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Influence of grapevine rootstocks on muscat flavour levels in Brown Muscat juice and wine

FINAL REPORT to
GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

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INFLUENCE OF GRAPEVINE ROOTSTOCKS ON MUSCAT FLAVOUR IN BROWN MUSCAT JUICE AND WINE

FINAL REPORT

TO

GRAPE AND WINE RESEARCH COUNCIL

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SUMMARY

Earlier research over five years has demonstrated considerable and consistent differences in yield and maturity of Brown Muscat grafted to a range of rootstocks in north eastern Victoria. A grant from the Grape and Wine Research Council has made possible the present study into rootstock affects on muscat wine quality over three seasons in two sites in north eastern Victoria.

Significant differences in fortified muscat wine quality, as determined by tasting panels, were apparent between some rootstocks. However, the differences were not large and were not consistent over the three years of study. There was some confounding of the wine assessment results due to the affects of bunch breakdown in two of the three seasons.

Analysis of volatile terpene concentrations (both free and potential) in juice and must samples revealed only small differences between rootstock treatments. There was no clear correlation of volatile terpene concentration with rootstock, wine quality score, or with any components of maturity.

Muscat wine score consistently showed a positive correlation with must sugar concentration, but in most comparisons the correlation was not statistically significant. Muscat wine score was also consistently inversely correlated with yield at one of the sites, but again these correlations were not significant.

At similar cropping levels vines trained on a wide T trellis showed no significant differences in wine score, volatile terpene concentrations or maturity to the standard two wire vertical trellis.

A comparison of two Brown Muscat scion selections showed some significant differences in wine score but these were not consistent over the different seasons and sites. Directions for further research are discussed in the report.

PROJECT OBJECTIVES

- To determine the influence of high yielding rootstocks on muscat wine quality in Muscat à Petits Grains rouge (Brown Muscat).

- To assess the differences in volatile terpene concentrations in juice samples from Brown Muscat on a range of rootstocks.

- To establish relationships between wine quality and volatile terpene concentrations, and components of maturity and yield.

- To assess changes in volatile terpene concentrations during ripening.

- To investigate the influence of trellis treatments on volatile terpene concentrations and wine quality.

- To compare a clonal selection of Brown Muscat with local mass selected scion material.

RESEARCH REPORT

Background

A high quality and well established style of fortified wine is produced from the Brown Muscat variety in north eastern Victoria. Whilst this region has dominated the production of quality fortified muscat in Australia, other regions, eg. Barossa Valley also produce this style of wine.

The insect pest of grapevines, phylloxera, is widely spread in the traditional vineyard areas of north eastern Victoria. The vines in this region must therefore be grafted onto phylloxera resistant rootstocks. The standard Brown Muscat vines in the district yield only 2 to 10 tonne per hectare due to a combination of virus infection, minimal irrigation and simple trellis systems. Recent rootstock trials have boosted yields to an average of 20 tonne per hectare and up to 35 tonne per hectare due to virus free plant material, bigger trellis systems and increased irrigation.

Vignerons in the area have expressed (understandable) concern that the quality of the fruit and ultimately the wine, will not be maintained at such high cropping levels. McCarthy (1985) has suggested that crop load plays an important part in determining the monoterpene content of Riesling juice and Nicholas (1985) has inferred a reduced concentration of potential volatile terpenes in higher yielding rootstocks with a number of muscat varieties. An affect of rootstock on muscat aroma has been noted by Boidron (1977).

The establishment of these two rootstock trials on Brown Muscat in north eastern Victoria in 1978, with funding support from the Phylloxera Board of South Australia, now provides the opportunity to study the influence of rootstocks on aspects of muscat quality in juice and wine.

Methodology

The two trials contain 12 rootstocks but only 6 rootstock treatments were selected for the project work. These stocks were selected on the basis of their differing yields, shown in previous assessments. The Milawa site was flood irrigated, heavily infested with phylloxera and had a clay-loam duplex soil. The Glenrowan site had overvine irrigation (used sparingly), was not heavily infested with phylloxera and had a sandy-loam duplex soil. The general vine growth differences between the two sites is illustrated in Plates 1 and 2.

Both trials were planted as randomised complete blocks but not all replications were used for sampling and harvesting. Our main comparison of rootstocks was based on a selected clone of Brown Muscat (ex CSIRO) grown on a standard trellis system (single wire and two wire vertical) in each site, set-up as split plots. The other trellis system investigated (wide T) was also arranged in split plots and the mass selected local Brown Muscat clone was planted as buffers within each rootstock treatment.



