Vitis 24, 17—31 (1985)

Roseworthy Agricultural College, Roseworthy, South Australia
South Australian Department of Agriculture, Adelaide, South Australia

Canopy microclimate modification for the cultivar Shiraz
I. Definition of canopy microclimate

by

R. E. SMART [1]), J. B. ROBINSON, G. R. DUE and C. J. BRIEN

Veränderungen des Mikroklimas der Laubwand bei der Rebsorte Shiraz
I. Definition des Mikroklimas der Laubwand

Zusammenfassung: Ausgewachsene Shiraz-Reben wurden am Gawler-River (Südaustralien) vier Behandlungsarten unterzogen, durch die das Mikroklima der Laubwand variiert wurde: T1 — Das Blattwerk wurde 30 d vor dem Weichwerden der Beeren auf einen kleineren Raum eingeengt. T2 — Die Triebe wurden zum selben Zeitpunkt auf etwa 9 Knoten zurückgeschnitten. T3 — Kontrolle mit normalem Triebwachstum. T4 — Geneva-double-curtain-Erziehung. In der Variante T1 war die Beschattung innerhalb der Laubwand gegenüber T3 erhöht, in T4 und T2 verringert. Messungen der photosynthetisch wirksamen Strahlung an den Trauben ergaben signifikante Unterschiede zwischen den vier Varianten. Auswirkungen der Wüchsigkeit auf das Mikroklima waren ebenfalls zu verzeichnen. Untersuchungen der K-Bilanz der Sprosse zeigten, daß die K-Gehalte der Blätter, Blattstiele und Sproßachsen zum Zeitpunkt des Weichwerdens durch Beschattung erhöht wurden.

Es wurde ein Schema für die visuelle Bonitierung des Mikroklimas der Laubwand und der Merkmale des Rebenwachstums ausgearbeitet; die hiermit gewonnenen Ergebnisse zeigten eine gute Korrelation zu den Messungen des Mikroklimas.

Es wird ein Modell vorgestellt, das erklärt, wie die Boden- und Klimafaktoren und die Kulturmaßnahmen das Mikroklima der Laubwand und hierdurch die Weinqualität beeinflussen können.

Key words: training, pruning, light, climate, potassium, photosynthesis.

Introduction

That potential wine quality is determined in the vineyard is a widely-accepted viewpoint. It is also commonly accepted that differences in wine quality between regions may be explained by climatic or soil variations. Such explanations are, however, less satisfactory to explain quality differences between neighbouring vineyards, where the macroclimate is identical, and mesoclimatic and soil differences can be indeed subtle. Quality differences of this kind are well recognised in regions with long traditions of viticulture, as for example in Europe. Generally it is held that high yields cause lower quality.

This study is presented in two parts. This, the first, deals with aspects of microclimate, and the second (SMART *et al.* 1985) with influences on must and wine composition. The study offers an explanation for differences in wine quality noted above. It is not presumed that the 'microclimate' explanation can account for all viticultural effects on wine quality, but that it may be applicable in many instances where vigour differences are involved. Simply stated, it is proposed that dense vine canopies cause a shaded canopy microclimate which is unfavourable to wine quality. The implications of canopy density on all aspects of microclimate were previously detailed (SMART 1982). Although

[1]) Present address: Ruakura Soil and Plant Research Station, Hamilton, New Zealand.

not immediately apparent, the above thesis allows for effects of cultural practices, and soil and climate variations, in affecting wine quality. Those factors which stimulate vine vigour — such as choice of vigorous rootstock, high availability of water and nutrients, freedem from pests and disease etc., cause increased leaf area. Unless the trellis (training) system is also improved concomitant with vigour increase, then self-shading within the canopy will increase. Of the canopy microclimate changes so produced, the largest effects are on radiation flux densities and windspeed, although there can also be significant effects on temperature and relative humidity.

Recent studies have demonstrated an effect of canopy microclimate on must and wine composition (SMART 1982; CARBONNEAU *et al.* 1978; CARBONNEAU and HUGLIN 1982). A previous study (SMART 1982) demonstrated that canopy shading caused high must and wine pH and lowered wine quality. This study further investigates that relationship with canopy microclimate and in particular the association with vine K levels. It is now recognised that high must and wine K concentrations lead to high pH and lowered quality of red table wines (SOMERS 1975). Advantage was taken of a naturally occurring variation in vine vigour to assess effect on microclimate and must composition and wine quality. The term 'high vigour' as used here applies to vines with longer shoots, larger leaves, more shoots and larger yields. High vigour in this vineyard was due to an improved soil water supply.

A further aim of the study was to investigate whether vines could be visually 'scored' as to their microclimate. A simple scoring system of eight canopy and growth characteristics was used. This scoring system was compared with detailed measurements of the radiation microclimate, which were performed to evaluate effects of treatment and vigour.

