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Water relations of grapevine cv. Cortese with different training systems[1])

by

V. NOVELLO[2]), A. SCHUBERT[3]), M. ANTONIETTO[3]) and A. BOSCHI[3])

[2]) Centro di Studio per il Miglioramento Genetico della Vite, C.N.R., Torino, Italia

[3]) Istituto di Coltivazioni Arboree dell'Università di Torino, Italia

Relations hydriques de vignes du cépage Cortese élevées sous différents systèmes de conduite

Résumé: Le potentiel hydrique des feuilles (LWP) et des tiges et la conductance stomatique (SC) ont été mésurés le long du jour sur des plantes de vigne élevés sous quatre systèmes de conduite: vigne palissée en taille Guyot, rideau simple, système Y, rideau double. Pendant la plupart du jour LWP a été plus réduit dans les vignes en Guyot tandis que le gradient de potentiel entre feuille et tige a été plus élevé chez le même système de conduite. Au contraire, les différences au niveau de SC ont été négligeables. Le potentiel osmotique de la feuille a peu changé le long du jour et entre les systèmes de conduite. Les vignes en Guyot ont produit moins de raisins et de sucre. Le mode de conduite peut affecter les relations hydriques de la vigne et donc modifier la production et la qualité du moût.

Key words: training, microclimate, transpiration, hydration, leaf, shoot, yield, must quality.

Introduction

The availability of water to leaves and clusters of cultivated grapevines influences both yield and berry composition (SMART and COOMBE 1983). In dry climates the water status of grapevines can be regulated by controlling the soil water supply, by means of irrigation. This technique is, however, unsuitable or forbidden in temperate viticultural areas, where it results in an excessive delay of ripening (CALAME 1984; MCCARTHY and COOMBE 1985; RÜHL and ALLEWELDT 1985); under these conditions other factors may relevantly influence the plant water status.

Several findings suggest that the training system may affect water relations of the grapevine. Stomatal conductance and transpiration are strongly reduced when grapevine leaves are shaded (SMART 1974); the training system used in the vineyard defines the canopy shape and leaf density, and may thus influence the degree of shading and the relative humidity within the canopy (VAN ZYL and VAN HUYSSTEEN 1980; SMART and COOMBE 1983). The height of the cane or the cordon in different training systems, and consequently the upward or downward shoot direction, may affect vine hydraulic conductivity (ZHANG and CARBONNEAU 1987) and water balance (BRANAS 1969; VAN ZYL and VAN HUYSSTEEN 1980). CARBONNEAU *et al.* (1978) observed that shoot vigor declines with the height of the trunk.

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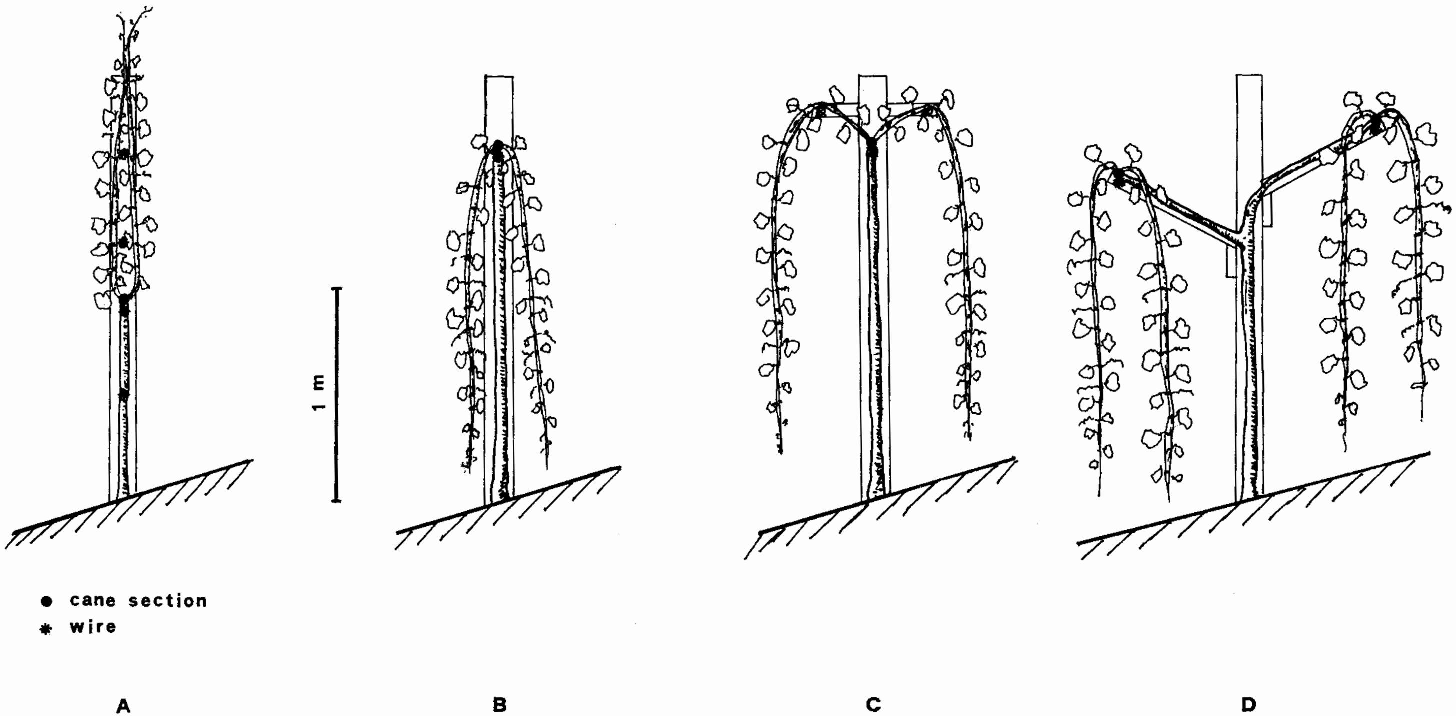


