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Production and growth of minimal pruned Sultana vines

by

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Traubenertrag und vegetatives Wachstum von Sultana-Reben bei minimalem Rebschnitt

Zusammenfassung. — Sultana-Reben blieben entweder 15 Jahre lang ohne jeden Rebschnitt, oder es wurden über einen Zeitraum von 6 Jahren nur die frei herunterhängenden Triebe auf eine bestimmte Länge zurückgestutzt, so daß die anfallenden Weinbergsarbeiten durchgeführt werden konnten (Minimalschnitt). Die Versuche zeigten, daß der Traubenertrag durch den herkömmlichen Rebschnitt beeinträchtigt wird — besonders deutlich in Jahren mit einem hohen Gebietsdurchschnitt. Der Minimalschnitt steigerte den Ertrag 50jähriger nicht verklonter Reben in den 6 Versuchsjahren um durchschnittlich 60 %. Diese Reben besaßen insgesamt mehr Trauben (106 : 43) und mehr Triebe (275 : 77), jedoch weniger Trauben je Trieb (0,40 : 0,55) und kleinere Trauben (231 : 373 g) als die herkömmlich geschnittenen Reben.

Bei der Traubenernte wies die Laubwand der minimal geschnittenen Reben ähnliche Werte (Blattgewicht, Blattfläche, Anzahl der Blätter je Rebe) auf wie jene der normal geschnittenen Reben. Die Relation Blatt : Frucht war infolgedessen verringert (11,6 : 17,0 $cm^2 \cdot g^{-1}$); trotzdem wurden die Trauben reif. Die minimal geschnittenen Reben entwickelten sich zu größeren Stöcken, da beim Rebschnitt nur 15 % des Holzes gegenüber 85 % bei den Kontrollstöcken entfernt wurden; das Gewicht des 1jährigen Holzes war jedoch verringert (1,0 : 2,3 kg). Die Triebe der minimal geschnittenen Reben waren kleiner (3,0 : 30,7 g), hatten weniger Blätter (11,4 : 41,1) und kürzere Internodien, wobei ihre endgültige Länge durch „Selbstschnitt“, d. h. Abfallen der nicht ausgereiften Enden, reguliert wurde. Minimal geschnittene Reben konnten von Hand gelesen werden, waren jedoch auch für die mechanische Ernte bestens geeignet.

Introduction

The aims and principles of traditional winter pruning of grapevines, deemed a necessity to maintain vine shape, productivity and fruit quality, are well documented. While systems vary for country, region and variety, traditional hand pruning is severe as 85—98 % of the annual growth of the vine is removed (Winkler *et al.* 1974). It is thus labour intensive. The recent adoption of mechanical pruning for wine and juice varieties in many countries (e.g. Australia: May and Clingeleffer 1977; Italy: Consiglio Nazionale Delle Ricerche 1981; U.S.A.: Pollock *et al.* 1977) suggest that concepts of pruning are changing in modern viticulture.

Sultanas (syn. Sultanina, Thompson Seedless) grown in irrigated Australian vineyards are cane-pruned because of low fertility in basal buds (Antcliff *et al.* 1955). Usually 6—12 canes of 10—20 nodes are tightly wrapped on a single wire trellis or the two wires of a 0.3 m T- or 0.4 m vertical trellis. The labour input of pruning can be reduced without a loss in production by loose attachment of canes (May 1965), arched cane pruning (May *et al.* 1978 a), the split system of traning (May *et al.* 1978 b), the swing arm trellis (Clingeleffer and May 1981), and hanging canes (May and Clingeleffer 1982).

Non-pruning has been shown to increase growth and production of Sultana (Lyon and Walters 1941) and several other varieties (Winkler 1958) but has never been considered practical because of effects attributed to "over-cropping". These effects include a greater fluctuation in yield between seasons, small bunch and berry size, delayed and uneven maturation, low sugar and acid levels, poor fruit colour and weak vine growth with poor development of renewal wood (LYON and WALTERS 1941, WINKLER 1954).

LYON and WALTERS (1941) considered that "over-cropping effects", when Sultanas were pruned to more than 6 canes, were due to limitations imposed by trellis design and cultural practices. The adoption of improved management practices (e.g. T-trellis, fertiliser and cover crops, deep working, improved irrigation and drainage) produced more vigorous vines capable of sustaining increased production when pruned to 8 canes. In further studies ANTCLIFF *et al.* (1956), ANTCLIFF (1965), MAY *et al.* (1973) pruned Sultanas to 10, 12 and 19 canes respectively without detrimental effects, obtaining only a small yield increase as cane numbers were increased. MAY *et al.* (1982) have further shown that production of Sultanas can be maintained by hedging to long spurs without detailed control of bud numbers. The year to year variation in production, a concern of WINKLER (1954), was shown to be climatic in origin rather than due to "over-cropping" (ANTCLIFF 1965).