Materials and methods

1. Vineyard site and treatments

The trial was carried out on the same site as that described by SMART (1982). The vineyard located at Gawler River, South Australia, was of the cultivar Shiraz and not irrigated. The vines, planted in 1970, were spaced at 3.4 × 2.7 m (row × vine), with rows running east-west. The vines were trellised to 0.4 m wide 'tee' trellis at 1.1 m height, and were spur-pruned. In 1978, one row was trained to Geneva double curtain (GDC, SHAULIS *et al.* 1966) with a 0.9 m 'tee' at 1.4 m height. Downward shoot positioning on GDC was carried out at flowering in November using moveable foliage wires.

The same treatments as used by SMART (1982) were again employed. These were:

Treatment 1 — shade (T 1): The vine foliage was constrained using a plastic bird netting (Xironet) to induce shading. Absorbance of radiation by the fine filaments of the netting was negligible.

Treatment 2 — slash (T 2): Shoots were trimmed with a hand-held knife to about 9 nodes per shoot. Due to dry conditions, there was no subsequent regrowth of lateral shoots.

Treatment 3 — control (T 3): The canopy was allowed to develop the normal growth habit. Where vines were vigorous, shoots tended to be pendant, but where less vigorous, the shorter shoots were more erect.

Treatment 4 — GDC (T 4): These vines were trained to GDC with proper downward shoot positioning.

Treatments were applied to three vine plots of which the outer two were unmeasured buffers. The first three treatments were randomised among plots in three rows adjacent to the GDC, using nine replicates. Blocks were arranged across a pronounced

Table 1

Vineyard scoring system for potential wine quality · Assessment to be carried out just before harvest

Bewertungsschema zur Ermittlung der potentiellen Weinqualität in der Rebanlage · Die Bonitierung muß kurz vor der Ernte durchgeführt werden

	Points
(1) Average canopy density (from side to side, fruit zone)	
Average 1— 3 layers thick	5
3— 5 layers thick	4
5— 8 layers thick	3
8—11 layers thick	2
> 11 layers thick	1
(2) Canopy gaps (from side to canopy, within area contained by 90 % of leaf area)	
> 50 %	5
21—50 %	4
11—20 %	3
6—10 %	2
0— 5 %	1
(3) Fruit exposure (as viewed from middle of row, the proportion of fruit visible)	
61—100 % exposure	5
41— 60 % exposure	4
21— 40 % exposure	3
10— 20 % exposure	2
< 10 % exposure	1
(4) Average shoot length	
10—14 nodes	5
15—20 nodes	4
21—30 nodes	3
> 30 nodes	2
5— 9 nodes	2
< 5 nodes	1

	Points
(5) Periderm development (on most shaded shoots)	
10—14 nodes	5
> 14 nodes	4
6— 9 nodes	3
2— 5 nodes	2
< 2 nodes	1
(6) Length of best developed lateral shoots	
Lateral 0— 4 nodes	5
shoots 5— 8 nodes	4
9—12 nodes	3
13—15 nodes	2
> 15 nodes	1
(7) Presence of growing tips (of all shoots, the proportion with actively growing tips)	
Growing 0—10 %	5
tips 11—20 %	4
21—40 %	3
41—80 %	2
> 80 %	1
(8) Mean leaf size — for this variety, are the biggest basal leaves relatively	
Average	5
Average-small	3
Average-large	3
Very small	1
Very large	1

Total point score ..... out of 40 = ... %

vigour gradient, with replicate 9 being the most vigorous and replicate 1 the least. This vigour gradient was due to variation in soil depth which affected stored water supply in this hot Mediterranean climate (see SMART 1982 for details of the climate).

Treatments 1, 2 and 3 were applied on 23 December 1980, some 29 d before veraison. Data were analysed using analysis of variance and regression analysis. Analysis of covariance was used to elucidate effects of vigour variation on measured parameters.

2. Canopy measurements

To determine the shoot K balance, shoot samples were taken, one from each plot, at 50 % flowering (13 November 1980), veraison (21 January 1981) and harvest (19 March 1981). Since treatments 1 and 2 were not applied until before veraison, samples were taken only from treatments 3 and 4 at flowering. Dry weights were determined after drying in an oven at 80 °C for several days.

The average area of main and lateral leaves was determined by comparing the fresh weight of discs of known area with leaf weight for 50 samples per plot, each for lateral and main leaves taken on 16 February 1981. K determinations were made on shoot, leaf, petiole and peduncle samples ashed at 450 °C for 16 h and taken up in 6N HCl before filtration and dilution. Fruit samples were homogenised in a blender before ashing. K content was determined in the homogenate for veraison samples, but for vintage samples, the homogenates were made up to a fixed volume with washings. K was determined with a flame photometer.

Periderm development was assessed on 21 January by counting the number of internodes per shoot with more than 50 % of surface turning brown or yellow. Only fruitful primary shoots were measured, and 20 shoots were sampled per plot.

