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Sultana (Vitis vinifera L.) canes and their exposure to light

by

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Die Tragruten der Sorte Sultana (Vitis vinifera L.) und ihre Besonnung

Zusammenfassung. — In einem dreijährigen Freilandversuch wurden an einer Anzahl von Rebstöcken der Sorte Sultana drei Typen von Tragruten herangezogen. Diese Rutentypen nahmen vom Beginn ihrer Entwicklung als Triebe bis zur Traubenreife unterschiedliche Stellungen innerhalb des Blattwerkes ein und wurden demnach unterschiedlich besonnt. An jedem Rebstock befanden sich zwei Ruten (S) außerhalb und zwei Ruten (B) unterhalb des hauptsächlich durch die vier T-Ruten gebildeten Blattwerkes.

In jenen Ertragsfaktoren, die hauptsächlich durch die Knospenentwicklung bestimmt werden, nämlich in % Knospenaustrieb, % fruchtbare je ausgetriebene Knospen und in der Anzahl der Gescheine je Knospe waren die B-Ruten den S- und T-Ruten unterlegen. Unterschiede zwischen den beiden letzteren waren statistisch nicht gesichert. In einem der beiden Jahre wurden keine Unterschiede im Zeitpunkt des Knospenaustriebes gefunden, aber im anderen Jahre trieben im Durchschnitt die S-Knospen zuerst und die B-Knospen zuletzt.

In dem Jahr, in dem der Traubenertrag gemessen wurde, lag dieser bei den S-Ruten um 20% höher als bei den T-Ruten und um etwa 50% höher als bei den B-Ruten. Dabei waren keine Unterschiede in der Beerenentwicklung, nämlich im Einzelbeerengewicht und in der Zuckerkonzentration des Saftes, festzustellen. Es gab keine B-Ruten mit großen, aber einige S- und T-Ruten mit kleinen Erträgen.

Diese Ergebnisse zeigen, daß die einzelnen Triebe einer Rebe direkt auf ihre oberirdische Umwelt reagieren und daß man die Produktivität der Sorte Sultana durch Erziehungsarten, die eine volle Besonnung der nächstjährigen Tragruten ermöglichen, und durch entsprechende Wahl der Tragruten verbessern kann.

Introduction

Previous papers (Shaulis and May 1971, May *et al.* 1973) described the response of Sultana (syn. Sultanina, Thompson Seedless) grapevines to modifications of shoot crowding within the foliage canopy which were brought about by changes in the configuration of the trellis and in vine training. In these experiments, components of yield influenced by bud development and consequently yield itself increased as shoot crowding decreased and, conversely, as the exposure of the shoots to sunlight increased.

The replacement canes carrying these buds had been selected for excellence, as visually judged from criteria established by Antcliff *et al.* (1958). However, there was no information available on the specific environmental conditions of individual shoots within the general environment of a vine during the season of bud formation. Thus, it was not possible to determine whether the effects of the various treatments of trellising and training were due to a "pooled" effect on the vine as a whole or to responses of individual shoots.

The experiment described in the present paper was designed to answer this question. For this, Sultana vines were trained in such a way that the aerial environment was varied for canes arising on the same vine both during the season of bud formation and of fruit ripening.