Plate 1 : Brown Muscat rootstock trial - Milawa site. Note poor growth of ungrafted vines, due to phylloxera, in the foreground and the vigour of grafted vines in the background.



Plate 2: Brown Muscat rootstock trial - Glenrowan site. Note the lower vigour at this site and the stressed condition of the vines.

Periodic berry sampling during ripening was carried out in 1988[1] and 1989, and all treatments were sampled (100-300 berries depending on site) immediately prior to harvest in all seasons. Either whole berry or juice samples were frozen for later analysis.

Harvest times coincided with the commercial harvest on the two properties in 1988 and 1989. In 1990 harvesting was completed earlier to avoid problems with bunch breakdown encountered in the previous seasons. Because of the relatively poor fruit condition in 1988 and 1989 the grapes were rapidly pressed, without fermentation on skins, and the juice fortified in duplicate batches. In 1990 the grapes were crushed and fermented on skins for 24 hours in a single batch and then fortified before pressing. Fortification was with neutral high strength spirit (95.5% $^{v}/_{v}$) to achieve final wine alcohol levels of 17%. All berry samples, harvesting and processing was conducted on the same day for each trial site.

The berry and juice samples were quick-thawed and analysed. Sub-samples of juice were used for analysing components of maturity. Volatile terpenes were assayed according to the procedure of Dimitriadis and Bruer (1984).

Wine tastings were conducted by experienced muscat winemakers from north eastern Victoria. In 1988 and 1990 wines were scored for quality using the standard 20 point system. In 1989, due to excessive botrytis character in the wines, overall muscat quality was scored out of 10, in addition to rating intensity of six descriptor aroma and flavour characters.

Prior tastings of the wines in 1988 and 1989 indicated no differences between the duplicate wine samples and only one wine replicate was assessed. All tastings were conducted 'blind' and the sequence of wines tasted was arranged to take account of residual effects (ie. to allow for the carryover taste of one wine influencing the score of the next wine). In 1988 the wines were presented three times to the judges in randomised order and in subsequent years two times.

All data from field replicates and wine tastings were analysed by analysis of variance and relationships between various parameters assessed by linear regression.

Results and Discussion

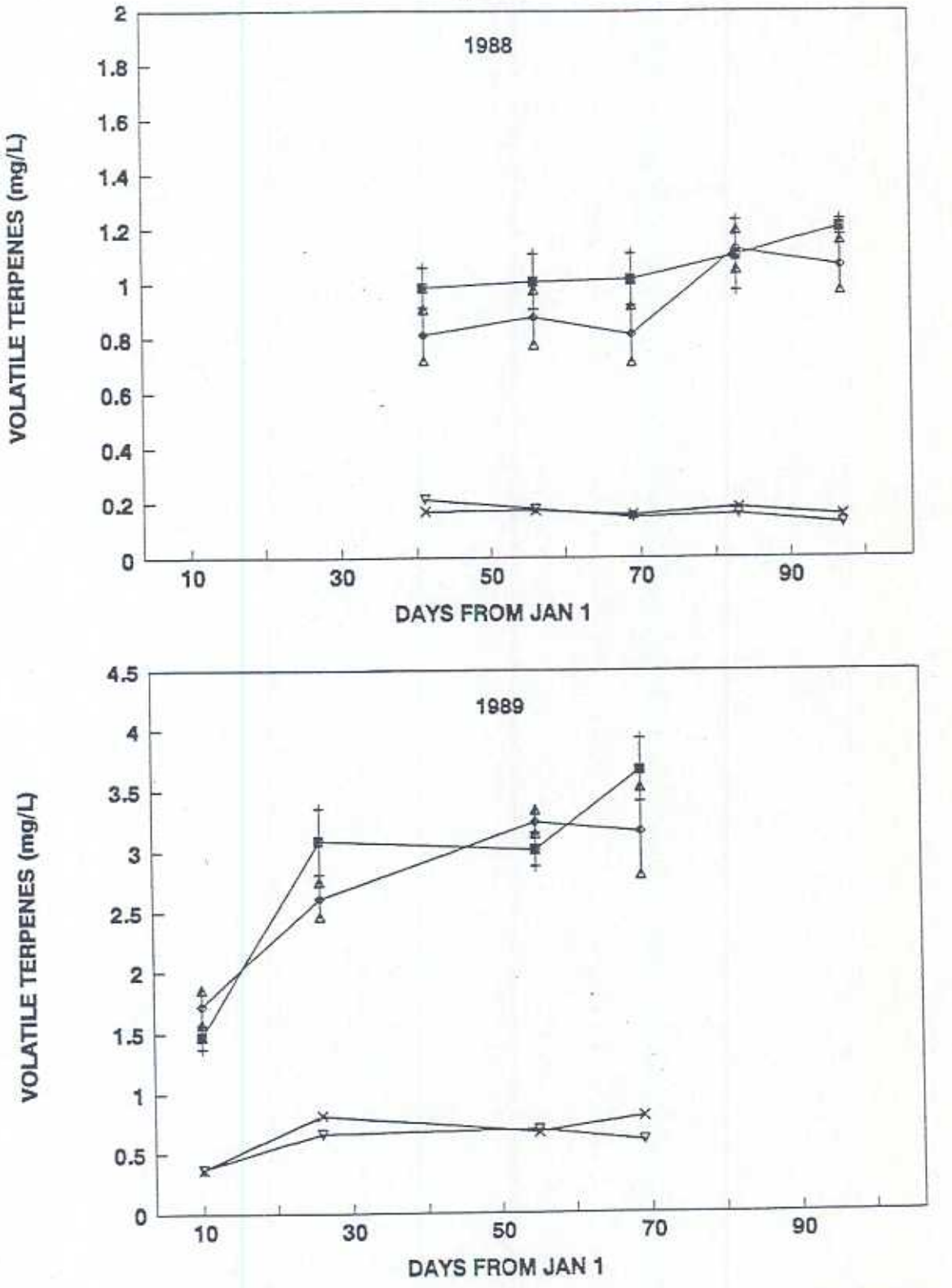
Changes in terpene concentrations during ripening:

