Producing high value dried grapes - Stage 1

Phil Chidgzey
Dried Fruits Australia Inc

Project Number: DG13004

DG13004

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the dried grape industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of Dried Fruits Australia Inc.

ISBN 0 7341 3426 6

Published and distributed by:
Horticulture Australia Ltd
Level 7
179 Elizabeth Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399

HAL
Horticulture Australia

Producing High Value Dried Grapes – Stage 1

Horticulture Australia Limited Project Nr. DG13004

HAL project number: DG13004 (October 2014)

This is the final report for the project

"Producing High Value Dried Grapes – Stage 1"

submitted October, 2014.

This project has been funded by HAL using voluntary contributions from Dried Fruits Australia Inc and matched funds from the Australian Government.

Confidential

CONTENTS

Table of Figures

Table of Tables

Media summary

In response to an identified 3,000 – 5,000 tonne market niche for light-coloured Sultana-type dried vine fruit (DVF), Dried Fruits Australia (DFA), with Horticulture Australia Limited (HAL) support, initiated work aimed at guiding Australian producers to consistently produce light-coloured DVF.

The first stage of this work involved trials on grape maturity and DVF colour, and on the use of covers to protect drying grapes.

The maturity component examined the relationship between berry maturity at the time that drying is initiated and final DVF colour. Crop load manipulation and multiple harvests were used to produce a limited range of maturities. Grapes were dried either in an oven to remove the effect of weather on final DVF colour, and on an open rack. The comparison confirmed that weather during drying was the single biggest influence on final DVF colour this season, but when that factor was eliminated, there was no colour penalty associated with high crop loads. The results underscore the importance of getting crops to mature sooner and dry quickly following summer pruning. Adoption of earlier maturing rain-tolerant varieties is clearly going to be an important part of the industry's future.

Rain during drying results in darker DVF, and most of the Australian DVF crop is dried on the vine. The use of plastic covers, as used in the table grape industry to prevent rain-related grape splitting, was investigated on summer-pruned Sultana and Sunmuscat to gain some practical experience but also to assess the impact of covers on the microclimate in the drying canopies. The air in drying canopies beneath covers was marginally warmer and dryer than air in canopies that weren't covered, but generally only in the afternoons and only when temperatures were above 20^{o}C. But, covers did not prevent drying grapes from being exposed to high ambient relative humidity. Final DVF colour was unaffected by covers, but the colour intensity was marginally greater with covers. It wasn't clear whether the higher temperatures and lower air moisture affected how quickly grapes dried. The data highlighted the need to examine vineyard floor and canopy management practices that accelerate drying by air movement and retention of heat.

Technical summary

A trial was conducted to separate the influence of grape maturity at the initiation of drying from the effect of grape physiological age at the initiation of drying on final DVF colour. Another trial was conducted to investigate the effect of plastic covers on the microclimate of grapes drying on the trellis and subsequent DVF colour.

Different maturities at the initiation of drying were induced by imposing a range of crop loads by removing bunches in January. Different physiological ages at the initiation of the drying were imposed by conducting two harvests a fortnight apart. The first trial originally involved Sultana and Sunmuscat, but significant rain in mid February resulted in Sultana berry splitting and this component was abandoned. At each Sunmuscat harvest, bunches were dipped in drying emulsion and either oven dried or dried on a rack under cover. The colour of the resulting DVF was assessed at the end of drying, the fruit were then stored under commercial conditions for two months and then the fruit colour was re-assessed.

Mean crop load and harvest date effects on maturity were only of the order of 1-3 ^{o}Brix. The strongest influence on DVF colour was the drying method; accounting for well over 50% of the variation in DVF colour and colour intensity. Rack dried fruit were much darker than oven dried fruit. When the analysis was confined to oven dried fruit, crop load was a significant influence on colour, and harvest date was a significant influence on DVF greenness, which dissipated during storage. Thus, when environmental influences during drying are removed, berry maturity at the initiation of drying does influence DVF colour, but the extent of the effect is small compared to the influence that drying method has on final DVF colour. But because the range of berry maturities induced by varying crop load was small too, due, possibly, to the timing of crop size manipulation, the robustness of the relationship between berry maturity and final DVF colour was not considered to have been comprehensively statistically tested.

The influence of plastic covers on the microclimate of grapes drying on the trellis and subsequent DVF colour was investigated by installing clear plastic covers on four rows of Sultana and Sunmuscat that had just been cut and sprayed with drying emulsion. The microclimate in the drying canopies of the covered rows was compared to the microclimate in the drying canopies of four adjacent uncovered rows. Across the board, the air temperature and relative humidity in the drying canopies beneath covers was approximately 1^{o}C warmer and 1% drier compared to the air in the drying canopies of uncovered rows. The temperature and humidity effects were confined to the afternoons, and were temperature dependent; these effects were not apparent when the air temperature was less than about 20^{o}C. The humidity effect was also not obvious when it rained; the relative humidity of covered and uncovered rows being 100% during these events.

The significance of the slightly warmer temperatures and slightly drier air on the time needed to dry grapes down to a level that allows mechanical harvesting is unknown. A structured sampling program could be designed that could answer that question, as well as identify when during the drying process that final DVF is compromised by adverse weather conditions. The colour of DVF produced from grapes under covers was not different to the colour of DVF produced from grapes that dried in the open. The colour of DVF produced from grapes that dried under covers was more intense, but not overly so.

Introduction, including review of literature

Inconsistent supplies of light coloured dried vine fruit (DVF) available to dried fruit processors over the last decade, and the frequency of adverse weather events at critical times in the production of DVF in recent years has prompted a revisit of the physiological/chemical processes that result in dark DVF and the on-farm factors that may predispose and initiate those processes.

DVF colour ranges from light yellow through to almost black. Green is occasionally seen, but red and brown-dark brown are more common. Black DVF is also seen, but this can also be attributable to the presence of compounds on the surface of the fruit produced by fungal pathogens.

The dark colours sometimes seen in DVF, and many other foods, are principally the result of the presence of two classes of compounds; oxidised polyphenols and Maillard reaction products. The colours range from black through to red.

The green colour, which is generally just a tinge, if at all, is due to the presence of chlorophyll.

The yellow colour is caused by carotenoids. Carotenoids are found in chloroplasts, and, with the green chlorophyll pigment, play a role in photosynthesis. The yellow carotenoid pigments become apparent when chlorophyll breaks down.

The instrument most widely used to measure DVF colour objectively is the KonicaMinolta Chroma Meter. This instrument measures the amount of light reflected off a sample when a beam of white light is directed at the sample surface at a fixed angle. The three measurements are L* (dark to light), a* (green to red) and b*(blue to yellow). The a* and b* values can be used to derive two other colour indices, namely hue angle (h^o) and chroma (C*). The hue angle describes the full spectrum of visible light as an angle (0-360^o), and C* describes the intensity of that colour as an arbitrary unit from 0 to 100, where 0 means that the colour intensity of h^o is weak, and 100 means that h^o is very intense. A C* of zero indicates black. A h^o value of 90 indicates yellow, and a h^o value of 0 indicates reddish colours.

Phenolics

Phenolic compounds belong to a group of compounds called secondary metabolites. These compounds are produced more or less continuously, and are involved in biotic and abiotic defense/tolerance mechanisms and reproduction. The phenolic compounds found in grapes are just one of several groups of compounds collectively called flavonoids; all are derived from a single compound: an amino acid called phenylalanine.

The various grape varieties are distinguished, amongst other attributes, by their propensity to produce more or less of the many compounds in each class of flavonoid and to form polymers of those compounds, and modify them in other ways (Cantos *et al.*, 2002; Downey *et al.*, 2003; Orak, 2007). White and red grapes are distinguished by the capacity to produce the coloured forms of the anthocyanidins. With some exceptions, the flavonoids are found at much higher concentrations in the berry skin compared to the berry pulp.

Logically, this raises the issue of what determines how much phenylalanine ends up being flavonoid.

Phenylalanine is produced at the end of the amino acid synthesis pathway (Schrader, 1984). If the plant senses that there is insufficient nitrogen available to synthesise new amino acids the nitrogen in phenylalanine is removed to be recycled. The rest of the phenylalanine molecule is then converted into flavonoids. As a result, nitrogen deficient plants tend to have higher levels of phenolics and other flavonoid compounds compared to nitrogen sufficient plants (Olsen *et al.*, 2009). The physiology of this relationship and its practical significance is still the subject of active research (Jones and Hartley, 1999; Koricheva *et al.*, 1998; Demotes-Mainard *et al.*, 2008).

Abiotic stresses such as drought can also result in more flavonoids being produced (Esteban *et al.*, 2001).

Phenolic compounds are stored in a compartment within the cell called a vacuole. Individual phenolic molecules are joined together to form poly-phenols, in much the same way as many individual glucose molecules are joined together to form starch. Vacuoles are used to store large amounts of metabolites and minerals away from the important metabolic machinery of the cell which is located in the cytoplasm; which is the fluid bounded by the cell membrane and external to the vacuole. Part of this metabolic machinery is the enzyme poly-phenol oxidase (PPO) which catalyses, or assists, the reaction of poly-phenols with oxygen (Tomás-Barberán and Espin, 2001; Vaughn and Duke, 1984).

PPO is normally separated from the compounds that it acts on. In the normal course of events this separation is maintained. But if plant tissue is mechanically damaged then PPO and the phenolic compounds in the area of the damage are mixed and the phenolics are oxidised. This is the basis of the dark colours seen on the cut surfaces of fresh vegetables and fruit after a few hours exposure to air.

Presumably that separation is more or less maintained as the berries dry, and is more likely to be maintained by applying the drying emulsion (Grncarevic and Hawker, 1971) and by drying the grapes quickly (Radler, 1964). Presumably also, that separation breaks down with time and is disrupted to some degree by re-hydration. On the latter point, the integrity of that physical separation is possibly inversely proportional to moisture content because DVF darkens the longer it is stored and that deterioration is hastened at higher moisture contents compared to lower moisture contents and at a higher storage temperature compared to a lower storage temperature (Frank *et al.*, 2004b).

It is tempting to conclude that levels of phenolic compounds present in grapes at the outset of the drying process in some way pre-dispose DVF to darken following an adverse weather event or during prolonged storage. But that may not be the case because the variegated Sultana mutant known as “Bruce’s sport” contains similar levels of phenolic compounds compared to normal H5 Sultana, but dries to be a lighter colour than the latter (Antcliff and Webster, 1962; Rathjen and Robinson, 1992). This difference was attributed to a disparity in PPO activity between the two genotypes; the mutant had only 25% of the PPO activity that normal Sultana exhibited. The availability of phenolic compounds to react with oxygen is therefore not the limiting factor in the development of dark colours in DVF; it is the presence of sufficient enzyme to facilitate that reaction that is important. But, it isn’t entirely clear whether the advantage of reduced PPO activity would be maintained if DVF from each variety were re-hydrated and re-dried because the

PPO enzyme which assists the reaction of phenolic compounds with oxygen isn't of itself consumed by the reaction. Thus darkening may occur, but over a longer timeframe.

