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Effect of various combinations of trellis, pruning, and rootstock on vigorous Sultana vines

by

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Der Einfluß verschiedener Kombinationen von Drahtrahmen, Rebschnitt und Unterlage auf starkwüchsige Sultana-Reben

Zusammenfassung. — Der vereinte Einfluß von drei Drahtrahmen-Typen und drei Schnittarten auf wurzelechte Sultana-Reben und auf Sultana, gepfropft auf den Unterlagen Salt Creek und 1613 C, die in einem leichten, Nematoden- und Phylloxera-freien Urboden des australischen Murray-Bewässerungsgebietes wuchsen, wurde untersucht. Alle Resultate wurden der Varianzanalyse unterworfen.

In den ersten vier Ertragsjahren nach der Pflanzung, die dem Versuch vorausgingen, war der Ertrag von Sultana auf Salt Creek um 40% höher als derjenige von wurzelechten oder auf 1613 C gepfropften Reben. In den folgenden vier Versuchsjahren betrug dieser Unterschied etwa 30%. Mehr und größere Trauben waren der Grund hierfür.

Die drei Drahtrahmen hatten die folgenden Dimensionen: Ein weiter, hoher Rahmen mit zwei Drähten, die mit 1,2 m Abstand 1,5 m über dem Boden angebracht waren; ein enger, hoher Rahmen (0,3 m × 1,5 m) und ein enger, niedriger Rahmen (0,3 m × 1,0 m) mit einem weiteren Draht für das Blattwerk. Am weiten Drahtrahmen teilte sich das Blattwerk spontan in zwei Hälften. In der ersten Vegetationsperiode nach dem Erstellen der Drahtrahmen war der Ertrag am weiten Rahmen etwas besser, vermutlich wegen des geringeren Fäulnisbefalles. In den folgenden drei Vegetationsperioden brachten die Reben am weiten Drahtrahmen um 40 bis 50% höhere Erträge, da mehr und größere Trauben vorhanden waren, während Beerengröße, Zucker- und Säuregehalt unverändert blieben. Auch das Gewicht des Schnittholzes war etwas größer.

Die Reben wurden zu 9, 14 oder 19 Tragruten von je 14 Knospen, demnach zu 126, 196 oder 266 Knospen, geschnitten. Am engen Drahtrahmen konnte man die höchste Knospenzahl in den letzten Jahren des Versuches nicht erhalten, und auch das Triebgewicht wurde kleiner. Im allgemeinen hatte die Verdopplung der Knospenzahl nur einen 20prozentigen Anstieg im Ertrag zur Folge.

Wechselwirkungen zwischen den Behandlungsarten Drahtrahmen, Schnitt und Unterlage kamen nur vereinzelt vor. Die vorteilhaften Einflüsse von weitem Drahtrahmen, Salt Creek-Unterlage und von höheren Knospenzahlen, wenigstens bis zu 196 Knospen je Rebe, waren additiv. Infolgedessen war der Ertrag der zu 196 Knospen geschnittenen Sultana auf Salt Creek und auf weitem Rahmen zweimal so groß wie derjenige der wurzelechten Sultana auf engem Rahmen mit 126 Knospen.

Es wird geschlossen, daß Sultanaknospen am weiten Drahtrahmen fruchtbarer sind und daß folglich im nächsten Jahr die Reben mehr Traubenbeeren tragen, die überdies durch Verbesserung der Photosynthese völlig ausreifen können. Die ökonomischen Verhältnisse für den Gebrauch von weiten Drahtrahmen werden diskutiert.

Introduction

In a recent paper, SHAULIS and MAY (1972) showed that the *Vitis vinifera* cultivar Sultana, growing in the Murray Valley irrigation area of Australia, and the *Vitis labrusca* hybrid Concord, growing in the north-east of USA, respond to reductions in shoot crowding in a similar way. This was the first indication that large improvements in yield may be obtainable for *Vitis vinifera* vines growing in a region with intense solar radiation by adopting the system of "Geneva Double Curtain" training which has proved optimal for large Concord vines under conditions of frequent cloudiness (SHAULIS *et al.* 1966).

The present paper expands, and confirms, the results reported by SHAULIS and MAY. It describes the responses of large Sultana vines, grown either on their own roots or on nematode-resistant rootstocks, to modifications of trellis and pruning.

Experimental

The vines used in this experiment were planted in winter 1962 in the CSIRO vineyard situated in the Coomealla (New South Wales) irrigation district of the Australian Murray Valley. Its virgin soil is classified as Dareton sandy loam (NORTHCOTE and BOEHM 1949). At planting time, the 324 vines were arranged in 108 randomized blocks of three single-vine plots. Each block comprised an own-rooted Sultana (S), a Sultana scion on Salt Creek rootstock (SC), and a Sultana scion on 1613 C rootstock (1613). The vines were planted 2.7 m apart in rows of 3.3 m spacing, trained on the standard T-trellis of the region with two cane-wires placed side by

Table 1

Fresh weight of fruit (kg) in the seasons prior to the commencement of the experiment, statistically analysed as if the trellis and pruning treatments had been applied

Traubenfrischgewicht (kg) in den Vorjahren der Untersuchung. Statistische Verrechnung wie unter den Bedingungen der Drahtrahmen- und Schnittversuche

Season	Trellis				Pruning				Rootstock			
	NL	NH	WH	LSD	9	14	19	LSD	S	1613 C	SC	LSD
1965	21.2	21.8	22.9	NS	20.9	23.4	21.5	NS	14.2	20.0	31.6	3.3
1966	22.7	20.9	21.7	NS	20.6	23.5	21.2	NS	18.8	20.5	26.0	2.7
1967	20.3	19.9	20.5	NS	19.9	19.9	21.0	NS	19.8	17.8	23.2	2.2
1968	34.6	34.3	34.8	NS	36.2	34.1	33.4	NS	34.0	30.7	39.0	3.1
$\bar{x}$ 1965/68	24.7	24.2	25.0		24.4	25.2	24.3		21.7	22.2	30.0	

LSD = Least significant difference at p = 0.05, NS = not significant.

