Breeding Temperate Zone Fruits Requiring Low Chilling in Australia

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Abstract

Horticultural production in Australia is widespread occurring in many diverse climatic zones ranging from cool temperate to tropical. Between and within these zones, there have been attempts to diversify production through either the introduction of crops from similar regions of the world or by evaluating cultivars normally adapted to other climatic zones. In both cases there is often a need to identify and develop improved locally adaped genotypes through genetic improvement programs.

In developing cultivars of deciduous fruiting tree crops, research programs have involved introduction, breeding, selection and subsequently evaluation of horticultural performance under local conditions. Clearly winter chilling requirements are important considerations in these programs. Better adapted cultivars are needed to maintain or extend production in regions where winter chilling is either marginal or clearly insufficient for currently available cultivars.

This paper presents an overview of genetic improvement research current in Australia which is aimed at the development of temperate fruiting tree crops in regions where climate in terms of winter chilling minimizes their performance.

Introduction

Australia is a vast country extending from 113° 9′ to 153′ 39′ East and between 10° 41′ and 43° 39′ South (fig. 1). Accordingly Australia's climate varies markedly from region to region. A warm marine climate prevails in Tasmania whilst tropical climates feature in the Northern Territory, northern Western Australia and Queensland. The reader is referred to Papadakis (1975) who describes the range of climates which occur in Australia. As a result of this wide range of climatic conditions, it is possible to produce most horticultural crops in at least one region of Australia and for some species in many regions allowing production seasons to be extended beyond those normally experienced in other countries.

The history of horticultural development on Australia can be traced back to settlement by European immigrants in the 18 th century. Settlement occurred mainly in subtropical and temperate regions and horticulture developed close to main centers of population. As a consequence, and because Australian horticulture has developed largely to satisfy European tastes, the crops introduced and grown were mainly

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grapes, pome, stone and citrus fruits. Even two hundred years after European settlement, Australian horticulture is still dominated largely by these crops, although in a few cases new locally bred and selected genotypes have become the main cultivars grown. For example, the main mandarin cultivars grown are Imperial and Ellendale which were both selected as open-pollinated seedlings in Australia. Similarly, Australian horticulture is still mainly confined to the temperate and subtropical regions, although in the past three decades greater momentum has been directed at diversifying horticultural production.

Diversification of Australian horticulture probably commenced in earnest during the 1960s. Attempts have been made both successfully and unsuccessfully to expand horticultural production either in new regions, e.g. tropical, or within established regions using either new crops or cultivars of established crops selected to be better adapted to local conditions. Often the reason for extending production with the more traditional crops such as grapes and stonefruit has been to lengthen the period over which fresh fruit supplies are available on domestic markets. In this respect earliness has been of prime concern. In these instances, cultivars selected and adapted to other climatic regions have been evaluated in warmer regions where earlier ripening is likely to occur. Thus, for example, commercial plantings of table grapes for production of early ripening fruit are now estabilshed in both the dry and wet regions within the tropical zone (Possingham *et al*., 1989). Whilst grape production in these regions has been successful, there has been a need to develop vine management techniques to ensure economic viability. Although about 40% of Australia's land mass is located in the tropical zone, only 42% of this area is completely frost-free. As a consequence, grapevines go dormant in the dry tropics where winter frosts can occur. In this situation, winter chilling is inadequate to break dormancy and treatment with hydrogen cyanamide is used to promote uniform budburst and also to advance fruit maturity (see McColl, 1986). In other tropical regions where vines are not forced into dormancy, conditions lead to continuous, rapid and vigorous shoot growth. Under these conditions, the vines remain evergreen and twice-yearly pruning techniques (Clingeleffer, 1987) can be employed to ensure manageable vines and economic yields.

Whilst grapevine production has been extended into Australia's warmer regions by manipulating vines using various management techniques, an alternative approach is to breed and select cultivars (and rootstocks) more suited to tropical environments. Possingham *et al*. (1989) have suggested that physiological problems of poor budburst may be reduced by selecting genotypes with low chilling requirements. As a consequence of the potential for improving grape production in the tropical zone, promising hybrids from CSIRO's grape breeding program have been entered into evaluation trials in Australia's tropics.

