Breeding grapevines for tropical environments

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Summary: Grapevines are increasingly grown in the latitudes between the Tropics of Cancer and Capricorn. In many cases environments modified by elevation are utilized to create temperate growing conditions. The majority of tropical grapes are consumed fresh but some are dried (India) and others are made into wine (Brazil, Venezuela). Currently most plantings are of pure *Vitis vinifera* varieties. Early ripening, low acid cultivars such as Cardinal, Perlette, Ribier and Thompson Seedless which have a relatively short cycle between budburst and harvest are commonly used, and pruning is timed to ensure maturation before the onset of heavy tropical rains. Other *V. vinifera* varieties used in the tropics such as Muscat Hamburg, Teneron, Anab-e-Shahi, and Italia have bunch and skin characteristics that give them some resistance to rain damage.

There are a number of grapevine varieties that are hybrids between *V. vinifera* and other *Vitis* species which are currently grown in the tropics. These have some degree of resistance to fungal diseases and include Isabella, Kyoho, Delaware, Himrod, Campbell Early (*V. labrusca* hybrids), the Criolla hybrids (*V. caribaea* hybrids and Villard blanc (a complex French hybrid based on American species).

There is considerable scope to increase the resistance of grapes to the main fungal diseases encountered in the tropics such as downy and powdery mildew, anthracnose and bunch rots by using a range of *Vitis* species as parents. These hybrids should be based on species that do not give strong 'foxy' flavours and could involve complex French hybrids, *V. rotundifolia* and also Asian species such as *V. amurensis* and *V. armata*. CSIRO Merbein has a small hybridisation program aimed at developing new varieties for tropical environments.

Key words: tropics, Australia, Asia, America, Africa, ecology, physiology, cultivation, variety of vine, rootstock, pest, disease, resistance, breeding, genetic engineering.

Introduction

Grape production in the latitudes between the Tropics of Cancer and Capricorn is increasing with the development and expansion of industries in South-East Asia (Australia, South China, India, Indonesia, Philippines, Thailand, Taiwan), Central and South America (Brazil, Colombia, Ecuador, Mexico, Venezuela, West Indies) and Africa (Kenya, Nigeria, Zimbabwe). The majority of tropical grapes are used fresh but some are dried (India) and others made into wine (Brazil, Venezuela). In general the fruit produced is low in sugar and acid, of low quality and used for local consumption. However some countries are now exporting table grapes (e. g. India, Thailand, Venezuela). The wide diversity of environments (climate and soil), varieties, production techniques and major disease and pest problems provides a substantial challenge to breeders. A recent worldwide survey was conducted by CSIRO Division of Horticulture, as part of its commitments to a tropical viticulture working group of the International Society of Horticultural Science, to provide detailed documentation on the many diverse approaches to tropical viticulture and supplement existing limited information. It will provide a more rational basis for approaches to tropical grapevine breeding.

The Division maintains an interest in tropical viticulture because table grape production has developed in tropical regions in northern Australia to provide early ripening fruit, ahead of the temperate zones. The Australian situation is unique because commercial developments, although in their infancy, have occurred in a diverse range of environments, including the three main situations identified in the survey, i. e. in both the wet and dry tropics and at higher elevations to create temperate growing conditions. Material from the CSIRO table grape varietal evaluation and breeding program (Possingham and Clingeleffer 1986) is evaluated in the Australian environments and has been widely distributed to many of the countries producing tropical grapes.

This paper aims to provide an overview of current practices in tropical viticulture, both in Australia and overseas, identify the major problems requiring attention by breeders and discuss relevant aspects of the Division's breeding program.

1. Tropical grape growing in Australia

Commercial plantings of table grapes for the production of early ripening fruit are located in both the dry and wet tropical regions of Australia.

Dry tropics

Plantings in the dry tropics are located in central Australia in the Northern Territory near Tea Tree, lat. 22 °S, in sandy-loam soils and irrigated by trickle irrigation from subterranean basins. The total rainfall of around 270 mm falls mainly in the summer, December-March. Average maximum daily temperatures range from 20 °C in June, July to 36 °C in summer, December-February.