The importance of trellis designs, which allow the development of larger Sultana vines, has been verified in experiments where large increases in production have been obtained with wide T-trellises, SHAULIS and MAY (1971), MAY and SCHOLEFIELD (1972), MAY *et al.* (1973), MAY *et al.* (1978 b), BALDWIN *et al.* (1979), MAY *et al.* (1982) or where replacement canes are supported vertically, MAY (1966), MAY and SCHOLEFIELD (1972), SCHOLEFIELD *et al.* (1977 a), BALDWIN *et al.* (1979).

This paper tests the hypothesis that pruning limits the production of Sultana vines. It demonstrates that minimally pruned vines (i.e. unpruned vines skirted to facilitate management) consistently outyield vines that are cane-pruned.

Materials and methods

The Sultana vines in the two trials were planted in the vineyard of the CSIRO Division of Horticultural Research, Merbein, Victoria at a 3.3 × 2.5 m row × vine spacing on soils classed as Coomealla sandy loam (Experiment 1) and Barmera sand (Experiment 2) (PENMAN *et al.* 1939). They were managed according to standard commercial practice including the use of furrow irrigation to apply about 1.0 m of water per annum. NPK (8 %, 4 %, 10 %) fertilizer was applied at a rate of 150 kg · ha^{-1} with an oat-medic cover-crop sown in alternate rows each year in autumn and incorporated into the soil prior to budburst.

1. Observations on unpruned vines

End vines in 4 rows of Sultana H4 (ANTCLIFF and HAWSON 1974) have been maintained since 1967 without pruning except for a severe hedging in 1970. The vines in the patch were planted as replants in 1964 and used for training and trellising experiments. Prior to 1967 the 4 vines were cane-pruned on a single wire trellis 1.0 m high, but when left unpruned they were also supported by the 1.4 m high trellis-end support. Yields of the unpruned vines (UP) were recorded 1975—82[1]), and compared both to control vines from within the pruning and tellising experiments which were trained to 8 canes on 1.0 m single wire trellis (C-1), and to similar boundary vines trained to 8 canes on a 1.0 m high 0.3 m T-trellis (C-2). Both controls had a foliage wire at 1.4 m.

[1]) Seasons extend over 2 calendar years: they are labelled by the year of harvest.

2. Minimal pruning

6 30-vine rows of 50-year-old Sultanas were used. These had initially been trainea on a 1.0 m high 0.3 m T-trellis but converted to a 1.4 m high, 0.9 m T-trellis with posts between every second vine in 1969. In winter 1976 (season 1977) a 1.4 m high single wire trellis was formed by removing half of each vine attached to one of the two trellis wires by making cuts at the original crown (i.e. at a height of 1.0 m) while the other wire with the spent fruiting canes still attached was positioned on top of the trellis posts. Two pruning treatments, minimal (M) and control (C) were then applied. The M-vines were left unpruned with the spent fruiting canes, 2 in either direction, forming cordons. The free hanging 1-year-old shoots were skirted 0.5 m below the wire in a horizontal plane with a hand-held electric hedge cutter fitted with a 0.3 m blade (Little Wonder Hedge and Shrub Trimmer; Little Wonder Inc., South Hampton, P.A.). The C-vines were cane-pruned to 8 canes of 10—20 nodes in the usual manner. Both treatments were maintained in subsequent seasons.

The experiment was planned as a completely randomized block design with 5 replicates. Each block consisted of 6 part-rows of 6 vines split into 3-row treatment plots. Production data were collected from vines 2—5 in the middle row of each plot, the other vines being treatment buffers. Bunch and shoot numbers were counted in spring and the yields recorded at harvest in mid-February for each vine. In 1980 and 1981 the buffer rows were mechanically harvested with a tractor-drawn, horizontal impact (Slapper), Upright harvester. In 1982 the fruit in the buffer rows was hand-

