APPLE DISEASE RESISTANCE BREEDING - INCLUDING SABBATICAL VISIT BY PROFESSOR J.N. CUMMINS

FINAL REPORT
AP104

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INDUSTRY SUMMARY

Project Objectives: To produce early, mid and late season apple varieties that have field resistance to the major apple diseases apple scab *(Venturia inaequalis)* and powdery mildew *(Podosphaera leucotricha)*.

Why?:

* Australian consumers want food produced with less chemicals. This attitude is particularly strongly felt about apples following recent and well publicised international chemical "scares" in relation to apples. The AAPGA is seeking to be proactive in addressing this with its agreement on chemical use reductions with consumer groups.

* Overseas markets are also sensitive to the issue of chemical use and residues. The availability to and adoption by industry of varieties with a significantly reduced chemical use will provide a substantial marketing edge for the Australian apple industry in its bid to increase exports.

* Profitability will be improved, both for the whole industry and individual producers. Farmers will be able to cut fungicide costs through the use of varieties which are resistant to the two major fungal diseases, apple scab and apple powdery mildew.

* Integrated Mite Control programmes will be easier to implement with less fungicides being used, thus enhancing the ability of industry to adopt improved IPM techniques. This will again reduce chemical use and further reduce costs of production.

TECHNICAL SUMMARY

The source of scab resistance derived from *Malus floribunda* available in the cultivar Prima has been used in sexual hybridizations to transmit the *Vf* gene to populations of apple progeny.

Crossing of susceptible with scab resistant parents has occured to produce populations of seedlings which are screened in the glasshouse using the method of Hough *et al* (1953). Susceptible seedlings are discarded and only the resistant seedlings are retained. This has been on the basis of inheritance for a major dominant gene giving a ratio of 50% resistant to 50% susceptible.

In 1993, crosses done in the United States using Liberty, Enterprise and Goldrush as sources of scab resistance, improved the quality component of the genetic base for the breeding program.

Following the sabattical visit to Stanthorpe by Dr Jim Cummins (report attached as Appendix 1), the procedure used at Cornell University was adopted resulting in more rigorous culling of susceptible seedlings. Retention rate of resistant seedlings has fallen to between 25 and 30 percent.

These are nursery planted for exposure to field levels of powdery mildew inoculum. Susceptible seedlings are discarded after one year before the remaining resistant lines are field planted in progeny blocks.

Field evaluation of genetically transformed apples produced by University of Sydney will determine the potential for this biotechnology to be incorporated into an overall plant improvement and breeding strategy.

INTRODUCTION

Project Objectives: To produce early, mid and late season apple varieties that have field resistance to the major apple diseases apple scab *(Venturia inaequalis)* and powdery mildew *(Podosphaera leucotricha)*.

This is being done because:

* Australian consumers want food produced with less chemicals. This attitude is particularly strongly felt about apples following recent and well publicised international chemical "scares" in relation to apples e.g. Alar®. The AAPGA is seeking to be proactive in addressing this with its agreement on chemical use reductions with consumer groups.

* Overseas markets are also sensitive to the issue of chemical use and residues. The availability to and adoption by industry of varieties which significantly reduce chemical use will provide a substantial marketing edge for the Australian apple industry in its bid to increase exports.

* Profitability, both for the whole industry and for individual producers, will be improved. Farmers will be able to cut fungicide costs through the use of varieties which are resistant to the two major fungal diseases, apple scab and apple powdery mildew.

* Integrated Mite Control programmes will be easier to implement if less fungicides are used, thus enhancing the ability of industry to adopt improved IPM techniques. This will again reduce chemical use and further reduce costs of production.

The success of apple variety introductions from overseas has been limited by the lack of adaptability of these varieties to the diverse climatic conditions of Australian apple growing regions, the significant disease pressures resultant from these conditions, and the different Australian market requirements. For these reasons, an Australian Apple Disease Resistance Breeding Program has been established at Applethorpe. This program utilises the resources and expertise held by Queensland Department of Primary Industries (QDPI) staff at Applethorpe, and has been substantially funded by the Australian apple industry through HRDC.

The benefits of new apple varieties developed in Australia and overseas in the last two to three decades are now being seen in a revitalization of apple marketing and replanting. The next stage of variety development will require a component of disease resistance to build on consumer confidence regarding pesticide reduction.

New, high quality, disease resistant varieties of apples are being developed to provide Australian apple growers with future marketing tools.

This project is part of a longer term approach to pesticide reduction. The hybridisation or first stage breeding is winding down as the fruit evaluation phase increases. This three year project builds on the previous breeding work commenced by QDPI to develop commercially acceptable early season varieties. Now the major objectives include the identification of superior quality and disease resistant selections for nation-wide industry testing.

Because of Australia's unique and diverse apple growing environments, overseas varieties do not always perform to expectation. Apple breeding in Australia has to date been primarily aimed at releasing to industry varieties suited to niche environments and markets. These released varieties are also improving grower returns and have the potential to lift overall consumption by providing highly marketable products.

Consumer demands are changing, and food produced with less chemicals is being sought. The Queensland programme recognises this with its major aims of releasing to industry varieties which offer disease resistance combined with consistent fruit quality. Firm red apples with a desirable flavour that are resistant to apple scab and powdery mildew are being sought through this project of breeding, evaluation and selection.

MATERIALS & METHODS

This project has involved two distinct substantive phases, as follows:-

Phase 1 : Involvement of Professor James Cummins (Professor of Pomology, Cornell University, New York State, USA) in the activities of the breeding program from October 1991 to late February 1992. Professor Cummins was requested to review the operations and directions of the current program, and to make specific recommendations on techniques and future directions for the program which will maximise its effective outcomes and relevance to industry needs. A full copy of Professor Cummins review and recommendations is attached as Appendix 1 to this project final report.

Phase 2 : Implementation of the specific recommendations made by Professor Cummins and planning for changes in the general objectives of the program. This included advancement of the existing project through crossing and back-crossing in accordance with Professor Cummins' recommendations to continue to produce populations for disease resistance screening. Resultant from these populations will be the evaluation and selection of seedlings for further field testing, and the identification of some 10 to 15 promising selections for planting and further evaluation at each of four Australian test sites.

A related but minor outcome of both Professor Cummins' review and the subsequent program has been an evaluation of the potential application of relevant biotechnology techniques (including gene transfer technology) in apple breeding and varietal improvement. As a consequence of this outcome, cooperative work has been undertaken with the University of Sydney's biotechnology program for the apple industry. This cooperative work has been in the areas of tissue culture for varietal stabilisation (currently the subject of a separate HRDC project) and the field evaluation of genetically transformed apples.

Genetic resistance to the apple scab fungus was incorporated as an objective of the apple breeding program at the Granite Belt Horticultural Research Station in 1984. The source of resistance used was the gene *Vf* (V from the pathogen *Venturia inaequalis* and f from *Malus floribunda* the first recognised source of the gene). This gene had formed the basis of the cooperative breeding program between the three USA universities - Purdue, Rutgers and Illinois (PRI) which began in the 1950s (Hough *et al*, 1953).

Since 1984 many individual importations of budwood, seeds and pollen carrying resistance genes have been made through Australian quarantine and 11,570 seedlings have been produced. A modified glasshouse screening method has enabled some 50% of seedlings to be identified as being disease resistant at the seedling stage. The seedlings are inoculated with Queensland isolates of *V. inaequalis*. These isolates have been differentiated on *Malus spp* imported from USA as race 1 strains (Heaton *et al.* 1991).

Field plantings were begun in 1985 and the first fruit evaluated in 1987. An initial 13 promising selections were planted at Batlow (NSW) and Applethorpe (Qld) for district evaluations (Table 2 in Results section). Scionwood was sent to WA and SA in 1992. This exposure to the full range of Australian environments and potential pathogen races will ensure final selections are of uniform high quality and have robust resistance. It is anticipated that an additional 10 to 20 promising selections will be identified each year.

Powdery mildew (*Podosphaera leucotricha*) resistance breeding is also being carried out at Applethorpe. Resistant germplasm was obtained from East Malling (UK) in 1988. Assessment of this material commenced with first fruiting of seedlings in 1992.

As part of Professor Cummins' work to establish directions for the program, an analysis of potential parents was undertaken. This evaluation is reproduced in Table 1 below, and utilises the best available information from published and unpublished international sources. This analysis has enabled the breeding and evaluation program to identify the most promising parents for use.

There have been approximately 85,000 apple seedlings (65,000 for apple scab resistance & 20,000 specifically for powdery mildew resistance) produced for this project since 1986. This includes some 27,000 from the USA that combine the best of the Australian and American germplasm. Based on the method of Hough *et* al, over 50% of seedlings are generally culled for disease susceptibility at an early stage and the resistant trees field planted to evaluate for fruit quality. Since the sabbatical visit of Professor Cummins, a modified method of glasshouse screening for disease resistance assessment has been adopted. This method results in only some 25% to 30% of seedlings being retained as having a high level of resistance to apple scab.

No more cross pollinations will be done and work will concentrate on fruit evaluations to select promising lines. These are propagated onto rootstocks and grown in a range of second test sites around Australia.

There has been a linking in with the HRDC biotechnology projects in NSW & VIC. At present, transformed plants from the University of Sydney are being field evaluated at Stanthorpe. These plants have a marker gene for kanamycin resistance incorporated into their genetic structure.

Table 1: Some attributes of potential parents in the apple breeding programmes

	Days	Scab	PM	Qual	Size	Store	Prod	Chill	Comments
NY66305-139	-60	Res	Res	Good	Med	Fair	Good	?	
Summerdel	-55	Susc	Med	VG	Med	VG	Med	M.Lo.	Mouldy Core
Coop 12	-55	Res	Susc	Good	Med	Poor	?	?	
Coop 19	-55	Res	Res	VG	M.Sm.	Poor	?	?	
Williams Pride	-51	Res	MR	VG	Med	Exc	?	?	
Coop 20	-45	Res	Susc	Good+	Sml	Exc	?	?	
Prima	-45	Res	Res	Good	M.Sm.	Fair	Fair	High	
Primicia	-45	Res	MR	Good	Med	Good	Med+	Low	
Princesa	-45	Susc	Susc	Good	Med	Fair	Exc	V.low	
Sansa	-45	MR?	?	Exc	Med	?	Exc	?	
Gala	-45	Susc	MS	VG	M.Sm.	Good	Good	M.Lo.	
Coop 14	-42	Res	Res	Astr	Sml	Poor	Exc	?	
Redfree(Coop 13)	-42	Res	MR	Good	M.Sm.	Good	Good	?	
Coop 7	-35	Res	Susc	Fair	Large	?	?	?	No drop
Dayton (Coop 21)	-29	Res	MR	Good	Med	Good	Good	?	
NY74828-12	-22	Res	Res	Good	MLge	Good	VG	?	
McShay	-20	Res	Res	Good	Med	Good	?	?	
Coop 8	-18	Res	MR	Fair	MLge	Poor	Poor	?	
Coop 15	-18	Res	Res	Good	Sml	Fair	Med	?	
NY66305-189	-15	Res	Med	Good	Med+	Good	Good	?	
Priscilla	-14	Res	Res	Good	M.Sm.	VG	Good	?	
Coop 9	-11	Res	MR	Fair	M.Lge.	?	?	?	No drop
Bonza	-10	MS	Susc	Good	Med+	Good	Good	?	
Jonafree(Coop22)	-7	Res	MS	Good	Med	Good	Good	?	
NY75414-1	-6	Res	Res	Good	M.Lge	Good	Good	?	Liberty x MacSpur
Britegold	-5	Res	?	Fair	Med+	Good	Fair	?	
Coop 24	-5	Res	Res	Fair	MSml	Poor	?	?	
Coop 25	-5	Res	MR	VG	?	Exc.	?	?	Hangs well
Sweet 16	-4	MR	?	Good	Med+	Good	Good	?	
Freedom	-3	Res	Med	Good	VLge	Good	Good	?	

Delicious	0	Susc	MR	VG	Med+	VG	Good	High	
	Days	**Scab**	**PM**	**Qual**	**Size**	**Store**	**Prod**	**Chill**	**Comments**
Coop 10	0	Res	MR	Fair	Med	Poor	Exc	?	
Coop 26	0	Res	Res	Fair	MSml	Poor	Exc	?	
Liberty	0	Res	Med	VG	Med+	VG	Exc	High	
NY75413-30	0	Res	Res	VG	VLge	VG	VG	?	Liberty x Delicious
NY65707-19	+2	Res	Res	Exc	Med	Exc	Med	?	
NY73334-35	+3	Res	Res	Good+	MLge	Good	Good	?	Liberty x Delicious
Keepsake	+5	MR	?	Good	Med	Exc	Low	?	
Novaspy	+5	Res	?	VG	Med	VG	Good	?	
Coop 27	+7	Res	MR	VG	M.Sml.	Exc	M+	?	
Trent	+8	Res	?	?	Lge	?	?	?	
Florina Q	+10	Res	MS	?	Med+	?	?	?	
NY75441-67	+10	Res	Res	Good	Med	Good	VG	?	
Golden Delicious	+10	MS	MS	Exc	MLge	Good	Exc	High	
Coop 11	+14	Res	MS	Fair	Med	Good	VG	?	
Coop 31	+14	Res	MR	VG	Susc	Good	Med+	?	
Coop 29	+18	Res	MR	Good	Med	Exc	Med+	?	
Coop 30	+18	Res	MR	Good	M.Sml.	Exc	Med+	?	
Coop 17	+25	Res	MR	Poor	Med	?	Exc	?	
Granny Smith	+35	Susc	MS	VG	MLge	Exc	Exc	M.Lo.	
Fuji	+45	Susc	MS	Exc	Lge	VG	VG	?	
Pink Lady	+60	Susc	Susc	Exc	MLge	Exc	VG	M.Lo.	
Sundowner	+75	Susc	Res	Exc	Med+	Exc	Exc	M.Lo.	
Lady Williams	+95	Susc	?	VG	Med+	Exc	VG	M.Lo.	

Legend: *Days* - Maturity time before (-) or after (+) Red Delicious
Scab - Resistance to apple scab : Res = resistant; Susc = susceptible; MR = moderately resistant; MS = moderately susceptible; ? = unknown.
PM - Resistance to powdery mildew : definition as per apple scab (above).
Qual - Fruit quality : VG = very good; Exc = excellent; Astr = astringent
Size - Fruit size : small, medium, large or combinations of these (e.g. M.Sm = medium to small)
Store - Storability; & *Prod* - Productivity : excellent, very good, good, medium, fair, poor or ? (unknown)
Chill - Chilling requirement : high =above 1000 hrs; M.Lo (medium low) = approx. 800 hrs; ? = unknown

RESULTS

CROSS POLLINATION.

In May 1993, Mr Tancred travelled to the USA to use the superior black spot resistant cultivars Liberty, Goldrush and Enterprise for cross pollination with pollen from 15 high quality commercial cultivars currently in production in Australia. This process circumvented the need for introduced material to be held in quarantine for four years prior to becoming available for incorporation into the breeding program. Over 27 000 seeds were produced from this cross pollination work and over 95 percent were successfully germinated and all have been screened with black spot spores to eliminate the susceptible seedlings. Culling of over 75% occurred and the remaining 4176 resistant seedlings were nursery planted. Some further culling occurred to remove those most susceptible to powdery mildew and the remaining seedlings were field planted in late winter of 1994.

Some of the progeny resulting from earlier crosses since commencing disease resistance breeding have been selected and are detailed in Table 2 below. Only one of these has shown a susceptibility to scab, lending confidence to the screening method being used in the glasshouse. These promising selections have been field planted at two interstate sites; Batlow in NSW and Lenswood in SA. Budwood has also been sent to WA and to a co-operating nursery in Tasmania.

FIELD SELECTION.

Drought conditions during the term of this project (three year period from 1992 to 1994) resulted in 28 out of the 36 months having below average rainfall (see Figure 1). This has made it difficult to assess fruit quality in the progeny blocks. Some seedlings have been flagged for further observation under normal seasonal conditions to get a more accurate assessment of their potential.