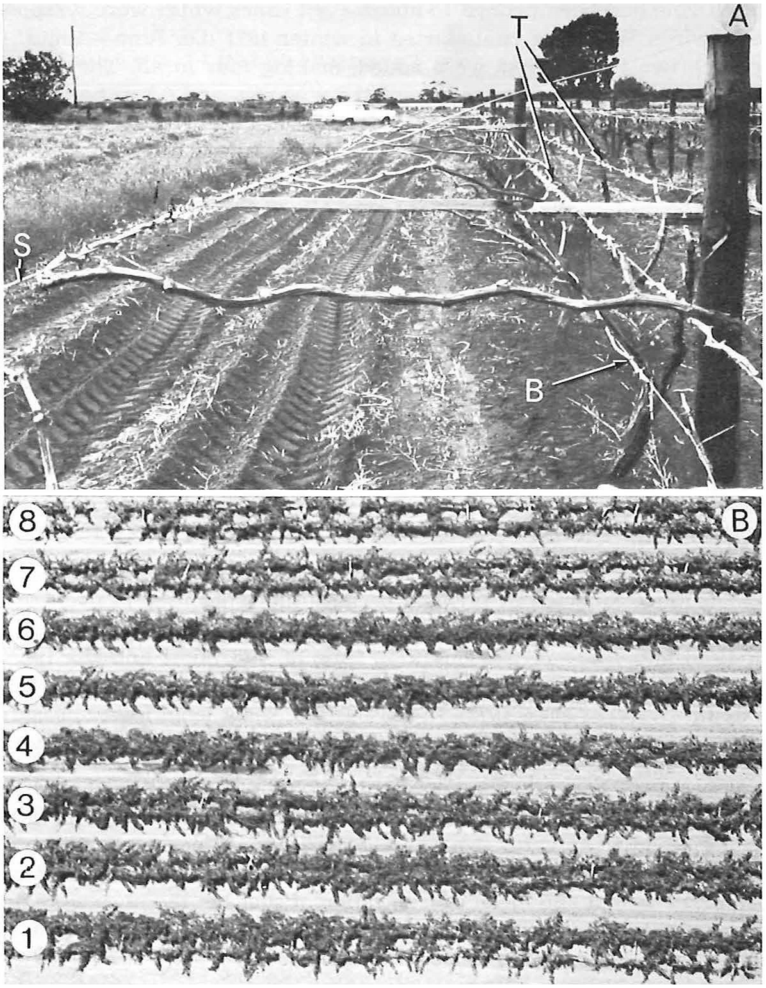

Fig. 1: A. Experimental Sultana vine. T = Top; B = Bottom; S = Side.
B. Aerial photograph of the experimental vineyard, taken December 7, 1972. Row 1: experimental row; rows 2 and 3: T-trellis with wires spaced 90 cm; rows 4, 5, 6: T-trellis with wires spaced 30 cm; rows 7 and 8: T-trellis with wires spaced 120 cm.
A. Versuchsrebe, Sorte Sultana (T, B, S, siehe Text).
B. Luftaufnahme der Versuchsanlage, 7. 12. 1972. Zeile 1: Versuchszeile; Zeilen 2 und 3: T-Drahtrahmen mit Drahtabstand 90 cm; Zeilen 4, 5, 6: T-Drahtrahmen mit Drahtabstand 30 cm; Zeilen 7 und 8: T-Drahtrahmen mit Drahtabstand 120 cm.

Material and Methods

For the experiment, we used 19 Sultana vines, about 15 years old, which formed part of the outside row along the N.W. boundary of a vineyard at Dareton, N.S.W., Australia. Up to and during the experiment the vines were furrow irrigated and treated according to standard commercial practice except for the experimental trellising and pruning treatments.

Prior to the experiment, the vines had been trained on a standard T-trellis consisting of two wires, placed 0.3 m apart in the horizontal plane and 1 m above ground level. Each vine had been pruned to about eight canes which were wrapped around the trellis wires. When the trial started in winter 1971 (i.e. June—August, southern hemisphere), two trellis wires were added, making four in all. The "Bottom" wire (B) was situated along the centre line of the vine row and 0.5 m below the level of the two original wires ("Top", T). The fourth wire ("Side", S) was placed at the same height as the T-wires, but in the boundary space 1.35 m to the N.W. of the centre line of the row. Views of the experiment are shown in Fig. 1, the experimental row being 1 in Fig. 1 B.

Each vine was pruned to eight canes of 14 nodes in winter 1971, 1972 and 1973, i.e. to four T-, two B- and two S-canes. In 1974, the vines were left unpruned. Each cane occupied singly, without overlapping, its own length of trellis wire. In 1971, the canes for the B-wire were shoots of two-year old canes brought downwards from the crown of the vine, the B-canes themselves being placed horizontally for their whole length. The canes for the S-wire were terminal shoots of two-year old canes which had been unwrapped from the outer T-wire and drawn towards the S-wire. During pruning for the following two seasons, replacement canes were selected from those arising at proximal nodes of spent canes on corresponding wires or from other nodes nearby. Thus, all canes arose at the level of the wires to which they were to be attached. Only the best available canes (ANTCLIFF *et al.* 1958) were retained.

No data were collected in 1971—72 because the canes used at pruning in winter 1971 had developed under pre-experimental conditions. During the seasons 1972—73 (season 1973) and 1973—74 (season 1974), time of bud burst and the type of shoot arising at each burst node were recorded, according to the method of the Merbein Bunch Count (ANTCLIFF *et al.* 1972). In season 1974, shoot length was measured and in spring 1974 (season 1975), all shoots were classified on eight unpruned vines.