Also interesting is the fact that Bruce's sport dries lighter then H5 Sultana in the absence of any adverse weather event during the drying process. If the darker colour of H5 compared to Bruce's sport was due to oxidation of poly-phenols it would suggest that even in the absence of circumstances that result in some breakdown in the separation of phenols and PPO, there is some inherent degree of leakiness or that there are sufficient phenolic compounds present in the cytoplasm to cause some degree of browning. Clearly, the advantage of reduced PPO activity is to reduce the degree to which this "background" or baseline darkening takes place.

Non-enzymic browning

In the so called Maillard reaction — which is actually a series of reactions — reducing sugars react with the nitrogen atoms in free amino acids. These reactions are not facilitated by an enzyme. The products of this reaction are generally dark coloured (Saltmarch and Labuza, 1982).

Most amino acids in plants are usually joined together to form proteins, but in grape berries a proportion of the total amino acids are present as free amino acids (Kliewer, 1970). The major free amino acids in Sultana grapes are arginine and proline; these two and six others normally account for between 60 and 90% of the free amino acids present in grapes (Frank *et al.*, 2004a). Concentrations of free amino acids in grape berries are a reflection of the vine's nitrogen supply in general (Kliewer, 1971), but particularly during the flowering to veraison period (Holzapfel and Treeby, 2007). Arginine levels in the skins of berries exposed to the sun during development are about a half to a third higher than the level of arginine levels in the skins of berries shaded during development (Frank *et al*., 2004a).

The free amino acids are present in both the cytoplasm of plant cells as well as the vacuoles, but it isn't entirely clear whether concentrations are higher in the vacuole relative to the cytoplasm. There is no specific information about the distribution of free amino acids in grape berry cells. Therefore, it cannot be stated with any confidence that there is any spatial separation of the two groups of compounds that are the reactants in the Maillard reaction.

Sugar is transported from the leaves to the berries as sucrose, and is split into its constituent sugars, namely glucose and fructose, when entering the vacuoles of the berry cells. Thus, these two sugars are present at high concentrations in the vacuoles of the berries' pulp cells.

The amount of arginine found in DVF decreases with length of storage, and is inversely related to the increase in the amount of Maillard reaction products during storage (Frank *et al.*, 2004a); in other words, more arginine in the DVF at the outset of storage, the greater the likelihood of Maillard products becoming obvious during storage.

There is evidence that other non-enzymic reactions occur in other foods; for example between flavonols and some of the intermediate products of the Maillard reaction (Es-Safi *et al.*, 2000). The possibility that these reactions also contribute to the non-enzymic browning seen in dried vine fruit has been raised, but no direct evidence exists to support the idea.

The Maillard reaction in DVF is more likely when the grapes originate from vines with a high nitrogen status (Frank *et al.*, 2005).

Chlorophyll and related pigments

Green grape berries effectively function as leaves up to a certain point in their development. Functional stomates are present for gas/water exchange and chloroplasts to fix carbon dioxide. Wax extrusion through the surface of the berry as the berry grows and the temperature-related transformation of the wax into an amorphous water repellent layer effectively make both redundant.

Chlorophyll, the green pigment responsible for fixing CO_2 into sugars, is broken down soon afterwards. Chlorophyll breakdown occurs sooner and more completely in fruit exposed to the sun ((Uhlig, 1998)). Shaded fruit tend to have a green tinge which is caused by some residual chlorophyll being present. Because chlorophyll is a nitrogen containing compound, and because chlorophyll is a significant part of a leaf's biomass, nitrogen deficient vines have yellow or pale leaves depending on the extent of the deficiency. It should also be recognised that deficiencies of other mineral elements can also result in less chlorophyll or chlorophyll dysfunction. That issue aside, a lack of chlorophyll due to nitrogen deficiency is also seen in the grapes; grapes off vines at the tops of furrow irrigated rows were often pale compared to grapes off vines at the bottom of those rows because the nitrogen was leached from the soil at the tops of the rows further down the row. At the other end of the scale, grapes off vines that have had an abundance of nitrogen supplied to them tend to be greener because of the additional chlorophyll and the shade from the extra canopy, both a result of being too well fed with nitrogen.

As pointed out earlier, chloroplasts contain both chlorophyll and carotenoid pigments. Both pigments break down as grapes mature. Under some circumstances chlorophyll breaks down at a faster rate than carotenoids. There is a genetic component to the breakdown of both pigments as well: carotenoids may breakdown more rapidly in H5 Sultana berries compared to Merbein Seedless in some seasons (Uhlig and Clingeleffer, 1998b).

Grape maturity

Uhlig and Clingeleffer (1998a) identified a narrow window of berry maturity (about 21-23^{o}Brix) that was associated with lighter DVF in H5 Sultana and Merbein Seedless, all other influences, such as drying conditions, being equal. Either side of the maturity range resulted in browner DVF. Presumaby, this effect is due to a combination of enzymic and non-enzymic browning processes that are enhanced or inhibited to some degree during berry maturation. Whether the berries were sourced from shaded or unshaded bunches would obviously be a confounding factor because sun exposed berries tend to have higher soluble solids levels, less chlorophyll, more arginine and more phenolics (Uhlig, 1998; Frank et al., 2004a).

The lower end of that maturity range is reached by Sultana at a time (early February) when the conditions for rapid drying are favourable. Industry experience suggests that that level of maturity is not achieved by Sunmuscat until mid February to early March; the chances of favourable drying conditions at this time are lower.

What is not apparent however is whether a large crop that doesn't reach 21^{o}Brix before late February will have a different DVF colour outcome at the completion of drying compared to a small crop that reached 21^{o}Brix in early February, drying conditions not withstanding. The small crop would be expected to be physiologically younger at the same level of maturity as the large crop. In other words, there is the possibility that there is a physiological age window that needs to be targeted as opposed to a maturity window.

Rehydration during drying

Rain during drying results in darker DVF. This phenomenon is more evident in trellis dried fruit, but rack dried fruit is also prone to darkening following rain. There is ample industry experience to conclude that preventing drying fruit from actually being wet by rain reduces the extent of darkening. For example, industry practices such as covering drying racks to prevent rain droplets being blown through the racks and wetting fruit in the middle of the tier results in the general colour grade for fruit off that rack being lighter compared to fruit off racks that weren't covered. As mentioned earlier, rewetting results in PPO-mediated oxidation of poly-phenols in the skin of the berries.

What isn't entirely clear is whether the drying berries re-absorb atmospheric moisture. Atmospheric relative humidity levels following significant rainfall is near 100% for sometime afterward unless strong dry winds remove the moisture-laden air. Support for the idea that drying grapes do adsorb atmospheric moisture can be garnered from the fact that grapes that received a high strength application of drying emulsion or multiple applications of strong drying emulsion tend to be more prone to darkening following rainfall than grapes that received only one application of a lower strength drying emulsion. Data were not found in the scientific literature that would support or dispel the idea. Given that the process DVF producers are trying to prevent (*viz.* the PPO-mediated oxidation of poly-phenols) takes place in what remains of the outer cell layers of the berry, any moisture adsorbed on the outside of the drying berry is available to be absorbed into the out layers of now dried skin, and there is no wax barrier present to prevent that from happening. Effectively, this may amount to being wet by rain.

This point is raised because it is logistically difficult to physically shelter fruit drying on the trellis from being wet by rain droplets. Further, even if grapes drying on a trellis were to be sheltered from rain by whatever means, the strategy may not be completely effective if atmospheric moisture is adsorbed by drying fruit. This is a knowledge gap that may need to be addressed.

Another knowledge gap is whether DVF exposed to any degree of rehydration during drying is more prone to darkening than DVF that hasn't undergone any rehydration during drying.

Materials & methods

Two trials were established and conducted on co-operating dried vine fruit (DVF) producers' properties to investigate the relationship between grape berry development at the start of drying and DVF colour at the end of drying, and to ascertain whether covers altered the microclimate around drying grapes and led to any differences in DVF colour.

Separating the effects of physiological age and maturation on DVF colour

On a property near Red Cliffs in north-west Victoria two rows each of Sunmuscat and Sultana on swing arm trellis were selected. Each pair of rows was separated by a row so that the orientation of the fruiting side was the same on each of the rows to be used. Maturation was manipulated by imposing crop loads, and physiological age was imposed by conducting two harvests a fortnight apart. Crop loads were imposed by tagging 10, 20, 40, 80 or 160 bunches on Sunmuscat vines and removing the remaining untagged bunches. The original plan called for a similar treatment structure to be imposed on the Sultana vines, but bunch numbers were insufficient to allow this. As a result, 5, 10, 20, 40 or 80 bunches were tagged on the Sultana vines. Untagged bunches were removed in January. The treatments were imposed in three blocks down each row. The experimental design was a split plot with 6 replicate vines for each crop load/harvest date combination.

A significant rainfall event (16 and 49 mm on February 14 and 15, respectively) immediately prior to the first scheduled harvest of Sultanas caused serious splitting, and a result this component was abandoned.

The Sunmuscats were unaffected by the rain.

Immediately prior to each Sunmuscat harvest (February 28 and March 14) berries were sampled to assess maturity. Two berries were taken from the from the top, two from the middle and one from the bottom about 10 bunches, stored in plastic bags in an esky, transported back to the laboratory and stored at 4^{o}C for analysis. The berries were removed from storage, allowed to warm to room temperature and were then crushed in the bags using a heavy flat object. Total soluble solids in the free running juice of the crushed berries were then measured on a temperature-compensated digital refractometer.

At each harvest, bunches were snipped off the vines, placed in heavy duty "onion" bags, dipped in drying emulsion (1.2% potassium carbonate and 1% esterified fatty acid), and dried at 55^{o}C for 7 days in a fan forced drying oven. Another set of samples was dipped and dried on an open rack.

Following removal from the drying oven and the rack, berry colour was measured (see below).

The dried fruit were then stored for 2 months under commercial conditions. Berry colour was then re-assessed.

The effect of covers on the microclimate of drying grapes

Eight adjacent rows of Sultana and of Sunmuscat vines on swing arm trellis were used to assess the effect of covers applied to the fruiting side of vines that had just been summer-pruned and sprayed with drying emulsion. One hundred metre lengths of 1.5 metre wide clear 100 µm plastic were fixed to the cordon and bottom wire using cable ties soon after cutting. Clear plastic was chosen based on experience gained and observations made during earlier, preliminary work that compared, on a smaller scale black, white and clear plastic. In each 8-row area, covers were installed on the first, second, fifth and sixth rows; resulting in pairs of covered and uncovered rows immediately adjacent to each other creating a representative micro-climate, and accounting for the alternate orientations of the sides of the vines carrying the current season's crop.