In the 1988 season the concentrations of free volatile terpenes (FVT) and potential (bound) volatile terpenes (PVT) were relatively low and only small changes occurred over the 8 week period before harvest (Figure 1). In 1989 the concentrations of FVT's and PVT's were higher overall and by commencing berry sampling at an earlier date a distinct increase in FVT's and PVT's was detected up until mid to late January. These results show similar trends to those of McCarthy (1985).

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[1] Seasons will be referred to by the year of harvest.

Figure 1 VOLATILE TERPENES IN BROWN MUSCAT JUICE



Rootstock affects on juice terpene concentrations:

The analysis of volatile terpenes from berry samples has shown significant differences between rootstocks in only one season at one trial site (Glenrowan, 1990) (Table 1). In this case Ramsey had a significantly higher concentration of FVT than all other rootstocks and Schwarzmann and 1202 had higher concentrations of PVT's than 110 Richter and own roots. There are no clear trends in the remaining results to conclude that any particular rootstock has a consistent affect on monoterpene concentrations. McCarthy (unpublished data) has shown no significant differences in FVT between selections of Muscat Blanc but some differences in PVT's.

The concentration of FVT's were similar at both sites in all years but PVT's were higher at the Glenrowan site in 1989 and 1990. It is generally accepted that the Glenrowan fruit makes better quality muscats than the Milawa fruit. This may relate to the PVT concentrations and McCarthy and Coombe (1985) have made similar observations for Riesling with irrigation treatments.

An analysis of the variances associated with the technique of measuring volatile terpenes shows most variance is associated with the field replicates. McCarthy (unpublished) has made a similar observation with FVT concentrations with selections of Muscat Blanc. Least variance was associated with the colorimetric assay and a moderate amount of variance was associated with the duplicate distillations of each sample in our work.

The components of maturity on the berry samples show some significant differences between rootstocks (Table 1) but the results were not consistent over the two trials or between years.

Relationships between volatile terpenes, components of maturity and berry weights for berry samples:

The FVT concentration between rootstocks was significantly inversely correlated with berry weight in one site in one year (Milawa, 1990). Differences in PVT's and FVT's between rootstocks were not significantly nor consistently correlated with any of the components of maturity. Reynolds and Wardle (1989) and McCarthy (unpublished) have noted a similar lack of correlation with a range of other treatments.

Wine quality assessments:

At Glenrowan significant differences in wine quality between rootstocks were found in 1988 when 1202 and Schwarzmann scored less than 110 Richter, own roots and Ramsey (Table 2). Over the three seasons there was not a consistent pattern in wine score and we conclude that at this site rootstock treatments have not consistently influenced the wine quality, despite yield differences of up to 250%.