In season 1973, harvest data could not be obtained as the fruit was lost due to extended rainy periods. In season 1974, the course of fruit maturation was observed from late December onwards, by sampling 100 berries per replicate on December 21, January 18 and February 1. At harvest time, each bunch was weighed individually. Mean berry weight and mean concentration of sugar in the juice were determined from samples taken from each treatment on each vine. Five vines were harvested on February 15 and 28, and nine vines on March 15.

To estimate the photosynthetic efficiency of "average" leaves from each treatment, the following method was used. On each of five randomly chosen vines, two shoots were selected from treatments B and S and four shoots from treatment T. Half the shoots came from node 5 and half from node 10; they had at least eleven fully expanded leaves. On January 8, 1974, five discs of 7.6 mm diameter (i.e. 226.7 mm^2 total leaf area) were sampled from the 10th and 11th leaf of each selected shoot. On January 11, each shoot was girdled below and above node 11. On January 16 and January 23, five discs per leaf were again taken from the previously sampled leaves. At each day of sampling, fresh weight and dry weight were measured. Each leaf was allotted, by visual inspection on January 23, to one of three classes according to the extent of its exposure to sunlight.

All variables used to characterize the effects of the treatments on a per-cane basis were statistically analysed by analyses of variance. Where appropriate, the trends along the canes were described either by fitting fourth order orthogonal polynomials or by plotting sliding means of three adjoining positions.

Results

1. Bud burst and fruitfulness of shoots

Treatment means per cane of time of burst (excluding nodes 1—3), % bud burst, % fruitful/burst nodes and bunches/node for seasons 1973, 1974 and 1975 are shown in Table 1. As a number of buds did not burst (mostly at the proximal positions) the data for time of burst and % fruitful/burst nodes were not orthogonal. For % fruitful/burst nodes, which is low at the proximal positions (Antcliff and Webster 1955), a value of zero was assumed for nodes where no buds had burst. Such nodes were ignored when calculating mean time of burst.

Table 1

Means of a number of yield components and of grape yield for cane types T, B and S
Mittelwerte einiger Ertragsfaktoren und des Traubenertrages für die Rutentypen T, B und S

Variable	Season	T	B	S	LSD_1	LSD_2
Days to burst after						
31. 8. 72	1973	7.14	7.13	7.41	NS	NS
26. 8. 73	1974	8.24	9.92	7.08	1.06	0.92
% Bud burst	1973	68.0	60.0	69.0	7.1	6.1
	1974	75.5	70.5	78.5	4.7	4.1
	1975	43.0	32.1	43.8	5.8	5.1
% Fruitful/burst nodes	1973	57.5	35.5	56.5	8.9	7.7
	1974	60.0	45.5	66.5	8.2	7.1
	1975	27.4	15.5	24.6	NS	NS
Bunches/node	1973	0.60	0.31	0.59	0.13	0.11
	1974	0.61	0.43	0.70	0.10	0.10
	1975	0.12	0.05	0.09	0.04	0.04
Berries/cane¹)	1974	1625	1031	2096	350	303
T.S.S. (° Brix)²,³)	1974	21.8	21.7	21.2	NS	NS
Berry weight (g)²)	1974	1.87	1.81	1.81	NS	NS
Fruit/cane (kg)	1974	2.95	1.79	3.71	0.61	0.53

LSD_1 = Least significant difference ($P = 0.05$) between means of T and B or S.
LSD_2 = Least significant difference ($P = 0.05$) between means of B and S.
NS = Not significant.
¹) Calculated from bunch weight and mean berry weight of sample.
²) For harvest on 28. 2. 1974.
³) Total soluble solids.

For time of burst, the treatments did not differ significantly in 1973, but buds of treatments B and T burst significantly later than those of treatment S in 1974. As shown in Fig. 2, these differences seemed to exist all along the canes, except at the most proximal nodes.