After leaf fall, the number of nodes on main and lateral shoots were counted for 40 shoots per vine, and shoot numbers and pruning weight determined. Leaf area per vine was calculated as the product of mean leaf area, nodes per shoot and shoots per vine for both lateral and main leaves.

The dimensions of the canopy were defined as including 90 % of leaf area, to avoid the occasional protruding shoot. These were measured on 28 February 1981, after vegetative growth had ceased. The vine shape for each treatment was approximately rectangular in end section and six samples of characteristic dimension were made. Canopy surface area was calculated using top and sides only, these being the canopy planes which intercept solar radiation.

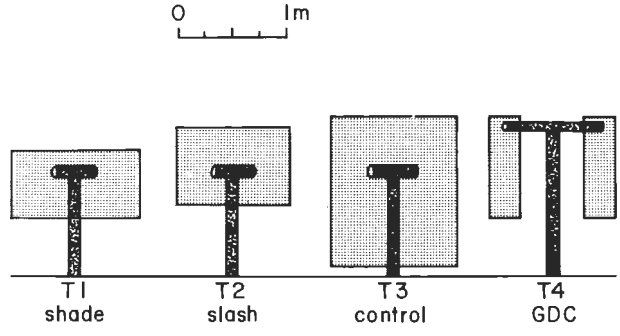

Fig. 1: Vine dimensions (in end-section) drawn to scale for the four treatments.

Abmessungen der Rebstöcke (Endansicht); maßstabsgerechte Darstellung der vier Behandlungsformen.

Table 2

Treatment effects on canopy dimensions, shoot growth and yield

Der Einfluß der Behandlung auf die Abmessungen der Laubwand, das Triebwachstum und den Traubenertrag

Canopy and vine characteristics	Treatment				
	T1 shade	T2 slash	T3 control	T4 GDC	LSD 5 %
Canopy surface area (1000 m^2 ha^{-1})	7.49	7.34	11.18	12.02	0.52
Canopy volume (m^3/vine)	2.2	2.1	4.4	1.6	0.3
Mean main leaf area (cm^2)	101	113	103	84	6
Mean lateral leaf area (cm^2)	39	25	33	31	6
Main nodes/shoot	13.1	8.8	12.5	12.0	0.7
Lateral nodes/shoot	2.6	3.4	1.6	3.2	NS
Leaf surface area (1000 m^2 ha^{-1})	22.61	17.82	22.50	14.21	3.17
Leaf area/canopy surface area	3.0	2.4	2.0	1.2	0.3
Yield/vine (kg)	17.5	16.4	16.0	18.6	NS
Clusters/vine	275	259	280	269	NS
Mean cluster wt (g)	64	64	56	69	NS
Shoots/vine	141	147	150	118	13
Pruning wt/vine (kg)	2.3	1.8	2.3	1.7	NS
Mean shoot wt (g)	15.8	12.3	15.2	14.8	NS
Leaf area/fruit wt (cm^2 g^{-1})	11.5	10.2	13.4	7.9	1.8
Canopy surface area/fruit wt (cm^2 g^{-1})	4.0	4.4	7.3	6.8	1.2
Nodes with periderm 21 Jan.	4.5	6.1	6.6	5.5	0.7

NS = Not significant.

3. Microclimate measurements

Measurements concentrated on the radiation microclimate, especially that waveband used in photosynthesis. Photosynthetically-active-radiation (PAR) is solar radiation between 400 and 700 nm, measured with a sensor with spectral response appropriate to the action spectrum of photosynthesis. Measurements of the flux density of PAR (photon flux/unit area/unit time) is now termed "photon fluence rate" (PFR).

The canopy structure was determined on 19 February 1981, using point quadrat analysis as described by SMART (1982). A thin 1 m long needle was passed into the canopy from side to side, in the fruit region, at angle 30 ° from the vertical. Contacts with leaves, shoots, stems and clusters were noted. The needle simulates the passage through the canopy of a beam of light. 25 random passes were made in each plot.

Measurements of PAR were made with a hand-held quantum sensor (Li-Cor) on 50 clusters selected haphazardly on several plots. The maximum and minimum PFR was measured for each cluster, as well as ambient above canopy horizontal PFR. During the measurement period (10.00—16.00 h on 4 March 1981) the sky was cloudless.

4. Vine scoring

Each plot was assessed by two persons (SMART, DUE) on 18 March 1981 just prior to vintage, using the score card shown in Table 1. The two scores were averaged prior to analysis. There were eight characters assessed, each carrying a maximum score of

5 points (total 40). The score card was designed to assess microclimate as well as growth characters. For some characters (average shoot length, periderm development and leaf size), the highest score was for an optimum in the middle of the range of values possible. The scorecard is based on observation of vineyards with quality reputations in Australia, USA and France.

