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Canopy microclimate modification for the cultivar Shiraz
II. Effects on must and wine composition

by

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Veränderungen des Mikroklimas der Laubwand bei der Rebsorte Shiraz
II. Beeinflussung der Most- und Weinzusammensetzung

Zusammenfassung: Bei der Rebsorte Shiraz wurde das Ausmaß der Beschattung innerhalb der Laubwand künstlich durch vier Behandlungsformen sowie natürlicherweise durch einen Wachstumsgradienten variiert. Beschattung bewirkte in den Traubenmosten eine Erniedrigung der Zuckergehalte und eine Erhöhung der Malat- und K-Konzentrationen sowie der pH-Werte. Die Weine dieser Moste wiesen ebenfalls höhere pH- und K-Werte sowie einen verringerten Anteil ionisierter Anthocyane auf. Statistische Berechnungen ergaben positive Korrelationen zwischen hohen pH- und K-Werten in Most und Wein einerseits und der Beschattung der Laubwand andererseits; die Farbintensität sowie die Konzentrationen der gesamten und ionisierten Anthocyane und der Phenole waren mit der Beschattung negativ korreliert.

Zur Beschreibung der Lichtverhältnisse in der Laubwand wurde ein Bonitierungsschema, das sich auf acht Merkmale stützt, verwendet; die hiermit gewonnenen Ergebnisse korrelierten mit Zucker, pH- und K-Werten des Mostes sowie mit pH, Säure, K, Farbintensität, gesamten und ionisierten Anthocyanen und Phenolen des Weines. Starkwüchsige Reben lieferten ähnliche Werte der Most- und Weinzusammensetzung wie solche mit künstlicher Beschattung.

Key words: climate, light, growth, must quality, wine quality, malic acid, potassium, acidity, anthocyanin.

Introduction

This paper is a companion to that by SMART *et al.* (1985), which described the effect of canopy manipulation on the radiation microclimate. Now the effects of microclimate change on must and wine composition are investigated.

The previous paper proposed that the effects of soil, climate and cultural practice on must composition and wine quality could be understood, at least in part, by recognising the effect of these factors on canopy microclimate.

A number of factors can cause stimulation of grapevine vigour and concomitantly yield, and unless there are changes made to the training system, increased within-canopy shading can be the consequence. Given that shading reduces wine quality as is demonstrated here, we believe that considering microclimate leads to an explanation of the common observation that high yields lead to reduced quality.

Recent studies have demonstrated an effect of canopy microclimate on must composition and wine quality (CARBONNEAU and HUGLIN 1982; SMART 1982). Common quality defects for Australian dry red table wines are high pH and low colour and phenol content (SOMERS 1975). The present study was designed to investigate whether a shaded

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canopy microclimate is associated with these problems. Four different methods of managing grapevine canopies were studied, as well as a naturally occurring variation in vine vigour, for effects on microclimate and must and wine composition. Furthermore, a system of visually assessing grapevine canopies was evaluated for association with must and wine composition.

Materials and methods

1. Vineyard treatments

Full details of the experimental site are given by SMART *et al.* 1985. Four treatments were used to provide a range of canopy microclimates:

Treatment 1 — shade (T1): The vine foliage was constrained into a smaller volume using a thin filament bird netting. This produced a very shaded microclimate.

Treatment 2 — slash (T2): Shoots were trimmed to about 9 nodes per shoot.

Treatment 3 — control (T3): The canopies grew in the normal growth habit.

Treatment 4 — GDC (T4): The vines were trained to Geneva double curtain with proper shoot positioning as described by SHAULIS *et al.* 1966.

There were nine replicates of each treatment. The blocks were arranged across a pronounced vigour measurement, with block 9 plots the most vigorous, and block 1 the least. The companion paper, SMART *et al.* 1985, outlined viticultural and microclimate measurements.

2. Fruit and wine measurements

50 berry samples were taken from each plot during ripening (9 February and 24 February). Juice was separated by pressing berries against a fine screen and then centrifuging before sugar, acid and pH determination. Samples diluted 1 : 1 were frozen for subsequent K and organic acid analysis.

The fruit from each plot was processed into wine using a procedure described by SMART (1982). Yields ranged from 7.4 to 30.5 kg/vine, with an average of 17.1 kg. Each must was adjusted to 7 g/l titratable acidity at the onset of fermentation. Many of the wines produced H_2S during fermentation which was treated with up to 3 ppm Cu^{2+} prior to bottling.