The plastic was installed on and removed from the Sultanas on February 25 and March 23, respectively. The comparable dates for the Sunmuscat vines were March 14 and April 25.

Environmental monitoring equipment in a Stevenson screen was installed a third of the way down each of the 8 rows in the trial to measure and log temperature and humidity record every 15 minutes through to mechanical harvesting to identify any differences in the microclimates of the drying canopies that could be attributable to covering the trellis with plastic covers.

Colour measurements

DVF colour was measured in two ways; with a Minolta Chroma Meter and a ColourVision system.

The principles of the tristimulus system used by the Chroma Meter were described earlier. The derived hue angle and chroma were used in this study.

The ColourVision system is a digital camera-based system that counts the number of pixels in an image that fall into five categories: dark, brown, medium-dark, medium and light, and provides a metric of the number of pixels in each class as a percentage. The ColourVision system also provides a metric of the number of green pixels. Only the green pixels data were utilised for this study.

To gain some perspective on what the various metrics provided by the two ways of measuring colour meant, the two systems were calibrated against three samples of DVF (Figure 1 and Table 1). Further, because h^o and C* are conceptually more easily understood, these two metrics were calculated as well.

Figure 1 DVF samples used to calibrate the Minolta Chroma Meter and the ColourVision systems

Top, Bruce's sport; bottom left, mottled Sultanas; bottom right, dark Sultanas.

The final DVF colour measuring protocol involved firstly taking a subsample of the DVF sufficient to fill a 100 mm wide plastic Petri dish, and taking 10 readings with the Chroma Meter as random spots across the dish. The mean of the ten readings was used for each sample for biometric analysis. Secondly, a 150 mm wide white plastic dish with 15 mm high walls was filled with DVF to two berries deep. The plate was positioned under the ColourVision lense, and a scan recorded. The plate was then up-ended, and refilled using the same subsample, the plate was repositioned under the lense and another scan recorded. This process was repeated another three times.

Table 1 Metrics provided by the Minolta Chroma Meter and the ColourVision systems for three DVF samples

Values presented are means of 10 and 5 scans of each sample using the Chroma Meter and ColorVision systems, respectively.

	Bruce's sport	Mottled sultanas	Dark sultanas
h^o	68	52	50
C*	18	9.5	10
Green	0.1	2.4	3.2

Results

Dried vine fruit colour: physiological age versus maturation

Effect of crop load and harvest date on berry soluble solids

The effect of crop load and harvest date are summarised in Table 2. The early harvested fruit had lower soluble solids than the late harvested fruit, but an effect of crop load on the accumulation of soluble solids was only apparent at the highest crop load. A significant interaction term suggested that the effect of crop load was only apparent in the early harvested fruit at the highest crop load, but soluble solids levels were significantly increased between the early and the late harvests in the two highest crop loads. Berry soluble solids levels did not improve between the early and the harvests for the three lower crop loads.

Table 2 Effect of crop load on Sunmuscat berry soluble solids on two harvest dates at Red Cliffs

Values presented are means (n=6, 12 and 30 for crop load by harvest date, crop load and harvest date, respectively. Different superscripted lower case letters indicate significant differences between the interaction means, different superscripted capital letters indicate significant differences between crop load main effects means, and the asterisk indicates that the late harvest mean is significantly different to the early harvest mean (P=0.05).

Crop load	Harvest early	Harvest late	Crop load main effects
10	22.3[bc]	23.0[bc]	22.7[AB]
20	22.4[b]	22.5[b]	22.4[B]
40	22.8[bc]	22.9[bc]	22.8[AB]
80	22.6[b]	23.6[c]	23.1[A]
160	20.2[a]	23.1[bc]	21.6[C]
Harvest main effects	22.1	23.0*	-

Importantly, the treatments imposed resulted in mean soluble solids levels at harvest of 20.2 to 23.6 ^{o}Brix, and 17.8 to 25 ^{o}Brix across the raw data. Thus the mean ^{o}Brix range successfully straddled the 21-23 ^{o}Brix range suggested as an optimum maturity range for final Sultana DVF colour, but not overly so.

Summaries of the analyses of variance for the Chroma Meter and ColourVision metrics of DVF colour before storage are presented in Table 3.

The way the grapes were dried was the most important influence on the metrics used to measure DVF colour (*i.e.* ho, C* and green pixels.). The extent of that effect is best illustrated by h^{o}; rack dried fruit had half the h^{o} of oven dried fruit. The difference between oven and rack dried fruit reflects the drying conditions experienced by rack dried fruit; drying fruit in an oven in a consistent manner removed the influence of climatic conditions of DVF colour.

Table 3 Summary of analyses of variance of h°, C* and green pixels for Sunmuscat DVF samples immediately after drying and before storage

*F prob., F probability of variance ratio; % var., proportion of total sums of squares; ***, significant at P<0.001; *, significant at P=0.05; n.s., not significant.*

	h°		C*		Green	
	F prob.	% var.	F prob.	% var.	F prob.	% var.
(1) Crop load	***	1	***	2	n.s.	1
(2) Harvest date	***	5	***	6	***	5
(3) Drying method	***	82	***	57	***	25
(4) Storage	n.s.	0	n.s.	0	*	2
(1) × (2)	n.s.	0	*	1	n.s.	1
(1) × (3)	n.s.	0	n.s.	1	***	4
(1) × (4)	***	4	***	10	***	19
(2) × (3)	n.s.	0	n.s.	0	n.s.	1
(2) × (4)	n.s.	0	n.s.	0	n.s.	0
(1) × (2) × (3)	n.s.	0	n.s.	0	***	4
(1) × (3) × (4)	n.s.	0	n.s.	0	n.s.	1
(2) × (3) × (4)	n.s.	0	n.s.	0	n.s.	0
(1) × (2) × (3) × (4)	n.s.	0	n.s.	0	n.s.	0
Unaccounted for variation		8		23		37

Table 4 Effect of drying method on mean colour parameters of dried Sunmuscat grapes

Values presented are means (n=60). Each rack dried mean was significantly different to the comparable oven dried mean.

	Oven	Rack
h°	70	35
C*	13	9.7
Green	2.2	2.9

The extent of the effect of drying method on DVF colour can be gauged from the Box-whisker plots for all h° , rack dried h° data and oven dried h° (Figure 2).

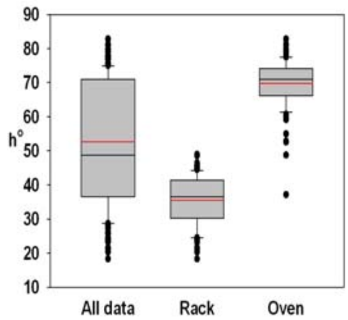


Figure 2 Box-whisker plots for h° of dried Sunmuscat grapes

From left, all data, rack dried only; and oven dried only.

The objective of the trial was to assess the impact of crop maturity and crop physiological age on DVF colour in the absence of environmental influences during drying. Consequently, the statistical analyses were confined to oven dried DVF.

Summaries of the analyses of variance conducted on the oven dried fruit are presented in Table 5.

Table 5 Summary of analyses of variance of colour metrics for Sunmuscat DVF after drying and after storage

*F prob., F probability of variance ratio; % var., proportion of total sums of squares; ***, significant at P<0.001; *, significant at P=0.05; n.s., not significant.*

	h°		C*		Green	
	F prob.	% var.	F prob.	% var.	F prob.	% var.
(1) Crop load	***	20	*	10	*	6
(2) Harvest date	n.s.	1	n.s.	2	***	29
(3) Storage	n.s.	1	n.s.	1	***	8
(1) × (2)	n.s.	4	*	8	n.s.	3
(1) × (3)	n.s.	2	n.s.	0	n.s.	1
(2) × (3)	n.s.	0	n.s.	0	n.s.	0
(1) × (2) × (3)	n.s.	1	n.s.	2	n.s.	1
Unaccounted for variation		71		77		52

Table 6 Crop load, harvest date and storage main effects on DVF colour

Values presented are means (n= 12, 30 and 30 for crop load, harvest date and storage, respectively). Different superscripted lowercase letters indicate a significant difference between crop load means. An asterisk on late harvest or after storage means indicates a significant difference between the late and early or between pre- and post-storage means.

	Bunches/vine					Harvest		Storage	
	10	20	40	80	160	Early	Late	Before	After
h°	66[a]	69[ab]	69[ab]	69[b]	76[c]	71	69	70	69
C*	12.1[a]	12.7[ab]	13.0[bc]	12.6[a]	13.4[c]	12.6	13.0	12.7	12.9
Green	2.2[a]	2.2[a]	2.3[ab]	2.1[a]	2.7[b]	2.7	1.9***	2.5	2.1***

Crop load was a significant influence on h° and C* and green values (Table 5). Harvest date and storage affected the measure of DVF greenness, and there was a significant interaction terms for crop load and harvest date for chroma. The proportions of the variation unaccounted for by the treatments and their interactions were over 50% for the three indices of DVF colour. The main effects presented in Table 6 indicate DVF produced from grapes off vines carrying a high crop load were more yellow and green colour than DVF produced from grapes off vines carrying a moderate or low crop load. A trend for chroma is less clear, but DVF produced from grapes off vines carrying moderate of low crops loads were generally less bright compared to DVF produced from grapes off vines carrying a high crop load.

The interactive effect of crop load and harvest date (Table 7) confirm the crop load main effects mentioned above, and suggest too that late picked fruit off vines carrying a high crop load were brighter than DVF produced from grapes picked earlier and DVF produced from grapes off vines carrying moderate or low crop loads harvested at the same time.

Overall, using the measurements made on the three standard mixes of DVF (*i.e.* Bruce's sport *etc*. - Figure 1), the DVF samples before storage would be classified as marginally darker than the mottled Sultanas).

Table 7 Interactive effect of crop load and harvest date on DVF chroma

Values presented are means (n= 12). Different super-scripted letters indicate a significant difference between means at P=0.05.

Bunches vine^{-1}	Harvest early	Harvest late
10	11.8[a]	12.5[ab]
20	12.4[ab]	13.1[b]
40	13.2[bc]	12.8[b]
80	13.0[b]	12.3[ab]
160	12.7[ab]	14.1[c]

An issue that was the basis of this trial was the relationship between berry maturity (as indicated by TSS) and final DVF colour on the one hand, and the relationship physiological age (imposed here by two harvest dates a fortnight apart) on the other. These were explored using the TSS data for each harvest and h° (Figure 3). Firstly, as indicated earlier, TSS ranged from about 18 to 25 °Brix; a range that well covers the 21-23 °Brix thought to be the optimum for producing light coloured Sultanas. Secondly, h° ranged from less than 50 to 84; red-orange through to almost yellow, in other words. There was no evidence that DVF colour was maximal between 21 and 23 °Brix, and there was no evidence that fruit that was physiologically older was more likely to dry darker than fruit that was physiologically younger.