Table 3

Block effects on canopy dimensions, shoot growth and yield · Block 9 most vigorous, block 1 the least

Der Einfluß der Blockposition auf die Abmessungen der Laubwand, das Triebwachstum und den Traubenertrag · Block 9 zeigt die stärkste, Block 1 die schwächste Wüchsigkeit

Canopy and vine characteristics	Block									
	1	2	3	4	5	6	7	8	9	Signif.
Canopy surface area (1000 m^2 ha^{-1})	8.38	8.71	8.96	8.69	9.94	9.94	9.66	9.88	10.51	*
Canopy volume (m^3/vine)	2.3	2.3	2.3	2.4	2.7	2.7	2.7	2.7	3.0	NS
Mean main leaf area (cm^2)	81	92	92	101	101	108	105	116	107	**
Mean lateral leaf area (cm^2)	30	32	28	33	32	34	36	28	35	NS
Main nodes/shoot	10.5	10.6	11.1	11.2	10.6	11.8	12.1	12.7	13.7	**
Lateral nodes/shoot	1.8	1.1	1.1	1.4	0.7	3.7	3.8	1.9	9.2	**
Leaf surface area (1000 m^2 ha^{-1})	13.2	14.3	15.1	18.0	15.6	19.5	23.3	25.7	29.0	**
Leaf area/canopy surface area	1.7	1.7	1.8	2.0	1.7	2.0	2.5	2.7	3.0	*
Yield/vine (kg)	11.5	14.7	15.4	16.5	16.1	17.2	15.5	22.5	24.7	*
Clusters/vine	225	257	241	269	294	236	300	308	307	NS
Mean cluster wt (g)	51	58	65	60	53	73	54	72	82	**
Shoots/vine	135	132	133	141	133	126	145	154	151	NS
Pruning wt/vine (kg)	1.2	1.6	1.7	1.6	1.8	2.4	2.7	2.4	2.8	**
Mean shoot wt (g)	9.0	12.6	12.6	11.1	13.6	19.1	18.2	15.6	18.9	**
Leaf area/fruit wt (cm^2 g^{-1})	11.2	9.2	9.9	10.7	10.4	10.2	13.4	10.2	11.5	NS
Canopy surface area/ fruit wt (cm^2 g^{-1})	7.4	5.5	5.9	5.4	6.6	5.4	5.9	4.3	4.0	NS
Nodes with periderm 21 Jan.	5.3	4.6	6.4	5.7	6.2	5.2	7.2	5.8	4.5	NS

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

Results

1. Canopy dimensions and growth

Average vine dimensions are shown to scale in Fig. 1 and measurements made on canopies in Table 2. Canopy surface areas was slightly increased by GDC training and reduced by the foliage-gathering shade treatment, and by slashing.

Relative to control vines, GDC training reduced main leaf area and the slash treatment slightly increased it. Shoot length, as measured by node number, was reduced by T2 slashing as expected. Total leaf area per ha was the same for control (T3) and shade (T1), but was reduced by slashing (T2) and by GDC training (T4). As a consequence of increased canopy surface area and reduced vine leaf area, the ratio of leaf area/canopy surface area (LA/SA) was least for GDC. There was no significant yield or cluster number difference between treatments, although shoot number was reduced by GDC training. Treatment had no significant effect on pruning weight or mean shoot weight, but large effects of vigour (replicates) were noted. The ratio of leaf area to fruit weight was lowest for GDC (T4) and highest for control (T3), while the ratio canopy surface area/fruit weight was highest for control (T3) and GDC (T4). Wood ripeness, as indicated by nodes with periderm at veraison was highest for control (T3) and least for shade treatment (T1).

Table 3 contains the block means for the same set of variables as Table 2. There was a notable trend for the more vigorous vines to have larger leaves, longer shoots and higher yield. As a result, shading was increased, as indicated by the ratio LA/SA, although leaf area/fruit weight ratio was little affected by vigour.

2. Canopy microclimate

Point quadrat analysis. — The greater the number of contacts per pass, the greater will be shading within the canopy. The frequency distribution of point

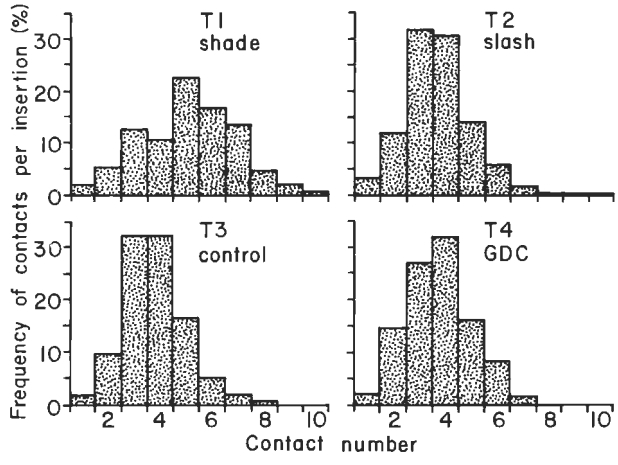

Fig. 2: Frequency analysis of numbers of contacts with leaf, fruit or shoot stems per insertion. Based on 450 passes per treatment.