The drought has also delayed the propagation process for superior types identified in earlier seasons. Lack of tree growth has meant poor propagation material for budding and grafting. Lack of water for overhead irrigation in the nursery further prevented any attempt to make trees to expand the second test sites in 1994. A review of nursery management and adoption of some improved techniques will result in some second test trees being available for planting in 1996. These will be planted at the Granite Belt Horticultural Research Station and one promising selection along with the scab resistant variety Liberty will be sent to the second-test evaluation site at Batlow, NSW.

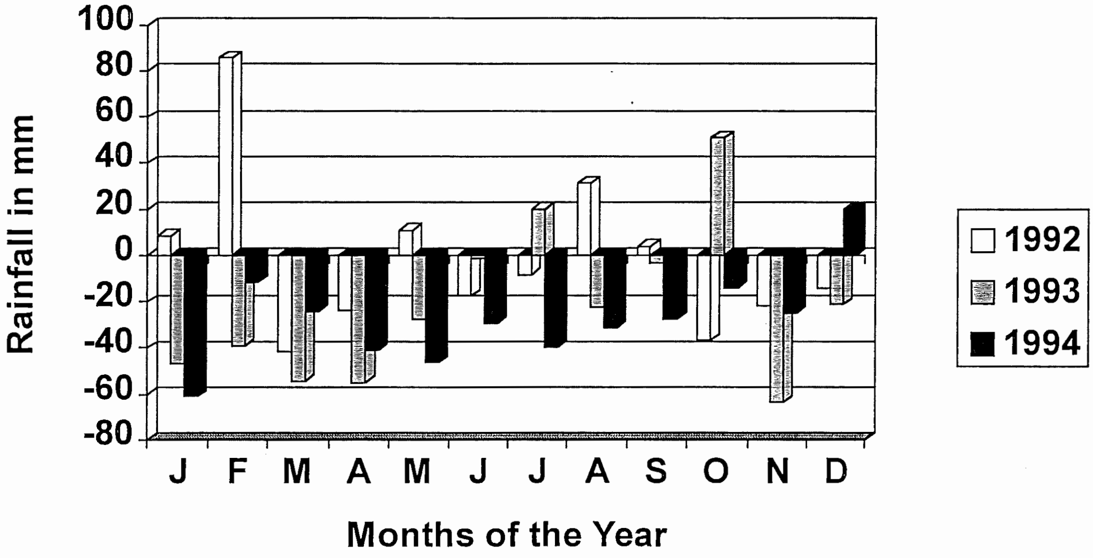
Despite the drought, assessment of fruit in progeny blocks does identify obviously inferior types. Culling of these is on-going.

A paper titled "Advancement of the Australian disease resistant apple breeding program by cooperation with the USA programs" by S. Tancred, J. Cummins, S. Dullahide, A. Zeppa and J. Heaton was published in 1995 in Fruit Varieties Journal. This paper details the progress of disease resistance apple breeding by QDPI to date.

Table 2. Parentage, disease rating and fruit quality of an initial 13 promising apple selections from the GBHRS breeding programme

Seedling Code	Parents		Glasshouse disease rating	Fruit characteristics
	Female	Male		
1-27	Prima	Granny Smith	0-2	Early, green, possibly too soft, develops red stripe later in season.
4-58	Prima	Summerdel	4	Early to midseason, average size, red, firm
5-67	Prima	Summerdel	0	Early season, red firm, acid
5-74	Prima	Summerdel	0	Early season, firm, white flesh, acid
6-27	Prima	63-43	4	Midseason, firm, sweet, may russet
8-84	Prima	Open pollinated	3	Early to midseason, firm, sweet, average size
8-90	Prima	Open pollinated	3	Midseason, large and sweet
8-93	Prima	Open pollinated	3	Midseason, large, firm, colour may be variable
9-93	Prima	Open pollinated	2	Early to midseason, red, susceptible to scab.
11-87	Prima	63-43	0	Midseason, red, sweet, firm, slight yellow flesh
17-22	Prima	Granny Smith	0-3	Midseason, stripey red, may soften
23-29	Prima	Granny Smith	0-3	Late season, red, good shape, may soften
29-73	Prima	Granny Smith	0-3	Late season, large and firm, appearance below average

Figure 1: Rainfall Values at Stanthorpe Above/Below Average 1992 to 1994



Disease resistant seedlings which have been progressively field planted since 1986 continue steadily to come into production and the fruit assessment phase of the breeding programme will now further intensify. Superior selections identified in 1986 have been grafted onto stocks and are established in second test sites at Stanthorpe (Qld) and Batlow (NSW). Budwood has also been sent to Lenswood (SA), Judbury (Tas) and Perth (WA).

Identification of further superior selections was also made in 1994 and is also currently occurring in the progeny blocks. The severe drought experienced in Queensland during this project significantly impeded this work. Generally fruit is much smaller and drought affected fruit is soft and dry. Identification of superior types is therefore very difficult as it is not possible to assess progeny under "normal" commercial production environments.

The drought further impeded the selection process. It has been difficult to successfully propagate superior selections onto rootstocks to expand the second test sites because:

- budwood from the parent seedlings in the progeny blocks is limited because of lack of extension growth, and
- the Applethorpe DPI nursery had not been overhead irrigated for two summers for lack of surface storage water.

However, a field nursery planted at Applethorpe in spring 1994 using T-tape irrigation with the limited water supply available has proved successful. A similar nursery was established in winter of 1994 for some superior selections using this system and purchasing water specifically for irrigation through the T-tape. This will enable these selections to be available for the second test sites in winter of 1996.

Apple scab race kits sent to apple growing regions in Australia have not been well maintained and there are missing trees in most kits. Replacement trees will be grafted in spring 1994 in order to be available for distribution in winter 1996.

BIOTECHNOLOGY.

In co-operation with Dr Peter Goodwin at the University of Sydney, genetically modified plants of Red Delicious were field planted in 1994 at Applethorpe DPI. The special tree planting ceremony was conducted by visiting Professor Jules Janick from Purdue University in the USA. The genetic transformation incorporates a benign marker gene which tells whether the test plant has been successfully transformed. Field testing of the transformed plants is being done to observe if the modified genetic structure has changed the way the plant looks and the fruit tastes.

If the transformation is successful without affecting desirable characteristics of the tree and fruit, it will be a major step towards incorporating useful genetic modifications to give disease resistance to the susceptible varieties now being grown.

Genetically modified trees of Pink Lady are currently being held in a shadehouse at Applethorpe DPI. Budwood from these will be propagated onto rootstocks for field planting in summer of 1996. It is anticipated that some of the Red Delicious will flower in spring of 1996. As a requirement by the Genetic Manipulation Advisory Committee (GMAC) trees will have to be individually contained during flowering and fruit ripening.

DISCUSSION

Selections listed in Table 2 (from early crosses done from the mid-1980's onwards) contain Prima as the scab resistant parent. Prima was the first of the Co-op series (Co-op 2) to become available in Australia having been released in the United States in 1970. It is only of mediocre quality and suitable mainly as a home-garden variety. However, it was the only source of scab resistance when the program commenced. As more resistant Co-op series became available the genetic base for scab resistance gradually improved.

The commercial quality parents used at that time e.g. Delicious, Summerdel and Granny Smith, and breeding lines 62-94 and 63-43 were some of the best available. It was not until the early 1990's that the increased popularity of newer varieties like the red Gala strains, Fuji, Braeburn and Pink Lady allowed for the incorporation of this higher quality material into the breeding program. This was further augmented with the USA series of crosses done in May 1993. With the incorporation of Liberty, Enterprise and Goldrush into the genetic pool, significant advancement of the Australian disease resistance breeding program has occurred. Resistant seedlings from these crosses were field planted in 1994 and should result in an improved line of selections being available for assessment from 1998 onwards.

EXTENSION TO / ADOPTION BY INDUSTRY

Superior selections which perform well in second-test evaluation sites will be further tested on properties of interested co-operating growers under standard non-propagation testing agreements. This enable further evaluation of selections under "standard" commercial production conditions. Fruit from selections which continue to perform well will be displayed at field days and other events to reach a wider target audience.

Scionwood of good performing selections will be made available to the nursery industry after application for Plant Variety Rights has been made. It is incumbent on the Australian apple industry and the Australian Pome Fruit Improvement Program (APFIP) to work collaboratively with the nursery industry to ensure wide-spread testing of selections occurs under the full diverse range of Australian growing conditions.

DIRECTIONS FOR FUTURE RESEARCH

Initial cropping at Stanthorpe enables promising selections to be made and further tested on rootstocks at a range of Australian second test sites. Joint assessment with interstate collaborators will be used to identify potential varieties for release to industry.

A subsequent current project (AP403 - Breeding high quality disease resistant apples for Australia) has been funded. This project will take the progeny which resulted from the cross pollination work undertaken under the auspices of project AP104 and continue the selection and evaluation process.

No additional significant volume or range of cross pollinations is anticipated to be required to meet the objectives originally set for project AP104.

Work in the current (AP403) and anticipated future projects will concentrate on selection and evaluation of quality disease resistant apple varieties, including commercial-scale testing of the most promising selections identified.

BENEFITS OF ADOPTION

The Australian apple industry will be the main beneficiary of new high quality disease resistant apple varieties. The industry priorities of pesticide reduction and varietal improvement are addressed by this project.

Quantifying the effect of a new variety in dollar terms is difficult, but the following aspects must be considered:

- increased demand and higher prices presently being paid for new high quality apple varieties;
- the effects of a future lack of consumer confidence in apples produced with high levels of chemical inputs;
- the possible future export market for apples produced with less chemicals;
- the present high costs of Black Spot control chemicals; and
- the loss of production in years of high disease pressure.

ACKNOWLEDGMENTS

Mr Stephen Tancred, formerly of QDPI, provided leadership of this project and his effort is duly acknowledged.

The Horticultural Research and Development Corporation (HRDC) is thanked for the financial support provided to this project.

Dr Jim Cummins, from Cornell University, provided a review of the Australian apple breeding programmes and his recommendations are greatly appreciated.

Australian Apple and Pear Growers Association (AAPGA) is also thanked for supprt and funding of the programme.

Thanks to Miss Chandra Smith for assistance with the compilation of this report.

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APPENDIX 1 - IMPROVING APPLE AND PEAR VARIETIES IN AUSTRALIA by Dr. James Cummins

FOREWORD

Improving Apple and Pear Varieties in Australia was written by Professor James Cummins as a conclusion to his sabbatical visit to Australia from 28 October 1991 to 8 February 1992.

The visit was funded by the Horticultural Research and Development Corporation as part of its ongoing commitment to the Australian apple and pear industries.

Whilst in Australia Professor Cummins visited every production district and most temperate fruit research stations. He also attended the First National Conference of the Australian Society of Horticultural Science and the Annual Conference of the Australian Canning Fruitgrowers Association, presenting papers at both.

More than half his time was spent with the two Australian apple breeding teams, Stephen Tancred and John Heaton at Stanthorpe and John Cripps in Perth. Productive working relationships between the Australian State Departments and Cornell University have been established with ongoing information and germplasm exchanges. Significant input was also made to the Australian Quarantine and Inspection Service, the nursery groups ANFIC and FNA and the fledgeling pear breeding and biotechnology teams.

The advice and recommendations Professor Cummins offered to growers, nurserymen and researchers during his visit will have an impact for years to come. His overview of world temperate fruit production coupled with a successful research career make him an elder statesman of the fruit industry. Additional biographical and contact information is provided on the inside back cover.

Appreciation for the funding from HRDC is acknowledged as well as secretarial input from Mrs Jillian Turpin for this report. Lastly, sincere gratitude is paid to Jim Cummins and his wife Cindy for the effort and dedication put into the sabbatical visit and report.

STEPHEN TANCRED
PROJECT LEADER
29th May 1992

EXECUTIVE SUMMARY

IMPROVING APPLE AND PEAR VARIETIES IN AUSTRALIA

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The apple industries around the world have been retooling for the last 20 years, discarding obsolete varieties and planting new varieties, developing new production systems, and modernizing their storage, packing and marketing facilities.

Tree removals following retrenchment after loss of favoured access to UK markets and as a part of Western Australia's battle against black spot have put Australia in a good position for building a new apple industry. Australian apple growers have been severely hampered by having little or no access to the world pool of improved varieties.

New Varieties Are Needed. Several factors fuel the drive for new varieties: Consumer demands for an ever-tastier apple variety form the basis for a major market incentive for variety change; both domestic and export markets now are demanding varieties with greater dessert quality than those now offered. The food safety issue has given rise to the AAPGA commitment to 50% reduction in pesticide tonnage by 1995. The spectre of eventual introduction of fire blight is a third significant factor driving us toward improving our varieties. Fourth, the producer wants change, primarily in reaction to the decreasing demand for older varieties.

The Australian pear industry is centered on `Packham's Triumph', unquestionably one of the finest varieties in existence, firmly entrenched in the export trade. From the viewpoint of variety quality then, the pear industry stands in a strong position both domestically and in the world market.

Improved varieties can come from only 3 sources:

1. From Australian breeding programs, e.g., `Pink Lady', `Sundowner', and `Summerdel';
2. As introductions from overseas, e.g., `Gala', `Fuji' and `Braeburn'; and (possibly in the future)
3. From applications of biotechnology.

EXCEUTIVE SUMMARY

Fruit Breeding in Australia. Australia's `Packham's Triumph', was introduced nearly 100 years ago, before the rediscovery of Mendel's Laws of Heredity. This is the oldest variety of any deciduous fruit crop found on commercial markets today that came into being at the breeder's hand. Since the turn of the century Australia has not been distinguished for her output of new varieties.

Now the first introductions of apples have appeared - `Pink Lady', `Sundowner' and now `Big Time' from Western Australia, `Earlidel' and `Summerdel' from the Granite Belt. These introductions have promise for filling major niches in Australia's apple production and marketing structure. More are needed.

The two apple breeding programs and the embryo pear improvement project should be sufficient to fill Australia's needs. Both apple programs are needed because each serves specific clienteles not served by overseas programs.

The most serious constraint for the apple and pear breeding programs is a crushing dearth of modern germplasm. Breeders, their administrators, and HRDC should focus their efforts in the immediate future to acquire, process through quarantine, and put into use a much more appropriate array of parent material than that available today. Access both to foreign introductions and to much-needed germplasm for the breeding programs is severely hampered by present policy and practice of AQIS.

Quarantine and Foreign Introductions. The tree fruit industry has encountered serious delays in bringing foreign varieties through quarantine. This has resulted in very significant retarding of variety transition. The present quarantine situation appears to be a very significant factor in encouraging smuggling of scionwood. Major improvements in quarantine protocol and improvement in management should substantially alleviate this problem.

Trialling of Introductions. New varieties have begun to trickle into the system, however, little or no testing of these introductions has been carried out prior to their deployment in commercial plantings. Australia urgently needs a systematic, scientific approach to variety trialling; I recommend a testing system patterned on the North American "NC-140" international cooperative. It is imperative that this testing program have full access to new varieties, including those imported from abroad and closely held by individual nurseries or nursery groups.

Fire Blight. For 70 years this disease has been endemic in New Zealand, and for much of that time trade between the two countries has been open, yet fire blight has not yet become lodged in Australia. Recent experience in western Europe suggests that sooner or later fire blight will enter Australia and will become entrenched here.

Australia's considerable plantings of `Hi Early Delicious' are resistant to fire blight, fortunately, but the new orchards of `Gala', `Fuji', and, probably, `Pink Lady' and `Sundowner' are quite susceptible. All of Australia's pears except the minor variety `Winter Cole' are highly susceptible to the disease.

EXECUTIVE SUMMARY

AQIS policy and procedures are highly effective in stopping importation of *Erwinia amylovora* through legitimate channels. Unfortunately, a concurrent result has been slow and expensive introduction of new varieties. As suggested above, this has been stimulating smuggling of scionwood from abroad, which I regard as the most probable route of invasion for fire blight.

The industry should support and advise AQIS in its continuing efforts for improving efficiency. At the same time, apple and pear growers and their supporting nurserymen should be recognizing smuggling as a crime, a major danger to their industry, and should be treating smugglers appropriately. In this connection, the industry should be encouraging AQIS and allied offices to develop and put into operation regulatory procedures and penalties that are more effective deterrents than those now in place.

