Development of rain tolerant drying varieties to meet market specifications

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CSIRO Plant Industry

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Statement of purpose:
Production and quality losses associated with rain damage at harvest, the development of mouldy fruit and inconsistent production due to variable fruitfulness and biennial bearing of Sultana are major problems for the Australian Dried Grape industry. To address these problems, this project aimed to develop improved rain tolerant drying varieties that meet market requirements and improve the economic sustainability of dried grape production.

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Media Summary

Production and quality losses associated with rain damage at harvest, the development of mouldy fruit and inconsistent production due to variable fruitfulness of Sultana are major problems for the Australian dried grape industry. This project has aimed to develop improved rain tolerant drying varieties that meet market requirements and hence, improve the economic sustainability of the dried grape industry. New selections, at varying stages of development, have been evaluated by drying and processing in the CSIRO small-scale processing facility. These stages include single vine seedling populations, multiplied and top-worked plantings and larger, semi-commercial trials on grower properties.

The key objectives of breeding have been to develop new seedless dried grape genotypes that are early ripening, rain tolerant and disease resistant. Each year, fruit was harvested and dried from more than 150 individual seedlings and 50 multiplied selections. The performance of the most promising selections has been assessed on semi-commercial grower sites which also provide sufficient fruit for processing and test marketing purposes. New varieties, introduced from overseas, have been included for comparative purposes.

Decisions on release of new varieties from the CSIRO dried grape breeding and evaluation program are made by the Unique Dried Grapes Steering Committee which has representatives from growers, processors and marketers, CSIRO and Horticulture Australia Ltd. Vines of an early ripening, disease resistant currant selection and a high yielding, light coloured, rain tolerant sultana type have been propagated to establish mother vine plantings to supply material to industry if they are formally released.

The USDA varieties, Diamond Muscat, Summer Muscat, DOVine and Selma Pete, which are available through the Australian Vine Improvement Association (AVIA) show considerable promise as part of a strategy to spread risks across the season as they are both early ripening and rapid drying, although they have smaller berries than Sultana. Similarly, the tissue cultured source of the Bruce's Sport Sultana offers significant potential to reduce the risks of fruit darkening if inclement weather occurs during the later stages of drying.

Technical Summary

Nature of the problem
Production and quality losses associated with rain damage at harvest, the development of mouldy fruit and inconsistent production due to variable fruitfulness and biennial bearing of Sultana are major problems for the Australian Dried Grape industry. There were substantial production and quality losses associated with rain damage at harvest in1999, 2000 and 2003, the subsequent development of mouldy fruit and related problems with toxins (Ochratoxin A). Key markets have introduced stringent minimum standards for Ochratoxin A that could render a significant proportion of Sultana production unmarketable in future wet seasons. The deficiencies of existing varieties and the need to develop rain tolerant sultana types and new earlier ripening varieties to extend the growing season to spread production risks was recognised in an industry research planning forum in 2003.

Science undertaken
The project had breeding and evaluation components. The key objectives of the breeding were to develop new dried grape genotypes with early ripening, rain tolerance and disease resistance. It included crosses between seedless parents and the use of *in-ovulo* embryo rescue techniques in tissue culture to produce new progeny.

New selections, at varying stages of development were evaluated by drying and processing in the CSIRO small-scale processing facility. These stages include single vine seedling populations, multiplied and top-worked plantings and larger, semi-commercial trials on grower properties. Each year, fruit was harvested and dried from more than 150 individual seedlings and 50 multiplied selections. The performance of the most promising selections was assessed on semi-commercial grower sites which also provided sufficient fruit for processing and test marketing. New varieties, which have been introduced from overseas, were included for comparative purposes.

Major research findings and industry outcomes
During the project a total of 60 promising selections were established in multiplication blocks with 50 top-worked onto existing rootstock material. A further 100 promising selections were identified in 2009 and material collected for propagation. This material will be evaluated in a new project funded by HA Ltd, DG 09000 (2009-2012).

A very fruitful, high yielding, rain tolerant Sultana type has shown excellent production, drying and processing characteristics. Material has been propagated to establish a mothervine planting to supply material to industry, should the selection be formally released.

A number of early ripening and rapid drying, imported USDA varieties (ie. Diamond Muscat, Summer Muscat, DOVine and Selma Pete) show considerable promise for planting as part of a strategy to spread risks across the season. However as they all have smaller berries than Sultana, issues with regard to market requirements for small berried types, including varieties with muscat flavour must be considered by industry. Similarly,

the low browning, tissue cultured Bruce's Sport Sultana clone offers significant potential to reduce the risks of fruit darkening if inclement weather occurs during the later stages of drying if grafted on high vigour Ramsey rootstock and managed on a swing-arm trellis.

An early ripening, disease resistance currant selection with high levels of anti oxidants which has a distinct 'spicy' flavour has shown significant potential. It is readily suited to 'low chemical'/ organic production and niche marketing and significant demand from that sector of the industry is expected. However, management on modern, cordon-based trellis systems with hanging canes to facilitate trellis drying has proven difficult because canes arising from the cordon are too short for attachment to lower wires. This issue is being addressed in further studies. In anticipation of a future release of the selection, 300 plants have been propagated to establish a mothervine planting as an industry source for propagation material.