Häufigkeitsverteilung der Anzahl der Kontakte mit Blättern, Trauben oder Sproßachsen je Einstich der Nadel. Die Werte errechnen sich aus 450 Durchgängen je Variante.

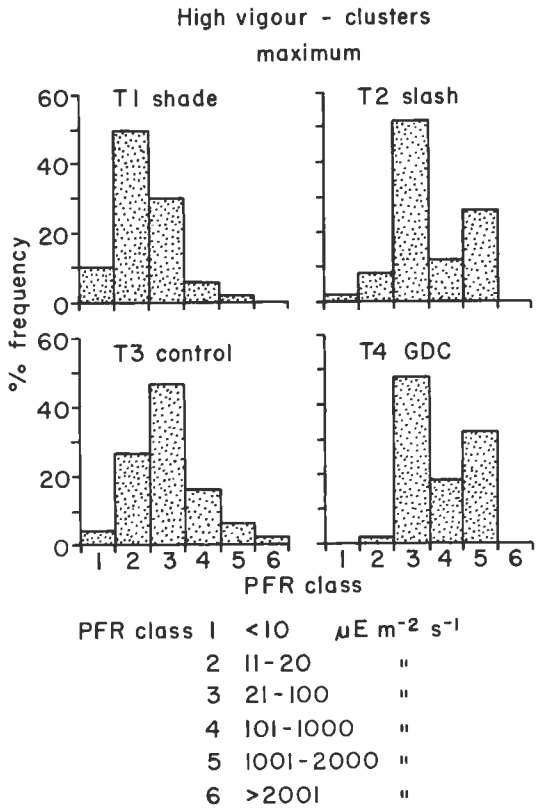

Fig. 3: Frequency analysis of maximum PFR readings for clusters on the high vigour block (9).
Häufigkeitsverteilung der maximalen PFR-Werte der Trauben im starkwüchsigsten Block (9).

quadrat contact with leaves, cluster or shoots is presented in Fig. 2. Canopy density, as assessed by the number of contacts per pass, was highest for T1 shade and similar for other treatments. Fruit occupied 14 % of the canopy face for GDC (T4) but only 1 % for shade (T1), 7 % for slash (T2) and 3 % for control (T3).

Photon fluence rate measurements. — PFR is exceedingly variable both in time and space within plant canopies. For example, measurements made on clusters varied over the range from less than 10 µE m^{-2} s^{-1} to the normal-incident maximum of 2250 µE m^{-2} s^{-1}. This variability is shown by frequency diagrams for PFR readings into clusters (Figs. 3 and 4). Six class intervals are used (less than 10, 11—20, 21—100, 101—1000, 1001—2000 and greater than 2001 µE m^{-2} s^{-1}). The higher proportion of shaded clusters for T1 shade, especially with high vigour, is quite evident. Treatments and vigour have more effect on maximum than minimum PFR measured on the clusters.

3. Vine potassium balance

Dry weight and K concentrations are presented in Table 4. At flowering, GDC vines had lower K concentration in inflorescences than for control. The K concentra-

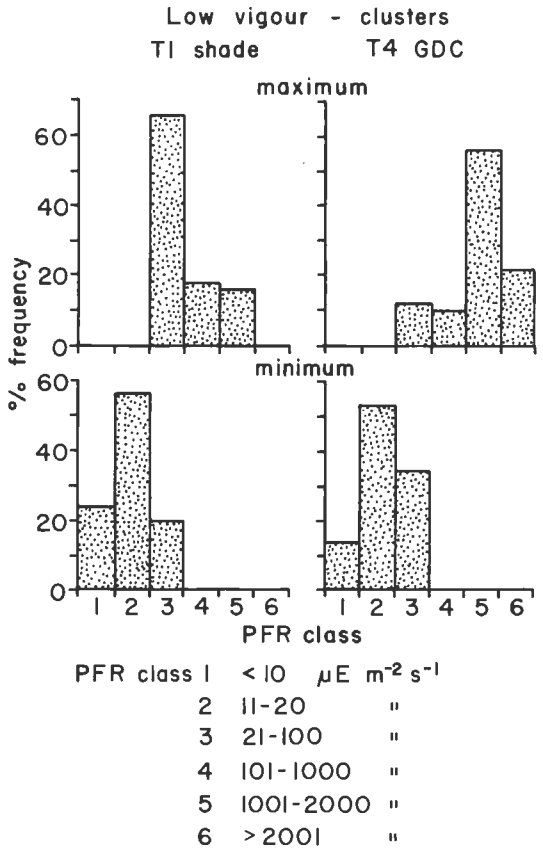

Fig. 4: Frequency analysis of maximum and minimum PFR readings onto clusters for the low vigour block (1).