Organic acid analyses were made with HPLC and cation concentrations by flame photometry. The spectral measurements due to SOMERS and EVANS (1977) were used.

Sensory evaluation was carried out on 20 October 1981, by six experienced enologists from the Australian wine industry. Ten different wines were presented to each judge in each of four sessions. Within each session, at least two wines were repeated to allow assessment of the judge's performance. The other eight wines consisted of two replicates of four treatments. Wines from replicate one were not subjected to evaluation due to presence of H_2S. Wines were scored with standard Australian Wine Show system (3 points for colour, 7 points for bouquet and aroma and 10 points for palate). Subjective ratings were also given for colour density and hue, and fruit flavour on the palate and nose (ex 5 points).

Taster reliability was evaluated by performing an analysis of variance on the pairs of scores for the eleven duplicated wines. The intraclass correlation coefficient was calculated as a measure of reliability.

Results

1. Fruit composition

Changes in fruit composition during ripening are shown in Table 1. Delayed maturity was evident for T1 shade, T2 slash and T4 GDC early in the period, but at harvest there was no significant difference. Juice K concentration and pH were lower for T4 GDC over the period, the highest for T1 shade. Malic acid levels were highest for T1 shade at 24 February. Replicate effects were significant only for sugar concentration, being highest on the low vigour plots.

Table 1

Changes in fruit composition during ripening

Die Veränderung der Beerenzusammensetzung während des Reifeverlaufes

Variable	Treatment				5 % LSD
	T1 shade	T2 slash	T3 control	T4 GDC	
9 February					
Sugar (° Brix)	15.2	17.2	18.5	16.6	1.3
Titratable acidity (g/l)	10.1	9.1	8.3	10.4	0.6
pH	3.16	3.13	3.21	3.05	0.03
K (ppm)	1 760	1 840	1 770	1 730	NS
Tartaric acid (g/l)	7.8	7.8	7.3	7.8	NS
Malic acid (g/l)	4.5	3.8	3.6	4.6	NS
24 February					
Sugar (° Brix)	18.5	20.2	21.3	19.5	1.0
Titratable acidity (g/l)	7.1	6.4	6.1	6.7	0.5
pH	3.54	3.44	3.54	3.36	0.04
K (ppm)	2 220	1 960	2 310	1 920	180
Tartaric acid (g/l)	6.4	7.0	7.3	7.2	NS
Malic acid (g/l)	4.1	2.3	2.5	2.9	0.6
19 March (harvest)					
Sugar (° Brix)	22.1	23.0	23.5	23.6	NS
Titratable acidity (g/l)	4.2	3.9	3.8	3.8	NS
pH	3.89	3.82	3.80	3.67	NS
K (ppm)	1 930	1 780	1 780	1 502	170

NS = Not significant.

2. Wine composition

Wine composition analyses, presented in Table 2, show that T4 GDC had generally the most desirable composition and T1 shade the least desirable. In particular, wines from T1 shade had lowest titratable acidity and tartaric acid, highest pH and K and succinic acid content, and lowest colour density, proportion of ionised anthocyanin, total and ionised anthocyanins and total phenols, and highest colour hue. Not all of these analyses reached significance at the 5 % level but the trends were consistent.

Table 2

Effects of treatment on wine composition

Der Einfluß der Behandlung auf die Weinzusammensetzung

Variable	Treatment				5 % LSD
	T1 shade	T2 slash	T3 control	T4 GDC	
Titratable acidity (g/l)	7.0	7.6	7.4	8.3	0.4
pH	3.62	3.46	3.54	3.35	0.09
K (ppm)	1 700	1 470	1 580	1 270	130
Tartaric acid (g/l)	2.24	2.44	2.28	2.91	0.16
Lactic acid (g/l)	0.82	0.75	0.71	0.83	0.047
Succinic acid (g/l)	0.23	0.18	0.22	0.15	0.029
Wine colour density[1])	8.6	11.8	12.6	12.2	NS
Wine colour hue[1])	0.54	0.48	0.49	0.45	NS
α (%)[1])	24.7	31.7	29.1	34.0	3.6
α' (%)[1])	27.3	33.9	31.7	37.8	2.8
Total anthocyanins (mg/l)[1])	340	371	437	405	NS
Ionised anthocyanins (mg/l)[1])	86	122	129	136	NS
Total phenols	33.9	38.5	43.3	41.3	NS

[1]) After techniques of SOMERS and EVANS (1977).
NS = Not significant.