Because frosts occur in winter, a result of continental influences on climate, the vines go dormant in winter. They are pruned in June-July and managed similar to those in more temperate regions on sloping T-trellis (Clingeleffer 1985) to produce only one crop per year. Winter chilling is insufficient to fully break the dormancy and hydrogen cyanamide (Dormex) at a rate of 2-3 % is used to both advance maturity (McColl 1986) and promote uniform budburst. Varieties grown for early ripening in November are Beauty Seedless, Perlette, Fresno Seedless (Possingham *et al.* 1989), Flame Seedless and Cardinal.

Sultana is also grown but due to later ripening in December may be damaged by monsoonal rains. All varieties except the less fruitful Sultana are spur pruned. Gibberellic acid (GA) is used for bunch elongation, berry thinning and to enhance berry size of the seedless varieties but the response is lower than in more temperate regions, possibly due to the higher temperatures. Fungal diseases have not been a problem, although control measures are required for oidium *(Uncinula necator)*. The major pest is the giant termite, *Mastotermes dariwiniensis* which can completely destroy vines.

CSIRO Division of Horticulture in collaboration with the Department of Primary Industry in the Northern Territory have established rootstock trials with about 20 genotypes of common nematode and phylloxera resistant rootstocks to evaluate those most suited to the very hot, dry arid environments.

Wet tropics

Commercial plantings in the wet tropics extend from as far north as Kununurra, lat. 16 °S in western Australia and Mareeba, 17 °S, Townsville, 15 °S, Charters Towers 20 °S and Rockhampton, 23 °S. Rainfall at all locations follows a distinct seasonal, wet-dry pattern with annual totals ranging from 665 mm in Charters Towers to 810 mm in Rockhampton. Soil types, even for one location may vary from sands to heavy clays.

Highland production

The high elevations at Mareeba (840 m) and Charters Towers (600 m) in Queensland provide temperature conditions with winter frosts. The growth pattern of the vines is similar to that described for the dry tropics and the vines are managed as temperate plantings. Muscat Hamburg is the dominant variety followed by Cardinal. Italia, Muscat Gordo blanco, Ribier and the disease resistant Isabella, a *V. labrusca* hybrid are also grown at Mareeba and Royal Ascot in Charters Towers.

Lowland production

Kununurra is the hottest and driest of these locations with daily maximum temperature exceeding 30 °C in all seasons and relative humidities of less than 50 % for the drier part of the year. Plantings are mainly experimental and include Flame Seedless, the Indian variety Anab-e-Shahi, the disease resistant species complexes Carolina Blackrose and Muscat St. Vallier and the Central American selection, Criolla negra.

Plantings at Rockhampton are dominated by Muscat Hamburg and Cardinal with some Italia and Early Muscat. In this locality, 23 °S on the tropic of Capricorn, frosts occur in winter and the vines are managed similar to in more temperate regions. By contrast, significant plantings at Townsville are in a frost free zone at low altitude. 730 mm of the annual rainfall of 873 mm falls between October and March, daily maximum temperatures, except for the peak of summer, range between 25 and 30 °C and the relative humidity between 50 and 75 % in the drier periods. These conditions produce continuous, rapid and vigorous shoot growth and the vines, which lack a period of winter chilling, remain evergreen without a period of dormancy. Twice yearly pruning techniques based on the Indian system of renewal pruning are used (Clingeleffer 1987). Longer fruiting canes of 6-8 nodes are retained in May-June to produce a crop in September-November and then pruned to short, unfruitful spurs for the development of renewal wood. The main varieties grown are Cardinal and Muscat Hamburg, but promising results have also been achieved with Sultana and Marroo Seedless, a large black berried variety, bred by CSIRO (Clingeleffer and Possingham 1988). Flame Seedless has not been productive. The vines are trained on sloping T-trellis and the pruning staggered so that the Cardinal, which has proved to be sensitive to rain, crops in September and Muscat Hamburg, which is rain tolerant, is harvested last in November. Hydrogen cyanamide is used to advance maturity and promote uniform budburst. The main fungal problems are anthracnose or black spot *(Elsinoe ampelina)*, downy mildew *(Plasmopara viticola)*, oidium or powdery mildew *(Uncinula necator)* and various bunch rots, in particular *Botrytis cinerea*. The major pests are mealy bug *(Pseudococcus adonidum)* and bunch mites *(Brevipalpus lewisi)*. Although nematodes have not been a problem, rootstocks, including the nematode resistant Ramsey *(V. champinii)* and the more common phylloxera resistant rootstocks, selected in Europe for wetter conditions e.g. SO4 and 5 BB *(V. berlandieri x V. riparia)* are currently being evaluated in collaboration with CSIRO. Plantings on Ramsey have been excessively vigorous and difficult to manage.