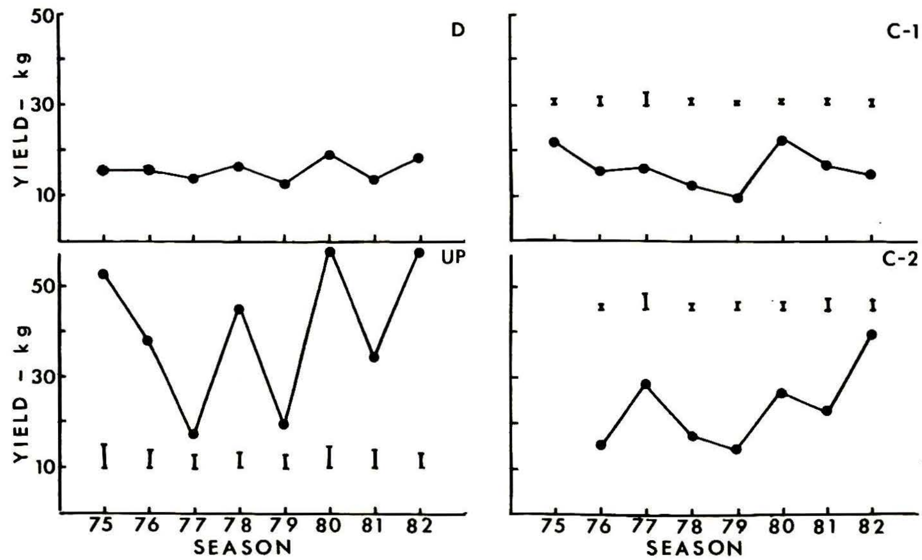

Fig. 1: Mean yield (kg per vine) of unpruned Sultana vines (UP) over 8 seasons compared to the calculated district average (D), pruned vines from within the pruning and trellising experiments (C-1) and in a boundary situation (C-2) similar to the UP-vines. Vertical bars represent the standard error.

Mittlerer Traubenertrag (kg/Rebe) nicht geschnittener Sultana-Reben (UP) während 8 Vegetationsperioden im Vergleich zum Gebietsdurchschnitt (D), zu normal geschnittenen Reben im Inneren des Schnitt- und Erziehungsversuchs (C-1) und in einer Randposition (C-2) ähnlich den UP-Reben. Senkrechte Balken: Standardabweichung.

picked by 3 2-man teams. The time taken and the number of 10 kg buckets were recorded for each 6-vine treatment plot.

Single vines of both treatments were randomly selected from the buffers in each replication to determine the total weight of wood, the amounts of 1-year-old, older and dead wood and the weight of wood removed at pruning in winters 1980—82. Similarly selected vines were used for leaf weight and leaf area determinations at harvests 1981, 1982. All leaves (including the petioles) were removed from the vines and weighed. The total leaf area of the vine was estimated by comparing the areas of individual leaves in a subsample of known weight with a series of "leaf shadows" of known area. In addition, the weight of leaves remaining on the vines after mechanical harvesting was determined in 1981.

Where appropriate, data were subjected to analysis of variance.

Results

1. Observations on unpruned vines

Between 1967 and 1975, before detailed observations of the UP-vines began, it was noted that the vines sprawled over the trellis wires and end supports, formed large canopies, had many bunches and large crops. They had many short shoots, positioned towards the outer part of the vine with little new growth inside the canopy. Subsequent observations have shown that fruitful shoots burst mainly from well matured canes that arise from the top of the vine. These canes were shorter, more closely noded and smaller in diameter than canes used for replacements in conventional pruning.

The annual production of UP-vines (1975—1982) is compared to the district average (D) and control vines C-1 and C-2 in Fig. 1. The yield of UP-vines ($\bar{x}$ = 40.4 kg per vine) was in all seasons greater than the district average ($\bar{x}$ = 15.7 kg), than of C-1 vines ($\bar{x}$ = 16.2 kg) and of C-2 vines ($\bar{x}$ = 23.6 kg), except in 1977 when some sunburn was noted. A significant linear relationship ($y = -60.1 + 6.5x$; $R^2 = 0.77$) between the yield of

Table 1

Bunch and shoot numbers per vine and derived variables (bunches per shoot and bunch weight) for minimal pruned (M) and control (C) vines over 6 seasons · LSD = least significant difference (P = 0.05)

Anzahl der Trauben und Triebe je Rebe und daraus abgeleitete Größen (Anzahl der Trauben je Trieb und Traubengewicht) von Reben mit Minimalschnitt (M) und von Kontrollreben (C) in 6 Vegetationsperioden · LSD für P = 0,05

Season	Bunches			Shoots			Bunches per shoot			Bunch weight (g)		
	M	C	LSD	M	C	LSD	M	C	LSD	M	C	LSD
1977	74	42	15	164	81	17	0.45	0.52	NS	243	379	65
1978	147	56	23	226	64	33	0.65	0.75	0.09	162	237	69
1979	84	41	19	314	91	46	0.27	0.46	0.09	212	282	ns
1980	144	48	14	327	81	41	0.44	0.59	0.08	209	420	66
1981	115	38	7	288	65	11	0.40	0.59	0.04	218	366	65
1982	72	32	11	334	78	24	0.21	0.41	0.08	344	551	133