Fig. 1: Training systems tested for their effects on water relations (cross sectional sketches): A) traditional trellis; B) central curtain; C) Y trellis; D) double curtain.

Systèmes de conduite dont les effets sur les relations hydriques ont été etudiées (section transversale): A) vigne taillée en Guyot; B) rideau simple; C) système Y; D) rideau double.

Although the literature on water relations of woody plants is very extensive (KOZLOWSKI 1968, 1972, 1974; JONES *et al.* 1985), surprisingly little information concerns the influence of training systems on water relations (GRANT and RYUGO 1983; CARBONNEAU and LOTH 1985; JONES *et al.* 1985). Consequently, we report in this paper the results of a field experiment where the effects of different training systems on grapevine water relations and yield were studied.

Materials and methods

Plants of *Vitis vinifera* L. cv. Cortese, grafted on *V. berlandieri* × *V. riparia* Kober 5 BB, were planted in 1979 at 3.10 m × 1.20 m in a vineyard located at Incisa Scapaccino, in the Asti province, Italy. The soil was sandy clay loam, with 30 % slope; soil water content was uniform in all parts of the vineyard, as we observed by psychometric soil water potential measurements in 1985. No irrigation was applied.

Cortese is a white grape variety, very vigorous, with large shoots which grow downwards when free. Row orientation was NE to SW, perpendicular to the hill slope. The plants were pruned to the following training systems in randomized block design (three rows each):

Traditional trellis: (Fig. 1 A): An 8-bud cane and a 2-bud spur were left on each vine; the fruiting cane was trained to a horizontal wire 0.90 m high, shoots were trained upright and tied to a wire 1.80 m high.

Central curtain (Fig. 1 B): Pruning was as above but canes were trained on a wire 1.60 m high, then shoots were allowed to grow freely.

Y trellis (Fig. 1 C): This was a modification of the previous system, where the shoots, originated from a cane trained on a wire 1.60 m high, were trained upon two horizontal wires 1.80 m high, 0.25 m apart from the central wire, and then allowed to grow freely.

Double curtain (Fig. 1 D): This method was essentially similar to the Duplex system. Because of the soil slope, the crossarms were fixed to the poles at different heights, in order to keep the wires at 1.60 m above soil and 0.60 m apart from the row axis on both sides of the row (ELIA *et al.* 1982). Two 8-bud canes and one 2-bud spur were left to each plant; canes were separately trained on one of the wires, shoots were allowed to grow freely. With this system plants had roughly twice the number of buds than in the other treatments (NOVELLO *et al.* 1988).

Plants were subjected to standard viticultural operations; summer pruning was reduced to a light shoot topping to allow mechanical soil cultivation in the three non-traditional systems.

