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Fruit Varieties Journal 49(3):152-157 1995

Advancement of the Australian Disease Resistant Apple Breeding Program by Cooperation with USA Programs

STEPHEN J. TANCRED,[1] JAMES N. CUMMINS,[2] SHANE R. DULLAHIDE,[1] ALDO G. ZEPPA[1] AND JOHN B. HEATON[1]

Abstract

The Australian disease-resistant apple breeding program has been conducted at Stanthorpe since 1984. High fruit quality and resistance to *Venturia inaequalis* and *Podosphaera leucotricha* are the joint aims. Visits in 1984 and 1991, by fruit breeders from the USA breeding programs, and germplasm exchanges have advanced the program. A cooperative pollination project in 1993 enabled advanced disease resistant cultivars from the USA to be incorporated into the program. Seventy-five thousand seedlings have been screened for disease resistance and are being evaluated for fruit quality.

Australian Apple Breeding

Since the 1850s nearly forty new Australian apple cultivars have been produced from organized breeding programs and by selection of chance seedlings. Growers, nurserymen, private breeders and State Departments have all played a role and several Australian cultivars have found a place in world pomology (10). Breeding for disease resistance in apples was begun in Australia by the New South Wales Department of Agriculture in the 1920s at Bathurst. The cultivar 'Redbow,' which is resistant to both apple scab (scab), *Venturia inaequalis* (Cke.) Wint., and powdery mildew, *Podosphaera leucotricha* (Ellis. & Everh.) E. S. Salmon, was released in 1961 (5). Since 1964 the Queensland Department of Primary Industries had been breeding high-quality early-season apples at the Granite Belt Horticultural Research Station (GBHRS) and three cultivars have been released to date (10). However the production of populations for selection of disease resistance was not initiated in Australia until the eminent apple breeder, the late Professor L. Fredric Hough, visited in 1984 and the subsequent importation of disease resistant seeds and scionwood from the USA. Professor Hough was the former apple breeder associated with the cooperative breeding program of Purdue University, Rutgers University and the University of Illinois, known as the PRI program (3).

In 1984 the breeding objectives were expanded to include resistance to apple scab and powdery mildew due to environmental reasons, to reduce production costs and because of the developing resistance of *V. inaequalis* to benzimidazole fungicides (1). Our breeding strategy has been to cross disease-resistant parents with different

[1]Granite Belt Horticultural Research Station, Department of Primary Industries, PO Box 501, Stanthorpe, Queensland 4380, Australia.
[2]New York State Agriculture Experiment Station, Geneva, New York 14456-0462, United States of America.

high-quality recurrent parents. This modified backcrossing is similar to the approach taken in the USA programs (8). Between 1985 and 1989 some seedlings were produced with the primary objective of powdery mildew resistance. Currently most seedlings are screened for resistance to apple scab at a young age, then for powdery mildew tolerance in the orchard.

In 1991 the Australian Apple and Pear Growers Association set a target to reduce pesticide use by 50% by 1996 (9). However this objective may be difficult to achieve using the present high quality commercial cultivars because often these are disease susceptible. The industry goal to reduce pesticide use has reinforced the need for disease resistance breeding.

Key elements of an efficient and successful breeding program include the choice of suitable parents and use of appropriate and rigorous progeny screening methods. To achieve the latter, screening methods developed in the USA over a period of 40 years were successfully adopted by the breeding team (6, 7). Screening out susceptible seedlings at an early stage enables progeny populations to be substantially reduced before field planting, thus decreasing costs and increasing the efficiency of breeding.

There were many constraints to parental selection to meet our program needs. Parents were chosen for high fruit quality characteristics and/or robust disease resistance, but parental selection was hampered by a shortage of resistant cultivars. Due to time delays and cost restrictions associated with plant quarantine the number of overseas parental cultivars and the speed with which they could be obtained was limited. Unfortunately, the disease resistant cultivars introduced from overseas are often not adapted to local growing conditions or suited to local markets. While several Australian chance seedlings are resistant to apple scab they are of lower fruit quality (10).

