapes were subjected to four different treatments: N: no leaf removal; E: leaf removal in the area of the clusters along the east side (at complete veraison); E/W: leaf removal in the area of the clusters along the east and west side (at complete veraison); and F: almost complete leaf removal along the west side (at complete veraison) and at pre-harvest also along the east side. Grapes of defoliated vines generally showed higher sugar content, lower titratable acidity, total flavonoids, flavonoids different from anthocyanins, and total phenolic content than grapes from non-defoliated vines while their total anthocyanin concentration was not affected by defoliation at a significant level. Concerning wines, alcohol content, residual soluble solids, different forms of anthocyanins but also volatile acidity were generally higher in samples from defoliated vines. Differences were also highlighted among the defoliation treatments: the best results in terms of dry matter, sugar and alcohol content were observed in the samples submitted to the more severe defoliation as a consequence of the higher light availability and berry temperature. Concerning the concentration of the individual phenolics, significant differences were highlighted for: caffeic and caftaric acids, peonidin- and malvidin-3-p-coumaroylglucoside, which were higher in the E wines; quercetin-3-glucoside, galactoside, and rhamnoside, and procyanidins, which were higher in F wines.

1. Introduction

Canopy management embraces a range of viticulture practices aimed to obtain a desired shoot arrangement and avoid an excessive foliage density which would shade and make humid the fruit zone; these microclimatic conditions are known to reduce the vine fruitfulness, the expression of grape variety characters and the overall grape quality, besides hampering the efforts at disease control. Leaf removal (defoliation) in the fruiting zone is a canopy management practice widely applied, at any time from fruit set to veraison, to enhance air circulation and light penetration in dense foliage (Smart & Robinson, 1991). Many studies showed that grapes well-exposed to sunlight have higher sugar, anthocyanin, and phenolic accumulation, and lower titratable acidity, pH and malic acid concentration than shaded grapes. As summarized by Dokoozlian and Kliewer (1996), the photoregulation of the invertase and phenylalanine-ammonia-lyase enzymes are thought to be primarily involved in these responses, together with the thermal regulation of the malic enzyme, considering that a rise in light availability normally induces also a rise of berry temperature.

Nevertheless, intense defoliations may expose the clusters to excess of light intensity and temperature, especially in warm climates; it is proved that very high temperatures may reduce the skin colour (Price, Breen, Valladao, & Watson, 1995) and lower the titratable acidity too much. Although the experimental results change with the grape variety and the growing environment, an average critical threshold for anthocyanin response might be individuated around 30 °C, as suggested by Downey, Dokoozlian, and Krstic (2006).

Besides the variety, the environment and the severity of leaf removal, and the overall defoliation effect depend also on its timing. According to Diago, Vilanova, and Tardaguila (2010), "early" defoliation leads to musts richer in total soluble solids, especially when leaf removal is carried out at pre-bloom, and has little or no effect on acidity. In their study, Tempranillo wines from early defoliated vines exhibited higher alcohol

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content than the control wines, but, in general, neither pH nor titratable acidity were significantly altered. The increase in alcohol concentration might have helped in extracting larger amounts of anthocyanins. Early defoliation improved the phenolic composition of Tempranillo wines also by favouring the accumulation of hydroxycinnamics, flavonols and anthocyanins, thus enhancing wine quality in terms of colour and sensory properties (Diago, Ayestarán, Guadalupe, Garrido, & Tardaguila, 2012). On the other hand, when Hunter, Ruffner, Volschenk, and Le Roux (1995) analysed the effects induced by two partial defoliation levels (33% and 66%), performed at different developmental stages, on grape skin colour and sugar content and on wine quality of Cabernet Sauvignon, they found that the anthocyanin content per berry was significantly higher in vines defoliated at veraison.

Since the concentration of phenolic compounds in the wine is intrinsically related to their concentration in the berries (Jensen, Demiray, & Egebo MandMeyer, 2008), and considering that both anthocyanin and flavonol biosynthetic pathways are regulated by enzymes that are light- and temperature-sensitive (Hunter, De Villiers, & Watts, 1991), any changes in microclimatic conditions, such as those imparted by defoliation, might have a significant impact on the synthesis and accumulation of these compounds in the berries and their concentration in wine.

The general consensus is that, regardless of the defoliation timing, leaf removal is an effective technique for improving the quality of wines since noticeable increases in constituents (anthocyanins, phenolics), colour density, cultivar character intensity, and overall quality are generally found in wines from defoliated vines. Therefore, this work was aimed to establish how defoliation, performed at veraison according to the local custom, can influence the physico-chemical composition of Nero di Troia grapes grown in Southern Italy and of the corresponding wines. In particular, the effects of three leaf removal treatments, differing for vine defoliation side and amounts of removed leaves, were compared to each other and to the results coming from non-defoliated control vines, with a specific focus on their consequence on grape and wine phenolic composition and colour parameters.