The Western Australian apple industry and Department of Agriculture appear to be psychologically and logistically prepared to eradicate fire blight, when and if it arrives there. The apple and pear industries of eastern Australia do not seem to be well informed nor well prepared to react. Some suggestions are offered for reducing the impact of the disease when it does arrive.

In the long haul, varietal resistance to fire blight would seem to be the answer -- the responsibility, ultimately, of the fruit breeding team.

Biotechnology and Variety Improvement. If one includes radiation mutation breeding under "biotechnology", then a few improvements such as `Belgolden', `Lysgolden', and `New Jonagold' could be credited to "biotechnology". However, we have yet to see our first apple or pear variety improved by "gene splicing".

The list of exotic genes currently available that might be useful for pome fruit improvement is very short. Australia's biotechnology effort should, for the present, probably focus on development of methodology, perhaps with New Zealand's ripening delay gene, and on peripheral issues such as fingerprinting and chimeral stabilization. I have serious reservations about the wisdom of commercial deployment of *Bt,* although this could be done rather readily. The time will soon be coming when genes such as *Vf* for scab resistance will become available, and the Australian team should be ready to utilize them.

The most critical single need is for useable resistance to fire blight.

Short Term Improvement of Apple Breeding. Two to 5 years will be required to build up a useable breeding collection of the very best potential parents. It would be wise economy to send breeders abroad to utilize "mother trees" of resistant varieties not in Australia. For <$5,000, e.g., a breeder could visit Purdue and Geneva, make crosses using genetically advanced, disease-resistant mother trees and Australian pollens, and so obtain thousands of hybrid seeds some years before this could be done on Australian soil.

Pollens from abroad cannot be brought into Australia for breeders' use. Although it may take some logistical manoevering, such as setting up a facility for keeping potted apple and pear trees at the Eagle Farm quarantine facility, this can be an effective means for advancing the program. At the same time, AQIS should be strongly encouraged to proceed with research on the question of whether fire blight can indeed be transmitted on pollens.

EXECUTIVE SUMMARY

Closing Note. In my 5 months in Australia, I saw a fruit industry that is vibrant, vital, forward looking and forward moving. The growers are strongly supportive of the breeding programs in particular and for Australia's research efforts in general.

Apple and pear variety improvement programs should not be considered as isolated, "stand alone" efforts. Australia now has in place an outstanding plum breeding project at Applethorpe and a modern cherry breeding project at Lenswood. The people involved in all these variety improvement activities would do well to carry yet further their mutual cooperation. For example, Cripps and a number of others have already been active in making the first pear crosses, and second testing of Applethorpe apple selections is underway in several States. In the near future, all these breeders will be looking for widespread cooperation in carrying out the 3rd testing of their selections, not only within this fruit breeding group but also with their colleagues in fruit production research.

IMPROVING APPLE AND PEAR VARIETIES IN AUSTRALIA

CONTENTS:

APPENDICES:

IMPROVING APPLE AND PEAR VARIETIES IN AUSTRALIA

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Apple and pear industries around the world are in a state of ferment, with major changes taking place in varieties, rootstocks, production technology, and in marketing and other socio-economic aspects.
The Australian Horticultural Research and Development Corporation (HRDC) have determined that "Varietal Improvement" has a high priority among needs of the apple and pear industries of Australia. HRDC has identified three closely related sets of activities that focus on varietal improvement:

1. Creation of new genotypes, either by conventional sexual breeding or by genetic engineering, their evaluation and introduction;
2. Coordinated introduction of new varieties and genetic material including rootstocks; and
3. Development of comprehensive variety and rootstock testing and evaluation programs.

Several factors have generated the need for major alterations in the Australian apple and pear industries:

1.0 FACTORS STIMULATING VARIETY CHANGES

1.1 Social and Economic Aspects

1.11 The International Fruit Trade has been severely impacted by:

(a) The very large increases in production of Delicious apples in Washington State, USA (an increase from 15 million bushels/year in the early 60s to nearly 85 million in 1991);
(b) The establishment and continuing expansion of European Common Market, with the removal of trade barriers among the countries of western Europe;
(c) The freeing of the captive populations of eastern Europe and their beginnings to engage in free trade;
(d) The very large increases in production of `Granny Smith' in both hemispheres;
(e) Heavy new plantings in Brazil and Chile of varieties suitable for the export trade, especially `Gala' and `Fuji';
(f) The shifting patterns of affluence, especially in Southeast Asia;
(g) Cheap apple juice concentrate from Argentina, Germany, and eastern Europe, which must be expected for an indefinitely long timespan. This will effectively block a sustained outlet for off-grade Australian apples (the 1992 juice apple price must, unfortunately, be regarded as an aberration!). This is

important because it reduces incentive for the packer to maintain high standards.

1.12 Enhanced Export Trading

There is substantial indication that a reconstitution of Australia's fruit export trade will be heavily dependent on influx of new fruit varieties. In England, for example, responses to early market-making for the `Pink Lady' apple suggest that there are excellent sales openings for uniquely interesting new varieties. Niche marketing and unique varieties may offer the greatest opportunities. It must be emphasized, though, that export trade depends not only on cosmetic aspects but also on the gustatory excellence of the fruit.

1.13 Pesticide-Related Issues

A major consumer rebellion is already underway over the issue of chemical residues in fruits and vegetables. Whether or not we regard this as justified by the data, the consumers' perception of the pesticide issue must become our reality. As an industry, we must be able to demonstrate our contribution to reducing chemical residues in food in order to rebuild consumer confidence in our products and increase consumption.

The AAPGA initiative to halve pesticide tonnage by 1996 poses a daunting challenge to our fruit industries. The fruit grower will be hard-pressed to accomplish this goal, even given the recent major advances in integrated pest management tools. The spectrum of pesticides available to us will continue to atrophy under social pressure and, because of the very high costs of registration, few new orchard chemicals can be hoped for in future. Long term development and deployment of varieties resistant to the major pests and diseases will be necessary to achieve and maintain low-input apple and pear production.

Diseases and pests not yet in Australia include cedar apple rust, tobacco ringspot virus, tomato ringspot virus, apple proliferation, and, potentially most dangerous of all, fire blight (see Appendix 1). Commonwealth quarantine programs have been highly effective in preventing their appearance in Australian fruit plantings. The Western Australia state quarantine has been very effective in keeping out apple scab and codling moth; outbreaks have been successfully eradicated.

1.14 Domestic Consumption

Australian apple and pear production has been focused on domestic markets, especially since the United Kingdom developed plans for joining the EEC. The average Australian now consumes less than 15 kg of apples and 5 kg of pears annually, about the same as the typical American; the typical German eats three times as much of these fruits. There is potential for gradual increase in domestic consumption of apples and pears - but probably never to approach the German standard. Obviously such an increase would greatly improve the economic future of our apple and pear industries.

The apple growers of Western Australia have an enviable monopoly in their own state. Quarantine serves as an effective barrier against importation of apples not only from overseas but also from eastern states, while the W.A. growers are free to export both to eastern Australia and to almost all markets abroad. W.A. red apple production is not adequate to meet total domestic demand, and prices tend to be high.

Major increases in domestic consumption appear to depend on:

(a) Presentation of visually attractive apples and pears with delivered eating qualities superior to what the consumer can purchase today. Harvesting spur type Delicious apples four weeks before proper maturity is not a route to increased consumption!

(b) Re-establishment of consumer confidence in the health safety of fruit offered for sale. Much damage has been done by adverse publicity on pesticide issues; the industry must now demonstrate its dedication to food safety not only by fulfilling the reduced pesticide commitment but also by moving forward with resistant varieties.

(c) Much more aggressive marketing and merchandising of Australian apples and Australian pears - along with solid advertising and publicity on food safety issues.

The Australian apple and pear industries cannot expect the existing quarantine against fire blight to stand as a permanent barrier to apple and pear imports from other countries. There is no fire blight in South Africa, Brazil and Chile, where there are vast new plantings of desirable varieties, including `Gala' and `Fuji', and very cheap labour to produce them. It is not unreasonable to expect to find in the future `Gala' and `Fuji' from South America and/or South Africa on the shelves of Australian supermarkets.

1.2 Environmental Factors

1.21 Diseases and Pests

Our fruit industries must anticipate continued extension of diseases and pests.

Fire Blight may not arrive for another decade, or perhaps several - but it could invade Australia next fortnight. The disease would be very serious in all districts, and devastating in the Goulburn Valley. (See Appendix 1.) Of special concern is the susceptibility of the new plantings of `Gala' and `Fuji'.

Black Spot (Scab) may now have been eradicated from Western Australia, but the threat of re-introduction is very real. The fungus has already demonstrated its capacity to adapt to some of our most potent fungicides. Apparently no advantage is being taken of the scab-resistant pear varieties now deployed. (See Appendix 2.)

Powdery Mildew. This fungus disease also requires significant pesticide application. Powdery mildew may cause serious damage to foliage, but damage to fruit is rare except on `Jonathan' and perhaps `Bonza'. Chemical control of powdery mildew is less a problem than is chemical control of black spot.

There are major differences among varieties in susceptibility to powdery mildew. `Delicious' and `Sundowner', for example, are nearly immune, `Jonathan' quite susceptible, with most varieties of intermediate status. A number of major genes for resistance have been reported, but their resistance is usually overcome quite rapidly by the fungus. Probably a horizontal resistance approach will be necessary. Both apple breeding programs have acquired from East Malling selections with apparently durable major gene resistance derived from *Malus zumi*.

Glomerella cingulata pv. *papulans* causes severe damage to foliage on `Golden Delicious' and its derivatives, including `Mutsu', `Jonagold', `Pink Lady' and `Sundowner'. It causes "blister spot" on `Mutsu' and, to a lesser extent, on `Pink Lady' and `Sundowner'.

Summer Diseases such as sooty blotch and flyspeck can assume critical importance as we change fungicide programs and/or introduce black spot-resistant varieties.

Mouldy Core appears to be increasing, especially in `Delicious' and its derivatives such as `Fuji' and `Earlidel'.

Codling Moth management in eastern Australia may become much simpler with commercial introduction of pheromone mating disruption systems. However, this approach may offer opportunity for other pests to become important as our total insecticide programs are reduced.

European Red Mite, not now in Western Australia, would require significant adjustments to their pest management strategies if introduced.

Two-Spotted Mite is distributed Australia-wide. Both mite species are proving increasingly difficult to control with pesticides. Genetic resistance in commercial varieties would be a major asset, and the genes for resistance are available in some small-fruited *Malus* species.

Nematodes appear to be a major factor causing replant problems. Replant disease will likely be more frequently encountered in the years just ahead. Fumigation has usually proved effective. My observations strongly support the general view that it is more economic to fumigate and then replant with MM.106 than to use a vigorous but inefficient rootstock, such as MI.793 or MM.109, without fumigation.

Tomato Ringspot Virus is thought not to be in Australia now, but there is potential for reintroduction. The nematode vector, the reservoir host and susceptible rootstocks are already present throughout the country.

Root Rots do not appear to be a major factor. However, some diagnoses of infections by *Rosellinia necatrix* and *Sclerotium rolfsii* may be taken as indicating potential for infections for which neither treatment nor prevention is known.

1.22 Climatic Factors

Chilling. Relatively little consideration to chilling requirements has been given in deployment of varieties, and in most years in most locations chilling appears to have been adequate. However, in some districts, especially in Western Australia, inadequate chilling can have serious effects on production and tree growth.

Growing Season for some important varieties will be too short in some districts. For example, the new Western Australian varieties would not seem well suited for the Batlow district.

Summer Heat in most districts will be excessive for most varieties, such as `Jonagold' and `Elstar', that were selected in cool climates.

1.3 Agronomic Factors

Multiple Harvest. Most varieties now available must be picked over 3 to 5 times to achieve appropriate color and eating quality. Varieties that would mature over shorter periods of time would reduce harvest costs and increase average fruit quality.

Precocious, Regular, Heavy Production has become more important to the producer as the capital investment in orchards has escalated. `Sundowner' and `Summerdel' are good standards for our productivity objectives.

2.0 SOURCES OF NEW VARIETIES

Australia can look to five potential sources for improved apple and pear varieties; only the first four have as yet yielded new varieties:

a. Chance seedlings discovered in Australia.

b. "Sports" discovered in Australia.

c. Breeding programs in Australia (including applications of biotechnology to variety improvement).

d. Varieties bred or discovered overseas and brought into Australia through AQIS.

e. Existing varieties improved through biotechnology.

2.1 Chance Seedlings of Australian Origin

`Granny Smith' is easily the most important apple variety discovered in Australia; this fine old variety continues to be a major player on the world market, although tonnage is gradually decreasing.

Other commercially planted apples found originally in Australia include `Abas', `Bonza' and `Lady William's. Varieties of Australian origin that were once but are no longer of commercial importance include `Crofton', `Democrat', `Legana' and `Statesman'.

Minor varieties that originated as chance seedlings in Australia include `King Cross', `Red Gem', `Richie', `Riverville Red', and `Russo Red'.

Finding another "fencerow variety" of the stature of `Granny Smith' should not be anticipated.

2.2 "Sports" Found in Australia

Several unnamed subclones of various `Delicious' sports, such as `Redchief Delicious' and `Starkrimson', have been selected in Australia; these appear to be more stable forms of periclinal chimeras, rather than true bud sports.

It is likely that sports of several of the newer varieties will be discovered. `Fuji', `Elstar', `Gala', and `Jonagold' seem particularly prone to production of sports with enhanced red color.

The `Sensation' pear, a red-blushed sport of `Williams' Bon Chretien', makes up only a small percentage of Australian plantings, but it is slowly becoming more important.

2.3 Varieties from Apple and Pear Breeding Programs

Western Australia's `Pink Lady' and `Sundowner' have been heavily planted, in the East as well as in the West, and many older trees of outdated varieties have been topworked. Plans for export of `Pink Lady' are being enthusiastically developed, and nurseries are making major investment in trees in anticipation of growing demand. `Big Time' has just been named but not yet deployed commercially.

From the Granite Belt breeding program, `Earlidel' and `Summerdel' both target specific niches in the pre-Delicious marketing season. `Earlidel' probably has been planted adequately to fill its niche. `Summerdel' has been enthusiastically received by growers in the Granite Belt and now plantings are being made in other districts. With the first plantings now well into production, confidence in the variety is solid and expanded plantings are underway. A new medium-chilling early selection, GB 63-43, will probably soon be introduced for lower altitudes.

The private breeder Henry Franklin introduced the early apple varieties `Adina' (Golden Delicious x William's Favourite) and `Goldina' (Adina x Golden Delicious) for production by private subscribers; the varieties have not been released to the public at large. Both varieties have been important in the pre-Gala season; it now seems probable that they will be replaced by `Earlidel', `Summerdel' and `Gala'.

`Meldale', a Golden Delicious x Cleopatra cross, was produced by a private breeder in Western Australia; it is no longer of commercial significance.

`Packham's Triumph' is the most important pear variety being grown in Australia; this is one of the first successful introductions from any hybridizing program of tree fruits anywhere in the world.

`Winter Cole' was also produced by deliberate crossing; although of only minor commercial importance, this variety may later prove valuable as a fire blight-resistant parent.

`Stanley', a Josephine de Malines x Winter Nelis hybrid, has never attained commercial standing.

2.4 Varieties Introduced from Overseas

In addition to Australia's own `Granny Smith', the apple industry is now based on a few relatively old varieties,- `Delicious' (including its sports, `Starkrimson', `Hi-Early' and `Royden Red'), `Golden Delicious' and its sports, and `Jonathan'. This list is now rapidly being adjusted with varieties from overseas breeding programs, mostly `Fuji' from Japan and `Gala' and `Braeburn' from New Zealand. The New York-bred `Jonagold' is being planted to a small degree in Tasmania. All these varieties are represented to a very large extent by sports selected for high color.

2.5 Varieties from Biotechnology

`Belgolden' and `Lysgolden' are "radiation mutants" of `Golden Delicious', produced at Angers, France. `New Jonagold' and some other subclones of `Jonagold' are slightly improved color sports derived by radiation breeding.

No improved apple or pear clones derived by molecular engineering have yet been produced.

3.0 APPLE AND PEAR BREEDING PROGRAMS IN AUSTRALIA

Australia supports two public apple breeding programs, which should be looked upon as complementary, and a pear breeding project in the beginning stages. A private apple breeder in the Granite Belt focusses on early varieties.

