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# Influence of cane girdling and plastic covering on leaf gas exchange, water potential and viticultural performance of table grape cv. Matilde

by

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Summary: Canes of field-grown uncovered and covered (plastic film) table grapes, cv. Matilde, were girdled at veraison. Leaves of girdled vines displayed lower rates of transpiration on a leaf area basis and lower rates of $CO_2$ uptake; stem and leaf water potentials were decreased. Both, covering and cane girdling stimulated vegetative growth and increased leaf area per vine. However, sugar accumulation in berries and fruit quality were not affected by cane girdling and were slightly reduced by covering. Therefore, harvesting dates were not advanced. Cane girdling appeared to influence carbohydrate partitioning by stimulating shoot growth at the expense of fruit production. It is concluded that the stage of rapid sugar accumulation was not yet reached by the time girdling took place. The development of a larger transpiring leaf surface area per vine is supposed to have lowered the vine water status.

Key words: Vitis vinifera, table grape, leaf net $CO_2$ uptake, leaf transpiration, water relations, shoot growth.

## Introduction

Interruption of phloem translocation of photosynthates to the root system is known to improve carbohydrate availability to bunches, thereby enhancing sugar accumulation of seeded grapes and berry size of seedless grapes (Winkler *et al.* 1974). To achieve this, girdling has to be performed at the onset of berry ripening, *i.e.* veraison, when rates of sugar accumulation in berries are highest (Weaver and McCune 1959; Peacock *et al.* 1977; Roper and Williams 1989).

However, girdling may reduce rates of gas exchange per unit leaf area which has been attributed to a feed-back effect of increased carbohydrate concentrations in leaves (Kriedemann and Lenz 1972) or to the inhibiting effect of leaf ABA accumulation on stomatal conductance (Düring 1978; Setter *et al.* 1980). The reduction of stomatal conductance and leaf transpiration rate in girdled vines was associated with a higher leaf water potential; the latter has been suggested to have positive effects on berry size (Williams *et al.* 1994).

Girdling also has negative effects on some berry characteristics, *e.g.* decrease of the malic acid concentration in must, reduction of fruit palatability (Orth *et al.* 1994), and decrease of total soluble solids, delaying fruit ripening (Harrel and Williams 1987).

In Italy, girdling and plastic covering are widely used in order to advance the time of harvest. Girdling is performed on canes, usually above the first shoot destined to be used as a renewal cane the following year.

The aim of the present work was to verify whether cane girdling has any effect on the time of ripening and on the viticultural performance of *Vitis vinifera* L. cv. Matilde (Italia x Cardinal). This cultivar is very vigorous, has elongated berries and ripens in mid-August; it is widely grown in Italy either uncovered or covered.

## Material and Methods

The trial was performed in 1996 on two plots of 5-year-old Matilde grapevines grafted onto 775 P. Vines were spaced 2.4 m x 2.4 m and trained to a tendone system (double cane-pruned). Vineyards were located at a commercial farm in Corato (Apulia, Italy) and each plot comprised an area of 12,500 $m^2$.

In mid-February, one plot was covered with plastic film consisting of horizontal and vertical panels (0.18 mm thick polyethylene + ethylenvinylacetate, Orolene)), while the other plot remained uncovered.

Budbreak of covered vines occurred in the second week of April and that of uncovered vines in late April. Vegetative growth was periodically determined from early-May until the end of July on 8 single vine replicates per plot. On each vine, the primary shoots were counted and one primary shoot per cane was sampled to measure shoot length, leaf number, and, at alternate nodes, leaf length and width.

Starting on May 20, the vertical plastic film was partially wound up during the warmer part of the day to allow ventilation and to avoid overheating. One week after bloom, drip irrigation was started (2,500 $m^3$ $ha^{-1}$ until harvest). Girdling was performed when the first visual symptoms of veraison appeared, on June 25 for covered vines and on July 10 for uncovered vines. Half of the vines in each plot were randomly cane-girdled by means of a double-bladed plier.

At midday 7 d and, again, 15 d after girdling, leaf gas exchange and plant water potential were measured on 4 sin-

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gle vines per treatment, by means of a portable infra-red gas analyzer (ADC LCA4 system, Analytical Development Company, UK) and a pressure chamber (Soilmoisture Equipment Corp., CA, USA), respectively. The following parameters were determined: net $CO_2$ assimilation (A), stomatal conductance ($g_s$), transpiration (E), photosynthetic photon flux density (PPFD), ambient $CO_2$ concentration ($C_a$), relative air humidity (RH), ambient temperature ($t_a$), leaf temperature ($t_{leaf}$), leaf water potential ($\psi_{leaf}$) and stem water potential ($\psi_{stem}$). Leaf gas exchange was measured at the top part of the canopy, on 5 leaves per vine in the middle of the shoot. The same leaves were used to assess $\psi_{leaf}$, while $\psi_{stem}$ was measured on 5 leaves per vine, according to TURNER (1981).