Recommendations

It is recommended that:-

- arrangements for commercial release of the very promising rain tolerant Sultana type be implemented, subject to approval of the Unique Dried Grapes Steering Committee and the USDA.
- arrangements for commercial release to industry of the low browning, tissue cultured Bruce's Sport Sultana clone be implemented, subject to approval of the Unique Dried Grapes Steering Committee.
- that the industry consider wider assessment of the recently released early ripening, rapid drying USDA varieties (Diamond Muscat, Summer Muscat, DOVine and Selma Pete) to spread risks across the season, although issues regarding rain susceptibility and market requirements for small berried, light fruit types must be addressed
- the Unique Dried Grapes Steering Committee be retained to provide ongoing input into the development and commercial release of new varieties.

Future work

The evaluation of material in the breeding pipeline (ie. seedling progeny, multiplied and top-worked selections and selections established on semi-commercial sites) will be completed in a new project funded through HA Ltd (2009-2012). Management studies will be conducted with the early ripening, disease resistant currant selection to address difficulties with cane replacement and attachment on modern, trellis drying systems. It is recommended that a comparator, PBR trial be established for the selection.

Introduction

Production and quality losses associated with rain damage at harvest, the development of mouldy fruit and inconsistent production due to variable fruitfulness and biennial bearing of Sultana are major problems for the Australian Dried Grape industry. There were substantial production and quality losses associated with rain damage at harvest in1999, 2000 and 2003, the subsequent development of mouldy fruit and related problems with toxins (Ochratoxin A). Key markets have introduced stringent minimum standards for Ochratoxin A that could render a significant proportion of Sultana production unmarketable in future wet seasons. The deficiencies of existing varieties, the need to develop rain tolerant sultana types was ranked as a very high priority by industry participants in an industry research planning forums in 2003. The development of new earlier ripening varieties to extend the growing season to spread production risks was also identified at that forum. Previously, in earlier forums the development of varieties with resistance to the major fungal diseases (downy and powdery mildew) had also been considered to be of high importance.

CSIRO Plant Industry has maintained a vine improvement program to provide the viticultural industries with material suited to Australian conditions and industry needs. As part of this program new seedless drying varieties have been developed by hybridisation or have been imported and maintained in the CSIRO germplasm collection. Varieties released for dried fruit production from the breeding program include Carina (1975), Merbein Seedless (1981), Marroo Seedless (1988), Sunmuscat (1997) and Shirana (2004). Previous studies evaluated the range of seedless varieties in the germplasm collection (Newman and Clingeleffer 1987) and identified large berried types as potential alternatives to seedless raisin varieties or for specialty lines. The best of the large berried types were included in a DFRDC funded project (CSH17, 'integration of alternative drying varieties with low input, production systems of management'). DFRDC and HA Ltd. provided on going support, 1992-1998, for trial establishment and evaluation of small and large berried Sultana types, new currant types, specialty lines, new raisin selections (the latter were included from DAV76 project) and disease resistant lines or breeding lines from *in-ovulo* embryo rescue (CSH24 and 54) and development of unique Australian dried grape varieties (DG01001).

This project aimed to build on outputs from the previous project (DG01001) and complete the evaluation of selections in multiplied or semi-commercial plots; evaluate new genotypes produced by breeding or imported from overseas; and, implement a breeding program based on enhanced understanding of the inheritance of key drying characteristics to develop new seedless dried grape selections with rain tolerance and disease resistance. To ensure that the dried fruit breeding objectives have been consistent with industry requirements, CSIRO has maintained close consultation with industry. The research has been overseen by the 'Unique Dried Grapes Steering Committee' to ensure that the CSIRO program is consistent with industry needs, to identify selections with most potential and to facilitate their commercial adoption. Members of this committee include representatives from all industry sectors, HA Ltd and researchers.

The project was designed to provide a direct benefit to the Australian dried vine fruits industry. It will lead to improved drying varieties which have potential to overcome problems/deficiencies of existing standard varieties. In particular, it aimed to develop and evaluate new fruitful and rain tolerant types to overcome the problems of variable production, losses due to rain, and minimise mould and Ochratoxin A development and maintain fruit quality. While the focus was on development of light coloured 'sultana' types the new varieties will facilitate expansion in export markets with new niche products, spread the risk of crop loss due to characteristics such as early maturity, disease resistance and adaption to more efficient management practices.

Materials and Methods

1. Breeding activities

The project implemented a breeding strategy based on knowledge of the inheritance of key dried fruit quality characteristics and disease resistance using both conventional breeding and *in-ovulo* embryo rescue techniques for crosses between seedless parents. The latter approach was chosen to increase the chances of producing seedless progeny. Key tasks included:-

- conduct of targeted crosses at flowering in spring, including emasculations and pollinations
- application of in-vitro, *in-ovulo* embryo rescue techniques for crosses between seedless parents. This involved ovule rescue in December and January, dissection and embryo recovery in February and March and climatisation of plantlets (April-December)
- harvest, seed removal, planting, stratification and propagation of seeds from conventional crosses
- planting and routine vine training of material from both breeding sources in spring and summer.