There are other instances where horticultural diversification for the production of early season fruit has occurred between and within climatic zones. These processes have involved both crop management techniques and plant breeding to solve dormancy and associated production problems due to inadequate winter chilling. Examples to illustrate this involving stonefruit species will be described in a later section.

Other attempts at the diversification of horticultural production in Australia have involved the introduction of new crops which are successful in other regions of the world. These have then been evaluated under similar conditions in Australia. For example, the potential for Australia's tropical regions for the production of tropical fruits has been investigated following the introduction of tree crops such as litchi, cashew, durian, jackfruit and mangosteen. Similarly, temperate zone species new to Australia have been introduced from overseas and in some cases, new infant horticultural industries have developed within the subtropical and mediterranean subtropical zones (see Fig. 1). Examples of new developments include the persimmon and pistachio industries. Development of Australia's pistachio industry has involved evaluation of introduced cultivars, selection of locally adaped genotypes from open-pollinated seedling populations and, more recently, the initiation of a breeding program which incorporates selection for chilling requirement amongst other important characteristics. Aspects of the research which has led to the establishment of the Australian pistachio industry are described in a later section of this paper.

This paper provides an overview of genetic improvement research in Australia aimed at the development of new genotypes adapted to regions where winter chilling is limiting for currently available cultivars. This overview will concentrate firstly on stonefruit species, which are long-established crops in Australia, and secondly on the pistachio, which is a relatively new crop.

Genetic improvement of stonefruit in Australia

Prior to the late 1960 s, the stonefruit cultivars grown in Australia were either introduced from overseas or had arisen as bud sports or open-pollinated seedlings derived from imported cultivars. These were all public cultivars and nothing much changed with regard to the available spectrum of cultivars for a long time. Changes began, however, with regard to cultivar availability in the late 1960s and '70s. During this period, new peach and nectarine cultivars, which were largely in the public domain, were introduced from the USA (Topp and Russell, 1993). These introductions continued until the 1980s when a change occurred away from public domain to privately bred and patented cultivars. These introduced cultivars now account for an increasingly larger proportion of commercial plantings in Australia. In considering the future, Topp and Russell (1993) suggest that overseas introductions will continue to provide the majority of Australia's new cultivars. In addition, however, as a result of increased activity in breeding stonefruit in Australia, there will be more locally bred cultivars available. Regardless of whether the genetic improvenment of stonefruit is via overseas or local breeding programs, there is a clear need for cultivars adapted specifically to Australian climatic conditions. Chilling requirement is a key criterion for selecting cultivars which exploit fully Australia's diverse range of growing environments. The markets which need to be considered in these breeding programs include both domestic and export and these need to be serviced with early, mid-season and late fruit.

There are nine stonefruit breeding programs operating in Australia (see Topp and Russell, 1993). These programs deal with a range of stonefruits and are located in different climatic regions, which also correspond to the major production areas. Although they do not all address low chilling requirement specifically, by being located within different regions, the performance of hybrid populations will be affected by a range of environmental conditions, not least of which will be degree of winter chilling, characteristic of the area in which the program is based. Thus the apricot breeding program conducted by the South Australian Research and Development Institute at Loxton, South Australia is in the heart of Australia's dried apricot production region. As apricots are severely restricted in their ecological adaptation (Bailey and Hough, 1975), being generally only of economic importance in a relatively narrow range of environmental conditions, it is generally acknowledged that cultivars need to be selected in the region in which they are to be grown. This provides a sound reason for a local breeding program in the 600 chill units in the dry winter environment of South Australia's Riverland. Similarly, a low-and medium-chill appricot breeding program has commenced in Queensland by the Department of Primary Industries (Topp and Russell, 1933). There are no low-chill commercial apricots available, although the commercial cultivar Glengarry is early ripening and can be grown successfully in medium-chill areas. The Queensland program involves crossing Glengarry with other early flowering cultivars and then screening progenies for early flowering under Queensland conditions.