In 1973 and 1974, each of the means for % bud burst, % fruitful/burst nodes and bunches/node was based on data from 14 nodes × 2 (B and S) or 4 (T) canes × 19 vines. For all variables, they were significantly lower in treatment B than in the other two treatments which did not differ significantly from each other. In 1975,

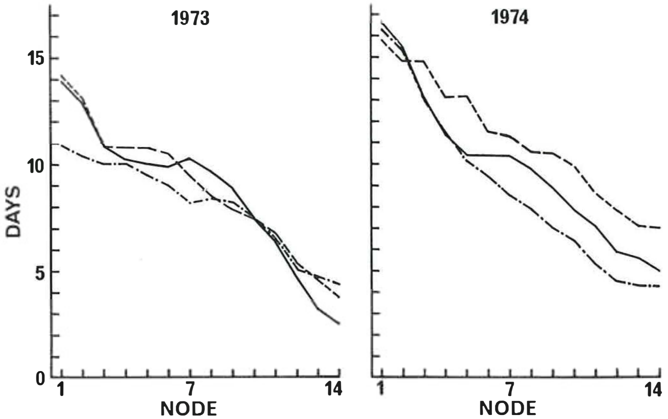

Fig. 2: Mean days to bud burst after August 30, 1972 (season 1973) and August 26, 1973 (season 1974) for node-positions 1—14 (plotted as sliding means of three adjacent node-positions) for three types of Sultana canes (T, B, S, see text), seasons 1973 and 1974. ——— = T; — — — = B; —·—·— = S.

Durchschnittliche Anzahl der Tage bis zum Knospenaustrieb nach dem 30. August 1972 (Versuchsjahr 1973) und nach dem 26. August 1973 (Versuchsjahr 1974) für die Knospenpositionen 1—14 (dargestellt als gleitende Mittel aus den Werten für drei benachbarte Knospenpositionen) für drei Typen von Sultana-Tragruten (T, B, S, siehe Text), Versuchsjahre 1973 und 1974. ——— = T; — — — = B; —·—·— = S.

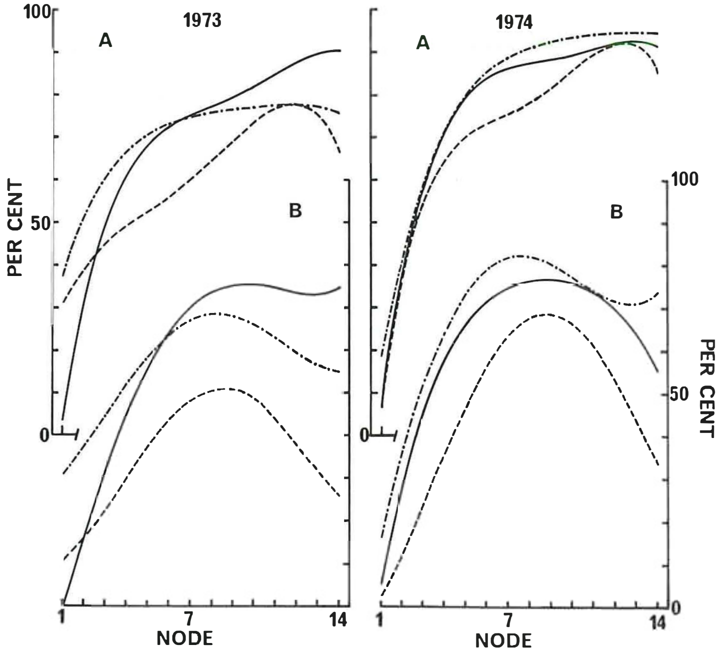

Fig. 3: Curves fitted to means of node-position 1—14 of % bud burst (A) and % fruitful/burst nodes (B) for three types of Sultana canes (T, B, S, see text), seasons 1973 and 1974. ——— = T; — — — = B; —·—·— = S.

Den Mittelwerten der Knospenpositionen 1—14 statistisch angepaßte Kurven für % ausgetriebene Knospen (A) und % fruchtbare/ausgetriebene Knospen (B) für drei Typen von Sultana-Tragruten (T, B, S, siehe Text), Versuchsjahre 1973 und 1974. ——— = T; — — — = B; —·—·— = S.

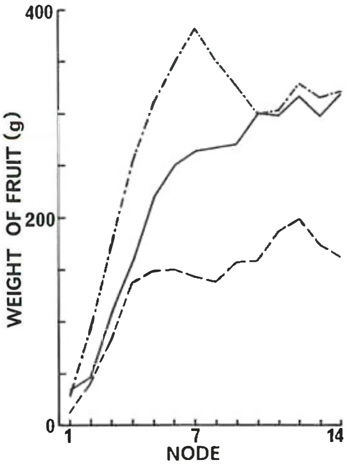

Fig. 4: Yield of grapes per node-position (plotted as sliding means of three adjacent node-positions) for three types of Sultana canes (T, B, S, see text), season 1974. ——— = T; — — — = B; —·—·— = S.