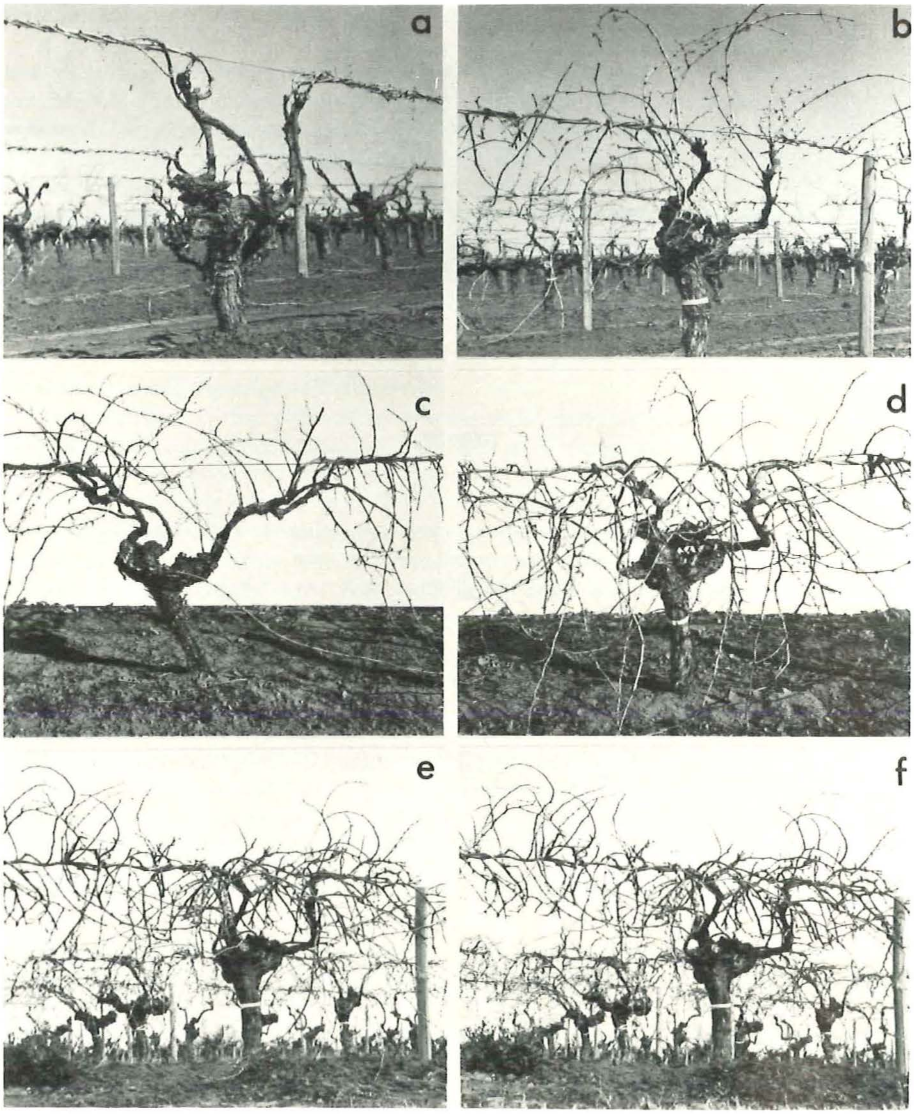

Fig. 2: Comparisons of pruned and minimal pruned Sultana vines. Controls are shown after pruning for season 1977 (a) and before pruning for season 1978 (b). The development of minimal pruned vines is shown for years 1, 2 in c and d, and for year 4, in e, f — before and after skirting.

Vergleich der herkömmlich geschnittenen und der minimal geschnittenen Sultana-Reben. a) Kontrolle nach dem Rebschnitt für die Vegetationsperiode 1978, b) Kontrolle vor dem Schnitt für die Vegetationsperiode 1978. c) Entwicklung minimal geschnittener Reben im 1. Versuchsjahr, d) im 2. Versuchsjahr. e) und f) Entwicklung im 4. Versuchsjahr vor bzw. nach dem Einkürzen der herunterhängenden 1jährigen Triebe.

UP-vines (y) and the district average (x) was found. This indicates that a large proportion of the seasonal variation in yield of UP-vines could be explained by variations in the district yield. This relationship indicates the potential of UP-vines to give large yields in seasons when the district average is high. A similar relationship between the yield of C-1 or C-2 vines and the district average was not found (R^2 = 0.20, 0.26 respectively). Compared to C-2 vines UP-vines (mean 1980—82) had smaller berries (1.34 : 1.58 g), lower sugars (19.8 : 21.1 °Brix) and similar pH and titratable acid values.

2. Minimal pruning

The development of minimal pruned vines (M) can be seen in Fig. 2 which compares control vines (C) and M-vines after pruning in season 1977 (year 1), before pruning in 1978 (year 2), and in season 1980 (year 4), the M-vines before and after skirting. The short, "self-pruned", well matured, closely noded, small diameter canes arising from the top of the vine are obvious (Fig. 2 e, f). As with the UP-vines these canes were the main bearers of fruit.