Varieties from other breeding programs were desired for parents, but apple pollen cannot be brought into Australia for use in hybridizations because of the risk of surface contamination with fireblight, (*Erwinia amylovora* (Burrill) Winslow et al.). Although apple seeds may be imported with no risk of fireblight infection, seeds were often open-pollinated and the supply of seed relied on the goodwill and resources of overseas collaborators. The ability to use suitable cultivars to generate seed of known parentage would be of great advantage. A solution to the problem of limited germplasm resources was identified in the review of apple and pear variety improvement in Australia by the Horticultural Research and Development Corporation (HRDC) (4). A recommendation was made that pollen from a range of apple varieties that perform well in Australia be transported to the USA and hybridized with the most advanced disease-resistant cultivars available, with the resultant seed being sent back to Australia for screening and selection in the GBHRS program. This is feasible because no plant quarantine restrictions apply for the entry of apple pollen into the USA and

Table 1. Seedlings produced in the Queensland apple breeding program, 1966 to 1994.

Primary breeding objective	Years crossed	Number of seedlings
Early season of ripening	1966-1993	25,020
Powdery mildew resistance	1985-1989	20,553
Apple scab resistance	1985-1994	75,849
Total		121,422

Table 2. Parentage, glasshouse and screening data of apple seedlings produced in the 1993 cooperative pollination project.

Seed parent	Pollen parent	Seeds produced	% Seeds germinated	% Seedlings[E] retained	No. seedlings[F] field planted
Coop 25[A]	Liberty	2425	99	21	96
Enterprise[B]	Bonza	1	100	0	6
Enterprise[B]	Fuji	7	100	17	6
Enterprise[B]	Splendour	2	100	14	6
Enterprise[B]	Sundowner	17	100	53	6
Fuji	Goldrush	183	99	30	44
Gala	Liberty	108	94	8	19
Gala	Enterprise	23	83	22	9
Golden Del.	Enterprise	813	89	26	60
Goldrush	Abas	432	99	27	78
Goldrush	Bonza	372	99	21	42
Goldrush	Earlidel	128	98	18	29
Goldrush	GB 65-1	284	98	25	201
Goldrush	Lady Williams	497	98	10	40
Goldrush	Royal Gala	1294	98	17	178
Goldrush	Summerdel	1581	99	18	313
Liberty	Abas	13	92	45	5
Liberty	Bonza	676	97	22	113
Liberty	Braeburn	1068	96	27	200
Liberty	Earlidel	1254	97	23	178
Liberty	Enterprise	147	95	50	51
Liberty	Fuji	707	99	27	154
Liberty	GB 63-43	684	96	21	101
Liberty	Goldina	686	97	19	41
Liberty	Granny Smith	1010	96	43	177
Liberty	Lady Williams	756	97	25	173
Liberty	Pink Lady	3814	97	13	402
Liberty	Royal Gala	586	96	28	116
Liberty	Splendour	933	94	20	196
Liberty	Summerdel	1569	93	25	307
Liberty	Sundowner	668	97	11	64
Splendour	Goldrush	59	98	21	40
NY65707-19[C]	Granny Smith	413	92	29	128
NY73334-35[C]	Abas	115	83	23	12
NY74840-1[C]	Summerdel	666	96	3	38
8C-5-62[D]	Enterprise	310	94	8	21
8C-31-110[D]	Liberty	680	91	36	190
8H-7-2[D]	Redfree	179	96	25	27
8H-9-2A[D]	Sir Prize	15	87	0	0
8S-46-2[D]	Goldrush	2105	99	21	309
Average			95.7%	23.3%	
Total		27,280			4176

[A]Advanced selection from PRI cooperative program.
[B]Low seed numbers are usual when Enterprise is emasculated and used as a seed parent (J. Janick pers comm.).
[C]Advanced selections from NYSAES, NY.
[D]Advanced selections from Summerland, BC.
[E]Only seedlings that exhibited a strongly resistant reaction to Venturia inaequalis were retained.
[F]Additional seedling losses occurred after disease screening and before field planting due to normal glasshouse mortalities.

apple seeds can be imported into Australia for general use after a surface sterilization treatment. This proposal was acceptable to the Australian Quarantine and Inspection Service and was adopted by HRDC.