Traubenertrag je Knospenposition (dargestellt als gleitende Mittel aus den Werten für drei benachbarte Knospenpositionen) für drei Typen von Sultana-Tragruten (T, B, S, siehe Text), Versuchsjahr 1974. ——— = T; — — — = B; —·—·— = S.

the treatment means were based on data from all the nodes of all mature shoots which had developed during the 1974 season. Again, the values for treatment B were lower than those of the other treatments but this difference did not reach significance for % fruitful/burst nodes. In general, the 1975 results are somewhat affected by the low % bud burst which was obviously due to the vines not having been pruned.

Curves fitted to node-position means of % bud burst and % fruitful/burst nodes are shown in Fig. 3.

In general, treatment differences were similar all along the cane. But in treatment T in 1973, the trend of % bud burst seemed to differ from the trends of the other two treatments.

2. Fruit development

Berry development on canes of the three treatments did not differ at any stage from before veraison to full ripeness, as determined by measuring mean berry weight and the concentration of total soluble solids. Therefore the data are not presented.

Yield data, combined for the three times of harvest in the absence of interaction between treatment and harvest time, are shown in Table 1 and Fig. 4. Despite similar values for berry weight, there were considerable differences in yield between the three treatments: a reduction of about 20% from S to T and of about 50% from S to B. These were due to fewer berries per cane, as a joint consequence of fewer bunches/cane and fewer berries/bunch.

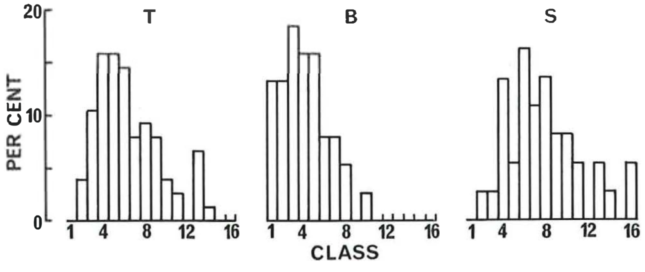

Fig. 5: Per cent of Sultana canes of each of the three cane types (T, B and S, see text) falling into one of 16 classes of cane yield (class interval = 500 g; class 1 = 0—500 g; class 16 = 7501—8000 g), season 1974.

Prozentuale Verteilung der drei Typen von Sultana-Tragruten (T, B, S, siehe Text), die in eine von 16 Klassen des Rutenertrages fallen (Klassenunterschied = 500 g; Klasse 1 = 0—500 g; Klasse 16 = 7501—8000 g), Versuchsjahr 1974.

The trends of yield per node are plotted in Fig. 4, as sliding means of three adjacent node-positions. The superiority of the S-canes over the T-canes appeared to be due to their high yield in the proximal and middle region of the cane.

The frequency distribution of cane yields over 16 yield-classes is shown in Fig. 5. In χ^2-tests, the distribution of yield per cane for treatment B differed from distributions for treatments T and S, which did not differ from each other. There were no high-yielding canes in treatment B, but there were some low-yielding canes in both S and T.

Table 2

A. Fresh and dry weight of leaf discs before and after shoot girdling. Girdles were applied on January 11 above and below the eleventh leaf of shoots arising at nodes 5 and 10 of three types of canes (T, B and S, see text). Leaves 19 and 11 were sampled.

B. Per cent of sampled leaves (leaf 11 only) which were in full sun, half shade or full shade.

A. Frisch- und Trockengewicht von Blattscheibchen vor und nach dem Triebringeln. Geringelt wurde am 11. Januar jeweils über und unter dem 11. Blatt von Trieben, die am 5. und 10. Knoten dreier Rutentypen wuchsen (T, B, S, siehe Text). Proben wurden von Blatt 10 und 11 genommen.