TABLE 1 - Terpene concentration and maturity analysis of juice from berry samples of Brown Muscat grafted to rootstocks.[a]

Trial Site	Season	Rootstock	Free Volatile Terpenes (mg/L)	Potential Volatile Terpenes (mg/L)	Harvest Sugar Level (°Brix)	Titratable Acid (g/L)	pH	Berry Weight (g)
Glenrowan	1988	1202	0.17	1.07	33.1	3.7	4.32	1.53
		Ramsey	0.28	1.68	30.0	3.1	4.28	1.50
		110 Richter	0.16	0.97	32.0	3.5	4.26	1.33
		Schwarzmann	0.24	1.36	37.7	3.8	4.44	1.39
		Own Roots	0.30	1.20	40.6	3.6	4.34	1.07
		Significance[b]	NS	NS	*	NS	NS	*
		LSD 5%	--	--	6.1	--	--	0.27
	1989	1202	0.56	3.39	25.2	--	--	1.50
		Ramsey	0.79	4.12	24.8	--	--	1.74
		110 Richter	0.59	3.58	26.6	--	--	1.59
		Schwarzmann	0.80	3.60	28.2	--	--	1.40
		Own Roots	0.51	3.32	25.7	--	--	1.66
		Significance	NS	NS	NS	NA	NA	NS
	1990	1202	0.35	2.39	29.9	5.7	3.66	1.14
		Ramsey	0.42	2.26	27.1	5.5	3.66	1.15
		110 Richter	0.34	1.86	28.0	5.7	3.73	0.99
		Schwarzmann	0.35	2.54	28.4	5.5	3.84	0.95
		Own Roots	0.34	1.94	30.0	4.9	3.85	1.21
		Significance	*	**	*	*	**	NS
		LSD 5%	0.06	0.40	1.8	0.5	0.13	--
		1%	--	0.55	--	--	0.18	--

Trial Site	Season	Rootstock	Free Volatile Terpenes (mg/L)	Potential Volatile Terpenes (mg/L)	Harvest Sugar Level (°Brix)	Titratable Acid (g/L)	pH	Berry Weight (g)
Milawa	1988	1202	0.17	1.16	25.1	4.0	3.85	1.86
		Ramsey	0.22	1.04	23.9	3.5	3.81	1.69
		110 Richter	0.14	0.96	24.7	3.5	3.89	1.59
		5BB Kober	0.16	1.05	26.5	3.7	3.93	1.98
		Schwarzmann	0.15	1.16	27.3	3.8	3.94	1.73
		5A Teleki	0.22	1.07	25.9	4.0	3.88	1.97
		Significance	NS	NS	NS	NS	NS	NS
	1989	1202	0.70	2.77	32.1	--	--	1.79
		Ramsey	0.58	2.45	31.1	--	--	2.03
		110 Richter	0.57	2.68	27.6	--	--	1.95
		Schwarzmann	0.66	2.84	31.5	--	--	1.93
		5A Teleki	0.80	2.74	30.8	--	--	1.88
		Significance	NS	NS	*	NA	NA	NS
		LSD 5%	--	--	4.2	--	--	--
	1990	1202	0.34	1.44	22.5	5.3	3.55	2.15
		Ramsey	0.37	1.64	21.6	5.8	3.46	2.00
		110 Richter	0.39	1.65	22.4	5.3	3.44	1.87
		Schwarzmann	0.38	1.49	22.4	5.2	3.57	1.89
		5A Teleki	0.32	1.34	23.1	5.6	3.49	2.29
		Significance	NS	NS	NS	NS	*	NS
		LSD 5%	--	--	--	--	0.10	--

(a) Analyses apply to berry samples taken immediately prior to harvest. All treatments harvested on the one day at each trial site.

(b) NS = not significant; * = significant at P = 0.05;
** = significant at P = 0.01; NA = not available

(c) LSD = Least Significant Difference

(c) All rootstocks harvested on the same day.