Treatment identification:

Trellis:	NL (narrow and low)	Cane wires 0.3 m apart, 1.0 m above ground
	NH (narrow and high)	Cane wires 0.3 m apart, 1.5 m above ground
	WH (wide and high)	Cane wires 1.2 m apart, 1.5 m above ground
Pruning:	9	9 canes, 126 nodes
	14	14 canes, 196 nodes
	19	19 canes, 266 nodes
Rootstock:	S	Sultana, own-rooted
	SC	Sultana scion on Salt Creek rootstock
	1613 C	Sultana scion on 1613 C rootstock

Erläuterung der Symbole:

Drahtrahmen:

NL = Drähte mit 0,3 m Abstand, 1,0 m über dem Erdboden
NH = Drähte mit 0,3 m Abstand, 1,5 m über dem Erdboden
WH = Drähte mit 1,2 m Abstand, 1,5 m über dem Erdboden

Schnitt:

9 = 9 Triebe, 126 Nodien
14 = 14 Triebe, 196 Nodien
19 = 19 Triebe, 226 Nodien

Unterlage:

S = Sultana, wurzelecht
SC = Sultana auf Salt Creek als Unterlage
1613 C = Sultana auf 1613 C als Unterlage

Fig. 1: (A) NL-vines (foreground) and WH-vines (background) at the beginning of the experiment, winter 1968. (B) WH-vines on 9th October, 1972. (C) Half-canopy of WH-14-S vine on 16th October, 1972. (D) Full canopy of NL-14-S vine on 16th October, 1972. For treatment identification, see legend, Table 1.

Abb. 1: (A) Reben der Variante NL (Vordergrund) und Reben der Variante WH (Hintergrund) bei Versuchsbeginn, Winter 1968. (B) Reben der Variante WH am 9. Oktober 1972. (C) Hälfte des Blattwerks der Variante WH-14-S am 16. Oktober 1972. (D) Gesamtes Blattwerk der Variante NL-14-S am 16. Oktober 1972. Symbole der Behandlungen siehe Erläuterung zu Table 1.

side 0.3 m apart about 1.0 m above ground level, with a single foliage wire about 0.35 m above the cane-wires. The vineyard was furrow-irrigated, maintained and, until the commencement of the experiment, pruned according to local commercial practice.

The experiment was started in winter 1968 with the treatments listed in Table 1. Three trellis and four pruning treatments were added to the three rootstock-scion treatments. For trellis treatment NL (narrow, low), the trellis described above was retained. For treatment NH (narrow, high) the two cane-wires, 0.3 m apart, were raised to 1.5 m height, and for treatment WH (wide, high), the two wires were spaced 1.2 m apart at 1.5 m height and, as in NH, the foliage wire was omitted. The trellis treatments NL and WH are shown in Fig. 1A.

The pruning treatments fell into two groups. In the first, "balanced pruned" group, the number of nodes per vine was related to the weight of the one-year-old canes produced during the preceding season. Three canes with 14 nodes each were retained for the first 454 g (1 lb) of prunings and one additional cane for each further 454 g. The second group, with "fixed pruning", comprised three treatments with set cane-numbers. The node number of treatment 14 (with 14 canes of 14 nodes each) corresponded to that of "balanced pruned" vines which had average pruning weights ($\bar{x}$) in winter 1968. The most severely pruned treatment 9 (with 9 canes) and the least severely pruned treatment 19 (with 19 canes) had node numbers comparable to "balanced pruned" vines with ($\bar{x} - \sigma$) and ($\bar{x} + \sigma$) pruning weight respectively of the normally distributed population of vines.

The experiment was laid out as a six times replicated split-split-plot. The trellis treatments formed the three main plots of each block; each main plot occupied one half-row of 18 vines. The pruning treatments formed the six sub-plots of each main plot, three sub-plots being "fixed pruned" and three "balanced pruned". The plot near the head- or footland of each half-row was always "balanced pruned" because it often contained exceptionally large vines; all other sub-plots were allotted at random. Each sub-plot contained three single-vine sub-sub-plots, which were the rootstock-scion combinations.

In each of the four seasons of the experiment, named 1969 to 1972 after the calendar year of harvest, pruning weight (i. e. the weight of the canes removed plus an estimate of the weight of the canes retained), bunch number, and fresh weight of fruit were determined for each vine. Mean berry weight, concentration of sugar and, in 1971, concentration of organic acids were determined from a sample of berries taken from each vine. Values of other yield components were calculated from these measurements and some additional observations are mentioned in the results section.

All measurements were statistically analysed, using the GENSTAT 4 statistical package (WILKINSON 1969; BAXTER and WILKINSON 1970) designed for the CSIRO computer network (CDC 3200/3600).

Results

This paper will describe mainly the results obtained for vines of "fixed pruning" although some reference will also be made to vines of "balanced pruning". Comparisons between the two types of pruning will be reported elsewhere.