1993 Australian-USA Cooperative Project

Pollen collection, storage and transport. Pollen from 15 apple cultivars (Table 2) was obtained from trees at GBHRS during the spring of 1992. Blossoms were harvested at the balloon stage to avoid contamination from visiting bees using the pollen collection methods described by Brown (1975). About 9 ml of dry pollen was collected from each cultivar. This was divided into five aliquots and complete sets of 15 vials were stored in freezers at five sites in Australia and the USA (Purdue and Cornell Universities). On 24th April 1993, the pollen vials were transported in refrigeration by the senior author to the USA. The pollen that had been forwarded to Purdue and Cornell Universities in October 1992 was recovered and remixed to ensure viability of pollen in case poor storage had occurred in some subsets.

Pollination sites and procedures. Three pollination sites were chosen for their availability of disease-resistant parent trees and geographic spread, namely: Western Maryland Research and Education Center (WMREC), Keedysville, Maryland; Purdue University, West Lafayette, Indiana; New York State Agriculture Experiment Station (NYSAES), Geneva, New York. Three diverse sites were chosen to reduce the risk of a damaging late spring freeze in one area and to allow a progression of crosses to be made. In addition, Dr. David Lane, apple breeder at the Summerland Research Station in British Columbia, Canada made five crosses and forwarded some 2190 seeds to Australia.

At WMREC, pollination tents were made from parachutes that were suspended on pipe frames and placed over large apple trees. These tents excluded bees and allowed pollination of opening blossoms without floral emasculation. At NYSAES and Purdue University, all pollinations were done on emasculated flowers. Although this method is more disruptive to the developing embryo and fruit set is usually lower (2), assistance from experienced labor at these sites allowed extra flowers to be pollinated to compensate.

Seed collection and treatment. Fruit were harvested in August-October 1993 and cool stored for a short period before seeds were cut from fruit. Dry seed was sent to Australia from WMREC and NYSAES but the seed from Purdue was kept in moist paper towel. Upon receipt, the seeds were stored cool (5 to 16°C), then surface sterilized by immersion in 0.1% sodium hypoclorite for 10 minutes then triple rinsed with distilled water. Stratification on moist filter paper at 2° C for 6-12 weeks overcame seed dormancy and germinating seeds were sown into pasteurized potting mix.

Disease resistance screening. Seedlings were screened at the 3-5 full leaf stage for apple scab resistance as described by Heaton et al. (1991 and 1994). This method has been proven to be effective and well correlated with disease resistance in the orchard (7).

Seedling Production

A total of 121,422 apple seedlings have been produced for selection since 1964 in the Queensland apple breeding program (Table 1). Of the 75,848 seedlings produced for screening for resistance to apple scab, 34% came from the 1993 USA and Canadian pollinations. (Figure 1). A full account of the 1993 USA pollinations is presented in Table 2. Several crosses were repeated at each location. The total seeds produced at each location are; Maryland—11,209, New York—5,742, Purdue—7,040, British Columbia—3,289. An additional 7,093 seeds were produced