The two public apple breeding programs have been given the most tangible evidences of industry support: (1) substantial plantings of most recent introductions; and (2) substantial and continuing financial support.

Queensland's Department of Primary Industries and Western Australia's Department of Agriculture have strongly supported their respective programs by assignment of research workers and provision of equipment and facilities. Through HRDC, major additional support has been provided, especially for skilled casual workers. In addition, the WA program has been receiving funding from local growers' organizations.

The Granite Belt Horticultural Research Station program was originally designed to service the Granite Belt in particular but now has been extended to include all those regions of Australia in which black spot is a problem. In the past, focus has been on the early pre-Delicious market, but this has now shifted to extend disease resistance breeding across the entire season.

The Western Australia program is directed toward development of high quality, medium chill varieties with unusually long storage capability and shelf life, without consideration of black spot and fire blight susceptibilities.

It is reasonable to expect that the high quality varieties developed in Western Australia will be heavily used as parents in the Granite Belt program, as indeed `Pink Lady' and `Sundowner' are being used now. If eventually black spot and/or fire blight should become entrenched in Western Australia, it will be most helpful to have available resistant varieties from the East that incorporate adaptive traits of the West.

3.1 Granite Belt Apple Breeding

This project was initiated in 1964 by R. Morwood, then Senior Horticulturist at this Station. It has been continued through the years by breeders C. W. Winks, L.B. Baxter, and now Stephen Tancred and plant pathologist John Heaton.

3.11 The "Early Red" Program.

The initial objective of the apple breeding program was "to produce an early maturing, red, dessert apple variety of good quality and performance". No deliberate attention was paid to developing disease-resistant varieties, although seedlings that were extremely susceptible to powdery mildew were eliminated. Some 11,000 seedlings were produced in this phase of the Applethorpe project; hybridizing ended in 1989. A total of 23,220 seedlings having been produced.

First realization of the goals of the "Early Red" program came in 1988 and 1989 with introduction of `Earlidel' and `Summerdel', both early maturing, red, dessert apple varieties of good quality and performance. `Summerdel' is being rapidly adopted by Granite Belt growers, with some 40 000 trees now in the ground; `Summerdel' has enjoyed excellent market reception and can be expected to become a very important pre-`Gala' variety. `Earlidel' has been planted less substantially, and will probably be an important variety only in the Granite Belt.

About 10 000 of the original seedlings are still being observed. Several selections are under second test at Applethorpe. One very promising selection under second test, GB 63-43, a sibling of `Summerdel', will probably be named soon. GB 63-43 ripens slightly later than `Summerdel'. GB 63-43 appears to be medium chilling, too low for the Granite Belt, but this characteristic may prove very valuable in some other districts including Western Australia.

3.12 Current "Disease Resistance" Program.

Increasing concern with pesticide-related issues prompted initiation of the "Disease Resistance" breeding program in 1984. Almost all apple varieties in production in Australia are highly susceptible to black spot and most require at least some pesticides to avoid serious powdery mildew injury. The general objective of this new program has been to produce a full season repertoire of varieties resistant to black spot and powdery mildew and having good dessert quality, attractive appearance, and suitable storage and shelf life.

Initially separate breeding approaches were made to achieve resistances to black spot and to powdery mildew. Approximately 16000 seedlings have been produced for black spot resistance testing and 21 000 for powdery mildew testing.

In 1991, the disease resistance objectives were expanded to include resistance to fire blight, since it is becoming recognized that, sooner or later, this disease will invade Australian orchards. Only `Prima' has been available as a source of resistances to all three diseases. However, recent crosses of `Jonafree' (resistant to black spot but susceptible to the other diseases) with `Delicious' (susceptible to black spot but resistant to powdery mildew and fire blight) should yield some progeny with all three resistances.

Because so much of the Australian apple industry is looking to future export trade, special attention must be given to postharvest attributes of fruit - bruise resistance, storability and shelf life.

In the apple and pear districts of South Australia, Western Australia, and in some years in other states, winter chilling may be insufficient for proper completion of dormancy for "high chill" varieties such as `Delicious' and `Golden Delicious'. Developing medium chill varieties, which `Pink Lady', `Sundowner' and `GB63-43' appear to be, is therefore a secondary, but important, priority in the new program.

3.13 Constraints in the GBHRS Program

3.131 Germplasm. The present breeding collection is woefully short of germplasm carrying resistances to black spot, to powdery mildew and to fire blight. In the present repertoire, only `Prima' carries all three resistances. `Jonafree' (Coop 22) is resistant only to black spot. Both these varieties were introduced early in the American resistance breeding effort; neither approaches commercial viability. `Prima' progenies tend to inherit its susceptibility to bitter pit, a nutritional/physiological disorder.

It is therefore urgent to acquire parents that are not only resistant to both diseases but also horticulturally advanced. A brief compendium of attributes of some potential sources of disease resistances is appended (Appendix 4). Included on the "urgently needed" list are the following varieties and elite selections, all resistant to black spot, powdery mildew and fire blight:

`Florina Querina' and Coop 26 (being brought through quarantine by Flemings Nurseries)
`Liberty' (available quickly from IR-2)
`Britegold'
`Williams Pride'
`Dayton'
`Keepsake'
NY 66305-139
NY 66305-289
NY 73334-35
NY 74828-12
NY 75413-30
Coop 27
Coop 29
Coop 30
Coop 31.

In addition, from Brazil the low-chilling, black spot-resistant `Primicia' and other advanced selections should be acquired as soon as possible.

3.132 Facilities and Staff

At Stanthorpe, the following are directly involved in apple breeding:

Stephen Tancred	Horticulturist	75%
John Heaton	Plant Pathologist	25%
Aldo Zeppa	Hort. Technician	75%
S. R. Dullahide	Plant Path. Technician	25%
Casual Support		30%

The staffing level has been adequate for the "Early Red" project and for the small-scale scab-resistance program. However, as the program matures, with much larger numbers of plants at all stages, additional staff will be required. Present professional horticultural staff should be sufficient but with the expanded program must be augmented by at least one additional casual support person. Some additional technical caliber support will be required on the pathology side, especially during early spring when scab inoculation and evaluation activities peak.

Greenhouse and laboratory facilities are adequate in quantity and excellent in quality. The disease inoculation chamber is very heavily used, not only for scab susceptibility screening but also in the plum breeding program and for general pathology research. Provision for backup should be arranged, including improved emergency services.

3.133 Land and Water - Limiting

Soils on the Station are typical of the Granite Belt - very sandy, very shallow, and in midsummer very hot; pH is usually about 6.

Irrigation is absolutely essential. An excellent irrigation system is in place and technical capacity for expansion and alteration is available. Lack of adequate water appears to be the most likely limiting factor for the entire program. Administrative staff will be seriously challenged to provide adequate space for this program as it expands and, of course, funds for routine maintenance will always be marginal.

3.2 The Western Australian Apple Breeding Program

From the Lady Williams x Golden Delicious cross, John Cripps and his breeding group at WA Department of Agriculture have already made two major introductions (`Pink Lady' and `Sundowner') especially suited to Western Australia. A third selection from the same cross has just been introduced as `Big Time'. They are aggressively moving forward to develop more new varieties. Although evaluated under the unique climatic, edaphic and biotic challenges of Western Australia, `Pink Lady', `Sundowner' and the new varieties anticipated will be valuable additions in other parts of Australia with long growing seasons. This project is strongly supported by HRDC and by Western Australian growers.

3.21 Challenges in Western Australia. Western Australia's isolation from the rest of the continent, strictly enforced quarantine, and rigorous eradication programs have effectively prevented permanent lodgement of apple scab (black spot) and codling moth. European red mite and Queensland fruit fly are also missing from Western Australia's biotic environment. Powdery mildew, light brown apple moth, woolly apple aphid, apple dimpling bug, apple mosaic virus, rubbery wood virus, and several nematode species are widely distributed and are commercially significant problems; the nematodes are probably responsible for most of the replant problems encountered. Blister spot, incited by *Pseudomonas syringae* pv. *papulans* occurs on `Mutsu', `Lady Williams' and `Pink Lady' but is not now perceived as important. Apple chlorotic leafspot virus, apple stem grooving virus and apple stem pitting virus are widespread, often latent with AMV, but there appears to be no economic problem associated directly with infection. The "summer fungi", such as sooty blotch and fly speck, do not appear to present significant economic problems, even though summer fungicide use is minimal. *Phytophthora* infections are uncommon, found only on wet microsites; in at least one instance, root rot problems appear to have been exacerbated by preplant fumigation with methyl bromide without chloropicrin. Damage from *Armillaria* is rarely observed. In some locales birds cause serious damage to late-ripening varieties.

The WA breeding program is directed to producing varieties uniquely suited to WA, taking notice of absence of apple scab, fire blight and codling moth and the requirement for relatively low chilling. The unusually long growing season offers opportunity for production of unique varieties that mature after `Fuji', `Braeburn' and `Granny Smith'. `Lady Williams' and her derivatives `Pink Lady' and `Sundowner' are outstanding examples of the breeding possibilities for the future. The major objectives therefore are focused on fruit-related attributes - fruit size, eating quality, finish, shape, eye appeal etc.; adaptability to modern harvest and handling systems; storability, including both refrigerated and CA storage; and shelf life. Particular attention is directed to need for avoidance of scald without DPA treatment.

3.22 Western Australia Personnel and Facilities.

In Western Australia, assigned personnel include

Mr. John Cripps	Horticulturist	50%
Ms. Anna Mairata	Technician	40%
Ms. Linley Richards	Technician	100%

Although present staffing of the Western Australia program is adequate, a major crisis in continuity of this program appears to have been resolved by an extension of the appointment of the Breeder John Cripps for a year beyond mandatory retirement age. It would be prudent to move with dispatch toward recruitment of a replacement for Cripps; I strongly recommend that arrangements be made for a transition "apprenticeship" under Cripps.

Today some 50,000 hybrid seedlings are in the ground, with first fruits to be evaluated in 1992. This number is being significantly reduced in the third year by screening for powdery mildew infection and for vegetative aspects associated with poor fruiting qualities.

Mr. Cripps expects to continue making crosses to bring another 50,000 hybrids into the selection stream. An extension of the spectrum of germplasm for this breeding program is urgently needed now and will be needed for the foreseeable future. Both scionwood and pollen of prospective parents are required from overseas breeders.

In some important instances, it will be necessary to make crosses in quarantine, using quarantined plants as seed parents. The South Perth the AQIS facility is well suited for this service.

3.3 Pear Variety Improvement

Australian fruit growers now export nearly 20,000 tonnes of fresh pears each year, mostly `Packham's Triumph'. Europe, southeast Asia, and North America are the major receivers. Substantial volume of canned pears (mostly `William's Bon Chretien') is also exported.

`Packham's Triumph' and `Williams Bon Chretien' (`Bartlett') are the most important varieties in production. Other significant varieties are `Buerre Bosc', `Josephine de Malines' (`Josephine'), `Winter Cole' and `Winter Nelis'.

3.31 Problems with Pears

`Packham's Triumph' fruits are large, attractive and high quality, with excellent storage qualities and shelf life. The skin tends to have a somewhat uneven appearance (pebbling), especially on young trees. Flesh is firm, but careful handling is required to avoid bruising.

Almost all the varieties above are susceptible to fire blight (*Erwinia amylovora*) and to pear scab (*Venturia pirinia*); `Winter Cole' is moderately resistant to fire blight, and `Josephine de Malines' is resistant to pear scab. The Asian pear ("nashi") varieties `Hosui', `Kosui' and `Twentieth Century' are being planted in respectable numbers; all are highly susceptible to fire blight.

3.32 Breeding Objectives and Priorities

The prevailing ideal for an improved Australian pear variety seems to be a `Packham's Triumph' type with better skin finish, better resistance to bruising, and improved storage and shelf life.

3.33 First Approaches to Pear Breeding

Small breeding collections have been assembled at Orange, Stoneville and Stanthorpe; enough hybridizing was done in 1991 to produce about 5 000 seeds from 10 families. In all crosses, `Packham's Triumph' was one parent.

All progeny will be susceptible to fire blight, since all 10 parents are susceptible. Nearly 70% of the hybrids are from the Packham's Triumph x Josephine de Malines cross or the reciprocal, so it is probable that at least some of the progeny will be resistant to black spot.

About 5% of progeny were interspecific hybrids of `Packham's Triumph' with `Tsu Li' and `Ya Li'.

3.34 Sources of Disease Resistances

<u>Fire Blight</u>. Of the varieties with commercial status in Australia, only `Winter Cole' has significant resistance to *Erwinia amylovora* . Other resistant varieties now in Australia include `Dawn', `Flordahome', `Kieffer', `Magness', and `Moonglow'. Resistant varieties apparently not yet in Australia include `Harrow Delight' and `Harvest Queen'. A very resistant selection from the United States Department of Agriculture will probably be introduced and named `Potomac' in 1992.

Of these fire blight-resistant varieties, `Winter Cole' and `Flordahome' have the advantage of having a relatively low chilling requirement, but their fruit size is at the low margin for commercial acceptability. `Potomac' is regarded in the USA as having the best prospects for success as a commercial replacement for `Williams', with high quality, firm flesh, and good productivity.

English breeders have chosen avoidance as their major approach to fire blight resistance breeding. The very late "rat-tail" bloom so often found in `William's Bon

Chretien' is the most frequent infection court in England. Selection against this physiological attribute appears to result in avoidance of infection. I doubt that this approach will be a major factor in fire blight resistance breeding in Australia.

Black Spot. Resistances have been very poorly evaluated to date. Besides `Josephine de Malines', `Buerre Hardy', `Conference' and `Kieffer' are known to be resistant.

Most, probably all the nashi varieties are susceptible to *Venturia nashicola* .

"Pear Blast", incited by the bacterium *Pseudomonas syringae,* is not regarded as a serious problem in Australia and it may not be in the future. This is rather surprising, since the climates of the Granite Belt, the Goulburn Valley and the Manjimup district appear to be favourable. (This pathogen also causes "blister spot" on `Mutsu' and some other apple varieties in the Manjimup district.) `Beurre d'Anjou' and `Forelle' are resistant to *P. syringae* .

4.0 APPLICATIONS OF BIOTECHNOLOGY TO VARIETY IMPROVEMENT

The classical breeder and the biotechnologist have a common goal: the production of improved varieties.

The classical breeder uses the tremendous power of the sexual cross to produce many thousands of totally unique new genotypes, and from these selects one, or perhaps an elite few, that will be introduced to the fruit industry.

The biotechnologist, on the other hand, seeks to produce a new genotype altered by just one or two attributes from an existing variety that is already established in the orchard and on the market. Essentially the biotechnologist proposes to make alterations similar to that induced by mutations, e.g., a russet-free `Golden Delicious' or a spur-type `Pink Lady'.

In both approaches, the new genotype must be thoroughly trialled before deployment in the nursery and orchard trade.

4.1 Opportunities for Genetic Engineering

There are solid opportunities for utilization of molecular engineering techniques for improvement of the repertoire of fruit varieties.

These opportunities may be categorized as follows:

1. Direct improvement of existing market varieties;
2. Direct improvement of existing genotypes for use as parents in conventional sexual hybridization;
3. Stabilization of chimeras;
4. Identification of genotypes of existing or new clones.

4.11 Direct Improvement of Varieties

4.111 Recombinant DNA. The first two opportunities above usually involve what is commonly called "gene splicing". Generally speaking, this involves the insertion of one or more useful genes into a nucleus followed by regeneration of a whole plant from that single cell. Specific steps in "gene splicing" may be categorized as:

1. Definition of the gene of concern, which may be of the host species or may come from a totally unrelated source;
2. Isolation and cloning of the required gene, usually with associated DNA.
3. Insertion of the cloned gene into a suitable nucleus.
4. Regeneration of a plant from the cell carrying that nucleus.
5. Evaluation of propagules of that regenerated plant.

Steps 3, 4 and 5 have been accomplished and indeed have become almost routine in many laboratories. Most laboratories work with the familiar *Agrobacterium tumefaciens;* a few with *A. rhizogenes*. At Geneva we also use direct insertion of DNA-coated projectiles by the "gene gun". Regeneration of transgenic plants, usually from leaf disc cuttings, has been thoroughly studied in both apples and pears, and some alternative systems are also being researched. Oddly enough, we have almost no experience in medium-term evaluation of transgenic propagules of these species.