2. Tropical grape growing around the world

Environment

Commercial grape production has expanded in the tropics in an extremely diverse range of environments. In South-East Asian countries (i. e. Indonesia, Philippines, Taiwan and Thailand) the main areas of production are frost free zones, at sea level in the wet monsoonal tropics which feature constant high temperatures around 30 °C, high relative humidity, greater than 75 %, and an annual rainfall of around 1,500 mm. Slightly drier, less humid conditions are found at elevated sites (600-900 m) in the main centres of production in South India near Bangalore (917 mm annual rainfall) and Maharashtra State in Central India, west of Bombay (700 mm annual rainfall). Elevated sites in Central America (Ecuador, Venezuela, Columbia) also have been selected to moderate climatic influences, the extreme case being in Ecuador where grapes are grown both at sea level in a frost free, warm arid environment and at 2,348 m in wetter (1,049 mm annual rainfall), humid but cooler conditions with an extended period of frost. The most arid tropical grape area is found in Mexico with an annual rainfall of less than 45 mm and extensive periods of frost.

Physiology

Production in the frost free, wetter regions provides a marked contrast to warm temperature viticulture. The constant high temperatures, high relative humidities and high rainfall (600-1,500 mm) produce rapid and vigorous shoot growth and amplify fungal and disease problems. The vines lack a period of winter chilling and remain evergreen without a period of dormancy. A number of crops may be produced in one year as the rapid rate of growth gives a very short growth cycle (e. g. Cardinal in the Philippines and Venezuela can produce 3 crops p. a.). It is not uncommon for vineyards to have vines at all stages of growth with production on a continual basis throughout the year. Time of pruning and pruning techniques are adjusted in some countries to minimise production during high rainfall periods (i. e. monsoonal wet seasons) when it is difficult to control pest and diseases and also to meet market demands. Tropical grape vines exhibit a high degree of apical dominance (Chadha 1984) attributed to the lack of winter chilling considered necessary in warm temperate climates for high and uniform budburst. Special pruning techniques (see below) are required to overcome this problem. Commercial attempts to control apical dominance by leaf removal prior to pruning or restricting irrigation after harvest to induce dormancy have been unsuccessful. The use of hydrogen cyanamide to promote a more uniform budburst is currently being tested.

Production constraints include a short vine life (e. g. 7-10 years in Thailand), low bud fruitfulness and poor maturity (i. e. lignification) of replacement wood. The short vine life is thought to be due to the long term depletion of carbohydrates caused by the rapid and continuous shoot growth and production of more than one crop p. a. (Olmo 1970). Depletion of nutritional resources, nematodes and copper toxicity from fungicides are also given as reasons for the short vine life. Low bud fruitfulness can be attributed to excessive shade associated with the overhead pergola trellis system and the rapid and excessive shoot growth (Chadha 1984). The poor maturation of replacement wood may also be associated with low carbohydrate levels (Olmo 1970), excessive shade, continuous growth and cropping, the lack of a dormant period and pruning soon after crop removal.

Management

Tropical vineyards, with few exceptions are low density plantings trained on overhead pergolas. This system contributes to excess vegetative growth, poor light interception, poor cane quality and poor colour development in berries (Chadha 1984). To achieve acceptable levels of production, high bud numbers are retained on cane pruned vines. Cane pruning is used because basal nodes are unfruitful. Retention of high bud numbers gives sufficient fruitful shoots and overcomes problems associated with apical dominance and non-uniform bud burst as it is usual for only the terminal nodes to burst.