Häufigkeitsverteilung der maximalen und minimalen PFR-Werte der Trauben im schwachwüchsigsten Block (1).

tion was higher in stems and leaves plus petioles for the T1 shade veraison sample over other treatments. The concentration of K dropped between veraison and harvest for shoots, leaves plus petioles, and rachis for all treatments. At harvest, T2 slash and T4 GDC had the lowest K concentrations in leaves plus petioles. A sample bias towards small shoots for T1 shade at veraison is evident in dry weight measurements; this was caused by the presence of the nets.

Fig. 5 shows the total K balance on a vine shoot basis calculated as a product of concentration and weight or volume. These values were calculated from average values of Table 4, except that the shoot, leaf and petiole and rachis and fruit weights for T3 control at veraison were used for T1 shade, thereby making an allowance for the biased sample. This adjustment could be made with confidence, as there was no effect noted of shoot or fruit weight on K concentration. The K amount in stems and leaves and petioles increased from flowering to veraison and then declined at harvest. K amount in rachis and fruit on the other hand increased throughout the season. There was an import of K into the shoot from flowering to veraison, but between veraison and har-

Table 4

Dry matter and potassium content of shoots, inflorescences and fruit

Trockensubstanz und Kaliumgehalt der Sprosse, Infloreszenzen und Früchte

	Treatment				
	T1 shade	T2 slash	T3 control	T4 GDC	5 % LSD
Flowering					
Stem dry wt (g)	—	—	5.1	3.9	NS
% K stems	—	—	1.74	1.75	NS
Leaves and petioles dry wt (g)	—	—	6.4	5.6	NS
% K leaves and petioles	—	—	1.47	1.46	NS
Inflorescence dry wt (g) [1]	—	—	0.35	0.55	NS
% K inflorescence	—	—	2.29	1.33	0.65
Veraison					
Stem dry wt (g)	10.4	11.1	20.6	9.5	3.4
% K stems	1.22	0.93	0.86	1.01	0.15
Leaves and petioles dry wt (g)	11.5	7.8	20.4	12.2	3.1
% K leaves and petioles	1.72	1.25	1.20	1.35	0.18
Rachis dry wt (g)	1.44	2.07	1.95	1.90	NS
% K rachis	2.58	2.21	2.16	2.58	0.08
Fruit volume (ml)	104	124	127	130	NS
K concentration fruit (mg/ml)	2.55	2.18	2.50	2.19	NS
Harvest					
Stem dry wt (g)	26.1	13.2	24.6	14.5	5.2
% K stems	0.77	0.66	0.69	0.74	NS
Leaves and petioles dry wt (g)	18.9	8.1	19.1	15.9	3.5
% K leaves and petioles	1.00	0.64	0.83	0.77	0.15
Rachis dry wt (g)	4.30	3.07	3.67	2.49	NS
% K rachis	2.29	1.84	2.06	2.36	0.18
Fruit weight (g)	181	168	172	151	NS
K concentration fruit (mg/g)	2.57	2.88	2.97	2.48	NS

[1]) Includes rachis weight with inflorescence.
NS = Not significant.

vest there was limited increase (for T2 slash, T3 control and T4 GDC) or no increase (T1 shade). The increase in fruit and rachis K between veraison and harvest is largely offset by decreased stem, leaf and petiole K amount.

4. Vineyard scoring

The results of vineyard scoring are presented in Table 5. GDC vines (T4) received the highest total score, with T2 slash and T3 control about equal, and all greater than T1 shade. Due to dry conditions, there was no current active shoot growth and all treatments received maximum values for this component.

Table 5

Results of vineyard scoring

Ergebnisse der Bonitierung in der Rebanlage

Character (maximum score)	Treatment				
	T1 shade	T2 slash	T3 control	T4 GDC	5 % LSD
Canopy density (5)	1.0	1.8	1.2	4.1	0.2
Gap presence (5)	1.1	1.7	2.2	4.1	0.3
Fruit exposure (5)	1.2	2.3	1.9	3.3	0.4
Shoot length (5)	3.2	2.8	3.4	4.2	0.3
Periderm extent (5)	2.0	3.0	2.8	3.5	0.5
Current lateral growth (5)	3.8	3.1	3.8	4.9	0.7
Current shoot growth (5)	5.0	5.0	5.0	5.0	NS
Leaf size (5)	4.3	4.8	4.3	4.1	NS
Total score (40)	21.6	24.5	24.7	33.1	1.7

NS = Not significant.