1) Fresh weight of fruit, pre-experiment period 1965—1968

Fresh weight of fruit per vine in the seasons prior to applying the trellising and pruning treatments were statistically analysed as if these treatments had in fact been applied. Rootstock treatments differed significantly, because SC-vines out-yielded the other two types in each season; over the four years, they produced about 40 per cent more crop. No trends or differences were observed which could have affected the validity of the subsequent experimental results.

2) Pruning weight and node numbers

During the course of the experiment, WH-vines tended to produce more pruning wood than NL- or NH-vines, and SC-vines tended to be larger than S- or 1613-vines. Lighter pruning tended to reduce pruning weigth in the later years of the experiment. All these trends reached significance only in 1972, but they were evident in the analysis of the 1970/72 three-year means, where WH-, 9-, and SC-vines were

Table 2

Weight of one-year old pruning wood (kg) and number of nodes per vine for three trellis, three "fixed pruning", and three rootstock treatments, seasons 1969 to 1972. For treatment identification, see legend, Table 1

Gewicht des einjährigen Schnittholzes in kg und Zahl der Nodi je Rebe bei drei Drahtrahmen-Typen, drei Schnittarten und drei Unterlagenvarianten, Jahrgänge 1969 bis 1972. Symbole für die Behandlungen siehe Erläuterung zu Table 1

Season	Trellis				Pruning				Rootstock			
	NL	NH	WH	LSD	9	14	19	LSD	S	1613 C	SC	LSD
					Pruning weight (kg)							
1969	5.2	4.9	4.9	NS	4.9	5.2	5.0	NS	4.3	5.7	5.1	0.53
1970	4.0	3.7	4.5	NS	4.1	4.1	3.9	NS	4.0	4.0	4.1	NS
1971	3.8	3.4	4.0	NS	3.9	3.8	3.5	NS	3.5	3.7	4.0	NS
1972	4.2	4.2	5.0	0.38	4.7	4.5	4.3	0.31	4.6	4.0	4.8	0.34
$\bar{x}$ 70/72	4.0	3.8	4.5	0.47	4.2	4.1	3.9	0.28	4.0	3.9	4.3	0.31
					Number of nodes/vine							
1969	177	180	181	NS	126	192	221	8.6	176	183	180	NS
1970	190	194	194	NS	126	193	259	5.6	191	194	193	NS
1971	174	189	195	10.9	124	189	245	8.2	184	187	186	NS
1972	159	182	193	9.4	125	181	228	9.3	179	179	175	NS
$\bar{x}$ 70/72	174	188	194	7.3	125	188	244	6.2	185	187	185	NS

LSD = Least significant difference at p = 0.05; NS = not significant.

biggest ($p < 0.05$). There were no significant interactions between the trellis, pruning, and rootstock treatments.

If correctly pruned, vines of treatments 9, 14, and 19 should have been given 126, 196, and 266 nodes respectively. Most vines of treatment 9 carried the correct node-number in each season. But in treatments 14 and 19, fewer than the prescribed number of nodes had to be retained in many cases (Table 2) to maintain the system of pruning accepted for the trial, i. e. to use only canes which arose on the proximal third of last year's canes, on spurs or as watershoots and which were of reasonable quality (ANTCLIFF *et al.* 1958) with at least eight mature nodes. Particularly on the NL-trellis, correct pruning became difficult on the lightly pruned vines as the experiment progressed, and significant trellis by pruning interactions were obtained in the 1971 and 1972 seasons and for the 1970/72 means. This is shown in Table 3; the two-way table for trellis and "fixed pruning" treatments gives the mean number of nodes per vine and the number of vines per 18-vine set (the six replicates of each of the three rootstocks) which were pruned to within five per cent of the theoretical node-number.

3) Number of bunches and fresh weight of fruit

In 1969, the season after trellis conversion, when the number of bunches was not counted, differences in bunch number between trellis or pruning treatments would have only been caused by differences in the proportion of buds that burst because conditions at the time of fruit bud differentiation had been uniform. In the following seasons, when conditions at bud differentiation were influenced by these treatments, WH-vines carried many more bunches than vines on the other two trellises ($p < 0.01$ or < 0.001), which in turn did not differ from each other. The superiority of the WH-vines was of the order of 40 per cent in 1972 and of 33 per cent over the

Table 3

Mean number of nodes per vine and number of vines whose node-number deviated by less than ±5 per cent from the prescribed number, for three trellis and three "fixed pruning" treatments. Seasons 1970 to 1972. For treatment identification, see legend, Table 1

Durchschnittsanzahl der Nodi je Rebe und Zahl der Reben, deren Knotenanzahl um weniger als ±5% von der theoretischen Anzahl abweicht, bei drei Drahtrahmen-Typen und drei Schnittarten. Jahrgänge 1970 bis 1972. Symbole für die Behandlungen siehe Erläuterung zu Table 1

Season	1970			1971			1972			$\bar{x}$ 1970—1972		
Pruning	9	14	19	9	14	19	9	14	19	9	14	19
Trellis						Number of nodes						
NL	126	190	254	125	179	217	124	157	195	125	176	222
NH	126	194	263	121	191	254	125	192	229	124	192	248
WH	126	195	262	126	196	264	126	193	259	126	195	262
S.E.	3.3			4.9			5.7			3.7		
						Number of vines						
NL	18	14	15	17	9	6	17	6	4			
NH	18	17	15	15[1]	17	13	17	16	6			
WH	18	17	17	18	18	17	17	17	13			

[1]) Three vines pruned wrongly in error; S.E. = Standard error.