Generally, T2 slash and T3 control were intermediate between the other two treatments. As shown in Table 3, there were also block differences in wine composition. Only two of the measured attributes were significant, but many approached significance at P = 0.05. Comparing Tables 2 and 3, it is evident that the effects of shade treatments are again comparable to those of high vigour (blocks).

3. Sensory evaluation

In evaluating taster reliability, 48 separate analyses were performed for each of the six judges' scores of the eight characters assessed. In only eleven cases did the analyses indicate a significant association between duplicate scores, and eight of these were due to two judges only. All judges were reliable in assessment of colour density. Significant treatment effects showed up for only one taster — these were for total score and fruit character on the nose. There was a preference for T3 control and T4 GDC over T1 shade and T2 slash for both characters. It was clear from the results that both taster, winemaking and uncontrollable field variability were larger than differences between treatments. Part of this variation could be ascribed to presence of H_2S in some wines at the tasting, and also the problems of winemaking with small and variable fruit amounts in each ferment.

4. Correlations between grapevine and must and wine measurements

Tables 4 and 5 present results of correlation analyses between vineyard measurements and must and wine analyses and wine spectral analysis. The analyses were per-

Table 3

Effects of blocks on wine composition · Block 9 most vigorous, block 1 least vigorous

Der Einfluß der Blockposition auf die Weinzusammensetzung · Block 9 am stärksten, Block 1 am schwächsten wüchsig

Variable	Replicate 1	2	3	4	5	6	7	8	9	Signif.
Titratable acidity (g/l)	8.1	8.1	7.9	7.5	7.5	7.8	7.4	7.1	6.8	NS
pH	3.44	3.43	3.46	3.45	3.52	3.50	3.52	3.49	3.64	NS
K (ppm)	1 320	1 390	1 330	1 460	1 610	1 580	1 610	1 460	1 790	NS
Tartaric acid (g/l)	2.5	2.5	2.6	2.7	2.5	2.5	2.5	2.3	2.3	NS
Lactic acid (g/l)	0.77	0.77	0.73	0.77	0.82	0.82	0.79	0.79	0.75	NS
Succinic acid (g/l)	0.15	0.14	0.17	0.16	0.20	0.19	0.19	0.25	0.33	***
Wine colour density	13.9	14.5	13.7	12.2	12.7	10.1	9.1	7.5	8.1	*
Wine colour hue	0.46	0.46	0.49	0.48	0.56	0.44	0.49	0.49	0.53	NS
α (%)	31.2	36.0	33.6	33.9	27.4	26.9	29.8	26.0	24.1	NS
α' (%)	34.3	37.3	35.2	35.3	32.3	31.4	31.8	30.0	26.3	NS
Total anthocyanins (mg/l)	480	424	413	369	478	414	304	294	320	NS
Ionised anthocyanins (mg/l)	151	153	138	125	133	112	92	79	80	NS
Total phenols	46.1	44.6	42.9	39.5	46.8	39.8	32.8	29.7	30.9	NS

* at P = 0.05.
*** at P = 0.01.
NS = Not significant.

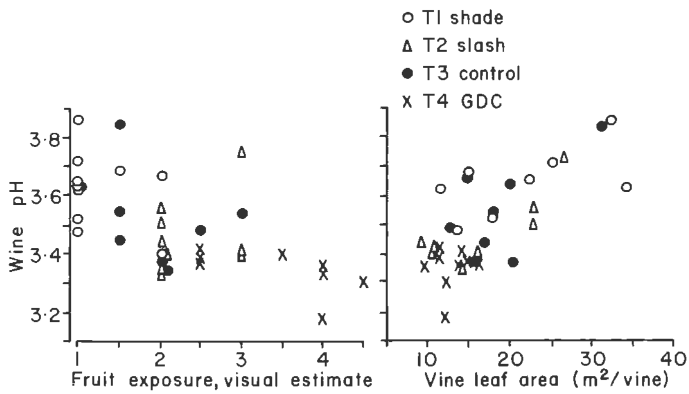

Fig. 1: The relationship between wine pH and (a) fruit exposure, visual estimate and (b) vine leaf area. Data for each plot presented.