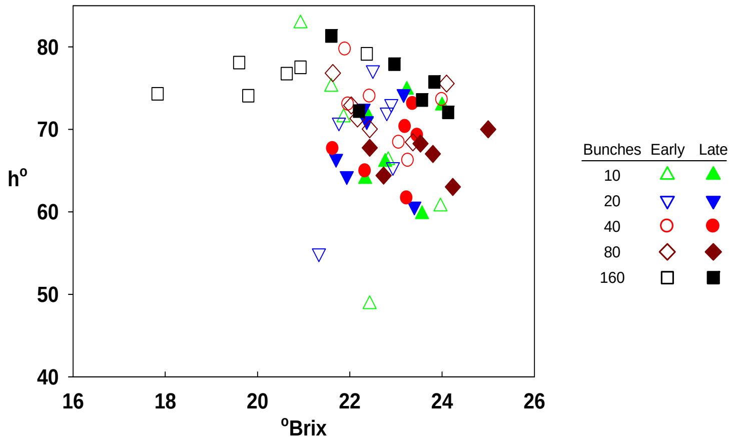


Figure 3 Scatterplot of TSS versus hue for oven-dried DVF

Values used are for individual vines.

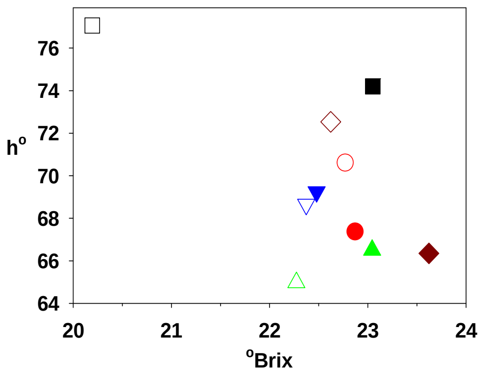


Figure 4 Scatterplot of TSS versus hue angle for oven dried DVF using crop load × harvest date means.

Values presented are means (n=12). See Figure 3 for symbol legend.

Taking a more conservative approach based on the crop load × harvest date treatment means (Figure 4) shows that the bunch removal treatments resulted in berry TSS levels at harvest centred approximately around 23 °Brix, which is the upper end of the 21-23 °Brix optimum maturity window. As indicated in the Table 2 and Table 6, the highest crop load imposed retarded the accumulation of soluble solids in the early harvested fruit, and the highest crop load was associated with a highest hue angle. The scatterplot of the crop load × harvest date treatment means though suggests that there may only be a marginal case for harvesting earlier, particularly with a large crop; most treatment means were between 22 and 24 °Brix and h° varied between by almost 10. This cannot be attributed to the treatments or their interactions (Table 5). The answer probably lies in the 71% of total variability in h° unaccounted for by the treatments.

The range of berry maturities achieved by the structured removal of bunches was limited by the timing of treatment imposition (*i.e.* after veraison). In an earlier study on the same variety (Singh *et al.*, 2009) crop loads of similar magnitude were imposed at flowering, and resulted in TSS at harvest ranging from less than 20 to almost 28°Brix. This range may be what is required to identify the basis for the hue angle to vary to the extent observed here.

The effect of covers on the microclimate of drying grapes

Daily temperature minima and maxima and the rainfall recorded at Mildura Airport for February 24 through to April 26 are presented in Figure 5.

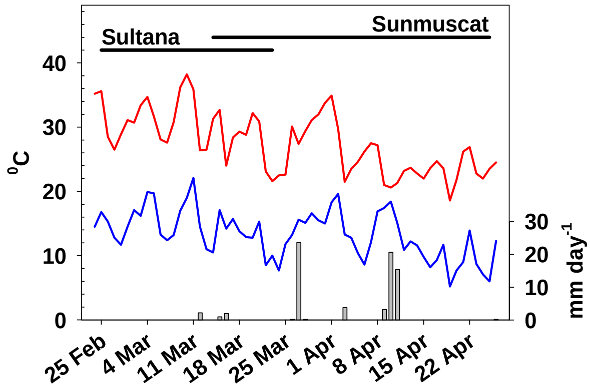


Figure 5 Daily air temperature minima and maxima (left axis) and rainfall (bars, right axis) for the period of February 24 through to April 26

—, temperature minima; —, temperature maxima. Horizontal lines represent periods that covers were on. Data courtesy of Bureau of Meteorology.

There were only three significant rain days; March 23 and April 10 and 11 (the 86th, 100th and 101st days of the year). No significant rain occurred when the covers were on the Sultanas. The rain days corresponded to days 9, 27 and 28 after the imposition of covers on the Sunmuscats.

Traces of the mean temperature and relative humidity in the drying canopies of the uncovered and covered Sultanas and Sunmuscats are presented in Figure 6 and Figure 7. Presented in this manner, it is difficult to identify any effect of the imposition of covers on the temperature and the relative humidity of the air in the drying canopies. Of more use is the difference in the temperature and the relative humidity of the air beneath covers relative to the temperature and the relative humidity of the air in the drying canopy without covers [*i.e.* covered air temperature (or relative humidity) minus the uncovered air temperature (or relative humidity)]. A positive difference indicates that the air under the covers was warmer or more humid than the air in the uncovered canopy, and a negative difference means the opposite.

The results of those calculations are presented in Figure 8 and Figure 9. The imposition of covers resulted in the air in the drying canopies beneath the covers being warmer by approximately 1°C and drier by approximately 1%. The blue inverted triangles in Figure 9 indicate when significant rain fell during the time that covers were on the Sunmuscat vines. The rain on days 27 and 28 were associated with some dampening of the effect of covers on the temperature and relative differentials. This is seen in greater detail in illustrated in Figure 10. On those two days there was almost no difference in the relative humidity of the air beneath covers and the air in uncovered canopies, and the temperature differential was below 1°C for most of the time. Importantly, also, the air in both canopies was saturated or near saturated with moisture for most the time on those days (Figure 7).

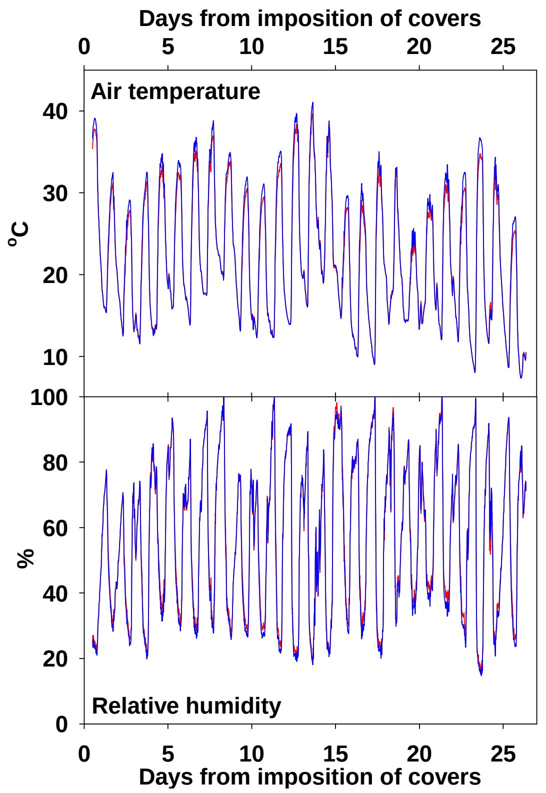


Figure 6 Traces of mean air temperature and relative humidity in drying Sultana canopies

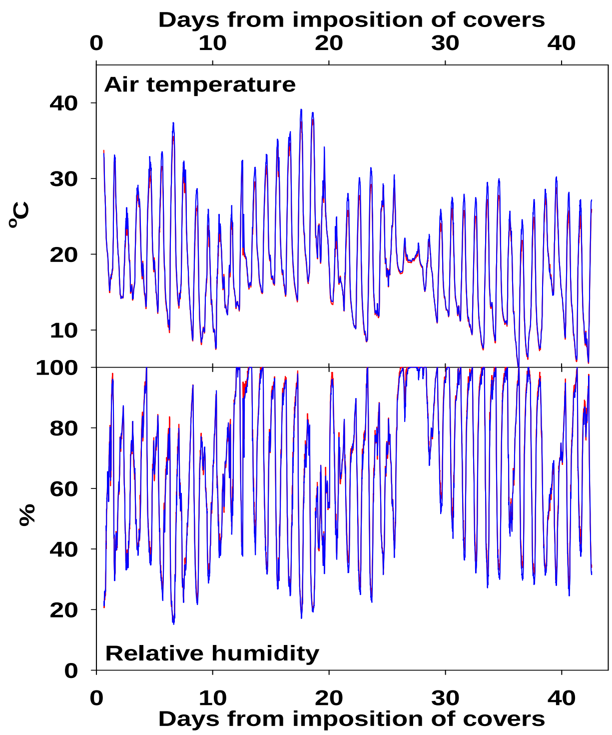


Figure 7 Traces of mean air temperature and relative humidity in drying Sunmuscat canopies s

—, uncovered; —, covered

—, uncovered; —, covered

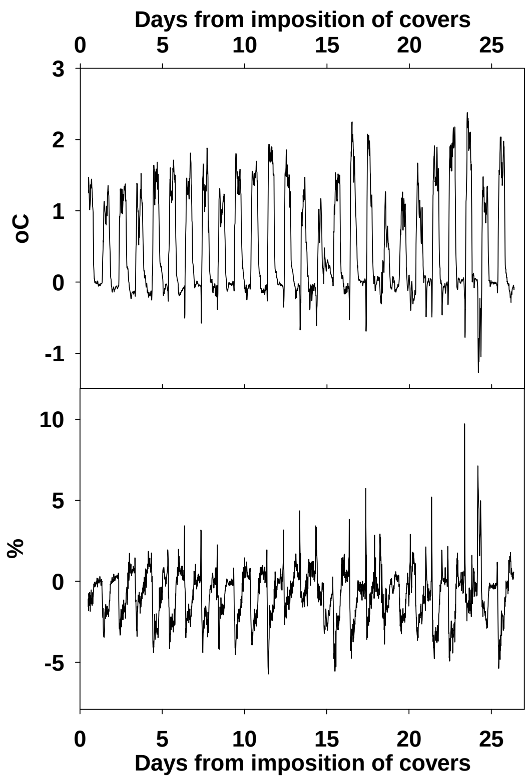


Figure 8 Temperature (top) and relative humidity (bottom) differences between air in covered and uncovered drying Sultana canopies

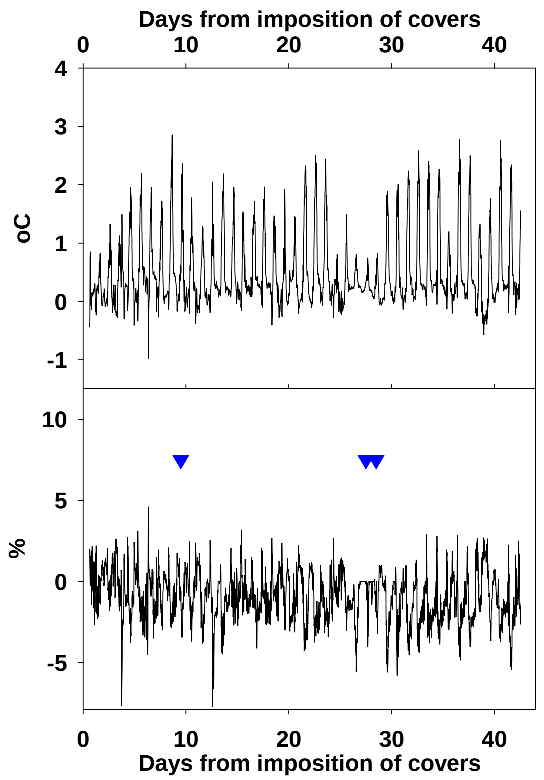


Figure 9 Temperature (top) and relative humidity (bottom) differences between air in covered and uncovered drying Sunmuscat canopies

Inverted blue triangles on days 9, 27 and 28 indicate significant rainfall.