Thus, rather than developing and using controlled chill requirement screening tests (eg Smith *et al*., 1992), Australian stonefruit breeding programs are being conducted in the regions where improved cultivars are required and hybrid populations are evaluated under specific local conditions. High quality genotypes, which are too low-chill for use where they are bred, are sometimes selected from breeding populations that are segregation for chilling requirement. These genotypes require testing for adaptation in warmer locations. For example, medium-chill segregants from the Queensland Department of Primary Industries' plum breeding program at the Granite Belt are tested in warmer growing regions of Queensland and Western Australia.

The objectives of the Japanese plum breeding program of the Queensland department of Primary Industries are early ripening, high quality and disease resistance. The breeding strategy outlined by Topp and Russell (1989) has involved the use of early and mid-season cultivars in first generation crosses followed by second generation crosses between selected hybrids and overseas germplasm, including low-chill University of Florida plums (see Topp and Sherman, 1990). In breeding for early ripening there is often indirect selection pressure for low chilling requirement. Low-chill stonefruit genotypes flower earlier than high-chill genotypes and so at a given harvest date will have a longer fruit development period. Genotypes with longer fruit development periods tend to produce fruits that are larger and sweeter than similar maturity time competitors with shorter fruit development periods. Hence a breeder selecting for the highest quality fruits ripening in a given time slot will often select low-chill genotypes. As a result, it is often worth testing the earliest ripening selections from high-chill breeding programs as potential sources of lower-chill germplasm.

The peach program conducted by the Victorian Department of Agriculture at Tatura provides another example of breeding for improved cultivars under local conditions. Canning peach cultivars and hybrids are evaluated for commercial characteristics and winter chilling requirements. As a part of this program, low chilling genes have been obtained through the use of South African cultivars as breeding parents. The winter chilling requirement for 36 cultivars has been measured over the Southern Hemisphere winter period of May to September. Early results have shown that in all cultivars the chill requirement measured as hours below 7°C varies substantially from year-to-year (Jerie, unpublished data). The relative ranking of horticultural performance between cultivars from year-to-year, however, is a better method of assessing promising genotypes for adaptation to specific regional chilling characteristics than trying to correlate hours of chilling to budburst and other indicators of plant response. Again this research supports the argument for locally based genetic improvement programs.

According to Possingham and Wren (1988), cherries are Australia's second most valuable fruit crop, ranking only behind strawberries on a value per ton basis. As with other stonefruits, early cherries on domestic markets provide high returns to growers and early cultivars are sought after. Selection for low-chill cultivars, however, has not been a feature of the cherry breeding program conducted by the South Australian Research and Development Institute at Lenswood. The aims of this program are to produce self-fertile cherries with export quality fruits which are large and cracking-resistant. Currently, Austra-