1970/72 period. Following their greater bunch-numbers, WH-vines produced more fresh fruit in each season from 1970 onwards ($p < 0.001$). Again, NL- and NH-vines did not differ significantly from each other. Compared with the NL-vines, WH-vines produced 40 to 50 per cent more crop, the three-year average being 43 per cent. In the initial season (1969), the yield of the WH-vines exceeded that of the NH-vines ($p < 0.05$), but not that of the NL-vines. This was probably related to the amount of mould-damage which occurred in this very rainy harvest-season. When the incidence of mould was rated visually for each vine on a scale of 0 to 4, WH-vines had a mean value of 0.93, NL-vines of 1.08 and NH-vines of 1.18, these values being inversely related to mean yield per vine.

As number of nodes per vine increased, more bunches and more fresh fruit was produced, but the increases were disproportionate. Over the three-year period 1970/72, the almost two-fold increase in node-number from 9-cane to 19-cane vines (Table 2) resulted in an increase of only about 30 per cent in bunch number and of less than 20 per cent in yield of fruit (Table 4).

In all seasons, SC-vines produced more bunches and considerably more fruit than S- or 1613-vines, which in turn did not differ from each other in either measurement.

Bunch-number per vine showed a significant trellis by rootstock interaction in 1971 due to unexpectedly low values for the 1613-vines on NH-trellis. More important was the significant trellis by pruning interaction in 1972 ($p < 0.01$), caused mainly by the deficiency in node-numbers on the lighter pruned NL- and NH-vines which did not occur on the WH-vines. Fresh weight of fruit per vine showed no interactions between the trellis, pruning, and rootstock treatments.

The three-way table of trellis, pruning, and rootstock treatments for the 1970/72 means of yield per vine (Table 5) illustrates the effects of the treatments and of their combinations. NL-9-S represents the Sultana grown commercially in the

Table 4

Bunch number and fresh weight of fruit per vine (kg) for three trellis, three "fixed pruning", and three rootstock treatments. Season 1969 to 1972. For treatment identification, see legend, Table 1

Anzahl und Frischgewicht der Trauben je Rebe in kg bei drei Drahtrahmen-Typen, drei Schnittarten und drei Unterlagenvarianten. Jahrgänge 1969 bis 1972. Symbole für die Behandlungen siehe Erläuterung zu Table 1

Season	Trellis				Pruning				Rootstock			
	NL	NH	WH	LSD	9	14	19	LSD	S	1613 C	SC	LSD
					Bunch number/vine							
1970	64	64	78	8.3	53	71	83	7.1	70	66	71	NS
1971	34	34	46	5.6	32	39	43	4.6	34	39	40	3.9
1972	55	60	78	6.9	59	64	69	6.0	60	65	68	6.2
$\bar{x}$ 70/72	51	53	68	3.8	48	58	65	3.9	55	57	60	3.7
					Weight of fruit/vine (kg)							
1969	13.7	12.7	16.7	3.0	11.4	15.1	16.6	2.7	10.5	13.9	18.7	2.7
1970	29.8	30.8	41.3	2.5	30.5	35.1	36.3	2.1	34.1	29.1	38.7	2.8
1971	12.1	13.5	18.5	2.7	14.0	14.3	15.8	NS	13.1	13.4	17.6	1.9
1972	23.1	24.8	33.2	3.8	24.2	26.7	29.3	2.8	24.8	24.0	32.3	2.8
$\bar{x}$ 70/72	21.6	23.0	31.0	1.4	22.9	25.7	27.1	1.5	24.0	22.2	29.5	1.7

LSD = Least significant difference at $p = 0.05$.

region. Leaving it with twice the number of nodes led to an increase in yield of less than 20 per cent which was statistically not significant. Using Salt Creek rootstock with standard trellis and pruning improved yield significantly (by about 30 per cent). Widening the trellis for own-rooted standardly-pruned vines increased yield significantly (by about 50 per cent). When Sultanas were grown on Salt Creek rootstock, trained on wide trellis and pruned to high node-numbers, yield was twice that of normally trained and pruned own-rooted Sultanas.

Number of bunches per node and yield of fruit per node, calculated from values of bunch-number, yield, and node-number per vine, are shown in Fig. 2 for the three trellis-treatments at the three levels of pruning. WH-vines were superior in

Table 5

Three-year means (1970/72) of fresh weight of fruit per vine (kg) for three trellis, three "fixed pruning", and three rootstock treatments. For treatment identification, see legend, Table 1

Dreijahresdurchschnitt (1970/72) des Traubenfrischgewichtes je Rebe in kg bei drei Drahtrahmen-Typen, drei Schnittarten und drei Unterlagenvarianten. Symbole für die Behandlungen siehe Erläuterung zu Table 1

Rootstock	S			1613 C			SC		
Trellis	NL	NH	WH	NL	NH	WH	NL	NH	WH
Pruning 9	18.5	18.8	27.8	18.3	15.7	25.4	24.3	25.9	31.4
14	18.9	22.8	30.9	19.3	18.9	30.6	25.5	28.5	35.7
19	21.9	25.9	30.5	19.6	21.5	30.1	28.4	29.3	36.9

Standard error = 1.79.