Grapes were harvested approximately at 14 °Brix (the reference total soluble solids (TSS) for Matilde harvesting). At that time, the following parameters were determined on random samples of 15 bunches and 50 berries per vine: bunch and berry weight, berry diameter, titratable acidity (TA) and TSS. Moreover, fruit palatability was evaluated by tasting berry samples at harvest. After harvest, 50 leaves were sampled from primary shoots in each plot to measure leaf length, width, and area (Li-Cor 3100 leaf area meter, Li-Cor Inc., Lincoln, NE, USA). A regression equation relating leaf area to the independent variable 'leaf length x leaf width' (ELSNER and JUBB 1988) was used to estimate the development of the primary shoot leaf area per vine; for nodes where leaf length and width had not been periodically taken, leaf area was calculated by interpolation.

Data were statistically analyzed using SAS packages (SAS Institute, Cary NC, USA). Physiological data are presented as mean values of the two-day measurements.

## Results

Ambient conditions during physiological measurements are summarized in Tab. 1. Although highly significant, leaf and air temperature and relative humidity showed little variation between the two plots. However, as expected, under covered conditions (HANAN *et al.* 1978; DÜRING 1988; LORENZO *et al.* 1990) PPFD was lowered (-654 µmol $m^{-2}$ $s^{-1}$) and $C_a$ was slightly decreased (-10 µmol $mol^{-1}$). Vines showed no water stress (Tab. 2). $CO_2$ assimilation (A) was in the range reported by DOWNTON *et al.* (1987). The photosynthetic rate of girdled vines was about 8 µmol $m^{-2}$ $s^{-1}$ in both plots. Non-girdled vines tended to have higher rates of gas exchange and water potential: $CO_2$ assimilation +30 %, stomatal conductance +23 % and transpiration +15 % of uncovered vines as well as for leaf water potential (+6 %) and stem water potential (+11 %) of covered vines. As observed in previous studies, $\psi_{stem}$ was more sensitive as an indicator of plant water status than $\psi_{leaf}$ (MCCUTCHAN and SHACKEL 1992; NOVELLO and de PALMA 1997).

Table 1

Ambient conditions of covered and uncovered vines

| | Covered | Uncovered | Sign. |
|---|---|---|---|
| PPFD (µmol·$m^{-2}$·$s^{-1}$) | 875.1 | 1529.3 | *** |
| Ambient temperature (°C) | 38.1 | 37.3 | *** |
| Leaf temperature (°C) | 38.7 | 38.4 | ns |
| Ambient $CO_2$ (µmol·$mol^{-1}$) | 356.7 | 366.3 | *** |
| Relative air humidity (%) | 61.0 | 52.3 | *** |

Stars indicate significance at $p<0.05$ (*), $p<0.01$ (**), and $p<0.001$ (***). PPFD: see Material and Methods.

Compared to uncovered vines, covered vines showed a significant increase in primary shoot growth and leaf area until June 20. In late-July, when shoot growth stopped, covered vines had higher leaf areas per vine (12.09 $m^2$), mostly due to longer primary shoots (+77 %), with a higher number of leaves (+26 %) and larger leaf laminae (+21 %) (Tab. 3). This vegetative response may be due to the favorable microclimatic conditions, *e.g.* high temperatures and reduced levels of global and U.V. radiation (MORGAN and SMITH 1981; KLEIN *et al.* 1978), which also occur under greenhouse conditions (HANAN *et al.* 1978; LERCARI *et al.* 1992). Moreover, periodical measurements showed that girdled vines further increased their shoot growth (+24 %), leaf number per shoot (+15 %), and leaf area per vine (+17 %) in the covered plot, while in uncovered vines the leaf area per vine increased only by 5 % after girdling.

Ripening (14 °Brix) was reached on July 28 (covered) and on August 16 (uncovered), thus the time difference observed at budbreak was maintained. Fruit sample analyses

Table 2

Effects of girdling and covering on leaf gas exchange and water potential

| | Covered | | | Uncovered | | |
|---|---|---|---|---|---|---|
| | Girdled | Non-girdled | Sign. | Girdled | Non-girdled | Sign. |
| A (µmol·$m^{-2}$·$s^{-1}$) | 8.48 | 8.69 | ns | 7.85 | 11.14 | ** |
| $g_s$ (mmol·$m^{-2}$·$s^{-1}$) | 110.00 | 130.00 | ns | 100.00 | 130.00 | * |
| E (mmol·$m^{-2}$·$s^{-1}$) | 4.04 | 4.58 | ns | 3.99 | 4.69 | * |
| $\Psi_{stem}$ (MPa) | -0.82 | -0.74 | ** | -0.63 | -0.61 | ns |
| $\Psi_{leaf}$ (MPa) | -1.09 | -1.03 | * | -0.86 | -0.79 | ns |

Stars indicate significance at $p<0.05$ (*) and $p<0.01$ (**). A, $g_s$, E, $\Psi$: see Material and Methods.