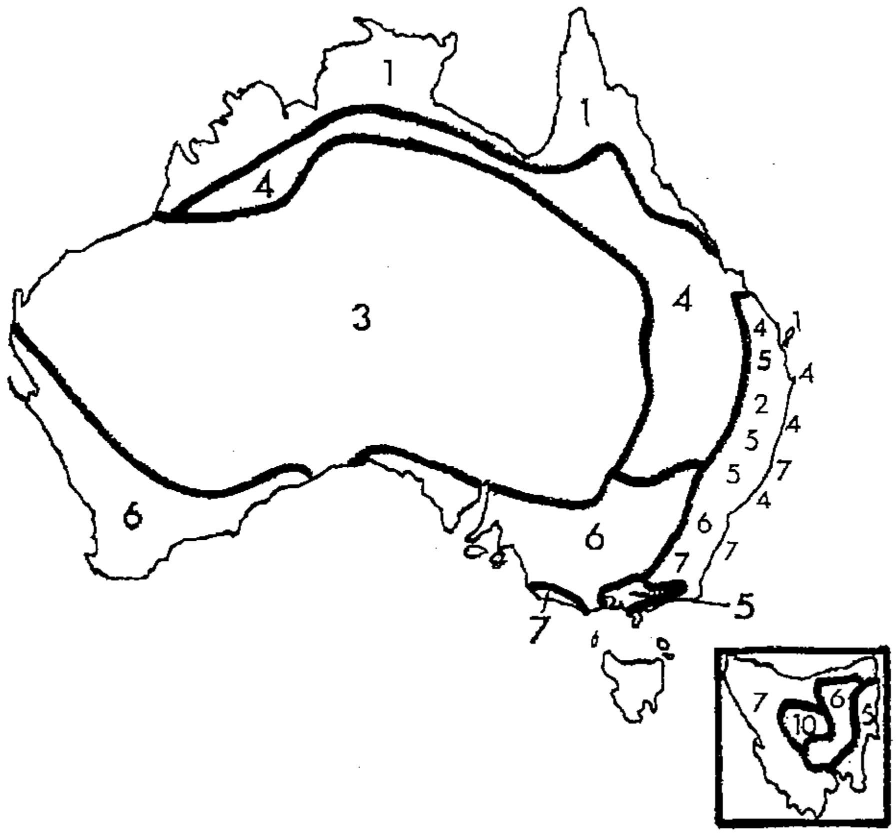

Fig. 1 A schematic map of the climates of Australia (from Papadakis, 1975).

1. Tropical. 2. Tierra Fria. 3. Desert. 4. Subtropical. 5. Pampean. 6. Mediterranean. 7. Marine. 10. Alpine.
(For further climate descriptions within the major zones see Papadakis, 1975.)

lia's main cherry-growing regions in Victoria, South Australia and NSW are located in areas where winter chilling is generally adequate for the commercial high-chill cultivars. However, mild winters occasionally occur and result in reduced yields. Large yield reductions occurred in a trial conducted at Lenswood following a mild winter in 1988 (Granger and Frensham, 1991). The total number of chill units recorded at Lenswood in 1988 was only 68% of the 20-year average of 2482. In considering the impact of enhanced greenhouse effect on warming and thus winter chilling, Pittock and Whetton (1990) have raised a possible scenario which suggests warmer winters for Victoria, and thus by inference equivalent areas in other southern Australian states. Pittock and Whetton have therefore suggested that programs need to be implemented for the introduction and/or breeding of cultivars with lower chilling requirements. If these projected scenarios prove to be accurate, then selection for low chill requirement may become a feature of cherry breeding programs in Australia.

Even if the scenario painted by Pittock and Whetton does not materialize, the development of low-chill cherry cultivars could lead to an expansion of the industry into other regions. For example, the Sunraysia region in N.W. Victoria is marginal for cherry production due to inadequate winter chilling (see Table 1 for winter temperatures), yet early cherries can be produced by applying growth regulators such as hydrogen cyanamide during dormancy (Sykes, unpublished data). Low-chill cherry cultivars could be grown in warmer areas such Sunraysia for early production of fruit and a program at the University of Western Sydney has commenced to produce low-chill genotypes in the range of 150-400 chill units (Topp and Russell, 1993). This program involves testing many close relatives from the cherry family which originate in a range of diverse regions. Clearly this is a long term project, yet the potential returns in expanding production of a high value crop may be far reaching.

Other stonefruit breeding programs are based in Queensland aimed at producing low-and medium-chill, high quality non-melting flesh peaches and nectarines. There is a need for greater efforts in breeding other low-chill stonefruit cultivars which have improved agronomic characteristics. The low-chill peach cultivar Flordaprince is the earliest maturing cultivar in Australia (Allan *et al*., 1993) and although its fruits are of good quality, they are small. Whilst Allan *et al*. (1993) have investigated and demonstrated the effects of girdling as an effective management practice for increasing fruit size, a genetic solution to this problem is more desirable so that production costs can be reduced.