2. Evaluation

Material for evaluation

New selections, at varying stages of development, have been evaluated by drying and processing in the CSIRO small-scale processing facility. These stages include single vine seedling populations, multiplied and top-worked plantings and larger, semi-commercial trials on grower properties. Key trials established previously and assessed in this project included:-

- a semi-commercial planting of an early ripening, disease resistant currant selection grafted on a range of rootstocks.
- a semi-commercial planning of seven, promising selections and sultana types which was planted in 2004. The planting included 3 rain tolerant sultana types; two early ripening, disease resistant and rain tolerant small-berried types; and, one selection with an attractive long berry.
- larger plantings of seedless selections with high potential from disease resistant and in-ovulo embryo breeding lines. These included 40 selections managed on swing-arm trellis and 0.3 m T-trellis.
- a trial with the low browning Sultana clone, Bruces Sport on own roots and Ramsey and managed on swing-arm trellis and 0.3 m T-trellis. The trial included a comparison with Bruce's Sport and a Bruce's Sport clone which had been tissue cultured, using fragmented shoot apex culture (FSAC) to potentially eliminate viruses.
- plantings of the USDA selections, Black Emerald, C88-89 (a. muscat flavoured selection), DOVine, Summer Muscat and Princess.

- a non-sprayed site with disease resistant selections to test field tolerance/ resistance by observation of leaves and fruit
- single vine seedling progeny from previous breeding activities, in total about 10,000 plants

During the course of the project new plantings and trials were established for evaluation. These included:-

- new single vine seedling progeny from breeding activities
- multiplied and top-worked selections identified from breeding progeny. Top-working onto well established, existing rootstock was used to facilitate more rapid assessment of selections.
- a one hectare, semi-commercial planting of a very promising, high yielding, rain tolerant type which was established by top-working onto Sultana grafted on Ramsey rootstock and trained on a swing-arm trellis.
- a one hectare, semi-commercial planting of the early ripening, disease resistant currant selection which was established by top-working onto Zante Currant grafted on Ramsey rootstock .The vines in this site were trained on a high cordon (1.5m) and managed with replacement canes attached to a lower wire, 0.4 m below the cordon.
- further releases of USDA varieties from quarantine, ie. Diamond Muscat and Selma Pete.

Routine drying assessments of the material listed above

Routine drying assessments included:-

- pre-harvest sampling for berry weight, sugar, acid and pH determination
- measurements of yield, and if appropriate bunch number, drying as naturals and or after treatment with drying emulsion on racks, by trellis drying (in a semi-commercial site) or artificial dehydration
- processing in the small-scale, CSIRO packing plant
- product evaluation, including colour and its uniformity, moisture, berry size, flavour, processing and storage characteristics.
- samples of the best selections were submitted to the 'Unique Dried Grapes Steering Committee' for assessment and also to processors and marketers for feedback on product potential. In addition, the growth characteristics and performance of promising selections in CSIRO trials and at semi-commercial trial sites was assessed during farm visits by the 'Unique Dried Grapes Steering Committee' prior to harvest in each year.
- assessment of processing characteristics and final product quality of fruit delivered from semi-commercial plantings and processed under commercial conditions

Results

1. Breeding activities

Crosses to develop new dried grape hybrid populations were undertaken at flowering, in October-November, in each year with the exception of 2008. A focus was on crosses between seedless parents with the aim to increase the chances of producing seedless progeny. Tissue culture techniques using i*n-ovulo* embryo rescue were applied to recover new hybrids for evaluation as seedling material from such crosses. On average, in each season 12 seedless x seedless crosses were made. These crosses included the use of some disease resistant seedless material developed by CSIRO in earlier studies (eg. DG01001). Depending on the season and parental combinations, up to 4000 ovules were recovered each year producing up to 1000 plants for establishment in the field. In addition, up to 12 further crosses between seeded and seedless parents, targeting early ripening, rain tolerance and disease resistance were made each year. These included crosses targeting the introduction of the Run 1 gene complex for powdery mildew and downy mildew resistance into dried grape breeding lines. To reduce the number of plants established in the field from these crosses, in latter seasons, material from these crosses was screened for powdery mildew tolerance under shadehouse conditions where fungicide treatments were not applied. Those showing susceptibility to powdery mildew were eliminated (ie. about 50%). It is estimated that a total of 7500 seedling plants were established in the field from breeding activities undertaken in this project.

2. Evaluation of seedling populations

In any season, about 10,000 hybrids plants from dried grape crosses were available for evaluation as new vines were planted and established while older vines, established in previous projects (eg. DG 01001), were culled. Fungicide treatments were not applied to populations targeted for disease resistance, in the last three years of the project. However, there were no major incidences of fungal diseases in those seasons due to the climatic conditions and field screening for tolerance/resistance was not useful.