Plant water status was measured on different days during July 1985 and July 1986, the months having the lowest rainfall in the two growing seasons. Data were recorded at 1-h intervals, from 0600 to 2000. At each time of measurement stomatal conductance and leaf temperature were measured on 5 fully developed leaves per treatment, with a Li-Cor LI-1600 steady-state porometer. Leaves were selected at the central node of the central shoot of vines, in a position fully exposed to sunlight.

After the porometric measurement, the leaves were detached and inserted into a PMS pressure chamber for measurement of water potential. Thereafter, the leaves were rapidly frozen in liquid nitrogen and stored at −20 °C. Osmotic concentration in mosmol/100 g was subsequently measured after standard thawing of the leaves to ambient temperature. Leaves were then pressed, and 100 µl sap samples were processed in a Roebling Automatik microosmometer; osmotic potential was then calculated using standard solutions. In this case one measurement in double was taken per treatment and per sampling time.

At harvest, the clusters of 16 vines per treatment were collected, weighed, pressed,

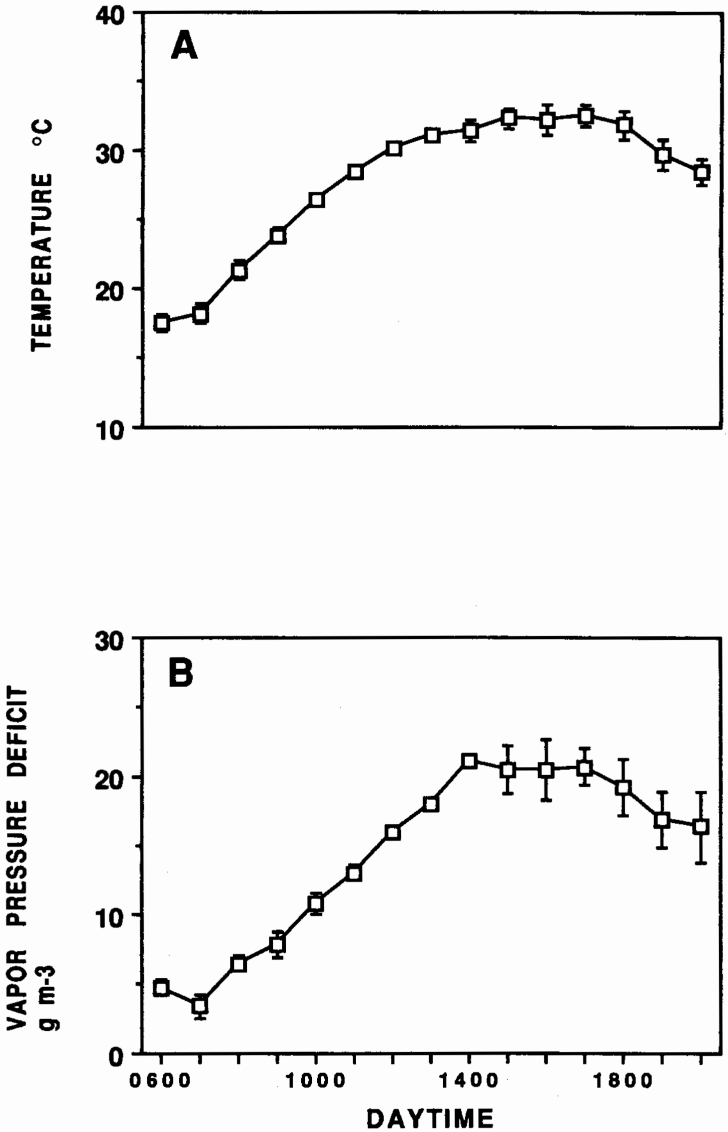


Fig. 2: Average temperature (A) and vapor pressure deficit (B) of air surrounding the leaves in the 4 days of measurement.

Température moyenne (A) et déficit de pression de vapeur (B) de l'air autour des feuilles dans les 4 jours de mesure.

and total soluble solids were assessed on 1-l must samples by refractometry.