TABLE 2 - Wine quality score, must sugar and yield of Brown Muscat grafted to rootstocks[a]

Trial Site	Season	Rootstock	Wine Quality Score[b]	Must Sugar (°Brix)	Fresh Yield (kg/vine)
Glenrowan	1988	1202	15.3	36.5	5.1
		Ramsey	16.2	33.6	4.9
		110 Richter	16.5	37.0	3.1
		Schwarzmann	15.1	36.4	3.0
		Own Roots	16.3	40.9	1.9
		Significance[c]	*	NA	*
		LSD 5%	0.8	--	2.6
	1989	1202	5.5	29.1	8.2
		Ramsey	4.6	27.3	6.8
		110 Richter	4.5	28.5	5.4
		Schwarzmann	6.0	33.3	4.4
		Own Roots	4.8	31.0	5.1
		Significance	NS	NA	NS
	1990	1202	16.4	29.5	4.5
		Ramsey	15.8	27.1	4.8
		110 Richter	16.3	29.2	3.4
		Schwarzmann	15.9	28.9	3.0
		Own Roots	16.5	31.8	3.6
		Significance	NS	NA	NA

Trial Site	Season	Rootstock	Wine Quality Score[b]	Must Sugar (°Brix)	Fresh Yield (kg/vine)
Milawa	1988	1202	14.0	30.8	13.2
		Ramsey	14.3	26.1	12.7
		110 Richter	14.9	30.6	10.9
		Schwarzmann	15.1	32.4	11.7
		5A Teleki	14.3	30.3	15.9
		Significance	NS	NA	NS
	1989	1202[d]	5.1	37.1	6.2
		Ramsey	3.5	35.6	8.9
		110 Richter	3.2	32.7	8.3
		Schwarzmann	3.5	27.1	10.4
		5A Teleki	3.7	34.5	9.5
		Significance	**	NA	NS
		LSD 5%	0.8	--	--
		1%	1.1	--	--
	1990	1202	13.9	19.7	22.7
		Ramsey	15.5	22.9	16.0
		110 Richter	15.2	22.0	20.2
		Schwarzmann	14.5	21.9	31.1
		5A Teleki	15.7	23.2	14.6
		Significance	*	NA	NA
		LSD 5%	1.1	--	--

(a) All treatment harvested on the one day at each trial site.

(b) 1988 and 1990 maximum score 20; 1989 maximum score 10.

(c) NS = not significant; * = significant at P=0.05
** = significant at P=0.01; NA = not available

(d) Wine made differently to the others (see text).

At the Milawa site significant differences in wine quality score occurred in two seasons (Table 2). In the 1989 season the fruit from 1202 rootstock was processed differently (crushed, then pressed) to the other treatments (pressed only). This could be the basis for the higher score for 1202 in this season. The other treatments were not processed in the same way as fruit from 1202 because the high levels of bunch rot were expected to have an adverse effect on the wines handled in this way. In hindsight it is clear that crushing and pressing may have produced the better wines despite the rot, although the 1202 wine was described as being more aged possibly due to the extra oxidation resulting from higher laccase levels due to crushing. In any case, no conclusion about wine quality can be made for this rootstock in this season due to the different processing.

To avoid the bunch rot problem in 1990, the fruit was picked at considerably lower sugar levels but in sound condition (see must sugar levels, Table 2). In this season wine from 1202 rootstock scored significantly lower than Ramsey, 110 Richter and 5A Teleki, and wine from Schwarzmann rootstock scored significantly lower than 5A Teleki. However, we conclude that in this site rootstock treatments have not consistently influenced the wine quality over the three seasons.

In the 1989 season descriptive analysis of the wines from both sites was also undertaken in an attempt to distinguish wines influenced by rot (botrytis character). Botrytis cinerea has been shown to influence monoterpenes in cultured juice and must and has been associated with a loss of varietal aroma in botrytised grapes (Strauss et al. 1986). We used principle component analysis (PCA) in an attempt to distinguish wines from various rootstocks according to descriptors. The PCA could not clearly distinguish between treatments. A summary of the descriptors and scores is presented in Table 3. The only significant differences occurred with 1202 rootstock at Milawa (as explained above, this wine was made differently to the others in this season). This wine had higher raisin and molasses scores which were associated with a more aged character ascribed to the wine by the judges.