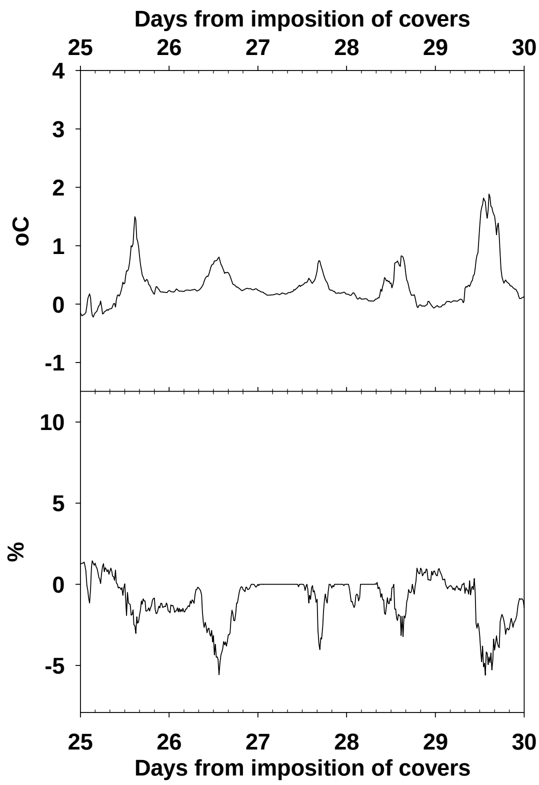


Figure 10 Differences between the temperature (top) and relative humidity (bottom) of the air in drying Sunmuscat canopies under covers and in uncovered drying canopies for days 25 to 30 after the imposition of covers

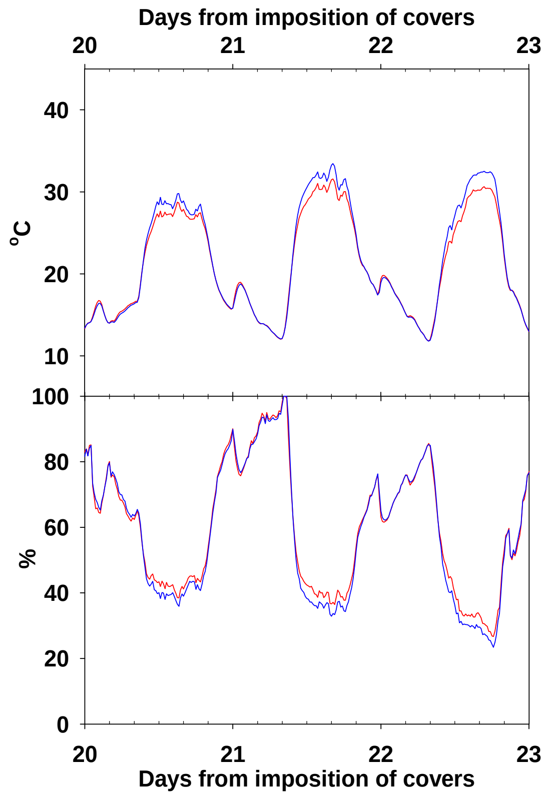


Figure 11 Air temperature (top) and relative humidity (bottom) in drying Sultana canopies for a three day period

—, uncovered; —, covered

The effect of rain aside, air temperatures and the relative humidity beneath the covers were not uniformly higher and lower over the each diurnal cycle. This is illustrated by the temperature and relative humidity for drying Sultana canopies data for three 24 hour periods about 3 weeks following the imposition of covers (Figure 11). The air temperature beneath covers was only higher from about mid-day through to the evening, and the air beneath covers was only drier during that time as well. Importantly, the relative humidity of the air in the canopies was in excess of 50% for about two-thirds every 24-hour period.

How warm the air was in the drying canopies under covers was related to how warm the air was in general, but how drier the air was in the drying canopies under covers was not as clearly related to how moist the air was in general. This can be seen in Figure 12 and Figure 13. Assuming that the air temperature in the uncovered canopies reflected the air temperature in general, it could be argued that the effect of covers on the temperature of the air in the drying canopies was only apparent when the ambient air was 20^{o}C or warmer. But, the spread in the data suggests that there were other factors affecting the extent of that effect.

There was some evidence of "structure" in the relative humidity differential plot for Sultana, but not for Sunmuscat. The significance of that structure in the case of Sultana is unknown, and the basis of the lack of structure for Sunmuscat relative to that of Sultana is also unknown. Possibly the difference may be related to row orientation: the Sultana site's rows ran south east-north-west, and the Sunmuscat site's rows ran north-east – south-west. Another factor may have been the timing of the imposition of covers; February 25 for the Sultana site and March 14 for the Sunmuscat site.

The covers were removed from each site, the DVF was mechanically harvested as per normal industry practice and subsamples from each row were taken. Colour measurements were conducted on the samples immediately after harvest, after dehydration to 13% moisture and after 2 months storage at 9°C.

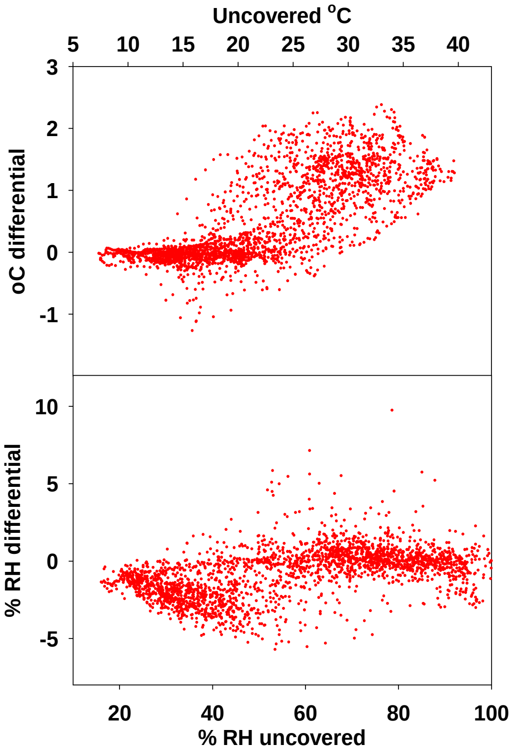


Figure 12 Air temperature and relative humidity in uncovered Sultana canopies versus the air temperature and relative humidity differential between covered and uncovered

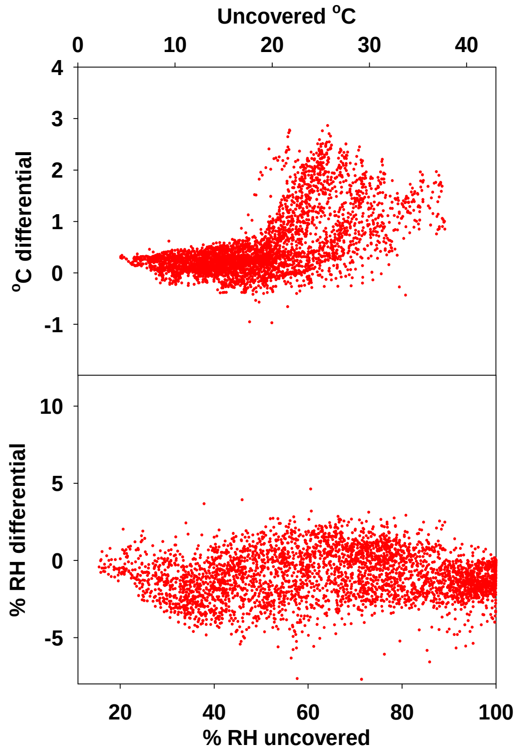


Figure 13 Air temperature and relative humidity in uncovered Sunmuscat canopies versus the air temperature and relative humidity differential between covered and uncovered canopies

The main effects of effects of row orientation, covers and storage on Sultana and Sunmuscat DVF colour are presented in Table 8 and Table 9. Relative to the "standards" used as yardsticks (Table 1 and Figure 1) the Sultana and Sunmuscat DVF were redder than the dark Sultanas, with about the same intensity of colour and the same level of greenness.

There were no significant interactions between row orientation, the imposition of covers and storage on any colour indice for either variety. Row orientation and storage were not significant sources of variation for Sultana or Sunmuscat DVF hue angle and greenness, but Sultana DVF that dried beneath covers had a significantly higher chroma, meaning the colour was more intense.

Row orientation, covers and storage were all significant influences on Sunmuscat DVF chroma. The colour of Sunmuscat DVF produced on rows with drying canopy facing north-west was less intensive than the colour of Sunmuscat DVF fruit produced on rows with drying canopies facing the south-east. Covers resulted in more intensive colour, and colour intensity decreased during storage.

Table 8 Row orientation, covers and storage main effects on Sultana DVF colour parameters

Values presented are means (n=8), and an "" indicates a significant difference between means at P=0.05*

		h°	C*	"green"
Row orientation	NE	43.8	11.3	2.95
	SW	42.4	10.8	3.23
Covers	uncovered	43.3	10.4	3.13
	covered	42.9	11.7*	3.05
Storage	before	42.8	10.8	3.05
	after	43.4	11.3	3.13

Table 9 Row orientation, covers and storage main effects on Sunmuscat DVF colour parameters

Values presented are means (n=8). "" and "**" indicate significant differences between means at P=0.05 and 0.01, respectively.*

		Colour parameter		
		hue	chroma	Green
Row orientation	SE	42.6	11.7	3.02
	NW	39.3	10.2**	3.02
Covers	uncovered	40.4	10.6	3.22
	covered	41.4	11.3*	2.82*
Storage	before	42.1	11.4	2.95
	after	39.8	10.5*	3.08

All of these effects were, however, relatively small in magnitude compared to the differences in the standards.