In July 1988, measurements of leaf and stem water potential were carried out on a single day from 1000 to 1830. For the leaf water potential measurements, leaves were covered with plastic bags immediately before their excision, and then inserted in the pressure chamber. Stem water potential was estimated by means of leaves which had been enclosed in radiation reflecting plastic bags 1 d before taking measurements, assuming that water potential of covered (not transpiring) leaves equilibrates with shoot water potential after 24 h (LIU *et al.* 1978; TURNER and LONG 1980; GARNIER and BERGER 1985). In both cases water potential was measured by inserting the bagged, excised leaves into the pressure chamber.

Data were analyzed using the ANOVA procedure, with a randomized block design.

Results

As the measurements taken showed a large variability among leaves, probably due to the fact that the sampled leaves were not of the same age, data from 4 different days

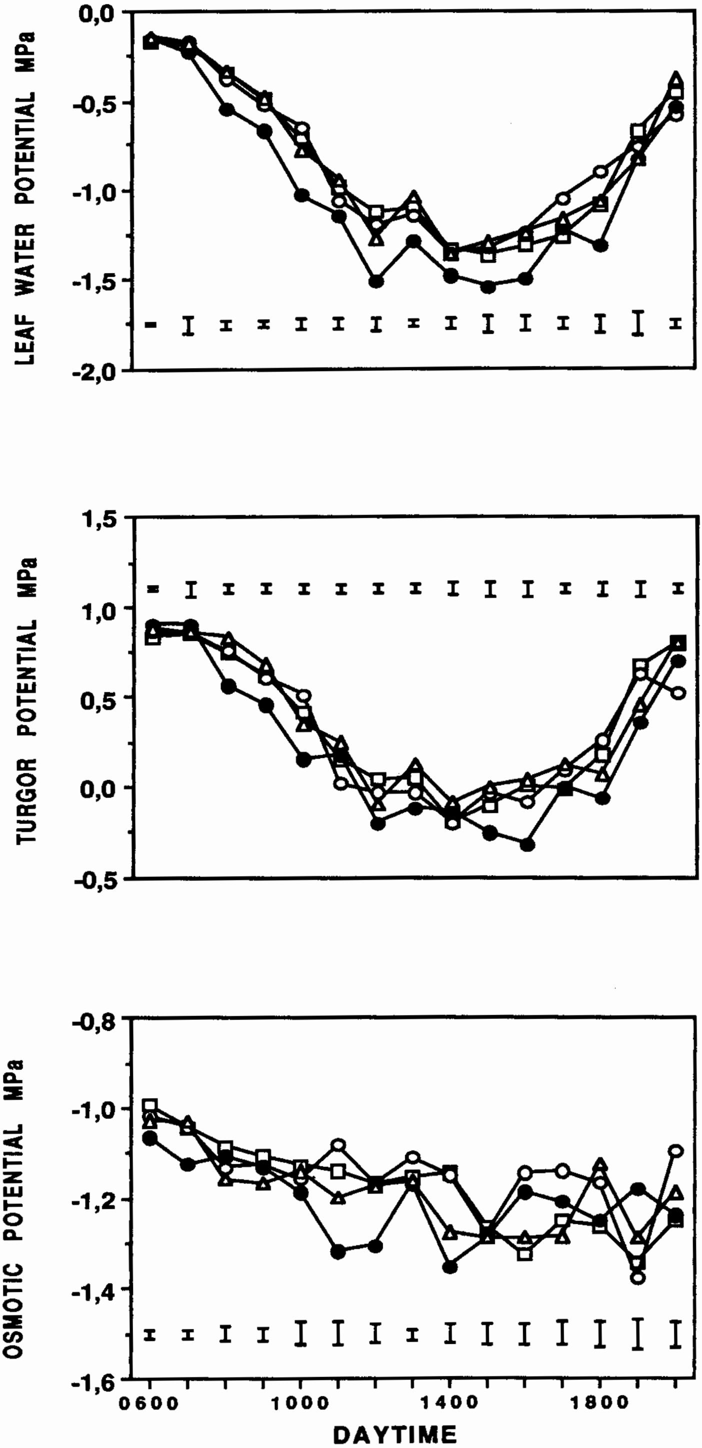
Table 1

Leaf and stem water potential and leaf to stem water potential gradient, 1988

Potentiel hydrique de feuilles et de tiges, et gradient de potentiel hydrique entre feuille et tige, 1988