Table 3

Effects of covering on vegetative characteristics at harvest

| | Covered | Uncoverd | Sign. |
|---|---|---|---|
| Shoot length (cm) | 269.50 | 152.10 | *** |
| Leaf number | 26.14 | 20.70 | ** |
| Leaf length (mm) | 110.80 | 95.20 | * |
| Leaf width (mm) | 146.80 | 121.60 | ** |
| Leaf area of primary shoot per vine ($m^2$) | 12.09 | 8.20 | * |

Stars indicate significance at $p<0.05$ (*), $p<0.01$ (**), and $p<0.001$ (***).

revealed that in covered vines cane girdling had a negative effect on bunch weight (-23 %), berry weight (-10 %), berry size (-3.5 %), TSS (-4 %) and TA (+12 %) (Tab. 4). In uncovered vines, cane girdling reduced berry diameters and accentuated elongation of berries. Other fruit characteristics were not significantly affected, even though a slight tendency for heavier bunches with smaller berries were observed in girdled vines.

On the whole, cane girdling negatively affected leaf gas exchange of uncovered vines, but had no relevant influence on their vegetative and reproductive performance. For covered vines, girdling markedly increased vigour, at the expense of qualitative and quantitative results.

No unpleasant taste, such as bitterness or grassiness, was found in berry samples from girdled vines.

## Discussion

Covering lowered differences between the leaf $CO_2$ assimilation rate of girdled and non-girdled vines. Among the ambient parameters tested in the experiment, PPFD and $C_a$ were possibly involved in this response since they were lowered by covering. Since PPFD under cover was close to the light saturation level (Kriedemann and Smart 1971), the reduction of light intensity was apparently not the main cause of limitation of photosynthetic activity. As for $C_a$, we calculated that a reduction by 10 $\mu$mol $mol^{-1}$ could lower A by about 3 $\mu$mol $m^{-2}$ $s^{-1}$, which is close to the leaf net $CO_2$ assimilation difference found between uncovered and covered vines. However, a decline in carboxylation efficiency for the protected vines could also be hypothesized, assuming that changes in light intensity and leaf temperature were small and not effective under our experimental conditions (Düring 1988).

Cane girdling not only lowered leaf gas exchange, but also plant water potential. Williams *et al.* (1994) found higher leaf water potentials in trunk-girdled compared to non-girdled vines. They pointed out that this response is related to a concomitant decline in leaf transpiration and excluded xylem damage caused by girdling. In the present study, the hypothesis of xylem damage affecting photosynthesis is supported by the differences in water potential between girdled and non-girdled vines; however, it is in contrast with results obtained in terms of vegetative growth. The increase of leaf area and shoot growth after cane girdling, causing an increase in total vine transpiration and consequently a decrease of water potential, could have masked the occurrence of any reduction of xylem flux.

Both covering and cane girdling stimulated growth, thus the synergistic effect of the treatments resulted in a very high leaf area per vine. On the other hand, cane girdling did not enhance sugar accumulation in berries of uncovered vines and slightly reduced it in covered vines. Thus the date of harvest was not advanced. Cane girdling apparently influenced carbohydrate partitioning, inducing higher shoot growth to the disadvantage of fruit production. This response might be explained by assuming that the stage of rapid sugar accumulation had not yet been reached by the time of girdling. Under these conditions, most of the carbohydrates could have been utilized for vegetative growth instead of sugar accumulation in berries. This reaction was probably enhanced by the high vigour; the development of a greater transpiring leaf area per vine might account for the lowering of the plant water status (Kramer and Boyer 1995).

Table 4

Effects of covering and girdling on yield structure and grape composition

| | Covered | | | Uncovered | | |
|---|---|---|---|---|---|---|
| | Girdled | Non-girdled | Sign. | Girdled | Non-girdled | Sign. |
| Yield per vine (kg) | 26.2 | 34.1 | * | 42.7 | 39.0 | ns |
| Bunch weight (g) | 782.3 | 1018.9 | * | 965.0 | 882.0 | ns |
| Berry weight (g) | 6.8 | 7.6 | ** | 7.6 | 7.9 | ns |
| Berry length (mm) | 25.3 | 26.0 | ** | 27.6 | 27.5 | ns |
| Berry width (mm) | 21.6 | 22.4 | ** | 21.9 | 22.4 | ** |
| Berry length:width ratio | 1.17 | 1.16 | ns | 1.26 | 1.23 | ** |
| TSS (°Brix) | 13.5 | 14.1 | * | 14.0 | 13.8 | ns |
| Titratable acidity (meq·$l^{-1}$) | 72.0 | 60.0 | * | 86.7 | 90.7 | ns |

Stars indicate significance at $p < 0.05$ (*) and $p < 0.01$ (**).

Positive effects of girdling might be obtained by delaying girdling so that sugar transport to the berries is intensified at the expense of sugar transport to vegetative organs.

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