5. Correlation between vine and canopy characteristics and canopy microclimates

The degree of shading in the canopy depends on the amount of foliage and the way that foliage is displayed. To ascertain which components of foliage amount are more important than others in causing shading, correlations were performed with various measures or estimates of microclimate (Table 6). (Although not in fact a 'component' of foliage density, yield is included for interest and shows limited correlation with micro-

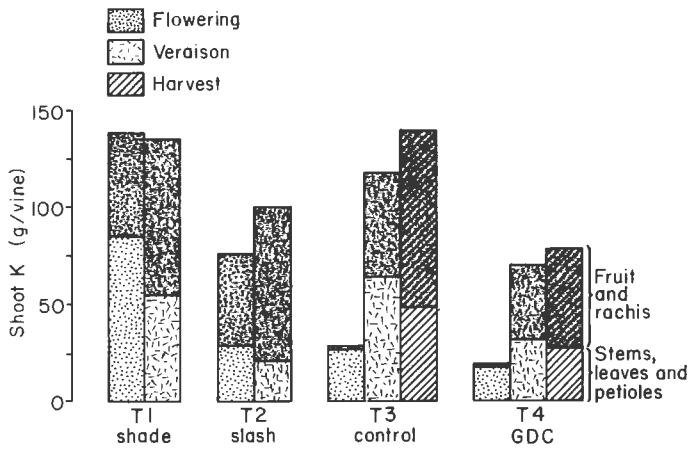

Fig. 5: Partition of K between fruit plus rachis and stems plus leaves plus petioles at different growth stages. Expressed as g K/vine.

Verteilung von K (g/Rebe) auf die Beeren mit Traubengerüst und die Sproßachsen mit Blättern und Blattstielen in verschiedenen Wachstumsphasen.

Table 6

Significant correlation coefficients (r) between vine and canopy characteristics and various measures of canopy microclimate

Signifikante Korrelationskoeffizienten (r) zwischen Reben, Merkmalen der Laubwand und verschiedenen Größen des Mikroklimas der Laubwand

Vine and canopy characteristics	Microclimate measure						
	Point quadrat			Visual estimates [1]			
	Mean contact number	Percent canopy face with fruit	Percent clusters first and second contact	Canopy density	Canopy gaps	Fruit exposure	Total score
Yield	0.34 [2]	—	—	—	—	—	—
Shoots/vine	—	−0.43	−0.33	0.55	0.55	0.48	0.62
Pruning weight	0.57	−0.30	−0.32	0.34	0.36	0.35	0.58
Mean shoot weight	0.50	—	—	—	—	—	0.29
Mean leaf no./shoot	0.58	—	−0.31	—	—	0.29	—
Mean leaf area	—	—	—	0.55	0.58	0.36	0.61
Lateral leaf area	0.47	—	—	—	—	—	—
Vine leaf area	0.56	−0.41	−0.39	0.51	0.54	0.51	0.73
Leaf area/surface area	0.66	−0.54	−0.65	0.69	0.78	0.63	0.86

[1]) The sign on all the correlation coefficients listed hereunder was changed from negative to positive since in the original assessment the highest scores were for the canopies with least shade (see Table 1).

[2]) Jf $r \geq 0.28$, $P < 0.05$.
$r \geq 0.39$, $P \leq 0.01$.
$r \geq 0.43$, $P \leq 0.005$.

climate.) Of the measures presented, the ratio LA/SA produced the highest order correlations with microclimate, always an improvement over vine leaf area alone. Shoot number per vine was generally better correlated than main or lateral leaf number or area. The high correlation ($r = 0.86$) between the total score from the visual estimate and the ratio LA/SA is noteworthy.

Discussion

The results will be discussed in terms of a conceptual model presented in Fig. 6, which is based on the thesis developed in the introduction. This model shows the effect of vigour stimulation, due to cultural practices or climate and soil characters, on foliage characteristics. Some examples of soil, climate and cultural factors are shown which are known to affect vigour. The resultant foliage characteristics in combination with the training system imposed, determine the canopy microclimate. In turn, the microclimate is the signal for physiological function, which then affects fruit composition and ultimate wine quality. The model does not deny that climatic, soil or cultural decisions can have d i r e c t effects on vine physiology, and hence wine quality, but merely emphasises how these factors can have 'indirect' effects (via microclimate) on wine quality.

In the present study, many factors were held constant (i.e., climate, variety and cultural practice apart from training system). Results demonstrated the significant effect of vigour stimulation (here assumed to be due to variation in soil water supply) and training system on canopy microclimate.

While it is recognised that canopy attenuation affects many climatic elements (SMART 1982), the largest microclimatic difference between dense and sparse canopies is for radiation flux densities. The considerable attenuation of light by grapevine canopies has been demonstrated (SMART 1974). Measurements showed only 9 % transmission of PAR by Shiraz leaves, and reflectance of PAR of 8 % by the soil and 6 % by the foliage. These measures demonstrate the very high absorbance (85 %) of PAR by vine leaves. Measurements of PFR onto clusters demonstrated marked differences due to treatment and vine vigour. Similar results were reported for PFR measurements onto leaves by SMART (1982). The results here emphasise the difficulties in making such spot