Each season, the fruit from up to 150 individual seedlings was harvested and racked dried after treatment with drying emulsion, except for black coloured selections which were dried naturally without treatment. Berry samples were also collected to determine berry weight, total soluble solids and titratable acidity. Dried grape samples were evaluated against a range of criteria, ie. berry size, colour, uniformity and flavour. Each winter, cutting material from the most promising selections was collected and propagated to establish multiplication blocks as own rooted vines or for top-working onto existing rootstock material to speed up the evaluation process. During the project a total of 60 promising selections have been planted and established in multiplication blocks with 50 top-worked onto existing rootstock material. In addition, in winter 2009, material was collected from a further 100 promising selections for propagation and planting in spring 2009. Material from these established plantings will be evaluated in a new project (DG 09000).

3. Evaluation of multiplied selections

Over the period of the project a portfolio of about 60 multiplied and top-worked selections has been available as mature vines for evaluation with removals and additions occurring each year. Each year dried fruit was produced from these selections. The current portfolio of multiplied selections includes 39 light coloured sultana types of which 22 are potentially disease resistant; 16 have small berries; 3 are very early ripening and 5 have larger berries. The portfolio also includes 12 muscat types of which 5 are potentially disease resistant with one very early ripening type and 3 black berried, currant types potentially with disease resistance. The smaller light coloured disease resistant types may also be useful for currant production if dried as naturals. Favourable climatic conditions over the period of the project did not allow assessment of rain tolerance or disease resistance in the field. It is likely that recommendations to establish semi-commercial plantings of the most promising types from the portfolio of multiplied selections will be made once the evaluations are completed as part of the new project (DG09000). In particular, it is anticipated that the performance of top-worked selections established in this project and managed on modern, low-input trellis systems will provide valuable support information to assist in the decision making processes.

4. Evaluation of selections on semi-commercial grower sites

Three grower sites for evaluation of selections under semi-commercial conditions were established during the project with full production only being achieved in the most recent seasons (ie. 2008 and 2009). They included a one hectare planting of an early ripening, disease resistant currant selection; a site with seven light coloured selections grafted on 1103 Paulsen and Ramsey and a one hectare site of a light coloured, rain tolerant Sultana type which has been top-worked on existing Sultana vines grafted on Ramsey. In addition vine performance of the early ripening, disease resistant currant selection on a range of rootstocks, established in the previous project (DG01001) was also monitored.

4.1. Early ripening, disease resistant currant type

(a) Comparison on different rootstocks

In season 2004, vines of the early ripening, disease resistant currant type, grafted on a range of rootstocks and established on a 0.3m T-trellis on a commercial property produced some crop for the first time. Over 4 seasons (2004-2007), best yields were obtained on 1103 Paulsen, 140 Ruggeri and Ramsey while yields were lowest on own roots and Kober 5BB (Table 1). Rootstocks did not have a significant effect on berry weight, total soluble solids, pH or titratable acidity.

Figure 4.1.1. Views of the early ripening, disease resistant currant selection managed on a 0.3 m T- trellis (left) and final dried product (right).

Table 1. Effect of rootstock on yield, berry weight, total soluble solids, pH and titratable acidity of the early ripening, disease resistant currant selection over 4 seasons (2004-2007). *** indicates significance difference ($p < 0.001$); ns =not significant.

Rootstock	Yield (kg/vine)	Berry wt. (g)	TSS (^{o}Brix)	pH	Acidity (g/L)
Own roots	5.07	.804	22.7	3.83	4.98
Ramsey	10.01	.911	21.9	3.78	4.85
140 Ruggeri	11.14	.842	21.4	3.80	4.93
Kobber 5BB	8.65	.868	21.3	3.83	4.63
1103 Paulsen	11.64	.756	21.5	3.71	5.50
Significance	***	ns	ns	Ns	ns

(b) Semi-commercial assessment on a grower site.

A one hectare planting of the early ripening, disease resistant currant selection was established in 2004 to assess potential for trellis drying on a tall trellis, mechanical harvesting and to provide sufficient fruit for processing and marketing purposes. This was achieved by top-working onto existing vines of Zante Currant, grafted on Ramsey rootstock. First crops were produced in season 2007. The vineyard was maintained without application of fungicides. Under these conditions the selection was very fruitful and consistently produced dry yields of 5 t/ha, similar to Carina planted on a similar site. However, the selection which has low shoot vigour produced short, close-noded canes leading to problems in attachment of the canes below the cordon and hence, difficulties with mechanisation of cane severance for trellis drying. It was possible to remove the high number of inflorescences on shoots arising from the cordon or basal parts of the fruiting canes using an application of calcium nitrate prior to flowering. Because of the problems with trellis drying due to the short cane development, a number of modified pruning treatments were imposed at the site in winter 2009 with the aim to stimulate shoot growth or facilitate alternative approaches to trellis drying. These treatments included a reduction in cordon length, adoption of a split cordon system where hanging canes were only retained on half of the vine and conventional cane pruning. (Note: it is also planned to establish a planting on Dog Ridge, a very high vigour rootstock).