Die Beziehungen zwischen Wein-pH und a) Traubenexposition (visuell bonitiert) und b) Blattfläche je Rebe. Sämtliche Einzelwerte sind aufgetragen.

formed using data for individual plots (30 total) and this assumes that the relationships between the pairs of variables are homogeneous over the treatments, and that this homogeneous relationship for a treatment is the same as the relationship between treatments.

These results show the effect of vigour (blocks) on vine growth and quality responses. For most variables analysed, there was a considerable spread of values and overlap occurred between treatments. This is shown in Fig. 1 and justifies the assumptions made above.

The correlations of Table 4 demonstrate that must pH and K concentration are positively associated with high leaf area and shading (as indicated by leaf area/canopy surface area ratio), and negatively associated with most components of the vineyard score, and their total. Must sugar and acidity were less well correlated with viticultural measurements. Shade in the canopy reduced sugar content. Wine pH and K concentration were positively correlated with vine leaf area, pruning weight and canopy shading,

Table 4

Significant correlation coefficients (r) between must and wine analyses and vineyard measurements

Signifikante Korrelationskoeffizienten (r) zwischen den Most- und Weinanalysen und den Messungen in der Rebanlage

Variable	Must				Wine		
	Sugar	Acidity	pH	K	pH	Acidity	K
Yield/vine	−0.53	—	—	—	—	−0.43	—
Shoots/vine	—	—	—	0.46	0.49	−0.59	0.40
Pruning wt/vine	—	—	—	—	0.51	−0.44	0.43
Mean main leaf area	−0.60	0.40	—	0.49	0.49	−0.61	0.51
Mean lateral leaf area	—	—	—	—	0.42	—	0.43
Leaf area/vine	−0.60	—	0.45	0.56	0.71	−0.72	0.65
Leaf area/canopy area	−0.53	—	0.53	0.64	0.67	−0.70	0.61
Leaf/fruit	—	—	—	—	0.52	—	0.45
Main nodes/shoot	—	—	—	—	—	—	—
Lateral nodes/shoot	−0.42	0.42	—	—	—	—	0.43
Mean contact number (point quadrat)	—	—	—	—	0.51	−0.45	0.44
Score — density	—	—	−0.45	−0.60	−0.58	0.53	−0.52
gaps	—	—	−0.50	−0.59	−0.62	0.62	−0.53
fruit exposure	—	—	−0.43	−0.59	−0.64	0.60	−0.51
shoot length	—	—	—	—	—	—	—
periderm	0.40	—	−0.67	−0.50	0.44	0.50	—
laterals	0.48	−0.45	−0.40	−0.39	−0.63	0.60	−0.57
leaf size	—	—	—	—	—	—	—
Total score	0.44	—	−0.59	−0.63	−0.69	0.68	−0.59

If $r \geq 0.43$, $P \leq 0.005$.
$r \geq 0.39$, $P \leq 0.01$.

Table 5

Significant correlation coefficients (r) between wine spectral analysis and vineyard measurements

Signifikante Korrelationskoeffizienten (r) zwischen der spektralen Weinanalyse und den Messungen in der Rebanlage

Variable	Colour density	Colour hue	α	α'	Total antho-cyanin	Ionised antho-cyanin	Phenols
Yield/vine	−0.60	—	—	—	−0.54	−0.54	−0.62
Shoots/vine	−0.53	—	—	−0.48	−0.37	−0.42	−0.41
Pruning wt/vine	−0.54	—	−0.39	−0.48	−0.43	−0.53	−0.49
Mean shoot wt	−0.39	—	—	—	—	—	—
Mean main leaf area	−0.53	—	−0.46	−0.57	−0.45	−0.55	−0.49
Leaf area/vine	−0.65	—	−0.52	−0.69	−0.58	−0.68	−0.63
Leaf area/canopy area	−0.57	—	−0.46	−0.65	−0.55	−0.62	−0.58
Lateral nodes/shoot	−0.42	—	—	0.41	−0.39	−0.42	−0.43
Mean contact number (point quadrat)	−0.53	—	−0.45	−0.53	—	−0.51	−0.47
Score — density	—	—	0.39	0.54	—	—	—
gaps	—	—	0.42	0.59	—	0.46	0.40
fruit exposure	—	—	—	0.53	—	0.42	—
shoot length	—	—	—	—	—	—	—
periderm	0.63	—	0.45	0.54	0.58	0.62	0.63
laterals	0.62	—	0.53	0.64	0.53	0.66	0.57
leaf size	0.49	—	—	—	0.44	0.46	0.46
Total score	0.55	—	0.52	0.68	0.51	0.61	0.54