Endogenous genes. Identification of useful genes in apples and pears has been accomplished to only a minute degree. Indeed, most of the attributes in which we are interested appear to be under polygenic control. The only characteristic under major gene control that is of primary importance in apple breeding is the *V* locus for black spot resistance; even *V*-type resistance is subject to modifier genes, probably tightly linked.

Similarly, we have made only limited progess in recovering and cloning endogenous genes. There is now intense activity in our laboratories at Geneva as well as at Angers, at East Malling, at Davis and perhaps elsewhere. Our primary interest is in the *Vf* gene and its associated modifiers as found in `Liberty'.

Exogenous Genes. For the present we are left with foreign genes, which merit our consideration now.

1. *Bt* has excited a great deal of interest around the world. The prospect of using genetic engineering to remove the necessity of applying normal pesticides for control of at least some insects is certainly appealing. *Bt* has been successfully inserted into a number of horticultural species, including walnut and cranberry. We should have no doubt that it can be done very readily with apple and pear; whether *Bt* should be deployed is considered later (cf. 6.2).

2. Delayed Ripening. Genes that are expressed as delayed ripening might be highly useful for producing fruit varieties with improved shelf life. These are now available from several sources, including that recovered in New Zealand from `Golden Delicious' apple. What, if any, side effects will be encountered is unknown.

3. Resistance to Viruses. Coat protein genes to several viruses have now been cloned and transgenic plants recovered and tested. Six months ago the Geneva the virology team successfully sequenced the coat protein gene for tomato ringspot virus, which is very serious on a number of fruit crops in North America, including apples. We will be putting this into susceptible rootstocks such as MM.106 apple, `Lovell' and `Nemared' peach, a range of plum stocks, into brambles and grapes.

We have a number of other viruses of major significance that may be susceptible to the biotechnologists' touch - prunus necrotic ringspot, prune dwarf virus, X-disease, and phony peach.

4. Anti-Bacterial. Several approaches to inhibiting growth of bacteria are now being explored. Whether one of these will be effective against fire blight or against *Pseudomonas* remains to be seen. First results at Geneva with modifying Malling 26 apple rootstock for resistance to *Erwinia* have been encouraging.

5. Burrknot Prevention. Burrknots are coded by two recessive genes, denoted *ss* and *tt*. A null-sense dominant at either locus should be effective in blocking burrknots in all our important apple rootstocks. Burrknots have generally not been a problem in Australia, but in perhaps one planting in 20 the problem has become quite serious. No full-scale investigation of this prospect has yet been undertaken. Reports from Poland of a spontaneous mutant of M.26 that is free of burrknots would suggest that the approach is valid.

4.112 Somoclonal Variation. In Belgium, Jacques Viseur has regenerated fire blight-resistant shoots from root callus culture of `Durandeau' pear, using the exotoxin "amylovorin" in a selective medium. At Geneva, Aldwinckle and Norelli are following a somewhat similar approach for several varieties of apples.

Somoclonal selection might be used for recovery of regenerants resistant to other pathogens, such as *Phytophthora* (already accomplished with strawberry) and *Pseudomonas*, and perhaps to drought stress.

New genotypes recovered by somoclonal selection will require most exacting evaluation. It is not likely that in a given regenerant, only the single desired attribute will have been reprogramd.

4.113 Protoplast Fusion. This technique has lead to a major breakthrough in developing new citrus rootstocks. To my knowledge, no apple or pear has yet been regenerated from protoplasts. Protoplasts of apple have been carried to approximately 50 cells, but workers have been unable to bring about further cell division.

4.114 Improved Rooting. Infection of difficult-to-root rootstocks with *Agrobacterium rhizogenes* appears to have possibilities for permanent enhancement of rooting. Appropriate subjects include Ottawa 3 and Merton Immune 793 apple rootstocks and the OHxF pear rootstocks. Whether selection from *A. rhizogenes*-transformed material will yield suitable plants for further propagation is being evaluated in France by Doug Tepfer at Versailles.

4.12 Stabilizing Chimeras

Periclinal chimeras are notoriously unstable. Traditionally the better nurserymen have attempted to stabilize their "sports" by subclonal selection through two or three fruiting generations. Too often, though, nurserymen have proceeded to deploy exciting new selections without stabilization; `MacSpur', in the United States, was so released and proved a real debacle for the nursery and for the apple industry.

Here in Australia, `Royal Gala' passed through quarantine and was released to the importing nurseries. They proceeded to propagate with inadequate orchard testing; the particular subclone that came from quarantine was extremely unstable, and many orchardists had over 70% reversion. `Royal Gala' has now been stabilized by rigorous phenotypic selection, but, because of the fundamental nature of periclinal chimeras, further reversions could occur in future.

If apples are regenerated from single cells in leaf disc cuttings in vitro, then at least some of the regenerants from chimeras should be pure. Since most of the imports from overseas are chimeras, this could be a major benefit to the industry. This would be of little importance in pears, since almost no commercial varieties, except the few red sports, are chimeric.

4.13 Genotype Identification

One of the major goals in the Geneva program for breeding disease resistant apples is to incorporate both *Vf* and polygenic resistance to black spot. At present our only means of determining genotype is by test crossing.

It would be most helpful in addressing this objective to be able to identify the nature of resistance in our preselections, i.e., whether a given selection carries *Vf* only, or polygenic resistance only, or both types.

Similarly, it would be highly useful to be able to use DNA probing or other techniques to identify seedlings carrying genes for resistance to fire blight without having to resort to testing with the pathogen. If this could be developed it would very greatly enhance Australian breeding programs for both apples and pears.

4.2 Biotechnology in Australian Fruit Breeding

Peter Goodwin at University of Sydney has already passed through much of the gauntlet of mistake-making in apple biotechnology. He has successfully carried a microclone of `Delicious' through transformation, regeneration and establishment; Goodwin and Tancred are moving forward with testing of transgenic plants for sexual expression of *kan* and *gus*.

The Knoxville team has moved forward very rapidly toward practical biotechnology applications to apples and pears and have been successful in regeneration and recovery of transgenic plants of both genera. Focussing on pear variety improvement, pomologists and biotechnologists are in the process of developing a coordinated project. For the present, this group is preparing to depend on later developments in biotechnology for resistance of pear varieties to fire blight.

Apparently CSIRO biotechnologists are not yet involved with pome crops but they have demonstrated their capacity with others.

5.0 INTRODUCTION OF FOREIGN VARIETIES AND PLANT QUARANTINE ISSUES

About 12 to 15 new apple varieties are named every year in other countries; of this number, usually 3 or 4 may be worth testing in Australia. Today most of these new varieties originate from deliberate hybridization; many are resistant to black spot, and some to fire blight.

Usually about 3 pear and nashi varieties are introduced each year; however, in the near future we may anticipate an increase in the number of disease-resistant pear varieties from Europe and North America.

5.1 Overseas Breeding Programs

Although there are no apple or pear breeding programs overseas that are located in climates exactly like those of Australia, several are producing varieties that merit testing under Australian conditions. All except the Brazilian and Arkansas projects are carried out under high chilling conditions. However, it should be noted that `Delicious', which is a major variety in Australia, has a high chilling requirement typical of all these programs. The major breeding projects and some of their introductions are:

Geneva, New York, USA. Apple varieties resistant to black spot, powdery mildew and fire blight; long chilling: `Liberty' and `Freedom'. High quality, long chilling apple varieties: `Jonagold', `Empire', `Spigold', `Cortland'. High quality pear varieties: `Highland', `Aurora', `Phelps', `Cayuga'. Apple and pear rootstocks resistant to fire blight and root rot: `Geneva 65' and `'Novole' apple rootstocks.

Purdue University, USA. Apples resistant to black spot; long chilling. The "Coop" or "PRI" series, including `Prima', `Priscilla', `Jonafree', and `Redfree'.

USDA, Kearneysville, West Virginia, USA. Pear varieties resistant to fire blight and basically similar to William's; long chilling: `Dawn', `Magness', `Moonglow', and `Potomac' pears.

Harrow, Ontario, Canada. Pears resistant to fire blight and basically similar to 'Williams'; long chilling: `Harrow Delight' and `Harvest Queen'.

University of Arkansas, USA. Apples tolerant of high summer temperatures, mostly of `Golden Delicious' type; medium chilling: AA62.

Summerland, British Columbia, Canada. High quality apples ripening from autumn through `Delicious' season; long chilling: `Sunrise', `Sumac', `Summerred', `Spartan'.

New Zealand. High quality apples and pears. High chilling. Black spot and powdery mildew program also. Gala, GS330, GS2085.

EMPASC, Cacador, Brazil. Low chilling, black spot resistant apples: `Primicia'. Low chilling apples: `Princessa'.

Japan (several locations). Large, high quality apples with high sugar and low acid; no screening for resistances; high chilling. `Fuji', `Mutsu', `Akane' and many others.

CTIFL, Angers, France. Pears resistant to fire blight; high chilling. High quality pears: `General LeClerc'. Apples resistant to black spot, powdery mildew and fire blight; high chilling: `Florina'. Radiation mutants from high quality, high chilling apples: `Belgolden', `Lysgolden', `Reine de Reinette Rouge'.

Rome, Italy. High quality, medium-high chilling pears.
Ahrensburg, Germany. Apples resistant to black spot and *Nectria* canker. Quality apples, high chilling: `Gloster'.

Pillnitz, Germany. High chilling apples resistant to black spot, powdery mildew and fireblight. High quality early apples: `Alkmene'.
Balsgard, Sweden. High quality, high chilling, very early apples and pears. Apple rootstocks: `Bemali'. Pear rootstocks.

5.2 Importation through Quarantine.

If Australian fruit growers are to be competitive on the world markets, they must be able to change varieties to meet the demands of those markets. This requires prompt movement through AQIS and thorough trialling before deployment of the variety.

Traditional importation of scionwood of desirable varieties through quarantine has not always been satisfactory. Time delays can be substantial; five or six years in quarantine has been common. Virus and fireblight screening are usually done sequentially, rather than concurrently, taking a minimum of five years, often longer.

Sometimes critically important accessions die or are lost in quarantine. `Liberty,' an especially valuable variety carrying resistance to black spot, fire blight and powdery mildew was released from the Geneva, New York program in 1978. QDPI imported it into quarantine in March 1983 for use as a parent in the breeding program. `Liberty' was being carried on AQIS inventory as "Still In Quarantine" through November1991, even though an inquiry in mid-1990 had revealed that it had died in quarantine some years earlier.

Substantial improvement in the flow through AQIS can be accomplished by some modest but safe revisions in protocol and by much improved management.

A substantial fee is now being charged for bringing an accession through quarantine.

Experiences with long delays in quarantine and the substantial fee being charged may combine to increase the amount of smuggling. This practice appears to be the most likely means of bringing fire blight into Australia.

5.3 Orchard Testing of Introductions

For all tree fruits, failure to initiate and carry out rigorous trials of new candidates is perhaps the greatest single deficiency of Australian fruit research. Fruit variety test plantings, scientifically designed and well executed, to yield maximum information for minimum input were observed only at GBHRS in my eight week review. The more typical test planting consisted of single replications of two tree plots, often with no controls. Although often abundant data were collected, variety comparisons have been seriously flawed by lack of appropriate replication, checks, and tree numbers.

The variety testing needed by the fruit production industries has been severely hampered by failure to obtain full cooperation from nurserymen. This has been especially serious with stone fruit varieties, with the rapidly changing repertoire of new introductions, but it has also been a problem with apples. I find it inconceivable that nurserymen would not be eager to have their candidates entered into well-conducted trials. I also find it nearly incredible that the orchardists would purchase large numbers of trees of new varieties that have not been tested in Australia, let alone in their own districts.

Two recent failures to pretest new varieties have resulted in significant losses to fruit growers:

(1) `Royal Gala' was brought through quarantine, distributed from quarantine to nurseries, and then propagated and sold without the fruit having been seen. The particular budwood delivered from quarantine was an unusually unstable periclinal chimera. On growers' farms, 60 to 75% of the trees reverted to standard `Gala', discovered 2 to 4 years after planting. Although this problem has since been almost corrected, the economic damage sustained by reversions in the initial deployment was very distressing to the growers involved.

(2) A number of nectarines and plums have been introduced from California. These have been passed through quarantine to the nurseries, propagated quickly and large numbers of trees sold without testing under Australian conditions. Some, but not all, of these California varieties have proved to be susceptible to *Xanthomonas campestris pruni*, the bacterial spot incitant. Again, the fruit growers have paid the price for failure to test.

6. RECOMMENDATIONS

6.1 Improving the Breeding Programs

The most important single improvement will be a major extension of the germplasm collection, especially including varieties that carry significant resistances to the three diseases of primary concern - black spot, fire blight, and powdery mildew. This will necessitate more efficient movement of accessions from abroad through the quarantine system. Almost equally important will be a re-examination, upgrading and systematic prioritizing of breeding objectives. I have strongly suggested inclusion of resistance to fire blight as a major objective.

Some minor alterations in techniques are suggested for consideration. Significant increases must be provided in support personnel, facilities and operating monies.

6.11 Breeding Objectives and Priorities

Objectives should be clearly defined, standards of performance established, and priorities assigned.

Apples. Objectives of both programs appear to be well understood by the breeding teams, but it would be valuable to establish on paper some solid definition of priorities. The GBHRS program has now determined that black spot resistance better than that of `Prima' is to be an "essential" objective, for example, while spur-type tree habit is assigned a third-rank "helpful" priority.

Pears. The present limited set of breeding objectives - `Packham's Triumph' with better skin finish, less bruising, and improved storage and shelf life - should be extended to include resistance to *Venturia pirinia*, *Erwinia amylovora*, and possibly other diseases, and a wider harvest season. Some attention might also be paid to the possibility of developing red-skinned pears superior to `Sensation'. Consideration should also be given to development of varieties better suited to processing than `William's Bon Chretien'.

6.12 Germplasm Collection

It is vital to all programs that suitable parent material be sought aggressively from all possible sources. Insofar as possible, the most advanced selections should be requested from foreign programs. Parents with especially valuable attributes, such as low chilling requirement, unusually long shelf life, resistance to scald, etc., should be sought.

A partial list of potential parents, many of which are not now in Australia, is shown in Appendix 4. Attributes of these clones are identified as far as possible.

6.121 Disease Resistant Apples. Black-spot resistance programs have been active in Germany, the USA, the former USSR, UK, France and Romania for a number of years; the German program began about 1932 and the American in 1946. Serendepitously, a small proportion of the introductions from these programs have proved to be resistant not only to black spot but also to fire blight and, sometimes, to powdery mildew. `Prima', the first variety named from any of these programs, has a number of horticultural shortcomings, but it does carry the desired multiple resistances.

Short-Term Improvement: At best, the first accessions above will become available as breeding trees on hand at Applethorpe and Stoneville in 1995. The AAGPA envision introduction by 1996 of four new disease resistant apple varieties, bred and developed in Australia. Obviously this cannot be achieved from a small program initiated in 1984. However, it is clear that it is important to have resistant varieties available for deployment very quickly. To expedite breeding and evaluation of such new varieties the following steps are suggested:

(a) Arrangements should be made for Queensland apple breeder Stephen Tancred to make working visits to Purdue University and Cornell University in April and May, 1993. There he would utilize mother trees of the most valuable disease resistant varieties, applying pollens from the best Australian varieties, such as `Summerdel', `Pink Lady', `Sundowner' and GB 63-43. Two crossing seasons, with his personal imput augmented by supervised local casuals, should provide a 2- to 4-year reservoir of hybrid seeds.

(b) At present, pollens from America, France and the UK are prohibited entry into Australia because of a perceived risk of fire blight (there is no evidence of real risk). A revised minimum risk protocol has been proposed to AQIS (cf 6.133 below). If this protocol is viewed favorably, then pollens of at least some of the needed parents could be brought in and used on disease-susceptible mother trees now at Applethorpe. For example, pollens of NY 73334-35 and `Williams' Pride' could be obtained in New York, treated according to the new protocol, and used at Applethorpe on `Earlidel', `Pink Lady' and `Summerdel'.