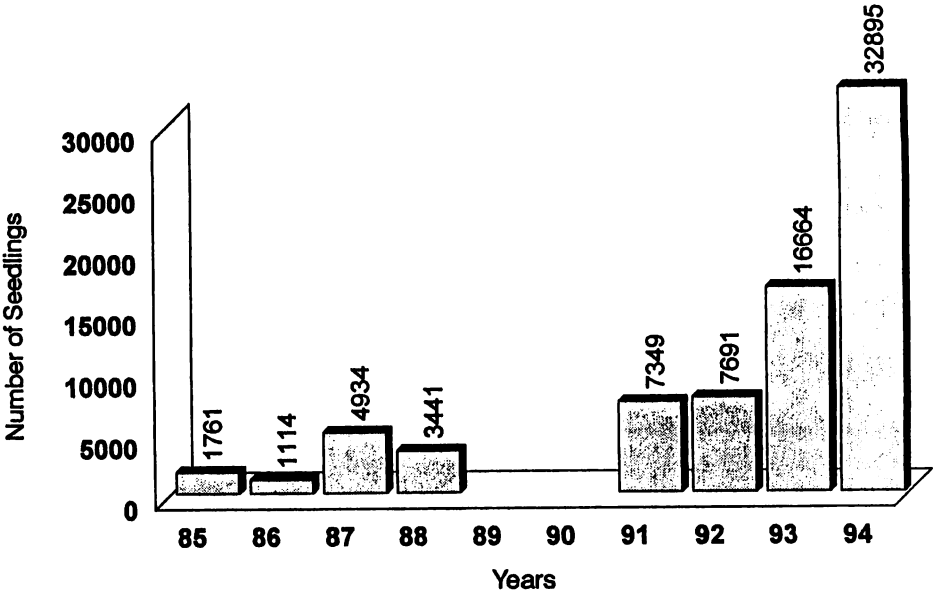

Figure 1. Annual population of apple seedlings screened for resistance to apple scab *(Venturia inaequalis)* at Stanthrope, Australia.

by crosses performed in October 1993, i.e. the southern hemisphere spring, at Stanthorpe, using resistant cultivars previously imported. The majority of seedlings are either fully or partially susceptible to the pathogen and retention rates after screening range from 0 to 53 % (average 22.3%). In the Stanthorpe program only seedlings rated 0,1,2 or M are retained (3, 7).

The number of seeds produced in the 1993 pollination project contribute significantly to the overall breeding program but are of added importance because of the superior fruit quality of the resistant parent cultivars available in the USA. To access the range of disease resistant parents used and obtain the same high numbers of seeds via conventional budwood introduction means would have taken an additional 5 to 7 years and incurred considerable quarantine expenses.

The Future

The strategic visits of the American breeders, Professors Hough and Cummins, to Australia, created significant links to established apple breeding programs. Exchanges of information and germplasm have allowed Australian breeders to build on overseas advances. A significant number of disease resistant seedlings from high quality parents are now being evaluated in the orchard for desirable fruit and horticultural characteristics. New hybridizations will be reduced to allow concentration on evaluation and selection of existing progenies. Future release of disease-resistant cultivars will assist Australian growers in realizing their objectives of pesticide reduction. However any apple scab resistant cultivars released to the industry may need some strategic fungicides applied to reduce the risk of gene breakdown to *V. inaequalis* and to control summer fruit rots that are now controlled coincidentally by apple scab fungicides (8).

Future prospects for cooperation between breeders include testing of seedlings for fireblight resistance or col-

laboration on biotechnology projects. This cooperation has been further strengthened by visits to Stanthorpe in 1994 by Professor Jules Janick from Purdue University and Associate Professor Susan Brown from Cornell University (NYSAES).

Acknowledgements

The following cooperators are thanked for their generous assistance with logistics, pollination and seed extraction during the 1993 cooperative project; Richard F. Heflebower and George R. Welsh at WMREC, Jules Janick and Anna Whipkey at Purdue University, Susan Brown and temporary labor at Cornell University (NYSAES), Philip Forsline at the Plant Genetics Resources Unit in Geneva, NY and David Lane at the Summerland Research Station in British Columbia, Canada. This work was partially funded by the Horticultural Research and Development Corporation as part of the project: Breeding Disease Resistant Apples for Australia.

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Atmospheric Influence of Strawberry

Temperature was most highly correlated with yield and fruit weight and this in the first 10 day period of May. In the second and third periods of May and June, lower temps and humidity were needed for high productivity. The reaction of genotypes differed 'Paula' and clone 547/5 showed few relationships with atmospheric factors and were better adapted to local conditions than 'Senga Sengana' and clone B-302. In the autumn of the previous year, lower temperatures were suitable for flower initiation in the third period of Sept. and in Oct. In late Aug., early Sept. and Nov. high temps, water deficit and sunshine were beneficial. The single fruit weight showed fewer correlations with atmospheric factors, but tendencies were similar to those for whole yield. From: Hortynski et al., 1994. J. Hort. Sci. 69:89-95.