If $r \geqslant 0.43$, $P \leqslant 0.005$.
$r \geqslant 0.39$, $P \leqslant 0.01$.

and negatively with the vineyard score and its components. Wine acidity was correlated with similar vineyard measurements to wine pH and K, with the sign the opposite. The general lack of correlations between yield and chemical composition is noteworthy.

Spectral analyses of the wines, apart from colour hue, correlated well with viticultural measurements (Table 5). Generally, the correlations were negative for vine growth parameters, including yield, but were positive for most components of vine score, and the total. The least useful components of the vine score, as judged by the number of significant correlations in Tables 4 and 5, were those of shoot length and mean leaf size.

Discussion

The effect of microclimate on must and wine composition will be explained in terms of the conceptual model presented in the companion paper (SMART *et al.* 1985; see Fig. 6).

The results of microclimate on sensory quality of wines reported here were not as clear cut as those obtained in the previous year (1980) at the same site (SMART 1982). Contributing to this were likely the smaller and more variable amounts of fruit fermented, and also the presence of H_2S in the wines in the second year. Measurements of leaf canopy microclimate in both years showed more shading in 1980 than 1981, especially for control T3 and shade T1. This seasonal variation could be accounted for by higher shoot numbers per vine and more lateral growth in 1980. There was less difference between measured microclimates in 1981 compared to 1980 and this may also have contributed to smaller differences between treatments in must and wine composition.

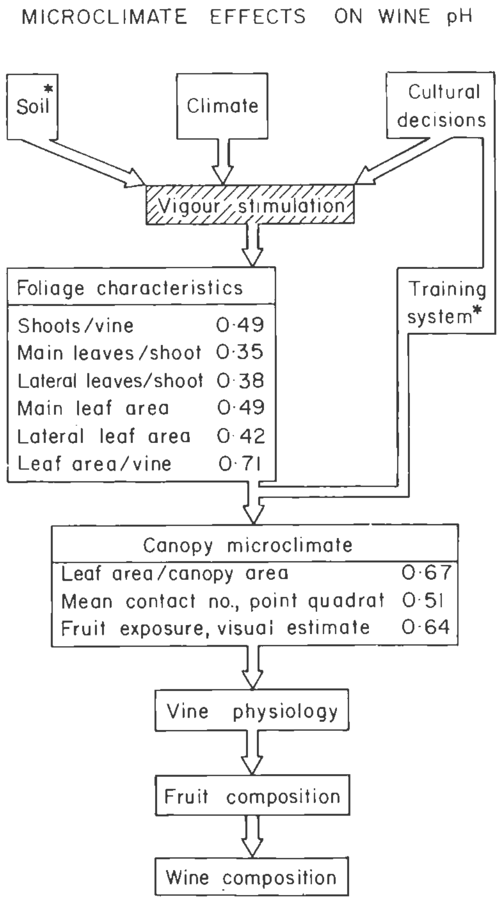

Fig. 2: An application of the model to show effects on wine pH. Values besides variables are correlation coefficients (r) with wine pH; * indicates significant effects on wine pH demonstrated by analysis of variance.

Anwendungsbeispiel des Modells, das die Beeinflussung des Wein-pH zeigt. Die Zahlenwerte neben den Variablen sind die Korrelationskoeffizienten (r) zwischen diesen und dem Wein-pH; * bedeutet einen signifikanten Einfluß auf den pH-Wert (Varianzanalyse).