Fig. 3 shows that M-vines consistently had more crop than C-vines, the difference being significant in all but the year of conversion (1977). Excluding season 1977, the mean yield was 24.3 kg (26.7 $t \cdot ha^{-1}$) for M-vines and 15.3 kg (16.8 $t \cdot ha^{-1}$) for C-vines (i.e. a 60 % yield increase). Significant linear relationships occurred between the average district yield (x) and the yields (y) of M- and C-vines; these were $y = 1.02 + 1.42\ x$, $R^2 = 0.66$ for M, and $y = 0.30 + 0.96\ x$, $R^2 = 0.62$ for C. These relationships show that yields of the 50-year-old C-vines were similar to district vines while yields of M-vines were always larger, particularly in seasons of high yields. A comparison of some aspects of fruit quality over 5 seasons showed that although berries were small on M-vines compared to C-vines (1.40 : 1.62 g) differences in soluble solids (21.3 : 22.6 °Brix), pH (3.58 : 3.67) and titratable acidity (5.37 : 5.24 $g \cdot l^{-1}$ as tartaric) were minor.

The results in Table 1 show that the M-vines had 2—3 times more bunches and 3.5—4.4 more shoots than C-vines, but that the fruitfulness of the shoots (bunches per shoot) was about 30 % lower and bunches were 25—51 % smaller. For both treatments a large proportion of the variation between seasons in bunch weight can be attributed

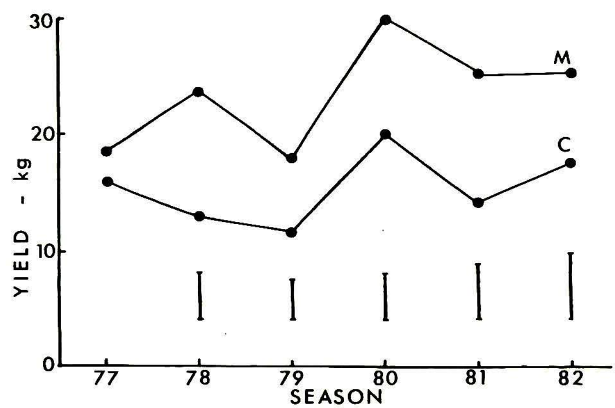

Fig. 3: Mean yield (kg per vine) of minimal pruned (M) and pruned (C) Sultana vines over 6 seasons. Vertical bars represent the least significant difference (P = 0.05).

Mittlerer Traubenertrag (kg/Rebe) minimal geschnittener (M) und herkömmlich geschnittener Sultana-Reben (C) in 6 Vegetationsperioden. Senkrechte Balken: LSD für P = 0,05.

to a negative linear relationship between bunch weight (y) and bunch number (x); these were $y = 368 - 1.3\,x$, $R^2 = 0.53$ for M, and $y = 780 - 9.5\,x$, $R^2 = 0.51$ for C. For M-vines, a correlation between yield (y) and bunch number (x) was obtained; $R^2 = 0.40$ over all seasons or $R^2 = 0.72$ ($y = 8.79 + 0.13\,x$) when season 1982 was excluded because of abnormal large berry size. A similar correlation was not found for C-vines ($R^2 = 0.001$). There was a strong correlation between yield (y) and bunch size (x) for C-vines, $y = 7.46 + 21.18\,x$, $R^2 = 0.56$ but not for M-vines ($R^2 = 0.002$). These linear relationships show that the main determinant of vine yield was bunch number for M-vines and bunch size for C-vines. The views of the C- and M-vines after leaf removal at harvest (Fig. 4 c, d) show that, although the bunches are spread over M-vines, many fall to the lower half of the vine. The bunches of C-vines were concentrated near the distal ends of the fruiting canes and positioned close to the trellis wire.

Complete leaf removal at harvest (seasons 1981, 1982; Table 2) showed that the canopies of M- and C-vines were similar as there was no significant difference in leaf weight, leaf area or leaf number per vine nor in the average weight and area of individual leaves. The large differences in the calculated values of leaf number per shoot (Table 2) show a difference in shoot development. The shoots of C-vines, in particular those arising at the ends of canes and from the crown, were longer, with more nodes