For least significant differences between the overall effects of trellis, pruning and rootstock, see Table 4.

both measurements, as was to be expected from the values for whole vines. With pruning becoming less severe, both variables decreased sharply in all three trellis treatments, and WH-vines showed the sharpest decrease. In 1971, this led to a significant trellis by pruning interaction.

The aberrant behaviour of the NL-19 vines in 1972 is probably due to their very low number of nodes which corresponded to that of treatment 14 on the other two trellises (Table 3).

4) Berry weight, bunch weight, berry number per vine, and concentrations of sugar and organic acids

Mean berry weight, measured in all seasons except 1971, was only slightly affected by trellis or pruning treatments. 1613-vines tended to produce smaller berries than S- or SC-vines. Even where significant, these differences amounted to less than five per cent.

Compared with NL- or NH-vines, WH-vines had larger bunches, obviously due to a tendency to carry more berries. It was calculated that NL-bunches had on the average 261 and 212 berries in 1970 and 1972 respectively, while WH-bunches averaged 272 and 233 berries. In 1972, this relationship was confirmed by actual counts of berries on ten bunches randomly chosen from every S-9 vine. In 1970 and 1971, but not in 1972, calculated weight of bunches became smaller as node-number per

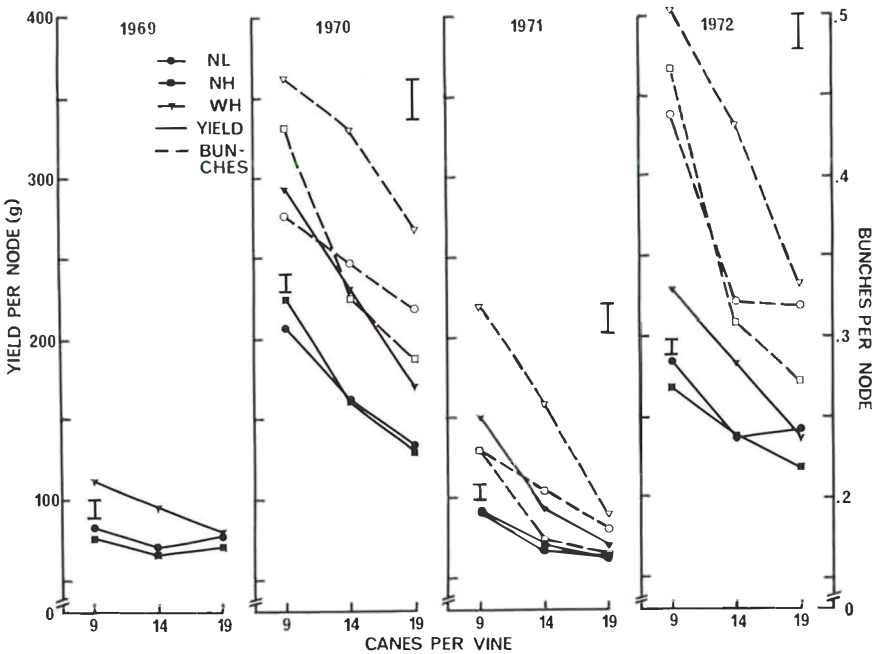

Fig. 2: Number of bunches per node and fresh weight of fruit per node for the three trellis treatments at the three "fixed pruning" treatments, pooled over the three rootstock treatments. Season 1969 to 1972. For treatment identification, see legend, Table 1. Least significant differences at p = 0.05 are shown.

Abb. 2: Anzahl Trauben je Nodus und Traubenfrischgewicht je Nodus in Beziehung zu den drei Drahtrahmen-Typen und den drei Schnittarten; die drei Unterlagenvarianten sind zusammengefaßt. Jahrgänge 1969—1972. Symbole der Behandlungen siehe Erläuterung zu Table 1. Signifikanzgrenzen bei p = 0,05 eingetragen.

Table 6

Mean berry weight (g), mean bunch weight (g), concentration of total soluble solids (°Brix) and of organic acids (as g/l tartaric acid) for three trellis, three "fixed pruning", and three rootstock treatments. Season 1969 to 1972. For treatment identification, see legend, Table 1

Durchschnittliches Beerengewicht in g, durchschnittliches Traubengewicht in g, Gehalt an gesamter löslicher Trockensubstanz (°Brix) und an organischen Säuren (als g Weinsäure/l), bei drei Drahtrahmen-Typen, drei Schnittarten und drei Unterlagenvarianten. Jahrgänge 1969—1972. Symbole für die Behandlungen siehe Erläuterung zu Table 1

Season	Trellis				Pruning				Rootstock			
	NL	NH	WH	LSD	9	14	19	LSD	S	1613 C	SC	LSD
					Berry weight (g)							
1969	1.91	1.82	1.91	0.08	1.88	1.88	1.87	NS	1.92	1.83	1.89	0.06
1970	1.93	1.97	2.02	NS	2.05	1.96	1.91	0.07	2.01	1.92	1.99	0.06
1972	2.01	1.86	1.86	0.12	1.95	1.90	1.88	NS	1.88	1.88	1.97	0.07
					Bunch weight (g)							
1970	501	496	550	39.8	584	516	447	45.5	526	458	563	42.4
1971	361	389	410	34.4	420	372	368	34.4	374	347	439	32.3
1972	426	421	434	NS	415	431	434	NS	426	369	485	36.7
					Berries per vine (×100)							
1969	72	70	88	NS	61	80	89	15	55	76	99	15
1970	155	158	209	16	149	181	192	14	172	153	198	18
1972	114	131	180	22	122	147	158	15	134	127	165	16
					Total soluble solids (°Brix)							
1969	20.4	20.5	20.7	NS	20.7	20.4	20.5	NS	20.5	20.2	20.9	0.28
1970	18.8	18.6	18.8	NS	19.0	18.6	18.6	NS	18.6	18.9	18.7	NS
1971	23.6	23.3	24.1	NS	23.9	23.6	23.4	NS	23.6	23.6	23.7	NS
1972	21.6	21.2	20.8	NS	21.4	21.2	21.0	NS	21.0	21.5	21.1	0.28
					Titrateable acidity (g/l)							
1971	5.42	5.72	5.22	NS	5.78	5.44	5.14	0.50	5.51	5.48	5.36	NS