Genetic improvement of pistachios in Australia

Pistacia vera is a deciduous tree grown successfully in many parts of the world for the edible nuts it produces. Climatically, pistachios require hot, dry weather in summers and early autumns, especially at harvest, and winters cool enough to provide sufficient chilling to ensure regular budburst in spring. Chilling requirement, in terms of number of hours at or below 7.5°C has not been determined precisely. However, US experience suggests that the cultivar Kerman requires about 1000 hours below 7.5°C to satisfy winter chilling requirements (Crane and Iwakiri, 1981; Crane and Maranto, 1988; Parfitt, 1991), whereas cultivars which originated in the Mediterranean region seem to require less (Crane and Iwakiri, 1981). Being a dioecious, wind-pollinated species, *Pistacia vera* requires sufficient winter chilling to ensure uniform budburst, growth and synchrony of flowering. Inadequate winter chilling was observed at Merbein in 1988 when only 619 hours below 7.5°C were recorded from April to September inclusive (Table 1). In spring 1988, budburst was irregular and flowering was delayed with a lack of synchrony between male and female genotypes. As a result yields in Autumn 1989 were reduced. These symptoms were similar to those reported by Crane and Takedo (1979) following a mild winter in California. Clearly inadequate winter chilling can affect pistachio production and there is scope for developing technology to overcome these problems.

As with a range of other deciduous fruit and nut tree species, growth regulators such as hydrogen cyanamide can be used to promote uniform budburst and bloom synchrony in pistachios (Pontikis, 1989; Ferguson and Sykes, 1933). In addition to this approach, however, it should be possible to breed and select genotypes specifically adapted to local winter chilling regimes and thus provide a genetic solution. This latter approach has been incorporated into the pistachio breeding program conducted by CSIRO at Merbein, Victoria.

Table 1 Hours below 7.5°C recorded between April and September inclusive in the Sunraysia region, NW Victoria

Year	hours	Year	hours
1960	821	1973	597
1961	563	1974	584
1962	581	1975	751
1963	824	1976	1178
1964	761	1977	1028
1965	936	1986	806*
1966	1046	1987	748
1967	887	1988	619
1968	862	1989	975
1969	830	1990	791
1970	849	1991	749
1971	734	1992	904
1972	700	1993	620**

* records were not been obtained for 1978–1985
* * records have not been obtained for September 1993

Genetic improvement of pistachios by CSIRO commenced in the mid–1960s and resulted in the selection of an open-pollinated seedling which was released as the cultivar Sirora (Maggs, 1981). The major adoption of Sirora by the Australian pistachio industry and the fact that it was selected from a small population of 13 seedlings, has indicated that there is potential for further genetic improvement via a more structured breeding program.

Historically, pistachio cultivars have been obtained in regions where they have been cultivated by selecting from either wild populations or seedlings grown from selected mature lines. Sirora originated via the latter avenue. Selection of other new cultivars (Chernova and Olekhnovich, 1977; Popov, 1979; Bolotov, 1979; Pontikis, 1986) and attempts at artificial hybridization have been reported (Whitehouse *et al*., 1964; Grundwag, 1975). Recently pistachio breeding programs have commenced in California, USA (Parfitt *et al*., 1990) and Australia.

The general aims of the various pistachio breeding and selection programs in different countries are similar. The single most important criterion which sets them apart, however, is their location. That is, for example, CSIRO's breeding program is based in Australia's Murray Valley whilst the University of California's program is conducted under Californian conditions. Very little is known about the inheritance of key characteristics of pistachios. Thus, little is known about genotype and environment interaction and whether or not a cultivar grown successfully in one area will perform equally well in another. Kerman is the main cultivar grown in California whereas the Australian industry has largely ignored Kerman choosing Sirora for its major cultivar. Prior to intiating a more structured genetic improvement program for pistachios better adapted to Australian conditions, CSIRO had conducted research in many areas related to pistachio cultivation. Observations concerning budburst, flowering times and bloom periods recorded over many seasons have supported data published by other laboratories and have indicated the potential for selecting genotypes which respond to varying amounts of winter chill. These observations have also enabled selection of male genotypes which are synchronised with female cultivars (Needs and Alexander, 1985). Recently observations for existing cultivars have been supported by data collected from hybrids between early and late budburst genotypes (Sykes and Lewis, unpublished data) indicating a genetic basis to the published variation.