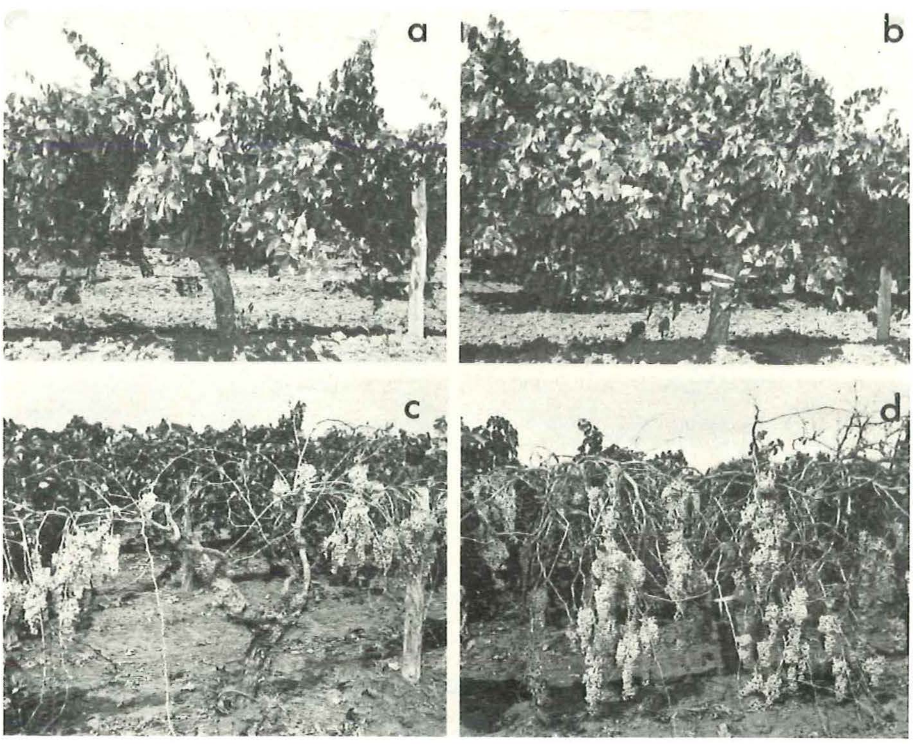

Fig. 4: Comparisons of pruned and minimal pruned Sultana vines in late spring (a, b respectively) and after leaf removal at harvest (c, d respectively).

Vergleich herkömmlich und minimal geschnittener Sultana-Reben im Spätfrühling (a bzw. b) und nach der Entfernung des Laubes zur Erntezeit (c bzw. d).

Table 2

Measured and derived variables determined from data obtained by the complete removal of leaves from Minimal pruned (M) and Control (C) vines at harvests 1981 and 1982

Gemessene und abgeleitete Größen aufgrund der vollständig entfernten Blätter von minimal geschnittenen (M) und Kontrollreben (C) zur Erntezeit 1981 und 1982

	1981		1982	
	M	C	M	C
Total leaf weight per vine (kg)[1]	6.16	6.24	4.94	4.98
Total leaf area per vine (m^2)[1]	33.0	26.4	24.8	27.0
Total leaf number per vine[1]	3527	2582	3246	3317
Average leaf weight (g)[1]	1.77	2.42	1.53	1.56
Average leaf area (cm^2)[1]	98.3	102.9	83.0	76.2
Leaf number per shoot	12.3	39.7	9.7	42.5
Leaf area × yield^{-1} ($cm^2 \cdot g^{-1}$)	13.3	18.7	9.9	15.3

[1]) Treatment differences not significant ($P > 0.05$).

and laterals and had much more leaves than the shorter shoots of M-vines. The comparison, in late November (Fig. 4 a, b) shows this difference in shoot development which leads to a more uniform canopy and balanced appearance of M-vines compared to C-vines. The ratio of leaf area to yield (Table 2) gives a measure of the crop load of both treatments in seasons 1981 and 1982. Leaf removal had a large effect on the subsequent years' crop. For vines defoliated in 1981, the yields per vine in 1982 were for M-vines 9.2 ± 2.7 compared to 25.1 (kg), and for C-vines 10.4 ± 3.0 compared to 17.6 (kg). It was noted that the defoliated vines had a poor budburst, weak and chlorotic shoots which appeared to be less fruitful and had small bunches.

The distribution of wood in winter (Table 3) shows that M-vines developed a larger permanent framework and were bigger than C-vines. They had less mature 1-year-old wood (i.e. the growth from the previous season), more 2-year-old or older wood and, in total, more wood. The amount of dead wood on M-vines was negligible. The total combined wood of M-vines would have been larger if the cordon, left on the wire for new shoot development, had been included. Wood removed at pruning was only 10—15 % of the total of M-vines but 82—85 % of C-vines. The large difference in the average mature shoot weight between M- and C-vines (Table 3) was greater than expected from shoot (Table 1) and leaf (Table 2) numbers, reflecting the combined effects of shorter shoots, the lack of lateral growth, closer node spacings, smaller shoot diameter and abscission of the non-mature wood on M-vines. Shoots burst the following spring along the cordons of M-vines after removal of the wood in winter. These shoots, while unfruitful, developed into canes capable of producing large crops and re-establishing a minimal pruned vine; the shoots arising from the cordons left in winter 1980 had no crop in season 1981 but in 1982 produced on average 41.9 ± 5.2 kg per vine compared to the 25.1 kg of M-vines.