LSD = Least significant difference at $p = 0.05$; NS = Not significant.

vine increased. In the last season there was a significant trellis by pruning interaction because only WH-vines reacted to less severe pruning by having smaller bunches. This was obviously related to the corresponding interaction in number of bunches per vine. Compared with own-rooted Sultanas, SC-vines had larger and 1613-vines had smaller bunches, because they differed in the numbers of berries per bunch (Table 7).

Berry number per vine (Table 6) was calculated from fresh weight of fruit and mean weight per berry. The differences express the effects of the various treatments on the combination of bunch number per vine and berry number per bunch.

Sugar concentration of the juice (measured as total soluble solids, °Brix) was not significantly affected by trellis or pruning (Table 6), but there was a tendency towards higher °Brix-values in WH-vines and lower °Brix-values in lightly pruned vines. Apparently sugar concentration suffered when yield of fruit was increased by leaving more nodes, but remained unaffected when it increased as the result of trellis modification.

Table 7

Number of berries per bunch for three rootstock treatments. Seasons 1970 and 1972
Anzahl der Beeren je Traube bei drei Unterlagenvarianten. Jahrgänge 1970 bis 1972

Season	Rootstock S	Rootstock 1613 C	Rootstock SC	LSD
1970	261	239	283	22.6
1972	227	197	246	18.9

LSD = Least significant difference at p = 0.05.

Titrateable acidity was measured in 1971 only (Table 6). The small differences between trellis treatments, though non-significant, seemed to be due to changes in fruit maturity as they were inversely related to the respective ^{0}Brix-values. On the other hand, the increase in yield by less severe pruning seemed to have led to a general lowering of fruit quality as concentrations of sugar and acids were reduced concurrently.

5) Total annual production of photosynthate

The seasonal production of photosynthate per vine, i. e. the amount of sugar (total soluble solids) and of mature wood, is shown in Fig. 3. The WH-vines produced significantly ($p < 0.001$) more sugar and, at the same time, tended to produce more wood than NL- or NH-vines from 1970 onwards. But the small increases in the yield of sugar caused by higher node-numbers were accompanied by a trend towards lowered production of wood. Over the 1970/72 period, WH-vines produced a total of 19.0 kg sugar and 13.5 kg pruning wood, compared with 13.4 kg sugar and 11.9 kg wood on NL-vines.

6) Overall trellis comparison

In the absence of major interactions between trellis, pruning, and rootstock treatments, the trellis effects were re-examined by including the "balanced pruned" vines and by analysing the trial as a six times replicated randomized block experiment in which each block contained three trellis-plots of 18 vines each (Fig. 4). This confirmed the above-mentioned results — vines on WH-trellis yielded much more fruit, mainly because they carried more bunches in response to better bud-fruitfulness (as shown by the greater number of bunches per node) and to a lesser extent, because more nodes were left at pruning (in response to better production of wood). On the other hand, berry development, expressed as berry weight or sugar concentration of the juice, was hardly affected by the trellis treatments.

Discussion

The trellising results of this experiment confirm the results reported by Shaulis and May (1972) and indicate the large potential of a wide trellis with split canopy, for improving the yield of large Sultana vines at peak productivity. On this type of trellis, yield of fruit, fresh or dry, was consistently and substantially greater in every season in which the crop originated from buds formed on shoots of the split canopy.

This beneficial effect on yield was brought about by more and larger bunches caused by better bud fruitfulness, and by proper maturation of the increased crop