TABLE 3 - Descriptor analysis of wines from the 1989 vintage made from Brown Muscat grafted to rootstocks (point score out of 10)

Trial	Treatment	DESCRIPTORS					
		Orange	Linalool	Vanillin	Almond	Raisin	Molasses
Glenrowan	110 Richter	3.9	4.8	3.9	2.5	2.6	1.4
	Own Roots	3.7	4.7	3.5	2.4	3.1	1.7
	Schwarzmann	5.1	4.8	4.2	3.6	3.2	1.7
	Ramsey	4.9	4.8	3.7	2.8	2.5	1.6
	1202	4.8	5.0	3.5	2.2	2.7	1.7
	Mean	4.5	4.8	3.8	2.7	2.8	1.6
	Significance	NS	NS	NS	NS	NS	NS
Milawa	5A Teleki	3.2	3.7	3.7	1.5	2.5	1.3
	Ramsey	3.4	3.9	3.7	1.9	2.1	0.9
	110 Richter	3.4	3.6	3.4	1.3	2.0	1.2
	Schwarzmann	4.0	4.1	3.8	1.7	2.2	1.2
	1202[a]	3.4	3.4	3.8	2.0	3.5	2.4
	Mean	3.5	3.7	3.6	1.6	2.4	1.3
	Significance	NS	NS	NS	NS	P=0.001	P=0.001

(a)

Due to limitations with fruit quality in the first two seasons we regard the wine quality results from the final season (1990) in both sites as being most meaningful. In summary, rootstock affects on wine quality appear to be small compared to other influences (for example, maturity level at harvest, fruit condition, crop load, site and processing method) and may not be consistent from season to season.

Relationships between wine score and other measures:

The must sugar concentration generally showed a positive linear correlation with wine score although this was only statistically significant in 1990 at the Milawa site. Higher must sugar levels result in higher wine residual sugar levels which provide weight or body in muscat wines and are often associated with higher wine scores.

No consistent trends were apparent in relating the must FVT's and PVT's (data not presented) to wine score, with both negative and positive linear correlations occurring, of which none were statistically significant. Must PVT was most closely correlated to wine score at Milawa in 1990 and at Glenrowan in 1989.

Yield was consistently inversely related to wine score, although no correlations were significant. The wines from Milawa, which came from rootstocks covering a wide range of yields, came closest to being significant in all three seasons. At Glenrowan, where the range of yields was much lower, only a weak inverse relationship was seen.

In 1989 berry weight was inversely related to wine quality score (although not quite significant) in wines from both sites. It is not clear why this should be so in one season that had particularly high levels of bunch rot (perhaps the smaller berries had less rot).

Influence of trellis:

In 1988 berry samples were collected at the Milawa site to compare a 1.0m wide T with the standard single wire trellis. There were no significant differences in components of maturity, berry weights or volatile terpene concentrations (FVT and PVT) between the two trellises.

In 1989 and 1990 the 1.0m wide T trellis was compared to a two wire vertical trellis at Milawa using Schwarzmann rootstock. No significant differences were found in must sugar, berry weight, FVT, PVT, yield or wine quality score between the two trellis systems. The lack of differences between the two trellis systems is most likely due to the relatively high and similar yield level, and that the standard trellis provides an adequate canopy configuration for this site.

Influence of clonal source of scion material:

Many of the vines grafted with the local mass selected scion material showed clear symptoms of virus infection which resulted in a lighter fruit colour.

At the Glenrowan site, significant differences between the CSIRO clone and the mass selected Rutherglen 'clone' were detected in two seasons (1988 and 1990). In both seasons the CSIRO selection rated higher in wine score than the mass selected Rutherglen material. However, in 1988 the results were confounded by the high bud number of the Rutherglen 'selection' which had been minimally pruned (with no crop thinning). The yield from the Rutherglen 'selection' was 2.75X the yield of the CSIRO selection on a standard trellis and this resulted in much lower sugar levels, lower FVT and PVT, and significantly lower wine score. The differences in that season are therefore primarily attributed to a crop load affect.

In 1990 the yields and maturities of the CSIRO and Rutherglen 'selections' at Glenrowan were similar. There were no significant differences in FVT or PVT concentration but the CSIRO selection had a greater wine score (data not presented).

At the Milawa site there were no significant differences in wine score between the CSIRO selection and the mass selected Rutherglen material in any season. The CSIRO selection tended to have the higher wine scores despite yielding considerably more than the Rutherglen 'selection' in two of the three seasons. There were no significant differences in FVT and PVT concentrations in any year.

CONCLUSIONS

1. Rootstocks had no consistent affect on Brown Muscat wine quality over the three seasons at the two sites. It appears that the rootstock affects were small in comparison with factors such as maturity level at harvest, crop load, fruit condition, site, and winemaking techniques.