In most situations, the canes are about 6-10 buds in length. In India they are selected from renewal spurs or water shoots on head pruned vines (Olmo 1970), in Venezuela from established cordons (Rojnic *et al.* 1972), and in Thailand from the terminal shoots of last seasons fruiting canes. In the Philippine island of Cebu the vines are planted in rows and trained on wide T-trellis with a central cordon along the rows. Canes from 2-bud renewal spurs are placed in a horizontal position at right angles to the direction of the row on both sides of the cordon, similar to the swing-arm trellis proposed for Sultana (Clingeleffer and May 1981).

The time of pruning is adjusted to stagger the supply, meet market demands and to avoid unfavourable climatic conditions during shoot and fruit development (Chadha 1984). In India, renewal pruning, where the vines are pruned to unfruitful short spurs, is used to avoid cropping during the wet season (Olmo 1970). This practice also favours the maintenance of the vine shape and improves 'cane quality'.

To improve fruit set, the shoots may be tipped just prior to, or at flowering. Standard bunch trimming and thinning (i. e. to one bunch per shoot) is used to improve berry size and bunch appearance. Leaf and lateral removal to develop an open canopy is also routinely used. Judicious use of supplementary irrigation and fertilizer, both inorganic and organic, is used to control the vigour on infertile soils. In Thailand the vines are planted in high mounds. The ditches between these mounds are used for the supply of supplementary irrigation and for drainage (PUNSRI and SUKUMALANDANA 1977).

Varieties

Contrary to popular opinion most plantings are of pure *V. vinifera* varieties. Some have bunch and skin characteristics that give them resistance to rain damage (e. g. Muscat Hamburg, Teneron, Anab-e-Shahi, Italia). Early ripening, low acid cultivars which have a relatively short cycle between budburst and harvest are commonly used to produce a number of crops per year or to ensure maturation before the onset of heavy tropical rains (e. g. Cardinal, Ribier, Perlette, Thompson Seedless, syn. Sultana). Hybrids between *V. vinifera* and other *Vitis* species are also grown. These have some degree of resistance to fungal disease and include *V. labrusca* hybrids (American hybrids), complex species hybrids (French hybrids) and *V. caribaea* hybrids (Criolla hybrids).

The main varieties grown in South-East Asia are Ribier (2-3 crops p. a.) in Indonesia, Cardinal (3 crops p. a.) in the Philippines and White Malaga (Teneron, 2 crops p. a.) and Cardinal (3 crops p. a.) in Thailand. The main varieties which produce 2 crops p. a., grown in Taiwan, are the *V. labrusca* hybrids Kyoho, Golden Muscat and Niagara and Cardinal, Black Queen and Italia. In South China Kyoho and Campbell Early, both *V. labrusca* hybrids are grown.

A diverse range of varieties producing 2 crops p. a. are grown in Bangalore, India. The most important are Sultana, Anab-e-Shahi and the *V. labrusca* hybrid Isabella (syn. Bangalore Blue) with smaller plantings of Perlette, Muscat Hamburg, Beauty Seedless, the local Indian selections Bhokri, Cheema Sahebi, Kali Sahebi and the *V. labrusca* hybrid, Himrod. In the more northern Indian regions only 1 crop p. a. is produced. Sultana, used for both table and drying purposes, is an important variety but Anab-e-Shahi, Ribier and Cheema Sahibi are also grown.

Varieties grown in the wetter frost free, low altitudes of Venezuela are Cardinal (3 crops p. a.), Italia and Isabella (both 2 crops p. a.) while at the more temperate, elevated sites common table grapes are grown, i. e. Ribier, Italia, Cardinal, Waltham Cross, Muscat Hamburg, Golden Champion, Emperor and Gros Colman (ROJNIC *et al.* 1972). The common varieties grown in Colombia are Ribier, Gros Colman, Italia and Isabella. Varieties grown at low altitudes to produce 2 crops p. a. in Ecuador are the *V. labrusca* hybrids Isabella and Niagara while Ribier is the most important variety grown at elevated sites. Varieties grown in Mexico are the standard table grape varieties from California.