If this procedure is not approved, then a less desirable alternative would be to house potted Australian mother trees in a quarantine facility remote from Stanthorpe, e.g., Eagle Farm, and there apply imported pollens.

(c) Fire blight does not occur in Brazil. It should therefore be possible to import pollens of their low-chilling introduction `Princessa' and low-chilling, black spot resistant `Primicia' directly. `Princessa' pollen could be used on `Akane', `Priscilla' and `Prima', while `Primicia' would be especially useful on `Delicious' and perhaps `Summerdel', `Sundowner' and `Pink Lady'. (Fire blight susceptibility of `Earlidel', `Summerdel', `Pink Lady', `Sundowner', `Primicia', `Princessa', `Lady Williams' and GB 63-43 will be determined at Geneva in August 1992.)

Long-Term Improvement. Scionwood of `Liberty' and `Keepsake' are being requested from the American "IR-2" phytosanitary repository and should move through quarantine quickly.

Several of the Purdue-Rutgers-Illinois (PRI) "Coop" series have been entered into the quarantine stream, and some have been released by AQIS to the sponsoring nursery. Cooperation of Fleming Nurseries has been solicited; it is hoped that germplasm of `Florina Querina', `Williams Pride', `Dayton', and Coop 26 through Coop 31 will be made available by Fleming, either as trees, scionwood, or pollen. If this does not come about, then the PRI officials will be solicited again.

Several New York selections have been requested; it will probably require 3 years for scionwood of most selections to clear Australian quarantine.

Three selections from Dresden-Pillnitz, Germany, are resistant to our 3 diseases; they will be requested in the near future.

Black spot resistant varieties from Romania and Czechoslovakia are being acquired at Geneva and, when received, will be tested there for fire blight susceptibility. Those that are resistant should be brought in as germplasm. The low-chilling, scab-resistant `Primicia' has been requested from Brazil, along with several advanced selections; they will be tested for fire blight susceptibility at Geneva. We are in the process of establishing a cooperative arrangement with Brazilian breeders to facilitate exchange of pollens and plant materials.

6.122 Germplasm for the WA "Classical" Apple Program. All the hybrid seedlings now planted at Stoneville and Manjimup will be susceptible to black spot. However, 40% have one parent resistant to powdery mildew and both parents of 12% of the seedlings are resistant. Furthermore, either `Delicious' or `Splendour' is a parent of 40% of the total holdings; both these varieties are moderately resistant to fire blight and transmit resistance to some progeny.

It would be appropriate to extend the range of germplasm to include varieties such as `Melrose', `Sansa', `Elan', `Fiesta', `Kent', `Braeburn', `Sunrise', and, if obtainable, GS 2085 (from New Zealand).

6.123 Pear Germplasm. The repertoire should be substantially expanded, especially sources of disease resistance. The fire blight-resistant `Potomac' will soon be released by the USDA breeding project. Pollens and scionwood of `Potomac' and advanced selections from this program should be acquired as soon as possible. Special arrangements should be made for carrying out crosses in quarantine.

Arrangements have been made with USDA breeder Richard Bell to produce a small number of hybrid seeds in 1992.

The recent South African introduction, `Ceres', is described as apparently identical to `Packham's Triumph' except for ripening two weeks earlier. `Ceres' merits prompt accession to be used as a parent in the breeding program and to be orchard-tested for extending `Packham's Triumph' season.

`Cascade' (Max Red Bartlett x Comice) and `Rogue Red' (also a `Comice' seedling) should be brought into play if red skin is to be a collateral objective.

6.13 Importing Germplasm

6.131 Heat-Treating Scionwood. Theoretically, the fire blight bacteria can be carried epiphytically on scionwood taken from an infested source and the disease spread to stocks budded in the nursery from such presumably infested scionwood. In actual practice, even with no precautions taken except visual selection of scionwood, this sort of transmission is extremely rare.

In a set of trials at Geneva sponsored by AQIS, dormant apple shoots with epiphytic infestations of *Erwinia amylovora* were treated in a 48°C hot water bath for 1 hour. No trace of the bacteria could be found, and about 50% of the apple buds were viable.

Imported scionwood should therefore be heat-treated as above and then should be propagated onto stocks highly susceptible to fireblight, e.g., Malling 26 or seedlings of `Fuji', `Gala', `Jonathan' or other very susceptible variety. The susceptible rootstock would then act as a fireblight indicator.

AQIS authorities must determine whether the hot water treatment is compatible with methyl bromide fumigation. Increased supply of budwood will be required to make up for expected increase in bud failure rate.

6.132 ***In vitro* culture** of apples is now a standard activity at many research stations, and micropropagation of pears has now been demonstrated. In my laboratory I routinely bathe microshoots from proliferation state in ethanol before micrografting. Proliferating cultures could be received in quarantine, microshoots bathed in ethanol, and then micrografted onto clean M.26.

6.133 Importing Germplasm as Pollen

Conventions at Geneva (USA) and Angers (France)

Dormant Shoot Method. In late winter, about 4 weeks before budbreak, dormant shoots with fruiting spurs and terminals are brought into the glasshouse and forced. As flowers open, anthers are plucked, then dried and pollen stored at about 40% RH and -20°C. Pollen is not usually separated from dried anthers and filaments.

Potted Tree Method. Potted trees in the glasshouse are given suitable chilling, then forced. Flowering usually is about 4 weeks earlier than normal outdoor bloom date. The potted trees have usually but not always been raised the previous season in the glasshouse or screenhouse. Pollen is collected and processed as above.

Open Orchard Collection. Occasionally flowers at full balloon stage are collected directly in the orchard. Pollen is collected and processed as above.

In all 3 methods, source trees used are healthy and apparently fireblight-free.

At Geneva, I have used all 3 methods for many years, without taking any precautions against fire blight infection of the stigmas of the flowers later pollinated. Many of our pollinations have been onto Malling 26, M.9, Bud.9 and other very susceptible female parents. We have never encountered even a single blighted blossom by these methods.

Modifications of Above Conventions to Minimise Risk

Dormant shoots bearing fruiting spurs and/or terminals from apparently disease-free apple trees are brought into isolation greenhouse in late winter, after satisfaction of chilling requirement and at least 2 weeks before outdoor budbreak. Shoots are held in water at 48°C for 1 hr; immersed and agitated for 1 min in EtOH 70%; rinsed 3 times in sterile water; and forced in clean growth chamber at about 23°C.

Flowers are plucked at full balloon stage, dipped briefly in EtOH-70, multirinsed. After drying flowers, anthers are plucked, dried, and pollen sieved out. Pollen is shipped or used immediately, or stored in dessicator at ca. -10°C.

Dormant Potted Trees. Spray to runoff with EtOH-70. Immerse tree tops in 10% hypochlorite solution for 10 minutes. Multi-rinse; grown on, then harvest and treat flowers as above.

Open Orchard. Process flowers as for dormant shoots above.

Pollen so processed should, in my view, be free of fire blight risk. However, these modifications to procedures now in place in Geneva and Angers have not been given rigorous risk assessment. This evaluation should be carried out as soon as possible, and AQIS officials should be urged to move promptly. In the meantime, arrangements should be made for carrying out pollinations in quarantine on a significant scale. This is especially important for pears, since offshore pollen is the only fire blight-resistant germplasm.

6.134 Seeds Importation

The present system can only be improved upon if money is available to allow specific controlled crosses to be done overseas. This hybridizing would be between quality Australian parents and overseas parents having multiple disease resistance, e.g., `Summerdel' (Australian, susceptible) X NY 73334-35 (American, resistant to black spot, powdery mildew and fire blight).

6.14 Planning Crosses

There are only 3 possible reasons for making any given cross:

(a) To provide a population from which ultimately to introduce a new variety that will make a place in commercial production;

(b) To provide a population from which to select a superior parent for future breeding; or

(c) To provide a sample from which to draw inferences on genetics.

The financial and time commitments implied in making any cross are so substantial that the decision to make a given cross must be most carefully taken, with very conscious concern given that it has acceptable potential for producing (a) that candidate worth introducing; or (b) an outstanding and necessary parent; or (c) essential genetic information.

6.141 Backcrossing. Repeated use of a parent has usually not been a productive strategy in apple breeding. Survivability tends to be reduced, and, more importantly, such crosses tend to emphasize adverse attributes of the backcross parent and to permit expression of otherwise recessive attributes. Problems with *Pseudomonas syringae* (blister spot) and the foliage disease caused by *Glomerella cingulata* are likely to be exacerbated by backcrossing with `Golden Delicious'.

There is a substantial amount of inbreeding in the WA program -- at least 22% (parentage of chance seedlings is unknown). Backcrosses include Gala x Hi Early, Gala x Golden Delicious, Lady Williams x Pink Lady, and Lady Williams x Sundowner. Sib- and half sib-crosses include Sundowner x Pink Lady, Gala x Sundowner, Gala x Pink Lady, and Gala x Fuji. It will be appropriate to keep inbreeding at or below this level to keep traits controlled by recessive genes from surfacing.

6.142 Open-Pollinated Seedlings. Open-pollinated seedlings should normally not play a significant role in a breeding program. The odds are so greatly against success for any individual seedling that every opportunity should be used to improve those odds; obviously this includes using the very best possible **pollen** parent.

An important exception to this general rule is to collect seeds in an orchard with only one possible pollen donor. For example, `Empire' came from a large number of O.P. `McIntosh' seeds, taken from an orchard in which only `Delicious' pollenizers were present. Another exception, now being employed at Stanthorpe, is to collect O.P. seed of a highly useful parent, such as NY 73334-35 with its multiple resistances, from trees on which the pollen donors were also highly advanced selections from the resistance breeding program.

6.15 Hybridizing Methods

Almost all apple and pear varieties are nearly self infertile, usually producing < 2% selfed seeds. Breeders would be well advised to determine self-fertility levels of prospective female parents. A small % of selfs -- up to perhaps 5% -- can be accepted when variety improvement is our objective. Usually these will be eliminated very early in the evaluation sequence. This low order of self-fertility can be utilized to advantage in the breeding program, although it is a liability when making genetic studies.

Three quite different hybridizing systems are now in use in the 2 Australian programs:

(1) <u>Anther Removal + Bagging</u>. At Stoneville and Manjimup, anthers are removed without damage to receptacle and small groups of flowers are covered with small paper bags. This practice is followed to avoid desiccation of radically emasculated flowers.

This system has permitted production of adequate numbers of seeds in the past. However, it is quite labour intensive and requires a substantially larger labour input than may be required by alternative means.

This method has the advantage that it permits very precise evaluation of parental potentials and could be useful for genetic studies in which contaminating pollens could be problems.

(2) <u>Caging bees</u> is the most efficient measure for obtaining very large numbers of hybrid seeds. Mother trees are caged, bouquets of a selected pollenizer are provided, and a small hive of bees inserted. This system has been adopted at Stanthorpe as the primary method of crossing.

Since most apple varieties are partially self-fertile, this procedure will result in a small % of selfs. This is of course intolerable for genetic studies, but is a minor inconvenience in programs for variety improvement.

This system is especially useful when using a black spot-susceptible female and a resistant pollen parent, e.g., Liberty x Summerdel. In such a progeny, all selfs would be eliminated in the black spot screen, along with the 50% of the hybrids that did not receive the *Vf* gene from the resistant parent. Surviving progeny can be used for genetic studies of attributes other than black spot resistance.

Small potted trees can be used instead of bouquets. This offers the obvious advantage of producing some seeds of the reciprocal cross.

(3) Radical Emasculation. This system is the most common among apple breeders and is used as a supplement to caging at Stanthorpe. One to 3 flowers per truss are emasculated and pollen is applied. Branches so treated may or may not be covered with muslin sleeves. Without bagging, a small amount of contamination (usually <3%) by windborne pollen may occur; radically emasculated flowers are ignored by bees. Bagging is necessary for genetical studies.

Rarely, emasculated flowers may be killed by desiccation. Usually, receptivity period is about the same as that of non-emasculated flowers and seed yield per fruit is similar.

A minor advantage is that mature fruit that has been emasculated is easily distinguished from fruit not emasculated.

The following suggestions are offered for increasing efficiency of the hybridizing activity:

(a) Caging bees should be used as extensively as possible, simply because of its potential for producing very large numbers of hybrid seeds at relatively low cost. This is especially appropriate at Stanthorpe, since cages and bees can be used in the plum breeding program as well.

(b) Funds should be made available to purchase fruit from growers. If inadequate numbers of flowers of a particular variety needed in the program are not available on the station, then arrangements should be made to do crossing on grower's orchards.

(c) The already established pattern of cooperation in hybridizing should be expanded, so that, e.g., crosses such as Pink Lady X Liberty could be made at Manjimup and seeds germinated and black spot screening carried out at Granite Belt.

(d) There will be situations, e.g., frost damage, that make it important for the breeders to make their crosses away from their bases. For example, it is possible for a frost to destroy most of the Summerdel blossoms at Stanthorpe; in such a case, it should be possible for the breeding group to travel to Batlow or Orange to make crosses. Such travel should be anticipated and contingency funding available.

(e) Consideration should be given to greater utilization of potted seed trees. Being able to make crosses under glass before normal bloom time has the significant advantage of extending hybridizing season by several days. Perhaps of greater advantage is earlier production of pollen.

(f) Double pollination should become standard practice. Repollination 20 to 30 hr after initial pollination will result in a 30 to 50% increase in seed production in most crosses because of the "pioneer pollen tube" effect.

(g) There would seem to be no compelling reason to continue effeminating flowers in Western Australia, if indeed the use of small bags is to be continued.

(h) The most efficient means of obtaining hybrid seeds by hand pollination would be to cage seed trees, perhaps several small trees in a row. This offers opportunity to apply several different pollens in the same cage without emasculation.

6.16 Screening for Disease Resistance

6.161 Testing for Black Spot Susceptibility--Stanthorpe. The breeding team has in place a very effective protocol for screening against susceptibility to *Venturia inaequalis,* however we have some concern that only Race 1 of the fungus can now be used in the screening. We now have some reports from Europe that suggest breakdown of resistance conferred by *Vf.* It will be prudent, therefore, to make arrangements for future testing of very advanced selections for susceptibility to other *V. inaequalis* races; it may be necessary to do this offshore, or it may be possible to make arrangements at an existing quarantine station. In either case, some modest additional financing will be required.

A few minor suggestions are offered to improve efficiency of the present program as plant numbers to be screened continue to increase.

(a) Germinating seeds can be planted into flats, rather than into individual pots. This reduces by about half the time required for planting.

(b) Incubation time in the precision facility can be reduced to 24-36 hr without compromising the levels of infection.

(c) Greater care might be taken to inoculate adaxial leaf surfaces. At the same time, it is important to keep droplet size small to avoid runoff.

(d) Plants that survive the first elimination should be reinoculated at once -- normally about 25 days after first inoculation.

(e) Spore concentration could appropriately be reduced about 8-fold to ca. 250 000/ml; this would permit better definition of 3's, especially when relying on polygenic sources of resistance.

(f) Discard all seedlings with "3" reactions to inoculation with the black spot fungus. Obviously this would drastically reduce % of progeny moving to first test level, and it might be inappropriate for progenies from `Prima', which is itself a "3". (A "3" reaction is the occasional sporulating lesion on leaves; no lesions have been reported on `Prima' fruit.)

6.162 Black Spot Susceptibility--Western Australia. Since Western Australia does not have *Venturia inaequalis* as a permanent resident, testing for susceptibility cannot be done in WA. It may be possible for such testing to be done with isolates of black spot from Western Australia at Brisbane, since facilities and expertise coexist there.

However, additional technical and financial support would be required. Testing for susceptibility to isolates from eastern Australia could be conducted at Stanthorpe.

We now assume that susceptibility to black spot will not prevent future introduction of an outstanding candidate, such as `Pink Lady'. Determination of black spot susceptibility therefore becomes important only in an advisory sense, not for decision-making vis-a-vis introduction. Given this, it seems most appropriate to conduct screening for susceptibility to black spot late in the third test. Numbers of clones to be tested in Brisbane and/or Stanthorpe would therefore be quite small.

6.163 Black Spot Susceptibility Screening--Pears. Presumably a protocol similar to that used for apples can be established, but none has yet been tested in Australia. Contacts have been made with pear breeders in America.