Time	Traditional trellis	Central curtain	Y trellis	Double curtain
		Leaf water potential (MPa)		
10.00	−0.66 b[1])	−0.59 c	−0.69 a	−0.51 d
12.00	−0.95	−0.93	−0.83	−0.82
14.30	−0.98	−0.89	−0.83	−0.89
16.30	−0.87	−0.90	−0.78	−0.78
18.30	−0.61	−0.59	−0.56	−0.54
		Stem water potential (MPa)		
10.00	−0.23 ab	−0.27 a	−0.19 b	−0.25 ab
12.00	−0.28	−0.38	−0.34	−0.41
14.30	−0.41	−0.35	−0.38	−0.39
16.30	−0.44	−0.41	−0.45	−0.43
18.30	−0.48 a	−0.33 ab	−0.34 ab	−0.26 b
		Gradient (MPa)		
10.00	−0.43	−0.32	−0.50	−0.26
12.00	−0.67	−0.55	−0.49	−0.41
14.30	−0.57	−0.54	−0.45	−0.50
16.30	−0.43	−0.49	−0.33	−0.35
18.30	−0.13	−0.26	−0.22	−0.28

[1]) For each measurement time, means with the same superscript letters are not significantly different at P = 0.05; where letters are omitted no significances were found.


0,0
-0,5
-1,0
-1,5
-2,0
LEAF WATER POTENTIAL MPa
1,5
1,0
0,5
0,0
-0,5
TURGOR POTENTIAL MPa
-0,8
-1,0
-1,2
-1,4
-1,6
OSMOTIC POTENTIAL MPa
0600
1000
1400
1800
DAYTIME

were pooled and analyzed together, in order to gain a better understanding of the differences between treatments. The days which were chosen had reasonably uniform temperature and humidity, both above the canopy and near the leaves (Fig. 2).

Leaf (LWP) and stem water potential: With all training systems LWP decreased from 0600 to the warmest hours of the day, generally 1500, reaching values as low as −1.5 MPa. Thereafter LWP increased again, to reach values only slightly lower at 2000 than at 0600 (Fig. 3). The same diurnal pattern has been shown by DÜRING and LOVEYS (1982).

Among the training systems, the traditional trellis showed, at most measurement times, a potential about 0.2 MPa lower than the other ones, this difference being reduced or absent in the early and late hours of the day. An overall statistically significant difference was observed among the traditional trellis and the other systems. In 1988, leaves protected from water loss just before excision showed a similar trend (Table 1). As this year was less dry than the previous ones, LWP values were less negative. Stem water potential was about the same in all treatments (Table 1), but the traditional trellis showed a continuous decline during the day, without recovering at the last measurement as the other trellis systems did. The gradient between stem and leaf water potential was higher in the traditional trellis during the middle part of the day (from 1200 to 1430).

Osmotic water potential: Vines in all treatments showed limited diurnal osmotic change; leaf osmotic potential decreased only slightly, from about −1.0 MPa at 0600, to an average of −1.2 MPa at the end of the day (Fig. 3). At some measurement times the traditional trellis had an osmotic potential lower than those of the other systems.

Turgor potential was estimated by subtracting osmotic potential from leaf water potential. Even though the interpretation of this difference as an estimate of

Table 2

Yield (t/ha) and concentration of soluble solids (° Brix) of grapevines with different training systems

Production de raisins (t/ha) et concentration en sucres (° Brix) du moût de vignes élevées selon différents modes de conduite

Training systems	Yield (t/ha)			Soluble solids (° Brix)		
	1985	1986	1987	1985	1986	1987
Traditional trellis	8.75 c[1])	10.37 c	10.77 b	18.4 a	17.3 a	16.0 a
Central curtain	11.28 c	9.62 c	12.71 b	17.8 a	18.2 a	15.6 a
Y trellis	21.09 b	16.80 b	13.48 b	18.0 a	17.8 a	16.2 a
Double curtain	30.19 a	23.43 a	26.28 a	16.6 a	17.5 a	16.2 a

[1]) For each column, means with the same superscript letters are not significantly different at P = 0.05.

Fig. 3: Water potentials of grapevine leaves with different training systems (●, traditional trellis; □, central curtain; Δ, Y trellis; ○, double curtain). Bars represent standard errors for each measurement time.