There was little difference in the time required to harvest equal quantities of fruit from M- or C-vines when hand-picked in season 1982. The mean harvest time per team was 95.7 ± 7.4 (M) and 91.8 ± 5.6 (C) $s \cdot 10\ kg^{-1}$ bucket, a total hand-picking time of 318 and 307 $min \cdot t^{-1}$. Mechanical harvest of both treatments was satisfactory in seasons

Table 3

Distribution of wood (kg per vine) on minimal pruned (M) and control (C) vines, winter 1980—82 Values exclude the trunk (M, C) and cordon (M) · An estimate of the average shoot weight is also given · LSD = least significant difference (P = 0.05)

Verteilung des Holzes (kg je Rebe) bei minimal geschnittenen (M) und Kontrollreben (C), Winter 1980—82 · In den Werten sind Stamm (M, C) und Cordon (M) nicht enthalten · Das geschätzte mittlere Triebgewicht wird ebenfalls angegeben · LSD für P = 0,05

	1980			1981			1982		
	M	C	LSD	M	C	LSD	M	C	LSD
Total 1-year-old wood[1])	0.8	2.5	0.8	1.0	2.4	0.9	1.1	1.9	ns
Total 2-year-old wood	3.3	0.6	0.4	4.1	0.9	1.0	3.8	0.9	1.6
Total combined wood	4.1	3.1		5.1	3.3	1.1	4.9	2.8	2.0
Removed at pruning[2])	0.6	2.6	—	0.6	2.8	—	0.5	2.3	—
Average shoot weight (g)	2.4	30.8	—	3.4	36.9	—	3.1	24.3	—

[1]) Includes an estimate (0.5 kg) of canes retained for C-vines.
[2]) Combined 1- and 2-year-old wood determined for M-vines after pruning the measured plots.

1980 and 1981. The only fruit not removed by the machine was situated below the height of the collection system for M-vines, while for the C-vines some fruit was left around the trellis posts. It was noted in 1980 that more leaves were left on the M-vines than on C-vines after mechanical harvesting. This was confirmed in 1981 when the weight of leaves left after mechanical harvesting was determined. The M- and C-vines had 2.9 and 1.9 kg of leaves/vine, respectively, the differences being significant ($P < 0.01$). The comparison of these values with those in Table 2 indicate that about 70 % of the leaves of C-vines compared to about 50 % of M-vines were removed by the machine.

Discussion

Results presented show that traditional pruning of Sultana vines is not only unnecessary but counter-productive. Adoption of minimal pruning will increase yields, reduce inputs and thus lower the cost of production. As Sultana is probably the world's most important cultivar used for wine, raisin, canning and table grapes these results are very important. Furthermore, other varieties grown under similar irrigated conditions or in areas where vine growth is vigorous may respond similarly. Experiments (CLINGELEFFER, unpublished) extending in some cases over 5 seasons with a range of varieties and promising hybrids confirm this view.

In the present experiments, two very different types of vines were used, i.e. a young, high yielding clonal planting in a boundary situation (unpruned, Experiment 1) and an old vineyard at the end of its economic life (minimal pruning, Experiment 2). For both types of vines yield was increased by either the non-pruning or minimal pruning treatment indicating that the standard system of training and pruning (i.e. 8 canes on either a T-trellis or single wire) restricted yield, particularly in seasons when the district average was high. For the young clonal vines, expected to have more bunches, more berries per bunch and a greater yield than unselected vines (ANTCLIFF *et al.* 1979), the strong correlation between the district yield and that of the unpruned vines indicates that the climatic factors which cause seasonal yield fluctuations (ANTCLIFF 1965) influenced their production. The lower yield and absence of a similar correlation for the controls suggest that the potential of these young clonal vines is stifled by the standard system, a conclusion supported by the results of other experiments in the same patch of vines where yields were increased by wide T-trellis, light pruning and hedging to long spurs (MAY *et al.* 1982) and the swing arm trellis (CLINGELEFFER and MAY 1981).

In the second experiment with unselected 50-year-old vines, yields of both the control and minimal pruned vines were correlated with the district yield, suggesting that the standard system was less limiting in that situation, a view supported by the smaller but consistent yield increase due to minimal pruning. The fact that both bunch number and bunch weight were important determinants of yield, for the minimal pruned and control treatments respectively, indicates the importance of factors controlling both fruit bud initiation and bunch development discussed by MAY (1961). Differences in berry size and berry number would have contributed to the difference in bunch weights between the two treatments (Table 1). The final berry number on bunches is determined by both the number of flowers on the inflorescence primordium, differentiated shortly after budburst (SCHOLEFIELD and WARD 1975) and by fruit set in November. The response to minimal pruning was similar to that reported by MAY *et al.* (1969) and SCHOLEFIELD *et al.* (1977 b) where altered leaf to fruit ratios, by leaf removal or harvest pruning, reduced flower numbers.