B. Prozent der Probenblätter (nur Blatt 11), die voll besonnt, halb beschattet oder voll beschattet waren.

	Leaf 10				Leaf 11			
	T	B	S	LSD	T	B	S	LSD
A. Fresh weight								
$(mg \times cm^{-2})$								
January 8	16.9	14.1	15.9		17.4	14.9	16.5	
January 16	14.8	11.6	14.8		17.5	14.3	17.4	
January 23	14.9	12.6	14.4		16.3	13.6	16.2	
				1.5_1				1.6_1
				1.4_2				1.2_2
Dry weight								
$(mg \times cm^{-2})$								
January 8	5.9	4.1	5.6		6.2	4.6	5.8	
January 16	6.4	4.3	5.9		7.1	5.3	7.0	
January 23	6.6	4.7	6.3		7.5	5.7	7.1	
				0.8_1				0.7_1
				0.4_2				0.3_2
Dry weight increase $(mg \times cm^{-2})$ from January 8 to:								
January 16	0.53	0.18	0.26		0.84	0.75	1.28	
				0.22_1				NS
January 23	0.64	0.55	0.63		1.28	1.15	1.32	
				NS				NS
B. % of leaves								
Fully lit	60	25	63					
Half shaded	17	44	25					
Fully shaded	23	31	12					

LSD_1 = Least significant difference ($P = 0.05$) for comparing means of different treatments.
LSD_2 = Least significant difference ($P = 0.05$) for comparing means of same treatment.
NS = Not significant.

3. Effects on vegetative growth

Mean length of the shoots growing during the 1974 season did not differ significantly between treatments. However, the shoots of treatment B had significantly longer internodes than those of the other treatments (7.4 cm for B, 6.5 cm and 6.3 cm for T and S respectively).

The results obtained from the sampling of leaf discs are given in Table 2, together with visual estimates of leaf shading. Before the girdling treatment was applied, both fresh weight and dry weight of the leaves from treatment B were less than those of the leaves from the other two treatments. The leaves below the proximal girdle gained in dry weight during the period January 8 to 23 in all three treatments. The fresh weight of leaves at the girdled node did not change significantly during the period of observation, while dry weight increased significantly in all three treatments at about the same rate.

Discussion

In the vineyards of the Murray Valley irrigation area, where the experimental vineyard was situated, light intensities of 4,200 to 12,000 ft-c (about 0.4—1.2 × $10^3 Wm^{-2}$) have been measured in the open during summer (Shaulis and May 1971). In the present experiment, shoots of S-canes would have intercepted most of the available radiation. On the T-canes, which singly occupied a space on the trellis wires, shoot density would have been comparable to that of vines in rows 7 and 8 of Fig. 1 B where the trellis wires were spaced 1.2 m apart and each wire carried two canes. These shoots were more favourably exposed than is the case on Sultanas in commercial vineyards of the region. There, at least two and sometimes up to six canes are wrapped around one section of trellis wire, leading to shoot densities as shown in rows 4, 5 and 6 of Fig. 1 B, where vines trained on a T-trellis of 30 cm width carried eight canes. Shoots of B-canes were provided with the least favourable radiation regime, with most of the leaves of the proximal ten nodes fully shaded. The visual estimates of leaf shading given in Table 2 indicate that these conditions were achieved at least at node 5, which is near the region of the canes from which replacement canes are chosen. The greater internode length of the B-canes, compared with the T- or S-canes further indicates that they had developed in shade (May and Antcliff 1963).

The data on weight of leaf discs (Table 2) also tend to confirm this. The leaves in treatment B were thinner than those in the other two treatments, and in other crops shade leaves are known to be thinner than leaves in the sun (e.g. in apples; Jackson and Beakbane 1970). On the other hand, it was not possible to demonstrate short term differences (i. e. over five days) in the rate of photosynthesis, as had been intended by measuring changes in dry weight of leaf discs from girdled nodes.

The results confirm earlier reports (Shaulis and May 1971, May *et al.* 1973) that reducing the shoot crowding within the Sultana canopy increases yield by increasing the productive potential of the buds. It extends the findings of these reports by showing that the individual shoots respond directly to an improved radiation environment, and that this effect is not mediated via the vine responding as a unit. These effects were obtained despite the vines of this experiment being rather weak. In the adjacent rows, about 1.7 kg of one year old pruning wood was produced per vine, compared with about 2.2 kg (Shaulis and May 1971) and about 4.0 kg (May *et al.* 1973) in the previous experiments. In bigger vines, still larger effects could be expected.