Potentiel hydrique de feuilles de vignes élevées sous différents systèmes de conduite (●, vigne taillée en Guyot; □, rideau simple; Δ, système Y; ○, rideau double). Les traits verticaux représentent les écarts types à chaque échantillonnage.

turgor is controversial, especially in the case of negative values (TYREE 1976), the data may indicate relative turgor values (SHACKEL *et al.* 1982). The traditional trellis generally had the lowest estimated turgor (Fig. 3), in comparison with the other systems, with overall statistically significant differences.

Stomatal conductance followed an increasing trend from the early morning up to 1500, then decreased (Fig. 4). The traditional trellis, which had the lowest LWP values, in this case was intermediate among the other systems. The double curtain had conductances significantly lower than those of the other systems.

Yield and must composition: Total yield in the traditional trellis was lower than in the double curtain and in the Y system (Table 2). The concentration of soluble solids in the must showed no significant differences among training systems; as a consequence, the production of sugars per plant (approximated as must yield × °Brix/100) was in both years lower in the traditional trellis than in the other systems.

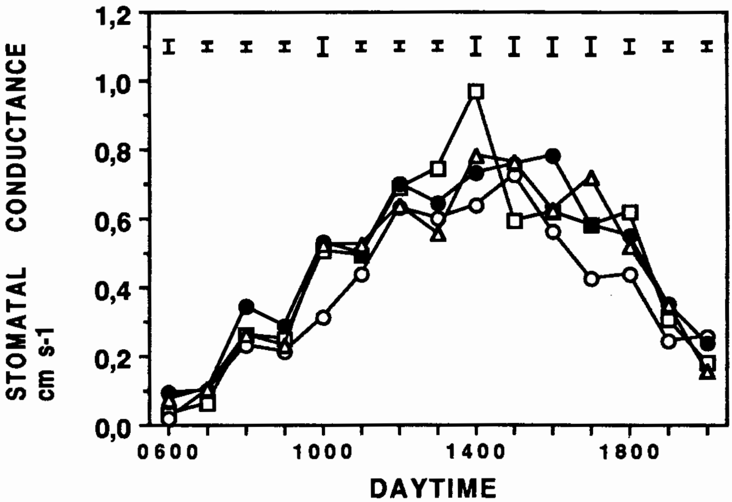


Fig. 4: Stomatal conductance to water vapor of grapevine leaves in different training systems. For symbols see caption to Fig. 3.

Conductance stomatique pour la vapeur d'eau de feuilles de vignes élevées sous différents systèmes de conduite. Pour les symboles v. Fig. 3.

Discussion

Grapevine training systems are normally designed or chosen taking into account their effects on the equilibrium between vegetative growth and yield, on the interception of solar radiation and on the possibility to ease operations such as pruning and harvesting.

Our results show that training systems may also affect water relations in the plant, even in a location typical of temperate climate viticulture, which does not normally experience severe drought periods.

In our work the traditional trellis showed LWPs significantly lower than the other systems, which, in two cases out of three, differed from it only in the geometrical distribution of the canopy. This decrease of LWP may be explained by higher transpiration in this training system, and this is confirmed by the larger stem-leaf water potential gradient observed (LIU *et al.* 1978). Since traditional trellis had lower leaf area, this could be explained by the higher radiation per unit leaf area (GRIBAUDO *et al.* 1988) and the reduction of boundary layer, caused by the open and thin structure of the canopy.

No differences were found between the traditional trellis and the other systems as concerns stomatal conductance, which is directly related to transpiration. This apparent discrepancy may be explained by the fact that leaves sampled for stomatal conductance were located at the external surface of the canopy, and were exposed to similar radiation and vapor pressure gradient in all training systems; on the contrary, the leaves used to assess stem to leaf water potential gradient were representative of the whole canopy. Microclimatic conditions, which influence stomatal conductance, may differ among the training systems when measured inside, and not on the surface of the canopies; this possibility is partly confirmed by the findings of GRIBAUDO *et al.* (1988) who showed that average radiation received per unit leaf area differs considerably among the same training system which were studied in this work in the same experimental field. Thus, a higher water loss from the leaves located inside the canopy of the traditional trellis trained vines may not have been reflected by porometer measurements taken in the external leaves. The decrease in LWP caused by high transpiration would, however, be observed in all leaves, including those at the canopy surface.