Both Spiegal-Roy *et al*. (1972) and Crane and Iwakiri (1986) reported Sfax and Kerman as early and late cultivars respectively. These reports support Crane and Iwakiri's (1981) statement that cultivars which originated in the Mediterranean region have lower winter chilling requirements compared to the Californian selected Kerman. Sfax, said to be a cultivar formerly grown around the town of Sfax in Tunisia, was introduced to the USA from Algeria (Joley, 1969). Being in a coastal region, the town of Sfax (34° 45′ N) has been described by Papadakis (1975) as having a subtropical, semi-arid mediterranean climate similar to Merbein. Kerman was selected as an open-pollinated seedling grown at the US Plant Introduction Station at Chico (39° 46′ N), California from seed collected in Iran (Brooks and Olmo, 1972). The 5° difference in latitude between the respective regions where they were selected possibly explains the difference between Sfax and Kerman with regard to time for budburst and flowering. Having originated in a cooler region, Kerman would appear to have a higher winter chilling requirement.

Observations at Merbein (Needs and Alexander, 1985) support the differences between Sfax and Kerman suggesting that Sfax requires less winter chilling than Kerman. Other observations (Sykes and Lewis, unpublished) made in 1988 following a mild winter lend further support in that Sfax was unaffected whereas budburst and flowering in a range of other varieties, including Kerman and Sirora, were delayed and irregular. The data in Table 1 suggest that approximately 25% of winters at Merbein will provide inadequate chilling for cultivars such as Kerman. This supports the argument for developing better adapted genotypes.

Sfax has been included as a parent in CSIRO's pistachio breeding program as a source of a number of important characterisics including earliness. Other parents include local open-pollinated selections, which also vary for budburst and flowering times, as well as other named cultivars such as Kerman and Sirora. Being a dioecious species, male parents have been locally selected open-pollinated seedlings and these have been crossed to the female parents in a North Carolina Model 2 design (see Mather and Jinks, 1971). Thus all males have been crossed to all females employing the methods described by Vithanage and Alexander (1985). Observations on the families which resulted from this series of crosses have demonstrated significant effects of both male and female parents on time of budburst and flowering, with progenies from early parents having earlier mean budburst and flowering times than progenies involving late parents (Sykes and Lewis, unpublished data). It appears feasible to breed and select for chilling requirements in pistachios if earliness is a function of winter chilling. For the cultivar Sfax, this appears to be a justified conclusion.

The observations reported above have all been recorded under natural conditions at Merbein and the response (i.e. budburst and flowering times) of the various cultivars, open-pollinated seedling selections and hybrids have all been dependent on year-to-year fluctuations in winter conditions. Although attempts have been made at Merbein to develop empirical screening procedures involving artificial chilling regimes followed by evaluation under controlled conditions, the preferred method for hybrid assessment with regard to response to winter chilling remains a field assessment over severl years in which local climatic variables are an intrinsic part of the evaluation process. This approach enables selection of the best genotypes under local conditions based on their overall performance of which adaptation to local chilling regime is one component.

Concluding remarks

In attempting to expand and diversify deciduous fruiting tree production in Australia, there is clearly a requirement to identify and develop through genetic improvement programs improved locally adapted genotypes with respect to winter chilling regimes. Depending on crop, this may require the use of low and medium-chill germplasm or may depend on plant breeders' skills to produce more finely tuned genotypes to minimise the effects of year-to-year fluctuations in winter climates. This paper has provided research overviews of both scenarios. Clearly the aims of these improvement programs are to produce superior cultivars for Australia conditions. In this respect introduction of new cultivars from overseas may be important, but unless cultivars are bred and developed under local, and sometimes unique conditions, as can be the situation with regard to winter chilling, local industries will never be confident that they are growing the best available cultivars. By developing an industry purely on introduced cultivars, growers may be using genotypes bred and selected specifically for other environmental conditions with the hope that they will be adapted perfectly to local conditions.