Discussion

The outcome of any research on perennial crops such as grapevines is notoriously dependent on seasonal conditions, and for this reason trials are usually conducted over multiple seasons to gain a reasonable opportunity for the influence of management variables to be identified amongst the "noise" of season-to-season effects. The scale of the difference in colour parameters seen between DVF produced in the normal manner and DVF produced in an oven provide ample testament to the influence of weather conditions during on DVF colour. The strongest influence on final DVF colour was the method by which grapes were dried; exposure to the elements during resulted in far darker fruit than was the case when grapes were dried in an oven at a constant temperature.

Even when drying conditions are standardised, the relationship between the soluble solids level of a subsample of grapes taken from a vine immediately prior to harvesting and final DVF colour of another subsample of grapes harvested subsequently was not as strong as the relationship between individual berries' maturity and their final colour (*e.g*. Uhlig and Clingeleffer, 1998a). Presumably this reflects the spread of maturities between grapes on the same bunch and between bunches on the same vine and between vines in the same management unit. This disparity raises the question whether measuring the colour characteristics of a bulk sample is appropriate, and whether sorting bulk samples into colour classes would be more informative. An examination of the "mottled" standard sample used to calibrate the Minolta Chroma Meter (Figure 1) supports this concept; some berries are light, some are dark, and the rest are intermediate, but that spread of individual berry colour is lost in the average of the 10 measurements taken over the whole petri dish of berries.

The berry-to-berry, bunch-to-bunch and vine-to-vine variability is an aspect of the berry age/maturity trial that probably contributed to the marginal nature of the effects observed. The range of berry maturities was reasonable, but the means for the crop load treatments weren't. This is most likely due to the timing of bunch thinning. Bunch thinning immediately after bunch shatter probably would have resulted in a far wider spread of berry maturities between the crop load treatments and between the harvest dates.

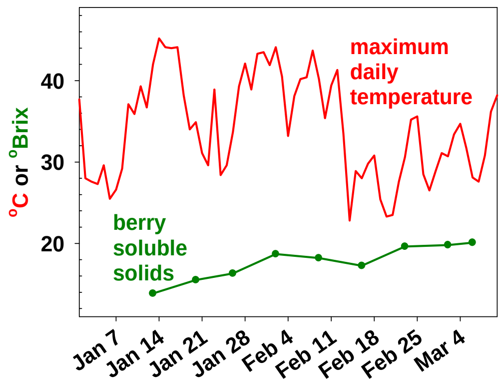


Figure 14 Daily temperature maxima at Mildura Airport for the first 69 days of 2014 and soluble solids accumulation by Sunmuscat grapes at Red Cliffs (Treeby and Treeby – unpublished data)

Temperature data courtesy of Bureau of Meteorology.

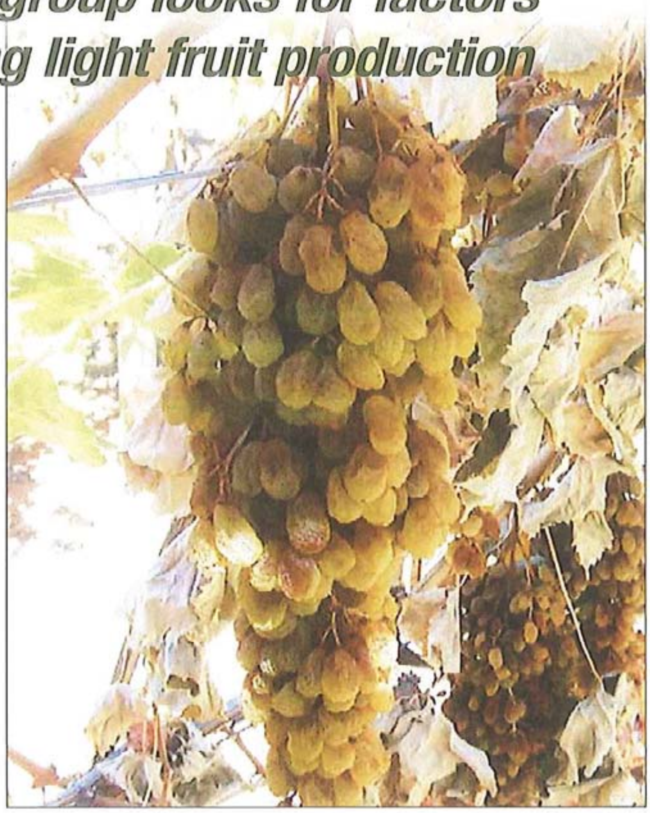
Seasonal effects may also have contributed here. The first harvest took place on February 28 and the second a fortnight later on March 14. Prior to the first harvest a significant run of hot days occurred (Figure 14) which retarded accumulation of soluble solids by Sunmuscat grapes on another site near the trial site. Thus, possibly, the spread of maturities was not as wide as it could have been, the lateness of the bunch thinning notwithstanding.

Covering drying canopies with clear plastic raised the air temperature by several degrees and lowered the relative humidity of the air in the canopies during some parts of the day. The significance of the higher temperature and the lower relative humidity of the scale measured here in terms of driving moisture loss from grapes is unknown. The basis for the testing of covers was the idea of preventing rain droplets wetting the drying grapes; this may or may not be an effective means of preventing such an occurrence in the event of rain. Although there was no significant rainfall event during the period that the covers were on the Sultanas, rain fell on three occasions when the covers were on the Sunmuscats. Whether the rain on those days actually wet the drying Sunmuscat grapes isn't known, but the relative humidity of the air around those drying grapes on those days was not any drier than the air around grapes in uncovered canopies. Indeed, on those days, the air was saturated or near saturated most of the time. In other words, covers did not appear to isolate the drying grapes beneath the covers from the bulk air. To determine definitively whether this was indeed the case and that, as a result, the drying rate was unaffected, would require a structured sampling program to determine grape moisture content over time, with intensive sampling before, during and after any rainfall event.

Technology transfer

Progress on the project was reported to DVF producers attending an industry DVF dehydration field day held at Irymple, Victoria. The project was also described to industry in articles in *The Vine*, the industry's magazine (Figure 15, Figure 16, Figure 17and Figure 18, and images from the trials were posted on social media. A poster was prepared and presented at the Mildura Horticultural Field Days in May and at a DFA field work on the issue of cane health and fruitfulness (Figure 19) shortly afterward.

Working group looks for factors impacting light fruit production



Consistent tonnages of light coloured dried fruit are needed by our marketers to maintain Australia's point of difference and prized place in export markets as a supplier of premium quality fruit.

To facilitate this and to gain a better understanding about what techniques could be adopted by growers and processors the Dried Fruits Australia Board recently established a Light Fruit Working Group.

At the first meeting of the working group it was decided that a literature review should be undertaken to establish what research had been conducted and to collate the findings. This would provide direction for further research to fill in the knowledge gaps.

The literature review was conducted by local research officer and grower Michael Treeby and covered both Australian and international research.

The review identified a number of factors that are more likely to cause darkening of dried grapes in the field and/or in storage.

Dried grapes will most likely darken in the field if:

- Berries are exposed to direct sunlight during development.
- Fruit is harvested below 21°Brix and over 23°Brix.
- Shaded during drying.
- Subjected to prolonged drying.
- Rehydration occurs during drying.

Dried grapes will more likely darken in storage if:

- Grapes have originated from vines with a high nitrogen content.
- Rehydration occurs.
- Grapes are stored at high temperature.
- Grapes are stored at too high a moisture content.
- Ample oxygen is available.
- Grapes are stored too long.

Industry Development Officer John Hawtin said that while much of the information about darkening of fruit was previously known, different aspects were often forgotten or easily overlooked and it was good to see a complete list of contributing factors.

He said ideal drying conditions were not possible each year; however growers could apply different management strategies to help improve the likelihood of light coloured fruit being produced. Furthermore, these strategies could be implemented immediately without imposing any additional costs.

The size and density of the vine canopy is critical in controlling the amount of light that filters through to the fruit and the subsequent level of shading.

The volume and timing of irrigations, particularly early in the season, is important to set the vines up to grow a balanced canopy and not produce an over-grown canopy that will shade out fruit. While this may mean limiting the water at some point, it is vital that the vines are not stressed at flowering and berry set and that vines have adequate water available to ripen the fruit to its potential.

Nitrogen fertilisers will also influence the amount of canopy growth, and can affect berry colouring. The ideal time for nitrogen application is in autumn as the vines are nearing dormancy. If nitrogen is applied after flowering, high amounts of nitrogen will be absorbed by the berries and the fruit is more likely to brown in storage.

Finally, growers should consider summer pruning at the optimum maturity of between 21°-23°Brix. This requires extensive maturity testing throughout the property to identify the earliest ripening fruit which are harvested first followed by the patches of next ripeness.

As can be seen from the few management strategies above there are many factors that can be manipulated during the growing and drying phase in the field, and also when brought into storage, with the aim of influencing the final colour of dried grapes.

The working group believes there are a number of long term projects which will help the industry understand why fruit darkens and to develop strategies that will increase the reliability of producing light coloured fruit. Funding applications for these research projects will be developed and submitted to Horticulture Australia (HAL) shortly.

(Oct - Dec 2013)

Figure 15 Article published in the October-December, 2013, edition of *The Vine*

Board news

Research projects initiated to investigate factors affecting light fruit production

Good supplies of light coloured fruit are needed if the industry is to attract premium prices.

Dried Fruits Australia has initiated two research projects to help focus attention on the techniques that can be used by growers and processors to produce light coloured fruit.

Dried Fruits Australia Chairman Mark King said the Australian dried grape industry's greatest challenge over the past five years had not been the vagaries of world pricing. Rather, it had been the industry's inability to produce sufficient quantities of light-coloured fruit on a consistent basis.

In the Oct-Dec 2013 edition, we reported that the Dried Fruits Australia Board had established a Light Fruit Working Group to address the problem. The group initiated a literature review which was conducted by local researcher Michael Treeby. He was kind enough to give up his time to pull together findings from previous research and provide direction for further research that may be required.

"The draft 2012-2016 Dried Grapes Strategic Investment Plan suggests that the market outlook over the next five years is very positive," Mr King said.

"There are shortages in world supply, demand is strong, and prices are at levels that can support viable production and processing operations."

He said dried grape processors/ marketers suggested a potential market for up to 5,000 tonnes of high quality, light-coloured dried grapes per year, provided the industry could maintain a consistent supply over a period of years.