2. In general despite large differences in crop levels between rootstocks comparable sugar levels were attained and wine quality scores were similar. There was however, a trend (not significant) for higher yielding rootstocks to produce wines with slightly lower wine quality scores at one site only (Milawa). Sugar level may be more important in determining quality than yield per sé as illustrated by the significant positive correlation between sugar concentration and wine score in 1990 at the Milawa site.

3. There were no consistent relationships between the FVT and PVT concentrations and the wine quality score. This suggests that factors other than terpene levels are important or can mask the assessment of muscat wine quality, or the concentrations of volatile terpenes in the juice are altered during processing and do not reflect the relative levels in the muscat wine.

4. The measurement of FVT and PVT concentrations has not been able to consistently distinguish between rootstocks. This could be due to the high variation associated with field replications but there is also some question as to whether the method used is sensitive or reliable enough to determine if small differences exist.

5. Volatile terpene concentrations changed markedly in the first few weeks after veraison, thereafter changes were relatively small.

6. Trellis treatments at similar cropping levels did not produce differences in wine score or terpene concentrations, although a minimal pruned treatment (higher crop) had a significant influence.

7. Some differences in wine score were detected between sources of scion material although further studies are required to see if the result is consistent.

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DIFFICULTIES ENCOUNTERED

Regular inspection of the vines was difficult for the first two years whilst Mr Whiting was based at Irymple. This resulted in some problems with pest and disease control. Also a reliance on the timing of harvest to immediately precede commercial harvesting resulted in some below average quality fruit in the first two years. In the third season, the trial was monitored more closely from Bendigo and harvest was undertaken before bunch breakdown became extensive.

The poor condition of the fruit in the first two seasons led us to press the grapes without crushing and fermenting on skins in an attempt to minimise the influence of botrytis on the wine. This method was successful in 1988, but in 1989 botrytis characters were still evident. In the final season sound fruit enabled us to ferment the wines on skins for a short time before fortification and this clearly resulted in wines with better colour, flavour and phenolic structure, although the grapes were picked at less than optimal sugar levels.

The technique for assessing volatile terpenes appeared to produce a reasonable amount of inconsistency and could not discriminate between juice samples from different treatments. Other workers have also encountered unreliability with the technique (A. Ewart pers.comm.). Most previously published reports have used the technique of Dimitriadis and Williams (A.J.Enol.Vitic. 35: 66-71, 1984), and have not reported any such problems.

RECOMMENDATIONS FOR FURTHER RESEARCH

Muscat aroma and flavour are not the only quality attributes of fortified muscat wines. Further research is required to investigate the relative importance of terpene concentrations with other factors such as sugar concentration, colour and total phenolics. It is also necessary to prepare a profile of the monoterpenes present in the Brown Muscat variety since total terpene levels, using the Dimitriadis and Bruer technique, includes the measurement of all monoterpenes but does not indicate aromatic intensities.

Arising from the wine tastings it is clear that some variation in the style of muscat wine can be produced by manipulating harvest time, fruit condition and processing techniques. Of particular interest were comments on rapid ageing of commercial muscat wines by processing with controlled amounts of oxidation and the creation of a range of styles by manipulating harvest and handling techniques. The former affect is being studied by one winery following our tasting sessions. Further research could be undertaken in utilising a range of management techniques to create various styles of muscat wine and to assess consumer demand for each style.

Our work has suggested some differences in muscat wine quality between selections of scion material. Further research should be conducted with a wider range of clones to clarify this issue. Also the relatively small influence on muscat wine quality of large variations in yield should be further investigated to determine yield limits for various styles of muscat wine.

APPLICATION OF THE RESULTS TO INDUSTRY

All participants in the project (growers and wine tasters), which included most of the major muscat producers in north eastern Victoria, have had summaries of each season's tastings provided to them. The project has had the direct involvement of, and impact on, the major muscat producers in Australia.

The relatively poor condition of the fruit in the first two seasons led us to delay the publication of results more widely to industry until we could obtain results free from such limitations.

Our first priority will be to complete and submit a paper to an industry journal for refereeing. Once approved we shall provide more active dissemination of results including popular industry journals and magazines, and a workshop/seminar at Rutherglen in 1991.

PUBLICATIONS

Summaries of wine tasting for each season - 1988, 1989 and 1990. J Whiting and D Noon (provided to participants in the project).

Influence of rootstocks on Brown Muscat flavour components and wine quality. J Whiting and D Noon (in preparation).

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