6.164 Fire Blight Testing. In some resistance breeding programs, the fire blight toxin, amylovorin, has been used to estimate resistance. However, research in New York has shown that this method selects for vessel size, rather than directly for biochemical resistance to the disease. Until some new technology is developed, the most realistic method will be one based on active inoculation with the incitant itself.

The ideal situation would be that used in the Geneva apple breeding program: after selection for resistance to *Venturia inaequalis* the survivors are grown to about 50 cm in the original flats. At this stage, the succulent shoot tips are inoculated by hypodermic syringe with ca. 100 000 bacteria of each of 5 isolates. Resistance is estimated on the basis of proportion of shoot killed; usually this procedure is carried out 3 times before the surviving plants that are judged to be susceptible are discarded. Usually about 10% of the original seedlings survive both black spot and fire blight screens.

Any testing done with *Erwinia amylovora* must be done offshore. Offshore contract work by its very nature must be much more expensive than to do the screening as a routine part of the program at the breeding station. This leaves open the question, "when should fire blight susceptibility be determined?"

(a) Doing the fire blight trial during 1st test stage would mean subpropagating hundreds, probably thousands of clones, almost all of which would later be discarded. This does not seem a viable option because of cost. (It would not be possible to use an overseas facility to have seeds germinated and seedlings screened for resistances to black spot and fire blight because the plants surviving after being tested would require long term quarantine for re-entry into Australia.

(b) Testing early selections would involve propagation of about 5% of the number planted in 1st test orchard--perhaps 500 clones from each 10 000 seedlings.

(c) From the 3 programs, likely 10 to 20 elite selections will be advanced to 3rd test level each year.

(d) The final option would be to test for fire blight when well into 3rd test -- perhaps only a year away from introduction. This has the advantage, of course, of minimum cash outlay for offshore testing, but more important, it would mean that much time and resource would have been wasted in orchard trials.

I strongly recommend (c) above. Fire blight susceptibility can be accurately determined in a single growing season at Geneva. This would coincide with the production of nursery trees for 3rd test. If a given candidate fails the fire blight test, then it can be removed from the 3rd test scheme before orchard planting.

6.17 Field Screening and Selection

This is the most time-consuming and most expensive activity in the fruit breeding program. Unfortunately, since most expenses are related to km of row rather than directly to tree numbers, early culling has little effect on total cost. However, early culling does give significant benefit to the breeder simply by reducing the number of trees to which he must devote his attention.

6.171 Powdery Mildew Susceptibility. In the first and sometimes through the second year, almost every seedling is highly susceptible to this pathogen. We have not found any method for screening at this stage that does not seem unacceptably harsh. Therefore powdery mildew screening is left until the third or fourth year of field testing. In common with most breeders, we eliminate those individuals that are severely attacked but not those with light infections. The practices now in place in Queensland and WA should be continued until a better method is found.

6.172 First Test. Purpose: rapid elimination of unfit and selection of preselections with possible merit. At Stanthorpe, survivors of the black spot prescreening are planted out in a nursery and grown on for one year. After this first season, they are dug and replanted at wider spacing in the fruiting orchard. No training or pruning is carried out. Irrigation is provided from time of first planting (water was inadequate in 1991-1992).

At Stoneville, since no prescreening for disease resistance is now carried out, all seedlings are set directly into the fruiting orchard.

As the pear breeding project comes on line, it is hoped that methods will be developed for screening for black spot susceptibility in the greenhouse. Otherwise it will be necessary to carry out the much more expensive procedure of field selection.

In all three projects, elimination for heavy infections with powdery mildew commence in the third year. Usually a small % of seedlings begin fruiting in year 3, and most trees have fruited by the 5th. Fruits are harvested, bagged and labelled, and stored until it is convenient to evaluate. A considerable spectrum of data has usually been recorded, even on fruit from obvious discards. The 1991/92 season has seen some increase in rigour.

Trees not fruiting by the 5th year have no significant chance of success, since a long non-fruiting period at Test 1 is expressed later in the orchard as non-precocity.

6.173 Selection & Second Testing. Purpose: to provide opportunity for direct comparison of early selections with standard varieties. Usually we expect to eliminate 80 or 90% of the early selections at this stage. Positive selection normally begins in the fourth year at both stations, based on outstanding presentation in the 4th year and often the 3rd. Selections are budded onto seedling or onto clonal rootstocks, grown in nursery, and set into test plots. These 2nd test plantings are made with single tree plots, with appropriate replications.

Some out-of-State 2nd testing has commenced already from both programs. First selections from the Queensland program are being planted in trial plots at Batlow and Western Australia, as well as the Granite Belt.

In the Western Australia program, selections are topworked onto mature trees to permit earlier assessment of fruit qualities.

Since each of the three programs is designed to serve the several fruit-producing districts of Australia, it would be appropriate at this stage to arrange for more extended interstate testing. An appropriate pattern for second testing for both programs might be, e.g., to have 3 or 4 replicated at Stoneville, at Lenswood, at Manjimup, at Stanthorpe and at Orange. Pear selections might be tested, e.g., at Orange, at the Tatura Station and at Stanthorpe.

Testing should be organized on a solid basis for comparability and effort should be made to reduce subjectivity of evaluation at this stage. This requires a modest number of replications -- four or perhaps six.

On an *ad hoc* basis, some of this out-of-State 2nd testing has commenced already from both programs. Researchers at several State stations have put forward requests for financial support to permit them to become actively and formally part of this effort. I strongly suggest that HRDC provide modest funding to facilitate this wider testing of candidates.

6.18 Advanced Orchard Evaluation (3rd Test)

Selections that have performed very well in 2nd test are propagated onto clonal rootstocks and distributed to testers throughout the country. A candidate that has advanced through second test has about a 20% chance of ultimate introduction.

It is valuable to remember that any candidate for introduction has only 2 possibilities: either (a) it must displace an existing variety that has a defined place on the market; or (b) it must fit into a niche not now occupied by another variety. Thus, (a) in the Granite Belt, \`Earlidel' is replacing \`Gravenstein', \`Akane' and \`Summerred', and \`Summerdel' is replacing \`Adina', \`Abbas' and \`Earliblaze'; and (b) in the United States, \`Prima', \`Liberty' and \`Freedom' are filling an open niche in the organic orchard.

Third testing should be done on semi-commercial scale at several locations, preferably in states other than that in which 2nd testing was done. We like to use at least 4 replications with at least 5 and preferably 10 trees per plot in a RCB design. If at least 3 locations are used, then we have a (3 variety X 4 reps X 3 locations X 5 subsample) plan to give 12 d.f.

Clonal rootstocks should be thoroughly indexed to be sure they are free of harmful viruses and other pathogens. It would be preferable to settle on 2 clonal stocks that have wide commercial acceptance, e.g., Northern Spy and MM.106 for apples, and D6 and OHxF 333 for pears.

There will be candidates ripening across the entire season. Care should be taken to divide the candidates according to ripening season and to have suitable standards in each set.

Thus `Summerdel', e.g., might be used as the standard for selections ripening in late January.

The "summer diseases " -- sooty blotch and fly speck -- should be observed on apple candidates during second test. Omitting fungicides will not only allow evaluation for response to these two pathogens but also will serve to confirm earlier selection for resistances to black spot and powdery mildew.

An obvious procedure is to have an excess supply of virus-free liners available in the nursery, to bud selections onto these, grow on, and then plant into replicated plots in the 2nd test orchard.

A second option is to have virus-free liners set directly in place in the 2nd test orchard in the spring and then to bud directly in place in a replicated pattern. This method brings the selections to fruiting a year earlier than method 1, and fruiting will be heavier. It has the disadvantage of slightly more difficulty in planning and execution of trial design.

The first option is suitable for an older program. However, for both the Queensland and the Western Australia programs, with their considerable senses of urgency, <u>I suggest that the 2nd option is preferable because of the acceleration it offers.</u>

In a given year, it is not likely that more than 3 to 6 new candidates will be ready for 3rd test, and it is likely that their maturity timing will be quite scattered. It is essential that suitable standard varieties be included in each trial.

If there are, e.g., 2 candidates to be trialled in each of 3 different maturity seasons, e.g., early with `Gala', midseason with `Hi Early', and very late with `Pink Lady', then the test for each planting should be made a separate trial. We are not interested in comparing directly the performance of a `Gala'-season selection with that of a `Pink Lady'-season candidate.

<u>Grower Testing.</u> A new variety cannot be regarded as successfully introduced until it has been deployed by the industry (commercial deployment, however, does not necessarily mean that the candidate should have been introduced!!).

The fruit grower is naturally -- and appropriately -- quite skeptical about any innovation, especially a new variety. He almost invariably will want to see the variety for himself, on his own grounds, before making a major commitment. Most often the grower will want to look at a candidate by topworking a few trees in an existing orchard.
The breeder should agree to this only if

(a) the grower agrees to provide suitable checks;
(b) the breeder can be reasonably sure that there will be no interference from virus content of the topworked tree; and
(c) since PVR appears likely to be required of all introductions, there must be an ironclad, written contract for non-propagation and non-desemination.

An alternative to the topworking ploy, which we favor, is to arrange for growers to have access to small "grower test packages". This might consist, for example, of 6 maiden trees each on MM.106 rootstock of `Hi-Early Delicious', Coop 26, NY 73334-35, and NY 75413-30, to be planted under our supervision in 3 replications, 2 trees per plot. (Incidentally, we would not "sell" trees to the grower -- rather, we would sell testing rights, to avoid abrogation of PVR eligibility.)

6.19 Making Introductions

Around the world and across time, most introductions have been made on essentially subjective bases, but all too few after objective trialling. Third level testing is essential for the long term success of an introduction--and of the breeder and the breeding program. Future introductions should be made with the greatest extent of information it is reasonable to provide. If at all possible, at least some of the production quirks of the new variety should be reported; for example, if at Geneva we had introduced the apple variety `Wayne' with appropriate information on training, cultural and harvesting techniques and rootstocks, the variety would have been a success instead of a resounding failure.

The breeding teams and their advisory bodies should consider carefully the advisability of distributing their introductions overseas. Obviously any overseas success of a patented variety would bring income, perhaps significant income, to the sponsors. However, having exclusive production rights of an outstanding new variety, such as `Pink Lady', could be a major advantage in establishing and holding an export market, while having competitors in other countries of the Southern Hemisphere could be devastating. On the other hand, it could be advantageous to work with a major supplier in the Northern Hemisphere to establish and maintain markets. Developments with New Zealand's GS 2085 should be followed closely as these decisions are being approached.

6.2 Bringing Biotechnology into the Variety Improvement Picture

The unifying focus, it seems to me, is that Australia, and indeed the world, needs dramatic improvement in fruit varieties. The need is especially pressing to develop varieties that require less chemical application for the control of diseases and pests.

Fruit variety improvement should be a unified, team effort. Administration and geographic barriers to team effort should be overridden. This effort will bring together the biotechnologist, the breeder, and the pathologist as a team.

It would be most unusual to find in a molecular geneticist real expertise in judging tree behaviour, fruit attributes, and all the subtleties of pomology. Therefore the breeder must take the primary responsibility for field evaluation of new genotypes, whether created by classical hybridizing or by gene splicing. Neither biotechnologists nor pathologists should be given reason to see themselves in a service position. All are involved, and involved at a common level.

<u>Some Reservations on Deployment of *Bt* Genes</u>. I submit that we should be proceeding with caution on this approach. "Dipel" and other "organic" insecticides incorporating *Bt* are used only modestly at this time, but when employed according to current strategy they are effective against target species. We should give careful consideration as to whether it is indeed desirable to be deploying this gene on a 24-hour/day, 7-days/week basis. We have already experienced insects developing resistance against *Bt*-based sprays.

We have 3 types of problems with introduction of transgenic apples and pears carrying ICP genes from *Bacillus thuringiensis*:

(a) The major target -- codling moth -- is not a foliage feeder; the newly hatched larva feeds only on the fruit. Therefore, although we might be able to kill insects such as light brown moth, the major target would be vulnerable only after successfully entering the fruit. This would result in "stung" fruit, unacceptable for first class packs.

(b) Field resistance to *B. thuringiensis* has already occurred in at least one species, which strongly suggests that it can occur in target pests of apples and pears. Mention was made in the main text of the likely effects of continuous exposure of *Bt* to the genetic attacks of target pests.

(c) We may well encounter problems of public concern with ICP expressed in our fruit. Oversprays of *B. thuringiensis* have not presented problems because ICP was produced for only a short time, and then only in the insect target.

These 3 problems are not unsolvable:

(1) Other approaches, such as mating disruption with phermone-impregnated "twistees", will control codling moth and thus reserve ICP for the other target pests.

(2) Although genes are not yet available for use, proteinase inhibitors offer an alternative method of control. Genes for ICP and for proteinase inhibitors could be "stacked" to offer control of foliage feeders.

(3) The biotechnologist should be able to so program the plant that ICP would not be expressed in the fruit.

6.3 Physical Facilities and Personnel

Additional water sourcing and storage should be arranged as soon as possible at all the breeding stations.

Hail netting is essential at Stanthorpe for Test 1 to assure that evaluation sequence not be disrupted.

Black spot test chambers at Stanthorpe require better "back up" facilities. The present facilities serve well in the present situation, but much larger progenies, and therefore much heavier demands on the equipment, should be anticipated in the immediate future.

6.4 Introducing Apple and Pear Varieties from Overseas for Commercial Use

At present, a new variety developed overseas enters Australia through Commonwealth quarantine stations at Burnley or Rydalmere, usually requiring 4 or 5 years to become available for distribution in eastern Australia. If required in Western Australia, the new introductions are then sent to the AQIS station at South Perth for further quarantine against the pests endemic in eastern Australia, notably apple scab and codling moth. This invariably results in Western Australia growers having access to a new variety at least 2 seasons later than their counterparts in the eastern states. Obviously this additional 2 years also increases the total cost of quarantine. (When fire blight becomes established in eastern Australia, this even more serious problem will require additional quarantine effort.) The economic rationalization of Commonwealth (AQIS) quarantine stations appears to have scheduled elimination of the WA facility.

6.41 An Alternative Quarantine Protocol for Importing Apple Varieties from Overseas

6.411 Initial Importation. Let South Perth be designated the normal port of entry for apples, unless otherwise specifically required by importer. At least 6 months before expected entry, importer advises WA AQIS, and apple seedlings are prepared. Importer arranges for incoming material to have received suitable chilling. Heat treatment for fire blight eradication (48^{o}C hot water bath for 60 min) would be highly desirable.

6.412 Treatment at WA AQIS. New accessions are budded onto virus-free liners -- 3 buds/seedling, 2 or 3 seedlings per accession. These seedlings should be fire blight susceptible; budding onto susceptible seedlings would be an effective means of confirming freedom from fire blight in the imported scions. (Seedlings of the FB-susceptible `Granny Smith', `Gala', `Fuji' and `Jonathan' would be ideal.) After a single growing season at South Perth, sufficient scion material will be available for virus indexing,either at South Perth or in eastern Australia.

6.413 Indexing on Woody Indicators. Fridlund's system for rapid indexing in the greenhouse should be adopted, using `Russian Seedling', `Virginia Crab', and either `Radiant' or `Sparkler' as primary indicators. Readings could be completed for the common latent viruses within 3 months. Secondary indicators, including those for fruit-deforming pathogens, should be used following Mink's new protocol.

6.414 Location of Virus Indexing. Glasshouse indexing could be efficiently conducted at Burnley, Rydalmere or South Perth, so long as the original plant(s) is retained at South Perth.

6.415 Distribution of Plant Material. All plant material, including original plants and the indexed plants, can be distributed to the importer under present rules. It would be highly desirable in most cases for budwood to be delivered to appropriate research personnel for evaluation in the districts concerned.

6.42 Sharing Costs of Quarantine

The present system of requiring quarantine payment by a sponsor followed by exclusive distribution to that sponsor has resulted in multiple introductions of a substantial number of fruit varieties. The present system of distribution has also resulted in "public" (non-PVR) varieties being sold exclusively by sponsoring nurseries, to the considerable detriment of the fruit industry.

Consideration should be given to development of a more rational pattern of importing and quarantine, so that a given clone need be brought through quarantine only once.