In developing new cultivars adapted to local winter chilling regimes, Australian breeders have depended largely on screening and evaluating breeding populations under the conditions in which new cultivars are required. Whilst empirical screening tests under controlled conditions and attempts to correlate hours of natural chilling to budburst and flowering have been investigated, the overall performance of genotypes from budburst to harvest over several years is crucial in making selections for further evaluation and eventual cultivar release. Chilling requirement is only one of many characteristics which breeders of deciduous fruiting woody perennials must consider in achieving their goals.

References

1) Allan, P., George, A. P., Nissen, R. J. and Rasmussen, T. S. (1993): Effects of girdling on time on growth, yield, and fruit maturity of the low chill peach cultivar Flordaprince. *Aust. J. Exptl. Agric.* 33, 781-785

2) Bailey, C. H. and Hough, L. F. (1975): Apricots, *In* ; Janick, J. and Moore, J. N. (eds.) Advances in Fruit Breeding. Purdue Univ. Press, West Layfayette, Indiana, 367-383.

3) Bolotov, S. (1979): Best forms of pistachio in southern Kirgizia. *In* : Bioekol. issled. vorekhovoplod, lesakh Yuzhn, Kirgizil, Furnze, Kirgizssr, from *Referativnyi Zhurnal* (1979) 6.55.747, [Russian].

4) Books, R. M. and Olmo, H. P. (1972): Register of new furit and nut varieties (second edition). Univ. of California Press. Berkeley, Los Angeles, London, 487

5) Chernova, G. M. and Olekhnovich, G. S. (1977): Breeding *Pistacia vera* in Tajikistan. *Subtropicheskie Kul'tury*, 5, 168-170.

6) Clingeleffer, P. R. (1987): Production of grapes in tropical areas. *Proc. 2nd Natl. Table Grape Conf.* July 1986, 46-49. Stanthorpe, Queensland, Australia.

7) Crane, J. C. and Iwakiri, B. T. (1981): Morphology and reproduction of Pistachio. *Hort. Rev.*, 3, 376-393.

8) Crane, J. C. and Iwakiri, B. T. (1986): Pollination and blooming habit of the pistachio, *California Pistachio Industry, Ann. Rep. – Crop Year* 1985-1986, 119.

9) Crane, J. C. and Maranto, J. (1988): Pistachio production Univ. of California, Division of Agriculture and Natural Resources Publication No.2279.

10) Crane, J. C. and Takeda, F. (1979): The unique response of the pistachio tree to inadequate winter chilling. *HortScience*, 14, 135-137.

11) Ferguson, L. and Sykes, S. R. (1993): Using hydrogen cyanamide and severe pruning to accelerate pistachio bloom. *Proc, Plant Growth Regulator Soc. America*, 20, 186-190.

12) Granger, A. R. and Frensham, A. B. (1991): Effect of three cherry rootstocks on the yield and fruiting of four sweet cherry (*Prunus avium* L.) varieties. *Aust. J. Exptl, Agric*, 31, 567-573.

13) Grundwag, M. (1975): Seed set in some *Pistacia* L. (Anarcardiaceae) species after inter-and intraspecific pollination. *Israel J. Botany*, 24, 205-211.

14) Joley, L. E. (1969): Pistachio *In* : Jaynes R. A. (ed.): Handbook of North American nut trees, The Northern Nut Growers Assoc., 348-361.

15) McColl, C. R. (1986): Cyanamide advances the maturity of table grages in central Australia. *Aust. J. Exptl, Agric.* 26, 505-509.

16) Maggs, D. H. (1981): Pistachio variety SIRORA.*J. Aust. Inst. Agric. Sci.* 1981, 109-110.

17) Mather, K. and Jinks, J. L. (1971): Biometrical Genetics; the study of continuous variation. Chapman and Hall Ltd., London. 382 pp.