Rootstocks

Rootstocks are not widely used in the tropics although nematodes are widely reported to affect productivity. Phylloxera is also reported in Mexico and Ecuador. CHADHA (1984) states that rootstocks will be necessary in India to overcome nematode problems, saline soils, low vine vigour and fruitfulness. In Thailand 1613 (Solonis x Othello) is used to some extent. The reported use of rootstocks in Ecuador includes local Criolla hybrids *(V. caribaea)*, Rupestris du Lot *(V. rupestris)* for phylloxera and SO 4 *(V. berlandieri x V. riparia)* and Richter *(V. berlandieri x V. rupestris)* for nematodes. Similarly, in Venezuela Criolla negra, 1103 Paulsen *(V. berlandieri x V. rupestris)* and 5 BB *(V. berlandieri x V. riparia)* are used for nematodes.

Pests and diseases

Copious quantities of fungicides are required for production of grapes in tropical environments. The *V. vinifera* varieties are susceptible to a large range of fungal diseases, a situation exacerbated by the tropical climate which favours microbial development. The fungal diseases anthracnose or black spot *(Elsinoe ampelina)*, downy mildew *(Plasmopara viticola)*, powdery mildew *(Uncinula necator)* and bunch rots, in particular *Botrytis cinerea* and miscellaneous secondary infections of damaged fruit are the major pests. Dead arm is reported as a problem in a number of countries although it is unclear whether it is *Phomopsis viticola* or dying arm *(Eutypa armeniacae)*. Unspecified rusts are reported as a problem in Asian countries.

Insect pests thrive under tropical conditions. The most serious problems are mealy bug (*Pseudococcus* spp.) and a range of mites including the bunch mites (*Brevipalpus* spp.) and *Eriophyes* spp. A diverse range of unspecified pests are also reported as problems. These include fruit piercing and sucking flies, moths, wasps, leaf hoppers and leaf skeletonizers, possibly thrips and aphids, stemboring beetles and American onion worm.

3. Breeding for tropical environments

Varietal information in the preceding sections indicates that tropical grape production has a narrow genetic base, limited to a narrow range of *V. vinifera* varieties and a few hybrid varieties grown for disease resistance. These include the *V. labrusca* hybrids Isabella, Delaware, Campbell Early, Kyoho, the complex French hybrids of American species, Villard blanc and Niagara and the *V. caribaea*, Criolla hybrids. More effort in vine breeding and varietal evaluation is required to fully exploit grapevine variability and develop varieties more suited to tropical environments. While the major benefits are likely to accrue from improved disease resistance, other areas of vine improvement must not be overlooked.

Physiological problems of poor budburst and apical dominance may be reduced by selection of varieties with a low chilling requirement, similar to stone fruit, or indirectly by the selection of varieties which are fruitful in basal nodes and suited to spur pruning. Selection of varieties which are more fruitful and develop larger bunches under tropical conditions which favour rapid shoot growth may improve productivity. The very high yields that are achieved with Anab-e-Shahi in India indicate that productivity should not be a limiting factor in tropical grape production. Fruit quality may be improved by selection of varieties with higher levels of acid and which mature to adequate sugar levels and have good fruit colour.

Priority should also be given to the development and selection of rootstocks for tropical conditions as they have the potential to regulate excessive vine vigour, reduce problems associated with soil type and soil born pests and improve vine longevity. For sandier soil types, in particular in drier regions, the nematode resistant rootstocks currently used for table grape production in Australia (Possingham *et al.* 1989) should be included in such a breeding and selection program, e.g. Ramsey *(V. champini)* or the lower vigour Teleki 5 A *(V. berlandieri x V. riparia)* and Schwarzmann *(V. rupestris x V. riparia)*. The drought tolerant types, e.g. 110 R and 1103 P (both *V. berlandieri x V. rupestris*) warrant study. Phylloxera resistant rootstocks selected for wetter areas in Europe, i.e. SO 4 and 5 BB (both *V. berlandieri x V. riparia*) should be included. The new selections of *V. rotundifolia* rootstocks developed by H. P. Olmo, University of California, Davis, which have some resistance to *Xiphinema index* nematode, have some potential to reduce fanleaf problems where it occurs and should also be tested. CSIRO has a rootstock breeding program which aims to develop multi-species complexes suited to a range of soil types incorporating genes for nematode resistance from *V. champini*, phylloxera resistance from *V. berlandieri*, *V. rupestris* and *V. riparia*, drought resistance, *V. rupestris* and tolerance of wetter conditions, *V. riparia*. Other species distributed in more tropical regions have also been included, i.e. *V. aestivalis*, *V. cinerea*, *V. caribaea*, *V. longii* and *V. rotundifolia*.