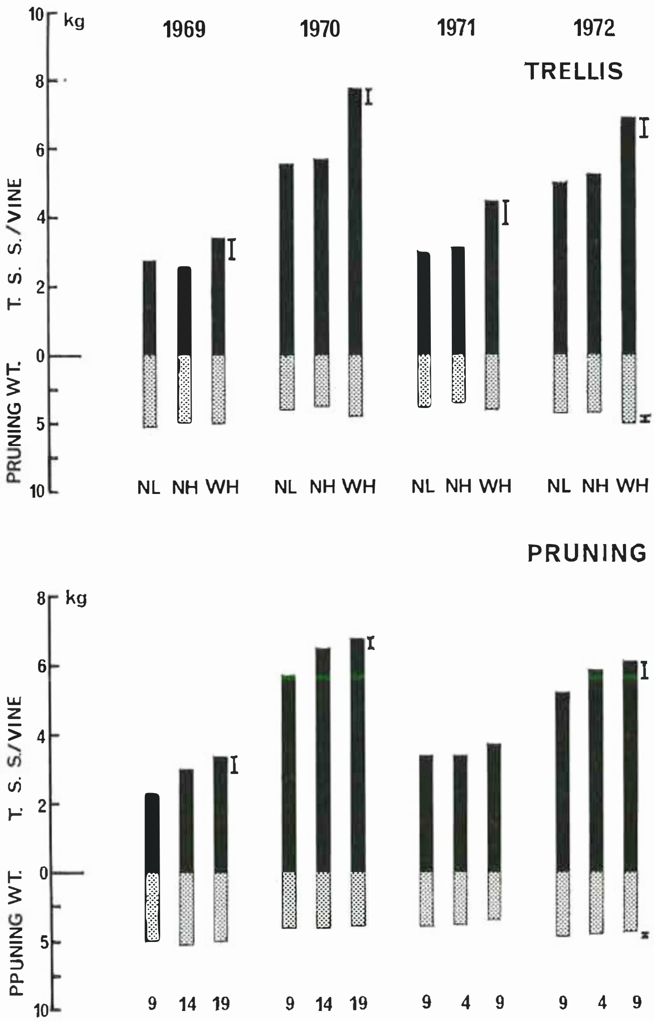

Fig. 3: Yield of sugar per vine (total soluble solids, T.S.S.) and pruning weight per vine for three trellis treatments and three "fixed pruning" treatments, pooled over the three rootstock treatments. Seasons 1969 to 1972. For treatment identification, see legend, Table 1. Least significant differences at p = 0.05 are shown.

Abb. 3: Zuckergehalt (gesamte lösliche Substanz, T.S.S.) je Rebe und Holzertrag je Rebe in Beziehung zu den drei Drahtrahmen-Typen und den drei Schnittarten; die drei Unterlagenvarianten sind zusammengefaßt. Jahrgänge 1969—1972. Symbole der Behandlungen siehe Erläuterungen zu Table 1. Signifikanzgrenzen bei p = 0,05 eingetragen.

due to greater production of photosynthate, which also provided for somewhat better vegetative growth.

The importance of high levels of solar radiation for satisfactory inflorescence initiation is well documented for whole Sultana vines (May and Antcliff 1963, Baldwin 1964, Buttrose 1970) and for individual Sultana buds (May 1965). Differences in the density of the foliage canopy were clearly established as early as mid-October

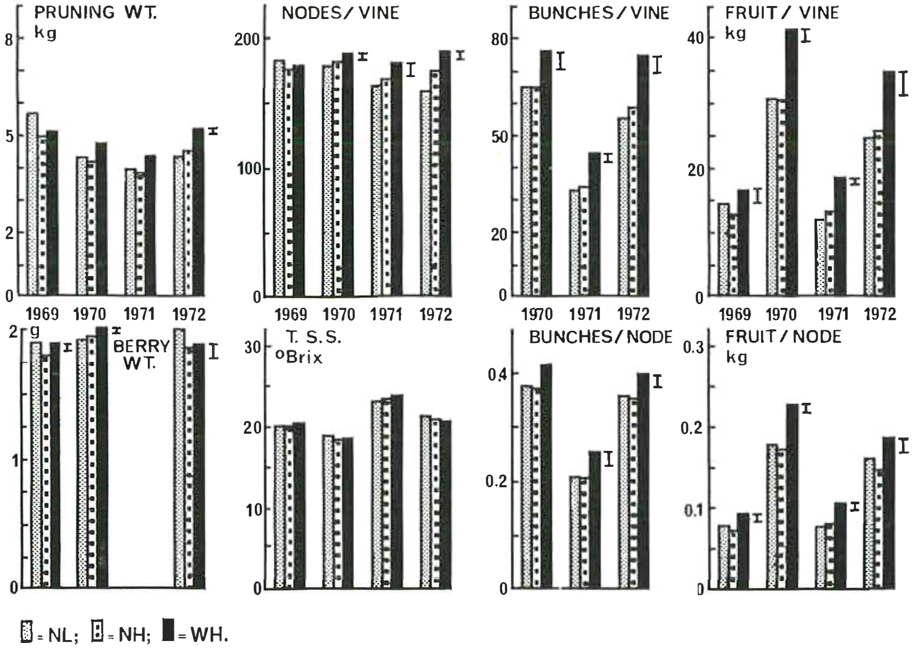

Fig. 4: Pruning weight, nodes per vine, bunches per vine, yield of fruit per vine, mean berry weight, mean sugar concentration (total soluble solids, T.S.S.), bunches per node and yield of fresh fruit per node for "fixed" and "balanced" pruned vines on three trellis treatments pooled over three rootstocks. Seasons 1969 to 1972. Least significant differences at p = 0.05 are shown.

Abb. 4: Holzertrag, Anzahl Knoten, Anzahl Trauben und Traubenertrag je Rebe, mittleres Beerengewicht, mittlere Zuckerkonzentration (gesamte lösliche Substanz, T.S.S.), Anzahl Trauben und Traubenfrischgewicht je Nodus bei „fixiertem" und „balanciertem" Schnitt in Beziehung zu den drei Drahtrahmen-Typen; die drei Unterlagenvarianten sind zusammengefaßt. Jahrgänge 1969—1972. Signifikanzgrenzen bei p = 0,05 eingetragen.

(Fig. 1B, C, D), half-way between bud burst and flowering and about one month before inflorescence initiation can be detected by microscopic examination (May 1964).

Photosynthetic acitivity must have been greater within the split canopy of the WH-vines than within the dense canopies of the NH- or NL-vines. Although measurements were not taken, the better light-penetration through the sparser WH-foliage was evident from the absence of yellowing basal leaves during the vegetation period. On narrow trellis, such leaves appeared quite early in summer and abscissed well before harvest. However, this improvement in photosynthetic activity could only be utilised when more productive units, i. e. berries, were present on the vine. In 1969, when this was not the case, berry weight and sugar concentration remained unaltered on wide trellis.