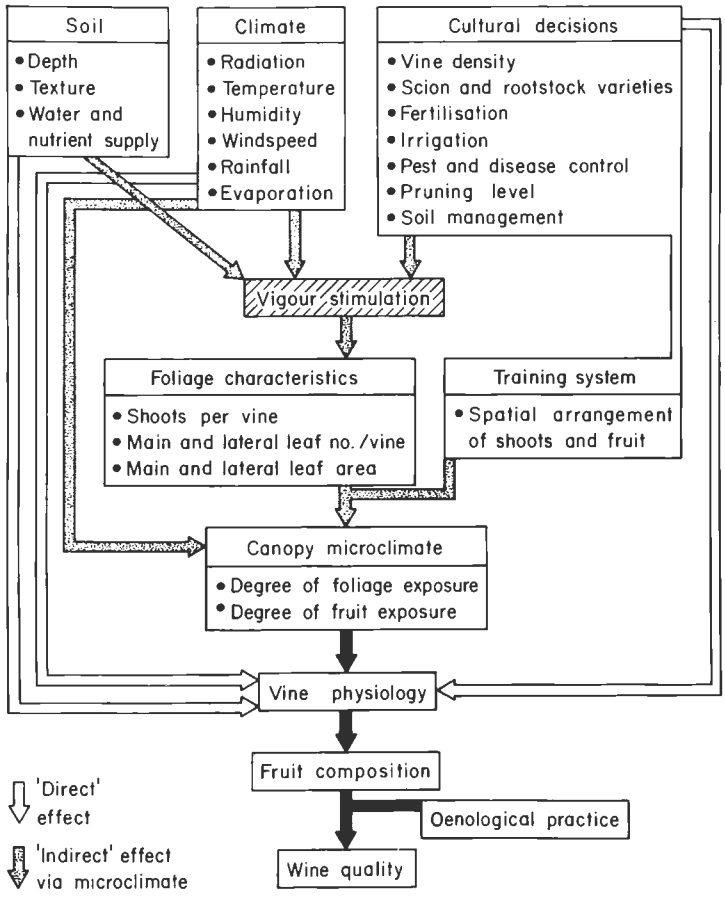

Fig. 6: General model proposing how soil and climate and cultural decisions can affect wine quality via effects on canopy microclimate.

Modell der Auswirkungen von Boden, Klima und Kulturmaßnahmen auf die Weinqualität über das Mikroklima der Laubwand.

measurements, due to variation in ambient irradiance and also spatial variation. The largest differences in PFR of clusters was for the maximum levels rather than the minimum. In other words, canopy microclimates differed in the proportion of "exterior" clusters.

In view of measuring microclimate, the merit of measurements of instantaneous PFR, of point quadrat analysis and measuring the ratio of canopy leaf area to canopy surface area were confirmed. GDC training and foliage trimming were demonstrated as being significant means of avoiding shading.

The significance of vine vigour in affecting microclimate had also been established and has been emphasised by regression analyses. For Mediterranean climates, vine water supply is an important regulator of vigour. The effect of water supply on shoot and leaf growth relative to fruit growth is emphasised in a recent review by SMART and COOMBE (1983). Vigour effects showed as significant differences in the number of main and lateral nodes per shoot, and main leaf area. GDC training also reduced mean main leaf area, perhaps a growth response to inverted shoots.

Canopy microclimate can be very simply evaluated using visual scoring, as was demonstrated by regression analysis. In view of the association between these scores and measured microclimate, this concept is worthy of further evaluation. Estimates of shoot length and leaf size appeared the least useful of the eight characters used in terms of correlation with must and wine analyses. A simple scoring system such as this could be used as a management tool to evaluate cultural practices affecting microclimate.

Results presented here show that K accumulates in the shoot between flowering and veraison and then is relatively constant to harvest. There is, however, a redistribution of K from the stems, leaves and petioles to the fruit during ripening. Shade at veraison caused higher K concentrations in leaves and petioles, stems and rachises, and this was subsequently associated with higher must K levels (see SMART *et al.* 1985). An early season effect cannot be ruled out, however, since GDC training showed lower K concentrations in the inflorescence at flowering.

The association between microclimate and must and wine composition is investigated in the companion paper (SMART *et al.* 1985).

Summary

Three treatments providing different canopy microclimates were applied to mature Shiraz grapevines at Gawler River 30 d before veraison. Constraining foliage into a smaller volume increased shading over control vines, and GDC training and slashing reduced it. Measurements demonstrated significant differences in terms of fruit exposure to solar radiation. Effects on microclimate due to vine vigour were also noted. A K balance made on vine shoots demonstrated that shade was associated with increased K concentrations in the leaves, petioles and stems at veraison.

A visual scoring system of microclimate and growth characteristics was evaluated, and results correlated well with microclimate measurements.

A conceptual model is proposed to explain how soil and climatic factors and cultural decision can affect canopy microclimate.

Acknowledgements

The authors acknowledge provision of the vineyard site by RON NORMAN, advice on chemical analysis from DAVID BRUER. This study was funded by a grant to Roseworthy College for small-scale winemaking research by the South Australian Government.

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Eingegangen am 13. 6. 1984

Dr. R. E. SMART
Ruakura Soil and Plant
Research Station
Private Bag
Hamilton
New Zealand