Osmotic potential remained fairly constant during the day. Osmotic adjustment has been reported in stressed vines only on apical leaves but not for mature leaves (DÜRING 1984). Thus, traditional trellis vines had, at most measurement times, turgor pressures 0.1—0.2 MPa lower than those of the other systems. Negative values of turgor have been previously shown (ACOCK and GRANGE 1981; SHACKEL *et al.* 1982; SHACKEL and HALL 1983; GIULIVO *et al.* 1985; NOVELLO and CRAVERO 1987). TYREE (1976) suggested that negative values of turgor resulted from dilution of the sap by cell wall water, causing overestimation of osmotic potential. However, SHACKEL (1982) supports the hypothesis that negative turgor potentials may occur regularly under field conditions and would not be associated with plasmolysis.

Grapevine water relations may affect quantity and quality of production (SMART and COOMBE 1983). In our case the traditional trellis trained vines gave lower yield and total sugar than the double curtain or Y trained ones. While the double curtain had the advantage of higher bud charge, this was not true for the Y system. A first explanation of the lower yield and number of clusters of the traditional trellis was given previously (GRIBAUDO *et al.* 1988; NOVELLO *et al.* 1988), observing that vines trained in this way received a lower amount of total radiation and had lower leaf surface. In addition, the present results show that these vines had higher stem water potential, which is considered an effective indicator of plant water status (GARNIER and BERGER 1985) and thus may have favored vegetative growth at the expenses of yield; a lower ratio between dry weight of clusters and dry weight of vegetative organs was actually observed for the traditional trellis, as opposed to the other systems (GRIBAUDO *et al.* 1988).

In temperate areas, where vineyards are normally not irrigated, the training system may be an important factor influencing water relations, and thus yield and must quality. Throughout the viticultural areas of the world, new training systems are being developed and traditional ones are being critically revised in order to reduce production costs and to increase grape quantity or, more often, quality. Testing these training systems for their effects on water relations may give a better insight into their potential influence on grape production.

Summary

Leaf (LWP) and stem water potential and stomatal conductance (SC) were measured during the day on grapevines trained with four different systems: traditional trellis, central curtain, Y trellis and double curtain. During most of the day LWP was lower and the stem to leaf water potential gradient was higher in the traditional trellis than in the other systems. On the contrary, very few differences were found as regards SC. Osmotic potential changed little during the day and among treatments. Traditional trellis vines had lower yield and total sugar production. The conclusion is drawn that training systems can affect water relations and in this way influence yield and must quality.

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Literature cited

ACOCK, B.; GRANGE, R. I.; 1981: Equilibrium models of leaf water relations. In: ROSE, D. A.; CHARLES-EDWARDS, D. A. (Eds.): Mathematics and Plant Physiology, 28—47. Academic Press, London.

BRANAS, J. (Ed.); 1969: 1er Symposium sur la Mode de Conduite Haute de la Vigne. Données Théoriques Fondamentales. O.I.V. , Montpellier.

CALAME, F.; 1984: Essais d'irrigation de la vigne à Leytron (Valais). Résultats intermédiaires. Rev. Suisse Viticult. Arboricult. Hort. **16**, 327—333.

CARBONNEAU, A.; CASTERAN, P.; LECLAIR, PH.; 1978: Essai de détermination en biologie de la plante entière de relations essentielles entre le bioclimat naturel, la physiologie de la vigne et la composition du raisin. Ann. Amélior. Plantes **28**, 195—221.

— — ; LOTH, CH.; 1985: Influence du régime d'éclairement journalier sur la résistance stomatique et la photosynthèse brute chez *Vitis vinifera* L. cv. Cabernet Sauvignon. Agronomie **5**, 631—638.

DÜRING, H.; 1984: Evidence for osmotic adjustment to drought in grapevines. Vitis **23**, 1—10.

— — ; LOVEYS, B. R.; 1982: Diurnal changes in water relations and abscisic acid in field grown *Vitis vinifera* cvs. I. Leaf water components and leaf conductance under humid temperate and semiarid conditions. Vitis **21**, 223—232.

ELIA, P.; BOVIO, M.; PARENA, S.; 1982: L'allevamento della vite a doppia cortina in funzione della potatura e della vendemmia meccanica. Quad. Vitic. Enol. Univ. Torino **6**, 393—404.

GARNIER, E.; BERGER, A.; 1985: Testing water potential in peach trees as an indicator of water stress. J. Hort. Sci. **60**, 47—56.