The major fungal disease problems, anthracnose, oidium, downy mildew and bunch rots found in the tropics have their origins in the American continent. Although there are varying degrees of susceptibility between various varieties of *V. vinifera*, which originate from the Central Asian/European regions, there appears to be little opportunity to breed disease resistant varieties without broadening the genetic base. Vine breeders at the turn of the century, both in Europe and the USA, who aimed to develop direct producers that were tolerant of phylloxera were also able to incorporate genes for disease resistance from various American species. These selections are commonly referred to as American hybrids, i. e. hyrids involving mainly *V. vinifera* and *V. labrusca* or French hybrids based on many American species, e. g. Villard blanc is an 8 species complex. Although some of these hybrids or their progeny are currently grown for disease resistance in the tropics for table grapes (e. g. Isabella, Kyoho, Campbell Early) or wine production (e. g. Villard blanc) their fruit characteristics are less than desirable as *V. labrusca* hybrids generally have a 'foxy' flavour. There is considerable scope to increase the resistance of grapes to diseases encountered in the tropics and to reduce the heavy reliance on chemical protection. Breeding programs now include routine screening for disease resistance by dual culture *in vitro* e. g. for downy mildew (STEIN *et al.* 1985; BARLASS *et al.* 1986) or oidium (STEIN *et al.* 1985). Detailed information can now be accessed by breeders to identify species and species combinations likely to be resistant to the various diseases. For example DOSTER and SCHNATHORST (1985) were able to show that cultivars of *V. labrusca* and hybrids between *V. vinifera* and *V. rupestris* were resistant to oidium. Most *V. vinifera* cultivars tested were not resistant. We also know that *V. labrusca* cultivars grown in the tropics are more resistant to anthracnose than *V. vinifera*. The Chinese have been particularly successful in the development of quality table grape varieties from hybrids of *V. labrusca* and *V. vinifera* (i. e. Fortuna 12, 14, 17, 18 and Phoenix 51). In the CSIRO breeding program, genes for resistance to downy mildew have been incorporated from complex hybrids. For example, Marroo Seedless, a cross of Carolina Blackrose and Ruby Seedless is resistant to downy mildew, even under wet tropical conditions in Townsville, a characteristic derived from its disease resistant breeding line which dates back to Villard blanc. Marroo Seedless is, however, susceptible to oidium. There is further potential to involve in breeding the Muscadine grape, *V. rotundifolia*, reported to be resistant to most diseases and also Asian species such as *V. amurensis* and *V. armata*.

There have been a number of new varieties recently released from breeding programs in the USA, reported to have disease resistant and acceptable fruit quality when grown in warm, humid environments in Florida, Arkansas and New York State. These varieties warrant testing in their own right and as parents in the tropics as they are resistant to anthracnose, oidium and powdery mildew and various bunch rots. They include the black *V. labrusca*, *V. vinifera* seedless selections, Reliance Seedless (MOORE 1983), Mars Seedless (MOORE 1985), and Einset Seedless (REISCH *et al.* 1986), very complex species hybrids involving *V. labrusca*, French hybrids and *V. aestivalis*, a native of Florida, Suwannee and Conquistador (MORTENSEN 1983), Orlando Seedless (MORTENSEN and GRAY 1987) and Remaily Seedless (POOL *et al.* 1981).