The dried product produced from the early ripening, disease resistant currant selection was processed through a commercial processing facility. There were no significant issues with respect to cap-stem removal, skin abrasion or removal of waste (ie. stalks and stems). It also had a notable spicy flavour which could offer an advantage over other currant varieties for some markets. In addition grape juice products were produced with fruit from the site through a commercial juice facility in Mildura and by a commercial company in Melbourne, using high pressure processing techniques. In both cases, the products were excellent examples of grape juice. Production of grape juice from the selection has been pursued as it may provide an alternative use whereby the fruit can be easily mechanically harvested as fresh grapes and because CSIRO testing has shown that it has very high anti-oxidant activity with potential health benefits.

Figure 4.1.2. View of the early ripening, disease resistant currant selection when trellis dried under semi-commercial conditions. Note: the development of short replacement canes arsing from the cordon.

(c) Conclusions re the early ripening, disease resistant currant selection

The currant selection shows considerable promise because of its early ripening, disease resistance, potential health benefits and flavour. Hence, it is readily suited to 'low chemical'/ organic production and niche marketing. It is also most likely to be a very water use efficient selection, combining the benefits of early ripening and low seasonal water use associated with the small canopy size. Issues around mechanisation of trellis drying require resolution before it can be recommended for large scale planting as an alternative to the late ripening, Carina Currant or the rain sensitive, Zante Currant. In anticipation of a future release of the selection, 300 plants were propagated as part of the project and provided to VAMVVIA (Victorian and Murray Valley Vine Improvement Association) to establish a mother vine planting as an industry source for propagation material.

4.2. Light coloured Sultana types

Seven light coloured selections were established in a semi-commercial trial on two rootstocks, 1103 Paulsen and Ramsey. For most selections, two 60 vine rows were established. The rootstocks were planted in 2004, grafted in spring 2005 and trained on a single bi-lateral cordon and pruned using hanging canes. (Note: A Shaw swing-arm trellis was installed in winter 2009 which will enable the assessments to include suitability for mechanised trellis drying). Significant crops were produced in 2008 and 2009. The planting included 3 rain tolerant sultana types; two early ripening, disease resistant and rain tolerant small-berried types; and, one selection with an attractive long berry. In 2009, a number of the selections suffered significant heat damage during a period of very high temperatures in January and February. This problem was exacerbated by row direction (N-S), management with hanging canes and limited water supply due to reduced allocations but should be minimised in the future when managed on a swing-arm trellis installed in winter 2009. There appeared to no significant problems with rootstock incompatibility. To date, one of the early ripening, disease resistant small-berried types has been eliminated from further assessment on the advice of the Unique Dried Grapes Steering Committee, as it produced very tight bunches which were difficult to treat with drying emulsion and there now appears to be limited demand for the product type. The established vines of this selection will be top-worked with the promising unnamed USDA muscat selection (see below) in spring 2009. The most promising rain tolerant Sultana type has also been established on a larger semi-commercial site (see below).

4.3. High yielding, rain tolerant Sultana type

A one hectare site of a light coloured, rain tolerant sultana type was established by top-working on existing Sultana vines grafted on Ramsey rootstock in spring 2005 with misses replaced in spring 2006 (Figure 3.1). The vines are trained on a swing-arm trellis. The Sultana crop was retained for the harvest in 2006, hence grafting success was reduced and shoot growth minimal. Some crop was produced on some vines in 2007. The selection has proven to be very fruitful with excellent crops produced from the site in the 2008 and 2009 seasons, ie. 11 t ha^{-1} and 13 t ha^{-1} of dried fruit, respectively (Figure 3.1). In season 2008 the selection produced an excellent light coloured product (Figure 3.2). In 2009, there was some darkening of the fruit due to intermittent periods of rain during drying. The dried berries were slightly larger (20%) than those produced on adjacent Sultana vines. Compared to the Sultana vines, maturity of the selection was delayed by about one week (ie. 1.5-2.0 ^{o}Brix) requiring cane cutting to be undertaken in early March to avoid issues of green tinge. The grower indicated that he had no problems in applying the drying emulsion or harvest of the fruit but was concerned with the number of second crop bunches. Observations during commercial processing indicated that capstems were easily removed and that skin damage was minimal, provided the processing equipment was adjusted correctly. In anticipation of a future release of the selection, 1000 plants were propagated as part of the project and provided to VAMVVIA (Victorian and Murray Valley Vine Improvement Association) to establish a mother vine planting as an industry source for propagation material.

Figure 4.3.1. Highly productive, rain tolerant sultana type under evaluation on a commercial property. The vine was established by top-working on an existing Sultana vine grafted on Ramsey rootstock and trained on a modern, cordon based swing-arm trellis.

Figure 4.3.2. Dried fruit samples, produced by trellis drying of the highly productive rain tolerant sultana type.