18) Needs, R. A. and Alexander, D. McE. (1985): Propagating male pistahio trees. *Australian Horticulture*, 83 (8), 26-30.

19) Papadakis, J. (1975): Climates of the world and their potentialities. Av. Cordoba 4564, Buenos Aires, Argentina.

20) Parfitt, D. E. (1991): Development of pistachio as a crop in the United States. *Ann. Rep. Northern Nut Growers Assoc.*, 82, 135-143.

21) Parfitt *et al*. (1990): Pistachio cultivar improvement – 1991, *California Pistachio Industry, Ann. Report-Crop Year* 1990-91, 118-119.

22) Pittock, A. B and Whetton, P. H. eds. (1990): Regional impact of the enhanced greenhouse effect on Victoria. Annual Report 1989-90, Climate Impact Group, CSIRO Division of Atmospheric Reserch.

23) Pontikis, C. A. (1986): 'Ponikis' Pistachio,*HortScience*, 21, 1074
24) Pontikis, C. A. (1989): Effects of hydrogen cyanamide on bloom advancement in female pistachio (*P. vera* L.) *Fruit Varieties J.*, 43, 125-128.
25) Possingham, J. V. and Wren, R. A. (1988): Australia's horticultural industries and their potential for future development. *In*: Potential for the Australian Horticultural Industry, Convenor Pitman M.G., Australian Academy of Science, September 1988.
26) Popv, K. K. (1979): Variability of pistachio nuts on the Apsheron peninsula. *Rastitel'nye Resurty*, 15, 127-131.
27) Possingham, J. V., Clingeleffer, P. R. and Kerridge, G. H. (1989): Breeding grapevines for tropical environments. In: *Proc.* 5 *th Intern, Symp. on Grape Breeding*, 12-16 Sept. 1989, St. Marin/Pfalz, FR of Germany, *Vitis special issue* 1990, 169-77.
28) Smith, W. S., Carroll, B. L. and Cheary, B. S. (1992): Chilling requirement of pecan. *J. Amer. Soc. Hort, Sci.*, 117, 745-748.
29) Spiegal-Roy, P., Assaf, R and Garmi, I, (1972): Essais d'acclimatation et de culture du pistachier (*Pistacia vera*) en Israel. *Fruits*, 27, 619-625.
30) Topp, B. L. and Russell, D. M. (1989): Breeding early ripening Japaniese plums. *Acta Horticulturae*, 240, 27-30.
31) Topp, B. L. and Russell, D. M. (1933): Stonefruit breeding in Australia. In: "The nature of the nineties" Proc. of a Pome and Stonefruit seminar, July 27, 1993, Batlow, NSW, Australia.
32) Topp, B. L. and Sherman, W. B. (1990): Potential for low chill Japanese plums in Florida *Proc. Fla, State Hort. Soc.*, 103, 294-298.
33) Vithanage, H. I. M. V. and Alexander, D. McE. (1985): Synchronous flowering and pollen storage techniques as aids to artificial hybridization in pistachio (*Pistacia* spp.) *J. Hort. Sci.*, 60, 107-113.
34) Whitehouse, W. E., Kock, E. J., Jones, L. E., Long, J. C. and Stone, C. L. (1964): Influence of pollens from diverse *Pistacia* species on development of pistachio nuts.*Proc. Am. Soc. Hort. Sci.*, 84, 224-229.

Discussion

Dennis, F. (USA): What is the source of low chilling characteristic in cherry? Are other species of *Prunus* being used ?

Answer: The information presented in the paper was provided by the second author, Bruce Topp. Research is carried out by Graeme Richards, University of Western Sydney, Richmond, NSW, and involves testing many close relatives from the cherry family which originate in a range of diverse regions, including Southeast Asia. I understand that other species of *Prunus* are being used.

Answer: Granger, A. (Australia): Wide crosses are being made with low chill *Prunus* species sourced from around the world with *Prunus avium*-sweet cherry. Some of the materials originate from China.