CSIRO Merbein has a hybridization program aimed at developing new varieties for tropical environments. A diverse range of genotypes with disease resistance, e. g. *V. rotundifolia* (DRX55), complex species hybrids such as Chambourcin, Muscat St. Vallier, Villard blanc, Aurelia, Carolina Blackrose, Lady Patricia, Illinois 271-1, S14664, SV 12-309, SV 12-303 and *V. labrusca* hybrids such as Isabella, Glenora, Mantey and Suffolk Red have been used in crosses with *V. vinifera* table grapes e. g. Muscat Hamburg. In addition to the named variety Marroo Seedless (CLINGELEFFER and POSSINGHAM 1988), a cross of Carolina Blackrose and Ruby Seedless, promising selections being evaluated include progeny from DRX55 x Aurelia, Carolina Blackrose x Flame Seedless, Kishmishi (a misnamed large, red berried seeded variety) x Lady Patricia, Bicane x Villard blanc, Muscat Hamburg x Lady Patricia, Blackrose x Illinois 271-1. In some cases 2nd and 3rd generation crosses have produced very complex and involved breeding lines. As well *in-ovulo* embryo culture from seedless x seedless genotypes (BARLASS *et al.* 1988) has been used to develop new breeding lines from material in the CSIRO germplasm collection or pollen imported from the USA.

4. Plant transformation

In addition to the conventional breeding strategies for tropical grapevine improvement, the emerging technologies of direct plant transformation must also be considered. The technology is already established for many herbaceous annuals and will doubtless be applied to woody perennials. Research within the CSIRO Division of Horticulture has been used to develop techniques for grapevine transformation and an experimental gene has been successfully introduced. The task lies ahead to introduce genes of economic importance. Of particular interest in relation to grapevine transformation is protection from fungal disease. Currently attention is being given to the response of plants to pathogenic infections. Many plants respond by synthesizing pathogenic response proteins (PR) which include hydrolytic enzymes to defend against pathogenic attack. Two such enzymes are chitinase which degrades chitin, the major cell wall component of oidium and β-glucanase which degrades β-glucans, constituents of cell walls of downy mildew hyphae.

In contrast to conventional breeding, where progeny are highly heterozygous and include varietal characteristics from both parents, a better approach might be to provide a selected variety with a gene for chitinase or β-glucanase or both, by plant transformation methodology. The aim would be to lyse the hyphae of invading fungal diseases. This would allow the conventional breeder to concentrate on the many pleiotropic (multigenic) gene characters which are not suited to these new methodologies, i. e. yield, flavours etc.

References

BARLASS, M.; MILLER, R. M.; ANTCLIFF, A. J.; 1986: Development of methods for screening grapevines for resistance to infection by downy mildew. I. Dual culture *in vitro*. Amer. J. Enol. Viticult. **27**, 61-66.

-- -- ; RAMMING, D. W.; DAVIS, H. P.; 1988: In-ovulo embryo culture: a breeding technique to rescue seedless x seedless table grape crosses. Austral. Grapegrower Winemaker, No. 272, 123-125.

CHADHA, K. L.; 1984: Grape research in India - priorities and suggested approach for the future. Indian J. Hort. **41**, 145-159.

CLINGELEFFER, P. R.; 1985: Specialised trellis design for table grape production. Proc. The Production, Promotion and Marketing of Western Australian Table Grapes, September, 1985, 68-71. Rural and Allied Industries Council, Perth, W. A.

-- -- ; 1987: Production of grapes in tropical areas. Proc. 2nd Natl. Table Grape Tech. Conf., July 1986, 46-49. Stanthorpe, Qld.

-- -- ; MAY, P.; 1981: The swing-arm trellis for Sultana grapevine management. S. Afr. J. Enol. Viticult. **2**, 37-44.

-- -- ; POSSINGHAM, J. V.; 1988: Marroo Seedless: A new table grape variety. Agricult. Sci. (Austral.) **1** (2), 18-19.

DOSTER, M. A.; SCHNATHORST, W. C.; 1985: Comparative susceptibility of various grapevine cultivars to the powdery mildew fungus, *Uncinula necator*. Amer. J. Enol. Viticult. **36**, 101-104.

MCCOLL, C. R.; 1986: Cyanamide advances the maturity of table grapes in central Australia. Austral. J. Exp. Agricult. **26**, 505-509.

MOORE, J. N.; 1983: 'Reliance' Seedless Grape. HortScience **18**, 963-964.

-- -- ; 1985: 'Mars' Seedless Grape. HortScience **20**, 313.

MORTENSEN, J. A.; 1983: 'Suwannee' and 'Conquistador' grapes. HortScience **18**, 767-769.