5. Evaluation of imported varieties

Dried samples from recent imports released from quarantine (Diamond Muscat, Summer Muscat, DOVine and Selma Pete) were produced, when available, from mothervine plantings of the Australian Vine Improvement Association in seasons 2007-2009. In 2009, when the vines were in full bearing, Diamond Muscat was the earliest ripening with a total soluble solids of 25.9 ^{o}Brix and a titratable acidity of 4.74 g/L on the 4th of February. Selma Pete and DoVine were also early ripening with total soluble solids of 25.0 ^{o}Brix and 24.7 ^{o}Brix and titratable acidities of 6.01 g/L and 4.20 g/L, respectively on that date. Summer Muscat, although considerable earlier than Sultana, was the latest ripening of the imported varieties with a total soluble solids of 22.9 ^{o}Brix and a titratable acidity of 5.51 g/L on the 4th of February. All four have consistently produced small berries compared to Sultana or Sunmuscat. Diamond Muscat and Summer Muscat both had distinct muscat flavours. Diamond Muscat, DoVine and Summer Muscat suffered from rain damage in January 2007. To date, the yield achieved by these selections growing on own roots has been low. Because these varieties are very early ripening and produce light products, they could be planted by growers as part of a strategy to spread risks across the season. Furthermore, tests undertaken by the breeder, Dr David Ramming (USDA), and very limited grower experiences with some varieties in Australia, indicate that these varieties will all dry faster than Sultana because of differences in skin characteristics, hence reducing exposure times during drying.

An unnamed, USDA muscat selection which has been evaluated in CSIRO multiplied plots has shown very strong potential. It appears to be completely rain tolerant, highly productive (>10 t/ha of dried fruit) and produces a light coloured dried product with attractive, full-bodied, floral muscat character. It has a similar ripening time and berry size but stronger muscat character than Sunmuscat. This selection will be top-worked on established vines on the semi-commercial grower site described above (section 4.2) in spring 2009.

The potential of the early ripening, black seedless USDA table grape variety, Black Emerald, was also assessed for drying. However, it was highly sensitive to rain damage and hence, considered to have no potential for drying purposes under Australian conditions.

6. Bruce's Sport trial

The first significant crops were produced from the Bruce's Sport trial in 2002 although not all vines were in full production until 2003. Where possible, 12 canes were retained each winter on the T-trellis vines while all available canes were retained on vines trained on the swing-arm trellis. Compared to own roots, there was a significant yield increase of Bruce's Sport when grown on Ramsey rootstock over the seasons (2.5 fold) and in each season (Table 1). The tissue cultured Bruce's Sport had higher yields than Bruce's Sport in only one season, 2006. Yields were higher on the swing-arm trellis in 2005 and 2006 compared to the T-trellis. The interaction between scion and rootstock treatments was not significant. By contrast there was a strong interaction ($p<0.001$) between scion and trellis treatments (Table 2). The interaction results show that untreated Bruce's Sport performed poorly on swing-arm trellis and that there was an improvement in yield of 16% with the tissue cultured Bruce's Sport, but only when trained on the larger, swing-arm trellis.

Table 1. Main treatment effects (Scion, Rootstock and Trellis) on mean yield (kg/vine) for Bruce's Sport (BS) compared with tissue cultured Bruce's Sport (TCBS), own roots (OR) compared to Ramsey rootstock (Ram) and T-trellis (T) compared to swing-arm trellis (SAT), over 5 seasons (2002-2007). Because of the large seasonal differences and interactions with treatments, statistical analyses were applied in each year and over the years. Superscripts indicate significant differences for each comparison ($P<0.05$).

Season	**Scion**		**Rootstock**		**Trellis**	
	BS	**TCBS**	**OR**	**Ram**	**T**	**SAT**
2002	7.45	7.45	3.30^{a}	11.32^{b}	8.12	6.50
2003	10.0	13.7	5.3^{a}	18.5^{b}	14.5	9.3
2004	21.9	20.4	12.3^{a}	30.0^{b}	22.5	19.8
2005	27.4	27.8	17.9^{a}	37.3^{b}	24.3^{a}	30.8^{b}
2006	14.2^{a}	22.3^{b}	5.1^{a}	31.4^{b}	15.0^{a}	21.5^{b}
2007	20.0	17.1	14.2^{a}	23.0^{b}	17.0	20.1
Mean (2003-07)	18.7	20.3	11.0^{a}	28.0^{b}	18.7	20.3

Table 2 Mean yields (kg/vine) for the significant Scion (Bruce's Sport, BS and Tissue Cultured Bruce's Sport, TCBS) x Trellis (T-trellis, T and swing-arm trellis, SAT) interaction, over 5 seasons (2003-2007). Because of the large seasonal differences and interactions with treatments, statistical analyses were applied in each year and over the years. Superscripts indicate significant differences for each comparison ($P<0.05$).