Results of chemical analyses were, however, consistent in both years. Shade was found to cause the following responses in quality attributes of musts and wines in the years of study noted: reduced sugar content (1980, 1981), increased must and wine pH and K content (1980, 1981), reduced wine colour density, total and caused anthocyanin and phenol content (1980), and reduced proportions of ionised anthocyanins (1980, 1981). Similar responses have also been found for Shiraz vines in the cooler climate of Coonawanna, South Australia (BRAJKOVICH and SMART, unpublished data). Similar effects of microclimate on table wine quality have been demonstrated in France by CARBONNEAU *et al.* (1980) and CARBONNEAU and HUGLIN (1982).

The particular aspect of red wine quality investigated here is that of high pH. Fig. 2 represents an application of the general model to this parameter and shows the correlation between some appropriate measured components and wine pH. High wine pH is associated with a shaded microclimate — and high leaf area per vine. In accord with the theory (BOULTON 1980), high must and wine pH are associated with high K levels. High must K are associated with a shaded microclimate (Table 4) although individual components of leaf number per shoot and leaf size showed less association than leaf area per vine. The shaded microclimate causes K accumulation in shoots before veraison (SMART *et al.* 1985) which is then associated with high K levels in the fruit.

The vineyard scoring system evaluated in this study was found to correlate with composition of musts and wines. It is recognised that in reality some of the characters assessed should have different weightings to others in the scorecard. Shoot length and leaf size, for example, showed limited or no correlation with must and wine composition. However, for a 'first approximation scorecard' the results were encouraging, and for example the visual inspection accounted for 35 % and 48 % respectively of variation in must and wine pH. In general, the total score correlated about as well as the shading index leaf area/canopy area, but of course the former is more simple to derive. The total score correlated with must sugar, pH and K, and with wine pH, acidity, K, colour density, ionised and total anthocyanins and phenol content. Its use is therefore suggested as a management tool to overcome these quality problems in the vineyard.

The concepts outlined in this paper make a contribution to understanding the yield wine quality relationship. As cultural practices are employed to increase vine vigour (for example, irrigation), yield responses are also commonly recorded. However, it is not reasonable to argue that the increased yield causes any quality decline noted. Our results suggest an alternative contention, i.e., that any quality decline can be due also to a more shaded microclimate, as more leaves are crowded into a restrictive canopy. The type of definitive treatments employed (especially treatments 1 and 3) here could be usefully evaluated for other cultivars in different environments, and in particular should be examined for white table wines.

Summary

The degree of shade in Shiraz grapevine canopies was varied by four treatments and a naturally occurring vigour gradient. A shaded canopy microclimate produced must compositions of reduced sugar content and higher malic acid and K concentrations, and pH. Wines from these musts also showed higher pH, K and reduced proportions of ionised anthocyanins. Correlation studies showed that high must and wine pH and K content were positively correlated with shading in the canopy, and that colour density, total and ionised anthocyanins and phenol concentrations were negatively correlated with shading.

An eight-character visual scorecard of grapevine canopies was used to describe the canopies, and the results correlated with must sugar, pH and K, and wine pH, acidity, K, colour density, total and ionised anthocyanins and phenol content. Vines of high vigour produced similar must and wine composition as shaded canopy treatments.

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Literature cited

BOULTON, R.; 1980: The general relationship between potassium sodium and pH in grapejuice and wine. Amer. J. Enol. Viticult. **31**, 182—186.

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 **2**, 195—221.

— — ; HUGLIN, P.; 1982: Adaption of training systems to French regions. Proc. Intern. Symp. Grapes and Wine, Davis, California, 1980, 377—385.

SHAULIS, N. J.; AMBERG, H.; CROWE, D.; 1966: Response of Concord grapes to light, exposure and Geneva double curtain training. Proc. Amer. Soc. Hortic. Sci. **89**, 268—280.

SOMERS, T. C.; 1975: In search of quality for red wines. Food Technol. Austral. **27**, 49—56.

— — ; EVANS, M. E.; 1977: Spectral evaluation of young red wines, anthocyan equilibria, total phenolics, free and molecular SO_2, chemical age. J. Sci. Food Agricult. **28**, 279—287.

SMART, R. E.; 1982: Vine manipulation to improve wine grape quality. Proc. Intern. Symp. Grapes and Wine, Davis, California, 1980, 362—375.

— — ; ROBINSON, J. B.; DUE, G. R.; BRIEN, C. J.; 1985: Canopy microclimate modification for the cultivar Shiraz. I. Effects on canopy microclimate. Vitis **24**, 17—31.

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