"These markets would offer sustainable margins for both producers and processors/marketers.

"Growers could expect to see a margin increase of $200 per tonne, but obtaining market share is difficult when supply is inconsistent from year to year."

Mr King said it was clear that there were many factors that could be manipulated during the growing and drying phase in the field, and also when brought into storage, with the aim of influencing the final colour of dried grapes.

The working group believes there are a number of research projects that will help the industry understand why fruit darkens and enable strategies to be developed that will increase the reliability of producing light coloured fruit.

Funding applications for a two stage research project to produce high value dried grapes have recently been developed and submitted to Horticulture Australia (HAL).

Stage 1 (DG13004) seeks immediate funding for the current year 2013/14 and is a short 6 month progam. Stage 2 (DG14000) is a more in-depth program and if approved will commence in 2014/15.

Stage 1

Consistent supply of this quantity and quality of dried grapes is a management challenge due to plant physiology issues that need to be juggled in the context of climate variability.

Two priority field trials will be conducted to:

- determine appropriate fruit maturity levels to initiate the drying process to optimise dried grape colour, and
- scope the potential impact of a covered trellis drying system on the range of dried grape quality parameters, particularly colour.

The project will have three ultimate success criteria:

a) delivery of industry accepted maturity targets for initiation of the drying process,

b) delivery of data on which a more informed decision can be made regarding establishing a more rigorous field trial to assess the impact of covered trellis drying systems over multiple seasons and varying climatic circumstances, and

c) gaining some practical experience regarding the use of covers.

Stage 2

As identified in a literature review, the key element of this project will be a meta-analysis to identify the relative effect of any known variables, with available scientific data, on the colour of dried grapes.

The results of the meta-analysis will provide clear guidance as to which variables most affect the colour of dried fruit. This information will be used to identify the best value for money extension and research activities to assist the industry in attaining its goal of consistently meeting the colour requirements of the identified markets.

Based on the results from the meta-analysis Dried Fruits Australia will negotiate the targets of the extension and research program in the remaining three years of the project.

The project will establish an industry wide maturity monitoring protocol and refine it with a sub-sample of producers and processors.

The overall outcomes of the two projects will be improved trellis drying management systems that consistently deliver high quality, light coloured dried grapes across increasingly erratic weather conditions during maturation/ drying/harvesting and storage.

(Jan-Mar 2014)

Figure 16 Article published in January-March, 2014, edition of *The Vine*

Project update – Producing high value dried grapes – Stage 1

Bunches were counted and tagged and untagged fruit removed to determine maturity levels to optimise the initiation of drying.

In response to an identified premium 3,000 to 5,000 tonne market niche Dried Fruits Australia established a group to guide the industry towards consistently high quality, light coloured dried grapes.

This market reportedly carries superior margins for all industry participants (e.g. $200 per tonne farm gate premium).

The consistent supply of this quantity and quality of dried grapes is a management challenge due to plant physiology issues that need to be balanced in the context of climate variability.

A brief literature review was prepared for the Light Fruit Working Group. This established that grapes are more likely to dry dark if:

- berries are sun exposed during development
- the fruit is harvested/cut at a maturity below 21°Brix and above 23 °Brix
- the fruit is shaded during drying
- drying is prolonged
- rehydration occurs during drying

And that dried grapes are more likely to darken in storage if:

- the fruit originated from high nitrogen vines
- rehydration occurs
- stored at a high temperature
- stored at too high a moisture content
- ample oxygen is available and
- stored for too long before processing.

This literature review and Dried Fruit Australia's current industry experience identified two priority field trials to be conducted. These are to:

1. Determine appropriate fruit maturity levels to initiate the drying process to optimise dried grape colour, and
2. Investigate the potential impact of a covered (plastic sheeting) drying system on the range of dried grape quality parameters, particularly colour.

These trials represent Stage 1 of the project; *Producing High Value Dried Grapes* which is intended to run for six months.

A project management committee was established and Michael Case employed as a Technical Officer to implement the setup of field trials, take measurements and compile data.

Trial sites have been selected on commercially managed properties in the Sunraysia area.

Determining appropriate maturity levels to optimise initiation of drying

Maturity trial sites were established on a property where the grower has both sultana and Sunmuscat grape varieties growing on Swingarm trellis. The single property was selected so that the management systems applied to the two grape varieties would be similar.

A randomised block design was used to identify groupings of vines and treatments were applied to impose set crop loads (or bunch counts). Bunches were counted and tagged and untagged bunches were removed. This procedure was intended to be done soon after final berry drop, but ended up being much later in the season.

The different crop loads were imposed to produce a range of maturities at the same point in the season allowing all of the treatments to be subject to the same drying conditions.

The maturity of the grapes has been monitored throughout the season.

The intention was to hand harvest the fruit at two points (2 weeks apart), with the first pick to take place close to commercial cutting.

Wet weather at the wrong time caused damage (ring splitting and the development of Botrytis type rotting) to the sultana grapes. It was decided that the likelihood of this fruit drying to a light colour was very unlikely, so this part of the trial was abandoned. The Sunmuscat grapes were largely unaffected by this and subsequent rain events.

The grower was advised, tags were removed from all bunches and the fruit was cut and sprayed.

The first pick of the Sunmuscats has been completed and the fruit was dried in a large oven at 40°C for approximately seven days.

The fruit has been cleaned to remove the berries from the main bunch structure and will be placed into cool storage (14°C). The colour will be assessed as the fruit goes into storage and then again two months later.

Protecting the quality of drying grapes on the trellis using plastic covers

Trail sites were established for this part of the project on another commercial property in the Sunraysia area.

In conjunction with the grower, sites were selected and established on sultana and Sunmuscat grapes.

The sites are eight rows of vines on Swingarm trellis.

36 The Vine

(Apr - Jun 2014)

Figure 17 First page of an article published in the April-June, 2014, edition of *The Vine*

Producing high value dried grapes

A premium niche market with a superior margin for all industry participants has been identified for 3,000 to 5,000 tonnes of light coloured dried grapes. Dried Fruits Australia has initiated a project aimed at assisting dried grape producers to consistently supply large quantities of high quality (light coloured) dried grapes.

Two experimental strategies were pursued this season, and data are still being collected. The field work has been undertaken on co-operating dried grape producers' properties at Red Cliffs and Cabarita.

Samples of fruit for the trials are collected as the fruit is harvested.

Grape maturity and physiological age effect on colour

The effect of fresh grape maturity and physiological age of fresh grapes at harvest on final dried grape colour is being investigated. A range of maturities was induced by only allowing set numbers of bunches to remain on vines, and different physiological ages at the outset of drying were produced by harvesting twice, a fortnight apart. Therefore, the physiological ages of the grapes at each harvest date would be different, and the range of maturities at each harvest date would also be expected to be different.

The experiments were conducted on sultana and Sunmuscat grape varieties on each property. A significant rainfall event on 14 February caused the sultana berries across the region to split. Sunmuscat berries were largely unaffected by this rainfall event.

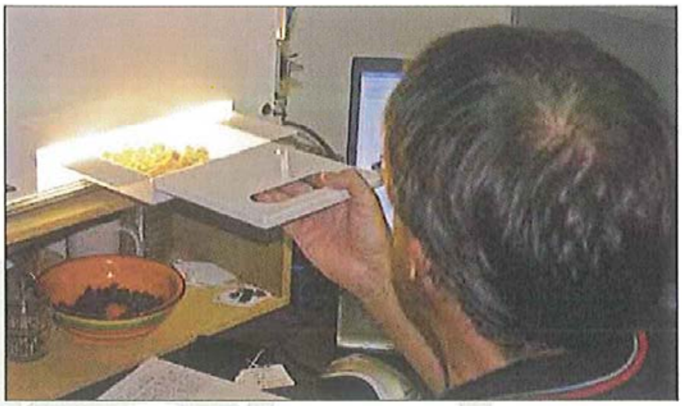
The management committee concluded that any sultana fruit harvested as part of the maturity trial would dry dark irrespective of any experimental treatment imposed. Further work on the sultanas was judged unlikely to produce any useful data, and the sultana component of this part of the project was abandoned accordingly.

The fruit were hand-picked and dipped in the standard Sunmuscat trellis drying mix (1% emulsifiable oil and 1.25% potash). One lot of samples was dried in a large fan-forced oven (at 40°C for 7 days) and another lot placed on a roofed open air drying rack. The drying oven was used so that fruit that were harvested and dried two weeks apart experienced the same drying conditions. This is important if we want to isolate the effect of maturity/physiological age on final dried grape colour from the effect of drying conditions (i.e. sunlight, day length, temperature, wind, humidity etc.) on final dried fruit colour. Obviously, drying conditions can vary enormously from early March (when most Sunmuscats are summer pruned) to mid-March.

Due to rain and persistent cooler weather late in the season, the rack dried fruit was 'finished' using dehydration.

Initial analysis of the maturity data suggests that, immediately prior to the first/early harvest, Sunmuscat grapes carrying the highest crop loads were 2° Brix less mature than fruit with half the number of bunches per vine or less. By the second harvest, a fortnight later, the differential in maturity had disappeared.

At the completion of drying the dried grapes were scanned for colour using two different instruments, and placed into cool (12°C) storage for two months in a commercial coolroom at one of the local processors. After this time, the fruit will be removed and re-assessed for colour. This re-assessment is to determine whether any darkening of the fruit during storage can be related to the maturity of the berries and/or the physiological age of the crop at the outset of drying.



The colour of dried fruit is measured before storage and after storage. A Minolta tri-stimulus machine and a Colour Vision instrument that measures the amount of pixels of different colour classes are used.

Covers, microclimate and colour

Covers are used widely by the Sunraysia table grape industry to protect ripening fruit from rain. The covers trial looks to see if this practice can be modified for dried grapes and the subsequent effect on dried fruit colour.

Plastic covers were applied to the fruiting side of Swingarm trellis as soon as possible after cutting and compared with grapes that had been summer pruned and left to dry normally (uncovered) on the trellis. The covers trial involved both sultana and Sunmuscat vines.

Monitoring equipment placed within the drying canopy of each row in the covers

Figure 18 First page of an article published in the July-September, 2014, edition of *The Vine*

Producing light-coloured grapes (DVF)

A niche market, that carries superior margins for all industry participants, exists for 3000 – 5000 tonnes of light-coloured dried vine fruit DVF.

Consistently supplying this quantity and quality of DVF is a challenge, especially given rain at crucial times.

Dried Fruits Australia (DFA) is investigating some of the on-farm issues that limit DVF producer's ability to produce light-coloured (DVF).

Work is being conducted on:

- when to start drying to optimize DVF fruit colour, and
- the impact of vine covers on DVF quality, particularly colour.

In one trial, crop loads and harvest dates were used to investigate the relationship between maturity and DVF colour. Different maturity levels were imposed by having specific crop loads (bunch counts).