	BS		**TCBS**	
Trellis	**T**	**SAT**	**T**	**SAT**
2003	14.5^{b}	5.6^{a}	14.5^{b}	13.0^{b}
2004	24.7	19.2	20.3	20.5
2005	26.8^{b}	28.0^{b}	21.9^{a}	33.7^{c}
2006	17.1^{b}	11.4^{a}	13.0^{a}	31.6^{c}
2007	18.3	21.8	15.8	18.5
Mean	20.3^{b}	17.1^{a}	17.1^{a}	23.5^{c}

In each season the vines were harvested at similar maturities ranging from 23.2- 24.3 ^{o}Brix (Table 3). Harvest dates varied from 12th February to 9th March There were significant effects of season on berry weight (1.21-1.64 g), pH (3.51-4.56) and titratable acidity (4.06-6.85 g/L). For each parameter, interactions between treatments and season were generally not significant. Hence, for simplicity only the mean values are presented in Table 4. Compared to the untreated Bruce's Sport, the tissue cultured Bruce's sport produced significantly smaller berries with higher levels of total soluble solids and higher levels of titratable acidity. Compared to own roots, Bruce's Sport on Ramsey rootstock had significantly larger berries, lower total soluble solids and higher levels of titratable acidity. Berry weights were smaller and total soluble solids lower on the swing-arm trellis compared to the T-trellis. When dried, the Bruce's Sport and the tissue cultured Bruce's Sport produced a very light dried fruit sample when grown on own roots or on Ramsey.

Table 3 Effect of season on mean berry weight (g), total soluble solids (^{o}Brix), pH and titratable acidity (g/l) over all scion, rootstock and trellis treatments

	2003	**2004**	**2005**	**2006**	**2007**	**2008**
Harvest date	25th Feb.	26th Feb.	9th March	2nd March	2nd March	12th Feb.
Berry wt. (g)	1.23	1.21	1.22	1.60	1.64	1.24
TSS (^{o}Brix)	23.5	23.6	24.3	23.2	24.0	23.5
pH	4.21	3.73	3.51	4.56	3.75	3.56
Acidity (g/L)	4.06	5.63	6.85	4.56	4.08	6.94

Table 4. Main treatment effects on mean berry weight (g), total soluble solids (^{o}Brix), pH and titratable acidity (g/l) of Bruce's Sport (BS) and tissue cultured Bruce's Sport (TCBS) grown as own rooted vines (OR) or grafted on Ramsey rootstock (Ram) and trained on either a 0.3 m T-trellis (T) or swing-arm trellis (SAT) over 6 seasons (2003-2008). Superscripts indicate significant differences for each comparison ($P<0.05$).

	Scion		**Rootstock**		**Trellis**	
	BS	**TCBS**	**OR**	**Ram**	**T**	**SAT**
Berry wt. (g)	1.40^{a}	1.31^{b}	1.27^{a}	1.44^{b}	1.42^{a}	1.29^{b}
TSS (^{o}Brix)	23.5^{a}	24.0^{b}	24.3^{a}	23.2^{b}	24.0^{a}	23.5^{b}
pH	3.91	3.87	3.88	3.90	3.89	3.88
Acidity (g/L)	5.21^{a}	5.50^{b}	5.15^{a}	5.55^{b}	5.35	5.36
Yield (kg/vine)	18.7	20.3	11.0^{a}	28.0^{b}	18.7	20.3

Conclusions regarding Tissue Cultured Bruce's Sport

Grafting of both sources of Bruce's Sport on Ramsey rootstock gave significant production advantages over material evaluated on own roots. There was a significant advantage using the tissue cultured material when managed on swing-arm trellis. This is most likely due to the elimination of debilitating leaf roll virus types by the culture of fragmented shoot tips in tissue culture (ie. FSAC). Elimination of a number of leaf roll viruses types has been confirmed by PCR testing. While Bruce's Sport has similar susceptibility to rain damage to Sultana, the maintenance of light fruit colour during the latter stages of drying and in storage would offer distinct advantages over Sultana. Hence it is recommended that material of Bruce's Sport be made available to industry for planting as part of risk management strategy to ensure supply of light product.

Discussion

The project aimed to develop improved rain tolerant drying varieties to minimise industry problems associated with rain damage at harvest, the development of mouldy fruit and inconsistent production due to variable fruitfulness and biennial bearing of Sultana, the main variety used for dried grape production in Australia. This has involved a breeding component to develop new dried grape genotypes with early ripening, rain tolerance and disease resistance, largely based on crosses between seedless and/or disease resistant parental lines. Selections, at varying stages of development, have been evaluated by drying and processing in the CSIRO small-scale processing facility. These stages include single vine seedling populations, multiplied and top-worked plantings and larger, semi-commercial trials on grower properties. In addition new varieties which have been introduced from overseas have been included for comparative purposes.

Each season, the fruit from up to 150 individual seedlings was harvested and racked dried. During the project a total of 60 promising selections have been planted and established in multiplication blocks with 50 top-worked onto existing rootstock material. In addition, in winter 2009, material was collected from a further 100 promising selections for propagation and planting in spring 2009. This material will be evaluated in a new project funded by HA Ltd, DG 09000 (2009-2012).

Over the course of the project, a very fruitful, high yielding, rain tolerant Sultana type has shown excellent production, drying and processing characteristics. It offers significant potential for enhancing the sustainability and profitability of the dried fruits industry. With the support of the Unique Dried Grapes Steering Committee, sufficient material has been propagated to establish mother vine plantings to supply material to industry should the selection be formally released.