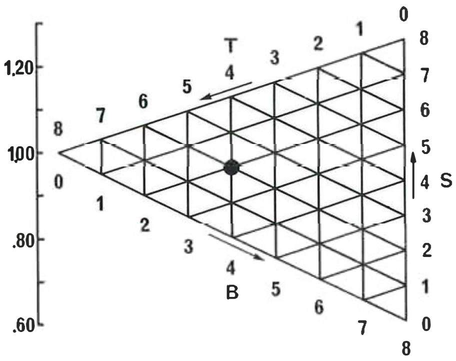

Fig. 6: Triangular plot of expected proportional changes in yield per vine when vines, pruned to eight canes, carry varying numbers of canes of type T, B or S. The following assumptions are made: Yields of T-, B-, and S-canes are the respective 1974 means; the yield of vines with eight T-canes is taken as the unit. 0—8 = number of canes per vine. T, B, S = types of canes (see text). The position of the experimental vines (4T + 2B + 2S) is given (●).

Dreieck-Darstellung der zu erwartenden proportionalen Veränderungen des Ertrages je Rebe, wenn an Reben mit acht Tragruten die Anzahl der T-, B- und S-Ruten geändert wird. Folgende Voraussetzungen wurden angenommen: Die Erträge der T-, B- und S-Ruten entsprechen den Mittelwerten des Versuchsjahres 1974; der Ertrag von Reben mit acht T-Ruten wird als Vergleichsnorm betrachtet. 0—8 = Anzahl der Ruten je Rebe. T, B, S = Rutentyp (siehe Text). Die Stellung der Versuchsreben (4T + 2B + 2S) innerhalb des Schaubildes ist angegeben (●).

The large increase in yield per cane from treatment T to treatment S in 1974 was due to the combined effects of greater % bud burst and greater % fruitful/burst nodes. Buttrose (1970) has shown that the development of leaf primordia in the developing bud is depressed if light intensity and temperature are reduced and Huglin (1958) has noted that buds are less likely to burst if they contain fewer preformed leaf primordia than is average. At least in the 1974 season, there were significant differences in time of bud burst between the three cane types, S-buds bursting first and B-buds last. These differences may have been related to the development of the buds prior to dormancy, particularly to bud fruitfulness. Fruitful Sultana buds tend to burst before otherwise comparable unfruitful buds (Antcliff and Webster 1955, Antcliff *et al.* 1957).

The effect of selecting, as far as possible, replacement canes of greatest yielding potential is illustrated by Fig. 6. This model is based on the assumptions that the yield of each T-, B- and S-cane is equal to the 1974-mean for the appropriate treatment, and that vines with eight T-canes represent the standard vine. The actual mean yield of the experimental vines was 22.8 kg. In the model, exchanging one T-cane by one B-cane would decrease vine yield by about 5% and one T-cane by one S-cane would increase yield by about 3%. Vines with eight B-canes would suffer a yield reduction of almost 40%, while vines with eight S-canes would have a yield increase of 26%. This model is based on yield data from only one season and the magnitude of the yield changes is likely to differ from year to year.

The results here presented indicate that the yield potential of individual canes is very strongly affected by the aerial environment surrounding them, which can cause large differences between canes on the same vine. This points to the potential of increasing yield of Sultanas by cane selection, or preferably by providing conditions within the canopy where sufficient canes are fully exposed to radiation, as are the S-canes of this experiment.

Training Sultanas in a manner similar to the Geneva Double Curtain (Shaulis *et al.* 1966) has already been shown to successfully achieve this (Shaulis and May 1971, May *et al.* 1973). However, by giving optimal exposure mainly to the shoots which will furnish replacement canes similar responses may be obtainable with less modification of vineyard design.

Summary

During three seasons, each of a number of Sultana vines were provided with three types of cane. These cane types differed, during the two seasons covering shoot development and fruit ripening, in their position within the vine canopy, and hence in exposure to solar radiation. On each vine, two canes (S) were placed outside and two canes (B) below the main body of the canopy formed in the main by the four T-canes.

In all the yield components determined mainly by bud development, i.e. % bud burst, % fruitful/burst nodes and bunches/node the B-canes were inferior to the S- and T-canes, which did not differ significantly from each other. In one season, time of bud burst did not differ, but in the other season the buds of the S-canes burst first and the buds of the B-canes last. In the season when yield itself was measured, S-canes yielded about 20% more than T-canes and about 50% more than B-canes, despite the absence of any differences in yield components related to berry development, i.e. mean berry weight and concentration of sugar. There were no high-yielding B-canes, but some low-yielding S- and T-canes.

It is concluded that individual shoots on the same vine respond directly to their aerial environment, and that proper cane selection or the choice of a training system allowing full exposure of the developing prospective canes can increase the productivity of Sultana vines.

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