-- -- ; GRAY, D. J.; 1987: 'Orlando Seedless' grape. HortScience **22**, 327-328.

OLMO, H. P.; 1970: Report to the Government of India. FAO/UNDP Report No. TA 2825. FAO, Rome.

POOL, R. M.; REMAILY, G. W.; REISCH, B. I.; WATSON, J. P.; KIMBALL, J. H.; 1981: 'Remaily Seedless' grape. HortScience **16**, 232-233.

POSSINGHAM, J. V.; CLINGELEFFER, P. R.; 1986: Selection and breeding of table grapes for Australia. Proc. 19th Intern. Viticultural and Oenological Congr. 1986, Santiago Chile, 808-819.

-- -- ; -- -- ; KERRIDGE, G. H.; 1989: Developments in the Australian table grape industry. Proc. 20th Intern. Viticultural and Oenological Congr. (in press).

PUNSRI, P.; SUKUMALANDANA, C.; 1977: Grape growing in Thailand. In: CHADHA, K. L.; RANDHAWA, G. S.; PAL, R. N. (Eds.): Viticulture in Tropics, 24-31. Horticultural Society of India, Bangalore.

REISCH, B. I.; REMAILY, G. W.; POOL, R. M.; WATSON, J. P.; 1986: 'Einset Seedless' grape. HortScience **21**, 155-156.

ROJNIC, I.; ROMERO, T.; SALAS, A.; 1972: Manual Practico para el Cultivo de la Vid en Estado Zulia. Fondo de Desarrollo Fruiticola - Fondefru. Caracas, Venezuela.

STEIN, U.; HEINTZ, C.; BLAICH, R.; 1985: The in-vitro testing of grapevine cultivars for oidium and plasmopara resistance. Z. Pflanzenkrankh. Pflanzensch. **92**, 355-359.

Breeding table grapes in Brazil

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Abstract: Brazil has two distinct grape growing areas: the southern states of Rio Grande do Sul and Santa Catarina which produce almost all of the wine grapes; and Sao Paulo State, the major table grape growing area, followed by an incipient area in northeast region of Brazil (Sao Francisco River Valley).

The organized grape breeding program at Instituto Agronômico de Campinas (I.A.C.) was started in 1938 in Sao Paulo State, although crosses have been performed since 1897. In 1945, tropical American native *Vitis* species like *V. shuttleworthii*, *V. smalliana*, *V. gigas* and *V. caribaea* were introduced in the I.A.C. grape breeding program as vigor and disease resistance germplasm sources. Several French, Italian and American hybrids were used in the crosses as well.

As a result, a number of table grape cultivars have been released in the past 30 years and are used by grape growers as alternatives to Red Niagara, the main table grape cultivar in Brazil:

IAC 871-41 'Patricia': IAC 501-6 (IAC 8-5 x Pirovano 215) x IAC 544-14 (IAC 339-21 x IAC 287-2); IAC 8-5: Highland x Golden Queen; IAC 339-21: Muscat Hamburg x *V. cinerea*; IAC 287-2: Red Niagara x Jumbo. Patricia is a late variety, seeded, with large-size clusters, medium (5-7 g) black berries, neutral taste.

IAC 871-13 'A Dona': same parentage as Patricia, is a late, seedless variety with medium clusters and small red berries (requires gibberellic acid).

IAC 457-11 'Paulistinha': Niagara x Sultanina; it is an early, seedless variety, with medium clusters and small white berries (requires gibberellic acid).

The IAC cultivars can also be useful as germplasm sources:

IAC 1353-1 'Yole': Red Muscat x IAC 1038-3 (= IAC 853-33 x IAC 892-24). IAC 853-33: IAC 3912 (= *V. caribaea* x Muscat Hamburg) x IAC 526-4 (= *V. gigas* x Pearl of Csaba); IAC 892-24: IAC 704 (= IAC 394-14 x Rosaki rosado) x IAC 540-3 (= IAC 337-11 x IAC 287-2); IAC 394-14: SR (*V. shuttleworthii* x *V. rufotomentosa*) x White Muscat; IAC 337-11: Hogg Muscat x *V. cinerea*; IAC 287-2: Red Niagara x Jumbo.