Shoot positioning, a prerequisite of true "Geneva Double Curtain" training (Shaulis *et al.* 1966) was not necessary. Apart from some inconvenience in cultivating the narrower row-interspace, the vines on wide trellis were maintained without additional expense. Raising the height of the trellis had no effect on yield as shown by the equal performance of the NL- and NH-vines, but it facilitated the operation of mechanical equipment. An occasional slight increase in the incidence of sunburnt fruit was possibly due to the absence of a foliage wire; obviously it reduced yield only to a very minor extent and had to be balanced against the reduction in mould-damage, observed during the wet 1969 harvest.

There was some advantage in increasing the number of canes from 9 to 14, particularly on wide trellis, but yield did not improve when still more canes were retained. Thus, variations in pruning severity lead to relatively small adjustments in yield not only on standard trellis (Antcliff 1965) but also on wide trellis. With very light pruning, bud burst is reduced and shoots are more crowded; consequently yield does not increase proportionally with increasing numbers of nodes. In addition, the retention of large numbers of canes per vine considerably increases the cost of the pruning operation.

In light-textured soils infected with plant-parasitic nematodes, Sultanas on Salt Creek rootstock produce more vegetative growth and larger yields of fruit (Sauer 1972). Here, on virgin soil initially free of plant-parasitic nematodes and entirely free of Phylloxera, such vines were only marginally bigger but yielded much better than own-rooted Sultanas because they carried more bunches with more berries. The reason for this beneficial effect is not clear; it may be related to the stock-scion affinity stipulated by Rives (1971). It could not be attributed to a non-specific grafting response, as the use of 1613-rootstock was of no benefit. This agrees with earlier results by Sauer (1972).

Light-textured soils similar to the soil-type on which the vines of this experiment were planted are common throughout Australia's irrigation areas. On such soils, the productivity of potentially high-yielding Sultanas will be considerably improved by using Salt Creek rootstock and a wide trellis which produces a split canopy. The use of clonally selected scions, which were not yet available when the experiment was commenced (Woodham and Alexander 1966) will further improve yield.

These yield increases can be obtained without significant increases in annual cost of production, because the more expensive planting material will be paid for by the large early crops (Table 1) and the extra cost of erecting the wide trellis will be more than paid for by the yield improvement of two full crops. A wide trellis is well adapted to mechanical harvesting; its application will ensure that harvest cost does not increase proportionally with yield.

Over the period 1970/72, which included two light crops and one exceptionally heavy crop, Sultanas on Salt Creek and trained on a wide trellis with nine canes outyielded own-rooted Sultanas on standard trellis with nine canes by the equivalent of 14 tonnes/ha/annum, and no differences in fruit quality showed up.

Establishing and maintaining an irrigated vineyard is very costly. To obtain a given tonnage of grapes, it is much cheaper to have a small, highly productive vineyard than a large, less productive vineyard, provided that fruit quality does not suffer and cost of production does not rise significantly. The experiment here described shows how this can be done with the Sultana.

Summary

The combined effects of three trellis, three pruning, and three rootstock treatments were tested on vigorous Sultana vines (*Vitis vinifera* L.) growing in a light-textured, nematode- and phylloxera-free, virgin soil of the Australian Murray Valley.

Vines on Salt Creek rootstock outyielded vines on 1613 C rootstock or on their own roots by about 40 per cent during the first four cropping seasons after planting, which preceded the experiment, and by about 30 per cent during the four seasons of the experiment, because they had more and larger bunches.

A wide, high trellis with two cane-wires 1.2 m apart and 1.5 m above ground level, a narrow, high trellis (0.3 m $\times$ 1.5 m) and a narrow, low trellis (0.3 m $\times$ 1.0 m) were compared. On the wide trellis, the foliage canopy was divided naturally into two halves. In the season following the trellis conversion, vines on the wide trellis yielded slightly better than those on either of the narrow trellises, possibly because there was less mould damage. In the subsequent seasons, the wide trellis was much more productive. It produced 40 to 50 per cent more crop because the vines had more bunches with more berries per bunch, while the concentration of sugar or acids remained unaltered. The amount of pruning wood was also somewhat greater.

For the three pruning treatments, vines were given 126, 196, or 266 nodes (i. e. 9, 14, or 19 canes of 14 nodes each). In the later years of the experiment, the lightest pruning level could not be maintained on the narrow trellis, and pruning weight tended to become smaller. Yield increased disproportionately with increasing node-number; a two-fold increase in the number of nodes led to only a 20 per cent increase in yield.

There were few interactions between the trellis, pruning, and rootstock treatments. The beneficial effects of wide trellis, Salt Creek rootstock and of light pruning, at least up to the level of 196 nodes per vine, tended to be additive. Thus lightly pruned Sultana vines on Salt Creek rootstock grown on a wide trellis with split canopy produced twice as much fruit as the conventionally treated Sultana, i. e. an own-rooted vine with 126 nodes grown on a narrow, low trellis.

It is concluded that Sultanas benefit from wide trellis through an effect on bud fruitfulness which leads to more berries per vine, and through better photosynthetic activity which allows full maturation of this increased crop potential. The economic implications of using wide trellises and Salt Creek rootstock are discussed.

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