The values for leaf to fruit ratios (Table 2) indicate that the canopy of the control vines could support larger crops, the values of 18.5, 15.3 $cm^2 \cdot g^{-1}$ being greater than 13.3, 9.9 $cm^2 \cdot g^{-1}$ of the minimal pruned vines in the two seasons measured and more than the values of 7.3 and 10.0 $cm^2 \cdot g^{-1}$ shown to be adequate for crop maturation of Sultanas by MAY *et al.* (1969) and KLIEWER and ANTCLIFF (1970). The lower values of minimal pruned vines did not approach the values 3.5—5.0 $cm^2 \cdot g^{-1}$ found to give overcropping symptoms in Tokay (KLIEWER and WEAVER 1971). Changes in photosynthetic efficiency in response to the altered crop load (BUTTROSE 1966) and increased total photosynthetic capacity resulting from a larger leaf area early in the season and improved canopy distribution (WINKLER 1958) may have contributed to the ability of minimal pruned vines to support larger crops. Experiments to study these factors in more detail are in progress (CLINGELEFFER and SHULMAN, unpublished).

The analysis of the distribution of wood in winter (Table 3) shows that minimal pruning gave a bigger vine with a much larger permanent framework. The capacity to produce large crops would be enhanced by the less severe pruning and retention of stored carbohydrate (WINKLER 1958) as about 85 % of the wood on the vine was retained compared to 15 % of control vines. Mature shoot length on minimal pruned vines was controlled by non-maturation and autumn abscission of much of the shoot. The remaining small-diameter, closely noded wood was adequate to produce a crop the following season, with most of the fruiting canes rising from the top of the vine and developing in a good light environment (MAY *et al.* 1976). The "self-regulation" of shoot growth due to minimal pruning is disturbed by pruning which promotes strong individual shoots and consequently requiring further pruning each winter. Minimal pruned vines with the lower leaf to crop ratios, had less mature wood, lower bud burst, fewer bunches per shoot and fewer berries per bunch (Tables 3, 1), a response similar to that produced by defoliation (MAY *et al.* 1969).

Minimal pruning is suited to mechanical harvesting as the fruit was easy to remove and vine damage less than for control vines. The large loss of leaves on the control vines when mechanically harvested (i.e. about 70 %) would lead to yield losses in subsequent seasons as SCHOLEFIELD *et al.* (1977 a) showed that defoliation beyond 60 % was detrimental.

During the experiment it has been unnecessary to reshape the minimal pruned vines. However, results where vines were cut back to the cordons show that vines can be re-established without major crop losses.

The improved fruit distribution of minimal pruning (Fig. 4) combined with the smaller bunches and berries should reduce losses from berry splitting and mould in wet seasons. As wine quality differences could not be detected (CLINGELEFFER, unpublished), minimal pruning with an inexpensive, tractor-mounted cutter bar combined with mechanical harvesting appears to be the ultimate system of vine management for wine production. For raisin production, the smaller berries and bunches should enhance drying if hand-picked, while in the future the fruit may be mechanically harvested fresh (MAY *et al.* 1974) or the principle of minimal pruning may be adapted to management systems which will allow mechanisation of raisin production (MAY and CLINGELEFFER 1982, MAY *et al.* 1982).

Summary

Experiments with Sultana vines left unpruned for 15 years or unpruned but skirted to facilitate management (minimal pruned) for 6 years have shown that traditional pruning limits production, particularly in seasons when the district average is high. Minimal pruing increased the production of 50-year-old, non-clonal vines over 6 seasons by about 60 %. They had more bunches (106 : 43) and more shoots (275 : 77) but fewer bunches per shoot (0.40 : 0.55) and smaller bunches (231 : 373 g) than pruned vines.

At harvest, minimal pruned vines had a canopy similar in size to the pruned vines, and thus a smaller leaf to fruit ratio, (11.6 : 17.0 $cm^2 \cdot g^{-1}$) but still matured the crop. Minimal pruned vines developed into larger vines because only 15 % of the wood was removed at pruning compared to 85 % from the controls but the weight of 1 year-old wood was lower (1.0 : 2.3 kg). The shoots of minimal pruned vines were smaller (3.0 : 30.7 g), had fewer leaves (11.0 : 41.1), closer nodes with their mature length regulated by "self pruning" (i.e. abscission of non-mature wood). Minimal pruned vines could be hand-harvested but were most suited to mechanical harvesting.

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