2. Materials and methods

2.1. Vineyard site and plant material

The field trial was carried out, in 2012 summer, at a privately owned vineyard located in San Ferdinando (Foggia province, Apulia region, 41°19′ N, 15°05′, altitude 68 m a.s.l.).

The climate of this area is Mediterranean semi-arid according to the De Martonne (1926) scale (aridity index = 18 within the 15–20 range defined as semi-arid). The annual mean temperature is 15.5 °C (maximum mean temperature 31.8 °C in July and August, minimum mean temperature 3.0 °C in February); mean annual rainfall is 470 mm, 34% of which in the warmer period, that is May–September. (CliNo, 1971–2000). The area totalizes 2170 GDD (IV region of the Winkler scale).

The soil is deep, calcareous, medium textured, fertile, and retains moisture in the deep layers.

Nero di Troia is one of the main red wine grape varieties grown in the Puglia and is the main component of many Controlled Designation of Origin wines. When grown in the Foggia province, this genotype shows a considerable vigour and produces lots of girth and large, rather compact, pyramidal clusters of violet coloured berries.

The vineyard was established in 2007 by planting vines of cv. Nero di Troia, grafted onto 140 Ru (*Vitis berlandieri* × *Vitis rupestris*) stock at 1.25 × 2.50 m apart, in N–S oriented rows. Vines were VSP trained and spur-cordon pruned. The cordon was positioned 0.60 m above the ground while the highest trellis wire was at 1.80 cm from the soil and the total canopy height reached about 2.20 m; the average main shoot length was 1.60 m.

In the year of the trial, the number of bunches per vine was 32 ± 1.

Fertilization was provided by means of soil applications, foliar nutrition and fertigation, with a total amount of about 45 kg N, 25 kg P_2O_5, 53 kg K_2O, 32 kg CaO, 20 kg MgO, 25 kg SO_3 per hectare; moreover, foliar application provided also about 50 kg alginic acid and 125 kg organic matter (both strong water soluble) per hectare.

Irrigation supplied about 1700 m^2 ha^{-1} of water, from July to early September, by a drip system.

2.2. Leaf removal treatments and leaf area evaluation

At complete veraison (mid August), the following four leaf removal treatments were manually applied:

- N: no leaf removal;
- E: 75% of fruit-zone leaves removed from the East canopy side;
- E/W: 75% removal of the fruit-zone leaves on the East and also on the West side of the canopy;
- F: Farm defoliation (2 steps), that is, almost 100% removal of fruit-zone leaves on the West side of the canopy at full veraison (1st step), plus almost 100% removal of fruit-zone leaves on the East side of the canopy about 15 days before grape harvest.

Defoliation percentage was visually estimated.

Treatments were replicated in three 4-row blocks; each replicate was assigned to one row and involved 16 vines.

In order to evaluate the amount of the removed and retained leaves consequent to the imposed treatments, the leaves removed from each replicate were immediately enclosed in plastic bags and transported to the lab where, after weighing, the weight-to-area ratio was applied using 100 leaf dishes (28 mm diameter) per replicate.

Moreover, aiming to express the data in terms of percentage of the total vine leaf area, half canopy of 5 representative vines was entirely defoliated and was subjected to the same procedure already described.

2.3. Field measurements

Measurements were taken in cloudless days of late summer (August 30th and 31st).

Air temperature and relative humidity at 2.00 m above the soil were measured (thermo-hygrometer HD 8501 H, Delta Ohm, PD, Italy) under midday conditions; average values were 33.37 ± 0.12 °C and 34.90 ± 0.31%.

When the East side of the canopy was fully lighted, the rate of photosynthetic active radiation (PAR) was measured as maximum photosynthetic photon flux (PPF) interceptable by orienting a solar bar (AccuPAR PAR/LAI LP-80, Decagon Dev. Inc. Pullman, WA, USA), and as PPF interceptable at the leaf surface of the East and of the West side of the vine canopy by positioning the solar bar along the canopy at 0.90 m above the cordon; 30 readings per type of measurements were recorded. The average values were the following: PPF max 1994.70 ± 2.63 μmol m^{-2} s^{-1}; PPF at East canopy side 1238.50 ± 6.71 μmol m^{-2} s^{-1}; PPF at West canopy side 95.10 ± 2.68 μmol m^{-2} s^{-1}. Immediately after, in order to assess the influence of the leaf removal treatments on the fruit-zone microclimate, PAR availability at East and at the West side of the vine canopy was measured by positioning the solar bar along the bunches and, moreover, the surface temperature of exposed bunches was measured using a non-contact infrared thermometer with laser pointer (TRI-88 Lafayette Electronic Supply Inc., Indiana, USA); 10 readings per each replicate and each type of measurement was recorded. The same set of measurements was taken in the afternoon, when the West side of the canopy was fully lighted. The average values of these readings are shown in Table 1. When the East canopy side was fully lighted, the photosynthetic photon flux intercepted at the east fruit-zone ranged from 236.17 μmol m^{-2} s^{-1} in the non defoliated vines (control) to