The early ripening and rapid drying, imported USDA varieties (ie. Diamond Muscat, Summer Muscat, DOVine and Selma Pete), which are available through the Australian Vine Improvement Association (AVIA), and evaluated on a limited scale in this project, warrant wider consideration by industry. They show considerable promise for planting as part of a strategy to spread risks across the season. However, issues with regard to market requirements for small berried Sultana types, including the muscat varieties should be assessed as they have all produced smaller berries than Sultana. Similarly, the tissue cultured source of the low browning Bruce's Sport Sultana clone offers significant potential to reduce the risks of fruit darkening if inclement weather occurs during the later stages of drying, and hence, should also be considered for release to industry provided it is propagated on a high vigour rootstocks, such as Ramsey. The full potential of this improved clone of Bruce's Sport, which can be linked to elimination of leaf roll virus types, was only achieved when managed on a swing-arm trellis system.

An imported, unnamed USDA selection which produces high yields of light fruit, with larger berries than Sultana that have a distinct muscat character, has also shown considerable promise, potentially as a seedless replacement for Muscat Gordo Blanco for

raisin production. To facilitate rapid assessment in the new project (DG09000), it will be top-worked onto existing vines to establish a semi-commercial site.

An early ripening, disease resistance currant selection with a distinct 'spicy' flavour has shown significant potential when evaluated in the project. Tests have also shown that it has high levels of anti-oxidants with potential health benefits. Hence it is readily suited to 'low chemical'/ organic production and niche marketing and significant demand from that sector of the industry is expected. However, management on modern, cordon-based trellis systems with hanging canes to facilitate trellis drying has proven difficult because canes arising from the cordon are too short for attachment to lower wires. Vine management studies, with potential to resolve this issue, have been implemented and will be evaluated in the new project (DG09000). This will include assessment of its performance on a high vigour rootstock, Dog Ridge. In anticipation of a future release of the selection, 300 plants have been propagated to establish a mothervine planting as an industry source for propagation material.

The project has been overseen by the Unique Dried Grapes Steering Committee, with delegates from all sectors of the industry (ie. production, processing and marketing), HA Ltd and CSIRO. This approach has provided the research team with excellent guidance with respect to both the breeding directions and decisions on commercialisation of new drying selections.

Technology Transfer

Technology transfer has been facilitated through regular meetings of the 'Unique Dried Grape Varieties Steering Committee'. Steering committee members have been provided with updates on the research and commercialisation at each meeting. Dried grape samples of the most promising selections and varieties have been provided for assessment. In addition, each year in January/February, a farm walk has been undertaken by the committee to view the performance of selections and varieties in CSIRO trials and at the semi-commercial sites.

Results of this project have been presented to industry on a regular basis at ADFA grower various forums, the ADFA Federal Council and the annual Riverlink research planning forums. Each year CSIRO has been represented by staff including posters and appropriate fruit samples for viewing or tasting at the Mildura field days in May. Updates on the project have been published on a regular basis in 'The Vine' magazine and HA Ltd annual reports (see bibliography below). Three scientific papers (Liu et al.) based on data generated in the previous project (DG01001) were completed and published within the timeframe of this project.

Recommendations

As a result of studies undertaken in this project it is recommended that:-

- evaluation be completed for seedling progeny, multiplied and top-worked selections and selections established on semi-commercial trial sites developed as outputs from this project. (Note: A new project has been funded through HA Ltd (2009-2012) to complete the evaluation of material in the breeding pipeline).
- arrangements for commercial release to industry of the very promising rain tolerant Sultana type be implemented, subject to approval of the Unique Dried Grapes Steering Committee and the USDA. It should be noted, that the formal release and naming will be undertaken jointly with the USDA.
- further management studies be conducted with the early ripening, disease resistant currant selection with the aim to overcome cane replacement issues when managed on a modern, cordon based system for trellis drying prior to consideration for industry release. Its compatibility with a high vigour rootstock, such as Dog Ridge, should be assessed as part of these studies. In the interim, it is recommended that a PBR trial be established with the selection and key comparators (Zante and Carina currants).
- arrangements for commercial release to industry of the low browning, tissue cultured Bruce's Sport Sultana clone be implemented, subject to approval of the Unique Dried Grapes Steering Committee.
- that the industry consider wider assessment of the recently released early ripening USDA varieties (Diamond Muscat, Summer Muscat, DOVine and Selma Pete) which are available through the Australian Vine Improvement Association (AVIA) as part of spreading risks across the season. However, the rain susceptibility of these selections requires further evaluation. In addition, because these varieties to date have all produced smaller berries than Sultana, market requirements for small berried types Sultana types, including the muscat varieties should be assessed.
- that the very promising rain tolerant, USDA selection with distinct muscat character be assessed under semi-commercial conditions. (Note: top-working of this selection onto Ramsey and 1103 Paulsen will occur at one of the semi-commercial sites in spring 2009)
- the Unique Dried Grapes Steering Committee be retained to provide ongoing input into the development and commercial release of new varieties.

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