GIULIVO, C.; PONCHIA, G.; OSELE, F.; PITACCO, A.; 1985: Studies on water relations of grapevine (*Vitis vinifera*). Effects of sinks on leaf water potential and transpiration in non-limiting soil water conditions. Acta Hort. **171**, 159—166.

GRANT, J. A.; RYUGO, K.; 1983: Influence of within-canopy shading on net photosynthetic rate, stomatal conductance, and chlorophyll content of kiwifruit leaves. HortScience **19**, 834—836.

GRIBAUDO, I.; SCHUBERT, A.; NOVELLO, V.; 1988: Produzione di sostanza secca ed intercettazione di energia luminosa nel vitigno 'Cortese' in quattro forme di allevamento. Vignevini **15** (3), 53—56.

JONES, H. G.; LAKSO, A. N.; SYVERTSEN, J. P.; 1985: Physiological control of water status in temperate and subtropical fruit trees. Hort. Rev. **7**, 301—344.

KOZLOWSKI, T. T.; 1968, 1972, 1974: Water Deficits and Plant Growth. Vols. **I**, **III**, **IV**. Academic Press, New York.

LIU, W. T.; WENKERT, W.; ALLEN, L. H. JR.; LEMON, E. R.; 1978: Soil plant water relations in a New York vineyard: resistances to water movement. J. Amer. Soc. Hort. Sci. **103**, 226—230.

McCarthy, M. G.; Coombe, B. G.; 1985: Water status and winegrape quality. Acta Hort. **171**, 447—456.

Novello, V.; Boschi, A.; Bo, G.; 1988: Confronto fra quattro forme di allevamento della vite (cultivar 'Cortese') con piante singole e binate. L'Informatore Agrario **44** (26), 59—70.

— — ; Cravero, M. C.; 1987: Relazioni idriche in viti cv. 'Barbera' in tre diverse forme d'allevamento. Quad. Vitic. Enol. Univ. Torino **11**, 153—166.

Rühl, E.; Alleweldt, G.; 1985: Investigations into the influence of time of irrigation on yield and quality of grapevines. Acta Hort. **171**, 457—462.

Shackel, K. A.; 1982: Genotypic differences in osmotic potential and water relations for sorghum and cowpea under field conditions. Ph. D. Diss., Univ. of California, Riverside.

— — ; Foster, K. W.; Hall, A. E.; 1982: Genotypic differences in leaf osmotic potential among grain sorghum cultivars grown under irrigation and drought. Crop Sci. **22**, 1121—1125.

— — ; Hall, A. E.; 1983: Comparison of water relations and osmotic adjustment in sorghum and cowpea under field conditions. Austral. J. Plant Physiol. **10**, 423—435.

Smart, R. E.; 1974: Aspects of water relations of the grapevine (*Vitis vinifera*). Amer. J. Enol. Viticult. **25**, 84—91.

— — ; 1985: Principles of grapevine canopy microclimate manipulation with implications for yield and quality. A review. Amer. J. Enol. Viticult. **36**, 230—239.

— — ; Coombe, B. G.; 1983: Water relations of grapevines. In: Kozlowski, T. T. (Ed.): Water Deficits and Plant Growth, Vol. **VII**, 137—196. Academic Press, London.

Turner, N. C.; Long, M. J.; 1980: Errors arising from rapid water loss in the measurement of leaf water potential by the pressure chamber technique. Austral. J. Plant Physiol. **7**, 527—537.

Tyree, M. T.; 1976: Negative turgor pressure in plant cells: fact or fallacy? Can. J. Bot. **54**, 2738—2746.

Van Zyl, J. L.; Van Huyssteen, L.; 1980: Comparative studies on wine grapes on different trellising systems. I. Consumptive water use. II. Micro-climatic studies, grape composition and wine quality. S. Afr. J. Enol. Viticult. **1**, 7—14, 15—25.

Zhang, D. P.; Carbonneau, A.; 1987: Etude du trajet de la sève brute en fonction de la longueur du tronc chez la vigne. In: Physiologie de la Vigne. 3. Symp. Intern. Physiologie de la Vigne, Bordeaux, 24.—27.6.1986, 190—196. O.I.V., Paris.

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Correspondence to:

V. Novello
Istituto Coltivazioni Arboree
Via P. Giuria, 15
I-10126 Torino
Italia