In another trial, covers were applied to the vines as soon as practical after cutting. Temperature and humidity was measured within the drying canopy and compared to uncovered drying canopies.

At this stage dried fruit samples have been collected from each trial and fruit colour will be assessed during storage.

DFA would like to thank D&D Lyons and R&K Trigg for the field sites and the Department of Environment & Primary Industries VIC, Sunbeam and Australian Premium Dried Fruits for using their equipment

HAL Horticulture Australia driedfruits australia dfa

Figure 19 Poster presented at Mildura Field Days on 24 and 25 May, 2014, and at a DFA field walk titled "What makes a cane a good cane?" held on 28 May, 2014.

Recommendations - scientific and industry

Isolating the effects on DVF colour of physiological age on the one hand and berry maturity on the other is difficult on a practical scale. Imposing treatments, such as varying crop loads, to produce a wider spread in berry maturities is a logical approach, but experience gained in this project and elsewhere suggests that this approach will be far more successful if imposed far earlier in the season; preferably immediately after bunch shatter. The spread of maturities and physiological ages within bunches, between bunches and between vines however may mean that linkages are being lost or relationships not discerned because current methods to measure DVF produce an average colour for samples of DVF, not individual berries. The technology exists to sort berries on an industrial scale, and the application of this technology on a scale suitable for sorting small samples of fruit should be investigated. That issue aside, the instrumentation available to measure colour has advanced greatly since the Chroma Meter first became available. Multi-wavelength spectrometers are far more robust and affordable now than ever before. Application of this type of instrumentation, whether applied to samples or to individual berries, may provide more information than was previously obtainable. Consideration should be given to acquiring this type of instrument if further work in this area is envisaged.

The significance of the higher temperatures and lower relative humidity under covers is unknown. It is also unknown whether in a warmer and drier season the temperature and relative humidity differentials would have greater, and, again, the significance of those two circumstances are unknown. If further work on covers is carried out, it is suggested that a structured sampling program be conducted to assess the time course of moisture loss. This would necessarily be a destructive process. Further, because of the scale of any exercise involving covers, availability of drying grapes would not be a limitation; a component of that structured sampling program could, therefore, involve completing the drying process of partially dried grapes collected as part of a structured program in an oven, thus removing the effect of weather conditions on part of the drying process. This could possibly shed light on when during the drying process weather conditions cause the huge disparity between the colour of DVF produced by drying on racks or on the vine and the colour of DVF produced by drying in an oven.

The over-riding factor in the determination of final DVF is the weather during drying. Clearly the impact of weather conditions is more likely to be important when prevailing temperatures decrease as summer ends and autumns starts. Taking every advantage of the generally warmer conditions in February would seem advantageous. Therefore, accelerating ripening and optimising drying conditions to accelerate moisture loss from grapes following summer pruning would seem to be logical priorities subjects for research.

Cultural practices associated with uninhibited and enhanced sugar accumulation by maturing grapes should be investigated and communicated. Obviously, irrigation and fertiliser practices that ensure optimum leaf function without promoting excessive vegetative growth are critical here. But, equally, developing management practices that enable vines to cope with adverse weather such as prolonged high air temperature, is likely to be important as well.

Accelerating drying would also seem important. Thus, the rate of moisture loss from drying grapes as affected by the concentrations of potassium carbonate and dipping oil used, and the number of applications, warrant re-visiting.

Equally, because the rate of moisture loss from grapes is the process that determines the length of drying, and that that rate is likely to be enhanced when the relative humidity of the air surrounding the drying berries is drier, it follows that air movement is critical. Thus, cultural practices (*e.g.* topping and leaf plucking) that allow better air flow would seem important. But, although some details of the microclimate that drying berries contend with in summer pruned canopies are now know because of the work described herein, little is known about the movement of air, and its moisture status, through vineyards during the drying process. Knowledge developed in this area may lead to improvements in vineyard design and cultural practices that promote the displacement of moist air around drying berries with dry bulk air.

To sum up, consideration should be given to:

- acquiring technology to sort and measure the colour of individual dried berries,
- continuing the investigation of the relationship between berry maturity and colour using the above technology, but ensuring a greater spread in maturities by more timely intervention,
- quantifying the maturity variability with berry colour variability using the above technology,
- quantifying the importance of the temperature and relatively humidity differentials associated with covers,
- investigating cultural practices that accelerate crop maturity,
- investigating management practices that accelerate drying and
- investigating the dynamics of air movement into, within and out off vineyards during the drying process.

Acknowledgments

The Project Management Committee gratefully acknowledges the co-operation of David and Diana Lyons of Red Cliffs and Rod and Kim Trigg of Cabarita in the conduct of the trials described in this report.

The technical support of Mr Michael Case and Mr John Hawtin in the setting up and conduct of the trials described herein is also gratefully acknowledged.

The Project Management Committee members are thanked for their input and feedback during the course of this project.

Literature cited

Antcliff, A.J., Webster, W.J., 1962. Bruce's sport - a mutant of the sultana. *Australian Journal of Experimental Agriculture and Animal Husbandry* 2, 97-100.

Cantos, E., Espin, J.C., Tomas-Barberan, F.A., 2002. Varietal differences among the polyphenol profiles of seven table grape cultivars studied by LC-DAD-MS-MS. *Journal of Agricultural and Food Chemistry* 50, 5691-5696.

Demotes-Mainard, S., Boumaza, R., Meyer, S., Cerovic, Z.G., 2008. Indicators of nitrogen status for ornamental woody plants based on optical measurements of leaf epidermal polyphenol and chlorophyll contents. *Scientia Horticulturae* 115, 377-385.

Downey, M.O., Harvey, J.S., Robinson, S.P., 2003. Synthesis of flavonols and expression of flavonol synthase genes in the developing grape berries of Shiraz and Chardonnay (*Vitis vinifera* L.). *Australian Journal of Grape and Wine Research* 9, 110-121.

Es-Safi, N.-E., Cheynier, V., Moutounet, M., 2000. Study of the reactions between (+)-catechin and furfural derivatives in the presence or absence of anthocyanins and their implication in food color change. *Journal of Agricultural and Food Chemistry* 48, 5946-5954.

Esteban, M.A., Villanueva, M.J., Lissarrague, J.R., 2001. Effect of irrigation on changes in the anthocyanin composition of the skin of cv Tempranillo (*Vitis vinifera* L) grape berries during ripening. *Journal of the Science of Food and Agriculture* 81, 409-420.

Frank, D., Gould, I., Millikan, M., 2004a. Browning reactions during storage of low-moisture Australian sultanas: evidence for arginine-mediated Maillard reactions. *Australian Journal of Grape and Wine Research* 10, 151-163.

Frank, D., Gould, I., Millikan, M., 2004b. Browning reactions during storage of low-moisture Australian sultanas: Further evidence for arginine-mediated Maillard reactions during storage, and some effects of vine-shading and harvest date. *Australian Journal of Grape and Wine Research* 10, 182-195.

Frank, D., Gould, I., Millikan, M., 2005. Browning reactions during storage of low-moisture Australian sultanas: effects of vine nitrogen nutrition on subsequent arginine-mediated Maillard reactions during storage of dried fruit. *Australian Journal of Grape and Wine Research* 11, 15-23.

Grncarevic, M., Hawker, J.S., 1971. Browning of sultana grape berries during drying. *Journal of the Science of Food and Agriculture* 22, 270-272.

Holzapfel, B.P., Treeby, M.T., 2007. Effects of timing and rate of N supply on leaf nitrogen status, grape yield and juice composition from Shiraz grapevines grafted to one of three different rootstocks. *Australian Journal of Grape and Wine Research* 13, 14-22.

Jones, C.G., Hartley, S.E., 1999. A protein competition model of phenolic allocation. Oikos 86, 27-44.

Kliewer, W.M., 1970. Free amino acids and other nitrogenous fractions in wine grapes. *Journal of Food Science* 35, 17-21.

Kliewer, W.M., 1971. Effect of nitrogen on growth and composition of fruits from "Thompson Seedless" grapevines. *Journal of the American Society for Horticultural Science* 96, 816-819.

Koricheva, J., Larsson, S., Haukioja, E., Keinanen, M., 1998. Regulation of woody plant secondary metabolism by resource availability: hypothesis testing by means of meta-analysis. *Oikos* 83, 212-226.

Olsen, K.M., Slimestad, R., Lea, U.S., Brede, C., Løvdal, T., Ruoff, P., Verheul, M., Lillo, C., 2009. Temperature and nitrogen effects on regulators and products of the flavonoid pathway: experimental and kinetic model studies. *Plant, Cell & Environment* 32, 286-299.

Orak, H.H., 2007. Total antioxidant activities, phenolics, anthocyanins, polyphenoloxidase activities of selected red grape cultivars and their correlations. *Scientia Horticulturae* 111, 235-241.

Radler, F., 1964. The prevention of browning during drying by the cold dipping treatment of sultana grapes. *Journal of the Science of Food and Agriculture* 15, 864-869.

Rathjen, H., Robinson, S., 1992. Characterisation of a variegated grapevine mutant showing reduced polyphenol oxidase activity. *Functional Plant Biology* 19, 43-54.

Saltmarch, M., Labuza, T.P., 1982. Nonenzymatic browning via the Maillard reaction in foods. *Diabetes* 31, 29-36.

Schrader, L.E., 1984. Functions and transformations of nitrogen in higher plants, in: Hauck, R.D. (Ed.), *Nitrogen in crop production*. American Society of Agronomy; Crop Science Society of America; Soil Science Society of America, Madison, Wis., pp. 55-65.

Singh, D.P., Treeby, M., Clingeleffer, P., 2009. *Sunmuscat fruit set and bunch shatter,* Final report to HAL for Project DG05002.
Tomás-Barberán, F., Espin, J.C., 2001. Phenolic compounds and related enzymes as determinants of quality in fruits and vegetables. *Journal of the Science of Food and Agriculture* 81, 853-876.
Uhlig, B.A., 1998. Effects of solar radiation on grape (*Vitis vinifera* L.) composition and dried fruit colour. *Journal of Horticultural Science and Biotechnology* 73, 111-123.
Uhlig, B.A., Clingeleffer, P.R., 1998a. The influence of grape (*Vitis vinifera* L.) berry maturity on dried fruit colour. *Journal of Horticultural Science and Biotechnology* 73, 329-339.
Uhlig, B.A., Clingeleffer, P.R., 1998b. Ripening characteristics of the fruit from *Vitis vinifera* L. drying cultivars Sultana and Merbein Seedless under furrow irrigation. *American Journal of Enology and Viticulture* 49, 375-382.
Vaughn, K.C., Duke, S.O., 1984. Function of polyphenol oxidase in higher plants. *Physiologia Plantarum* 60, 106-112.