6.43 Improved Indicator Methods

Recent advances in biotechnology have made DNA probes and ELISA testing a reality for several viruses and other pathogens. No doubt these will be incorporated into AQIS protocol in near future.

6.5 Evaluating Introductions from Abroad

Australia should be instituting a national program for trialling new varieties of all the deciduous tree fruits. I would recommend a program patterned after the highly successful "NC-140" cooperative in North America, with identical trials of a given commodity being set in 20 to 30 different locations around the country, exposed to the wide differences in climate, soils, and other growing conditions. This will be especially important as selections come on line from the various breeding programs, but it is critical for evaluation of introductions from offshore.

6.6 Liason with Fruit Breeders Overseas

Significant contacts with breeders in other countries have already been established, but there are many opportunities as yet untapped. A number of these breeding programs are cited in Sect. 5.1 above.

It will be especially valuable for Stephen Tancred, apple breeder at Stanthorpe, to make contact with counterparts in USA and France. I recommended in Sect. 6.121 that Mr Tancred undertake a working visit to the Purdue and Geneva programs at earliest possible date. Besides the hybridizing exercise suggested, extended personal contact with the Geneva breeding team -- including breeders, pathologists, biochemists, and biotechnologists -- will be invaluable.

It would be prudent for the project leader of the pear program to undertake a similar activity. Indirect contact has been made with Dr. Richard Bell at the USDA Kearneysville, West Virginia station; Dr. Bell has kindly offered to make "pilot" crosses in 1992 for the new Australian program. The pear breeding activities at Angers, France, should be given high priority; the biotechnology group on the Angers breeding team is already well advanced in attempting to introduce fire blight resistance *in vitro*.

Appendix 1: FIRE BLIGHT

Fire blight, caused by the bacterium *Erwinia amylovora*, is now present in almost every apple and pear producing region in the world. It seems highly likely that in the near future Australia will also be invaded; in other countries, eradication efforts have generally not been effective and it should not be expected that eradication will be effective here. It would be prudent to consider fire blight susceptibility when designing new apple plantings.

Fire blight must be anticipated in Australia; the most probable mode of entrance is infected scionwood smuggled past quarantine. Chances of entrance via epiphytic infection on fruit would seem to be very remote.

In the United States, but not western Europe, streptomycin sprays are registered for control of fire blight; however, the bacterium is fairly rapidly developing resistance. Americans believe this material will not long be available. There have been some reports that "Aliette", active ingredient ~ phosphorous acid, may have some value in fire blight control.

In Australia, all the commercially important pear varieties except `Winter Cole' are either susceptible or highly susceptible to fire blight. Of the apple varieties of interest in Australia, most of those tested at New York State Agricultural Experiment Station, Geneva, have proved to be susceptible to the disease (Table 1).

Table 1. Susceptibilities of some important apple varieties to fire blight in New York trials.

Susceptible	Intermediate	Resistant
Democrat	Blushing Golden	Delicious
Fuji	Empire	Liberty
Gala	Golden Delicious	Prima
Granny Smith	Delicious (spurs)	Priscilla
Jonagold	Freedom	Splendour
Mutsu		Keepsake
Ozark Gold		
Rome Beauty		
Summerred		
Braeburn		

In addition, a number of introductions and selections from black spot-resistance breeding programs have potential value as sources of fire blight resistance (Table 2).

Table 2. Scab-resistant varieties and selections that are also resistant to fire blight.

Dayton	Coop 12	NY 65707-19
Florina Querina	Coop 15	NY 66305-139
Redfree	Coop 19	NY 73334-35
Williams Pride	Coop 20	NY 74828-12
	Coop 24	NY 75413-30
	Coop 26	
	Coop 27	
	Coop 29	
	Coop 30	

A number of varieties of interest in Australia have not been tested but will be during 1992 and 1993 (Table 3).

Table 3. Important apple varieties not yet tested for fire blight susceptibility.

Abas	Earlidel	Pink Lady
Adina	Earligold	Sansa
Akane	Elstar	Summerdel
Arlet	Goldina	Sundowner
Bonza	Lady Williams	Sunrise

Rootstocks and Fire Blight. Susceptibility of the rootstock becomes important if an infection occurs in the scion variety. There appear to be two significant infection courts on the rootstock:

(1) The bacteria may move downward internally through the bark tissue of the variety without causing symptoms. When the bacteria enters the susceptible rootstock, there is a virtual "population explosion", and a lesion results that extends rapidly both vertically and around the trunk. This lesion may girdle and kill the tree in a matter of a few weeks.

(2) A shoot from the base of the rootstock shank or a root sucker can become infected if the shoot tip is succulent. This is most likely to happen if aphids or other sucking insects are present.

Generally speaking, tree death is more likely to occur because of fire blight infection in the rootstock trunk than because of fire blight infection in the aboveground parts of the tree. The most effective control is to use a rootstock that is resistant or tolerant to the disease (Table 4).

Table 4. Susceptibilities of Some Apple Rootstocks to Fire Blight (in order of vigour).

Malling 27	Susceptible
Geneva 65	Very Resistant
Malling 9	Susceptible
Mark	Susceptible
Ottawa 3	Susceptible
Malling 26	Very Susceptible
Cornell-Geneva 11	Very Resistant
Bemali	Moderately Resistant
Malling 7	Moderately Resistant
Cornell-Geneva 30	Resistant
Malling-Merton 106	Tolerant
Malling 4	Intermediate
Cornell-Geneva 239	Very Resistant
Spy	Tolerant
MM.104	Tolerant
MM.111	Intermediate
MM.109	Tolerant
Merton Immune 778	Intermediate
Merton Immune 793	Intermediate
Malling 1	Very Susceptible
Alnarp 2	Very Susceptible
Novole	Very Resistant

Breeding for Resistance to Fire Blight

Resistance to fire blight appears to be under oligogenic control. Besides `Delicious', sources of resistance include `Splendour' and the black spot-resistant `Liberty' and `Florina' (see above), plus several black spot-resistant advanced selections from Cornell University and Purdue University. Coop 26, NY 73334-35 and NY 75413-30 could be especially useful in breeding for fire blight resistance, since they may derive their resistances from both *Malus floribunda* and from `Delicious'.

Breeding fire blight resistant apple rootstocks continues at Geneva. Breeding resistant pear rootstocks continues at Harrow, Ontario, and Geneva.

Some Additional Fire Blight Issues

Fire blight is usually considered to be a disease of apples and pears. However, in addition to most pear varieties and many apple varieties, *Erwinia amylovora* also attacks a number of other genera of the rose family. Some highly susceptible alternate hosts are:

Quince (*Cydonia* spp.)
Hawthorne (*Crataegus* spp.)
Cotoneaster spp.

Firethorn (*Pyracantha* spp.)
Mountain Ash (Rowan) (*Sorbus* spp.)

Quince rootstocks are used to produce dwarf pear trees, and quince varieties are grown for fruit in many gardens. Cotoneaster, *Pyracantha* and *Sorbus* are widely planted ornamentals. *Hawthorne* hedges were much planted a century ago to enclose paddocks, especially in the Orange and Batlow districts; hawthorne trees now abound in pasturelands.

Although most clones in all five of these genera are highly susceptible to fire blight, we regard *Crataegus* (hawthorne) as most likely to present serious problems to the pear and apple industries. Haws bloom over a considerable span of time, about a month after pears flower. A number of kinds of birds, including starlings, frequent the hawthorne hedge. Experience in Europe has shown that the starling can be a very significant factor in spread of fire blight within and between districts.

In anticipation of the eventual arrival of the fire blight pathogen, it would be prudent now to begin to reduce the population of alternate hosts:

1. Hawthornes should be removed, whether in hedges or in open paddocks. This measure would be especially helpful in the Batlow and Orange districts and in the Goulburn Valley.
2. Resistant varieties of *Cotoneaster*, *Crataegus*, *Pyracantha* and *Sorbus* have been developed in breeding programs in the United States and The Netherlands. These varieties should be acquired, passed through quarantine, and entered into the nursery trade.
3. The susceptible varieties of these species should then be removed from all nursery offerings.

Appendix 2: BLACK SPOT (APPLE SCAB).

This disease is responsible for the largest pesticide requirement for apples and for much of that required on the pear crop. The causal fungi, *Venturia inaequalis* on apple and *V. pirinia* on pear, overwinter on leaves infected during the previous growing season. Ascospores released in early spring initiate the annual cycle; fruits are infected by spores released during the growing season. The most effective IPM tool now in use is application of 2 postharvest urea sprays, designed to cause infected leaves to rot during the winter.

Apple Scab. No commercially useful resistant varieties have been deployed in Australia. A French candidate, `Florina', has now passed through Australian quarantine. The American introduction `Liberty' may possibly have a place in commercial production; unfortunately it was lost in the quarantine process and must be re-introduced in 1992.

Two types of genetic resistance are known: the major "*V* " genes, always acting in concert with modifying minor genes; and polygenes such as found in `Antonovka 600 Grams', `Alfrediston', and, perhaps, `Akane', `Sansa' `Jonathan' and `Bonza'. Almost all breeding activity has involved the major *Vf* gene approach; a few introductions have other or additional resistances.

Pear Scab. `Beurre Hardy', `Conference', `Josephine de Malines', and `Kieffer' are considered resistant to *Venturia pyricola* but their behaviour as parents has not been well defined.

Black spot of nashi is caused by *V. nashicola*. Attributes, epidemiology and varietal interactions of pear and nashi black spot are not as well understood as apple black spot.

Appendix 3: SUSCEPTIBILITIES OF PEAR VARIETIES TO DISEASES

	Fire Blight	Black Spot	*Pseudomonas syringae*
European Varieties			
Alexandre Lucas	Susc.		
Ayers	Res		
Beurre' Bosc	VS	Susc	VS
Beurre' d'Anjou	VS	Susc	
Beurre' Superfin	Susc		
Bristol Cross	Susc		
Clapp's Favourite	VS		
Columbia Red Anjou	VS		
Conference		Res	
Dabney	VR		
Devoe	Susc		
Douglas	VR		
Doyenne' du Comice	Susc	Susc	M.Susc.
Dr. Jules Guyot	Susc		
Fertility	Susc		
Flemish Beauty	Susc		
Forelle	Res		
Gebhart Red Anjou	V.Susc VR		
Josephine de Malines	Susc	MR	Susc
Kieffer	MR		
Lincoln	Interm.		
Magness	Res		
Maxine	Interm		
Max Red Bartlett	Susc.	Interm.	
Moonglow	Res.		
Packham's Triumph	VS	Very Susc.	
Passe Crassanne	VS		
Phelps	Susc.	Res	
Tyson	Res		
Williams Bon Chr.	Susc	Interm.	Res.
Winter Cole	Res		
Winter Nelis	Susc		
Asian Varieties			
Chojuro	V.Susc		
Nijiiseiki	V.Susc.		
Ya Li	V.Susc.		

Appendix 4: SOME ATTRIBUTES OF POTENTIAL PARENTS IN THE APPLE BREEDING PROGRAMS

	Days	Scab	CAR	PM	FB	Qual	Size	Stor	Prod	Chill
NY66305-139 -60	Res	Res	Res	Res	Good	Med	Fair	Good	?	
Summerdel	-55	Susc	?	Med	?	VG	Med	VG	Med	M.Lo.
Coop 12	-55	Res	Res	Susc	MR	Good	Med	Poor		?
Coop 19	-55	Res	Res	Res	MR	VG	M.Sm.	Poor	?	
Williams Pride	-51	Res	Res	MR	Res	VG	Med	Exc.		?
Coop 20	-45	Res	VS	Susc	MR	G+	Sml	Exc.		?
Prima	-45	Res	Susc	Res	MR	Good	MSm	Fair	Fair	High
Primicia	-45	Res	?	MR	?	Good	Med	Good	M+	Low
Princesa	-45	Susc	?	Susc	?	Good	Med	Fair	Exc	Low
Sansa	-45	MR?	?	?	?	Exc	Med	?	Exc	?
Gala	-45	Susc	?	MS	VS	VG	M.Sm.	G	G	M.Lo.
Coop 14	-42	Res	Res	Res	MR	Astr	Sml	Poor	Exc	?
Redfree(Coop 13)	-42	Res	Res	MR	MR	Good	M.Sm.	Good	Good	
Coop 7 -35	Res	Res	Susc	MR	Fair	Lrge			?	
Dayton (Coop 21)	-29	Res	MS	MR	MR	Good	Med	Good	Good	?
NY74828-12	-22	Res	Res	Res	Res	Good	MLge	Good	VG	?
McShay	-20	Res	?	Res	?	Good	Med	Good	Ann.	?
Coop 8	-18	Res	Res	MR	MR	Fair	MLge	Poor	Poor	?
Coop 15	-18	Res	MS	Res	MR	Good	Sml	Fair	Med	?
NY66305-189 -15	Res	Med	Med	Med	Good	M+	Good	Good	?	
Priscilla	-14	Res	Res	Res	Res	Good	M.Sm.	VG	Good	?
Coop 9	-11	Res	Susc	MR	MR	Fair	M.Lge.			
Bonza	-10	MS	?	Susc	?	Good	M+	Good	Good	?
Jonafree(Coop22)	-7	Res	MS	MS	MS	Good	Med	Good	Good	?

	Days	Scab	CAR	PM	FB	Qual	Size	Stor	Prod	Chill
NY75414-1	-6	Res	Res	Res	Med	Good	MLge	Good	Good	?
Liberty x MacSpur										
Britegold	-5	Res	VS	?	?	Fair	M+	Good	Fair	?
Coop 24	-5	Res	Susc	Res	MR	Fair	MSml	Poor		?
Coop 25	-5	Res	VR	MR	VS	VG		Exc.		?
Sweet 16	-4	MR	MR	?	MR	Good	M+	Good	Good	?
Freedom	-3	Res	Med	Med	Med	Good	VLge	Good	Good	?
Delicious	0	Susc	MR	MR	MR	VG	M+	VG	Good	High
Coop 10	0	Res	Res	MR	MR	Fair	Med	Poor	Exc	?
Coop 26	0	Res	Res	Res	Res	Fair	MSml	Poor	Exc.	?
Liberty	0	Res	Res	Med	Res	VG	M+	VG	Exc	High
NY75413-30	0	Res	Res	Res	Res	VG	VLge	VG	VG	?
Liberty X Delicious										
NY65707-19	+2	Res	Res	Res	Med	Exc	Med	Exc	Mod.	?
NY73334-35	+3	Res	Res	Res	?	G+	MLge	Good	Good	?
Liberty x Delicious										
Keepsake	+5	MR	MR	?	MR	Good	Med	Exc	Low	?
Novaspy	+5	Res	?	?	?	VG	Med	VG	Good	?
Coop 27	+7	Res	Res	MR	Res	VG	M.Sm.	Exc	M+	
Trent	+8	Res	Susc				Lge			
Florina Q.	+10	Res	?	MS	MR		M+			
NY75441-67	+10	Res	Res	Res	Med	Good	Med	Good	VG	?
Golden Delicious	+10	MS	MS	MS	MS	Exc	MLge.	Good	Exc	High
Coop 11	+14	Res	Res	MS	Res	Fair	Med	Good	VP	?
Coop 31	+14	Res	MS	MR	MR	VG	Susc	Good	M+	?
Coop 29	+18	Res	Res	MR	Res	Good	Med	Exc	M+	?
Coop 30	+18	Res	Res	MR	Res	Good	M.Sm.	Exc	M+	?

	Days	Scab	CAR	PM	FB	Qual	Size	Stor	Prod	Chill
Coop 17	+25	Res	Susc	MR	MR	Poor	Med		Exc	?
Granny Smith	+35	Susc	?	MS	Susc	VG	ML	Exc	Exc	M.Lo.
Fuji	+45	Susc	?	MS	Susc	Exc	Lge	VG	VG	?
Pink Lady	+60	Susc	?	Susc	?	Exc	ML	Exc	VG	M.Lo.
Sundowner	+75	Susc	?	Res	?	Exc	M+	Exc	Exc	M.Lo.
Lady Williams	+95	Susc	?	?	?	VG	M+	Exc	VG	M.Lo.

Appendix 5: SOME QUARANTINE ISSUES

1 Fire Blight, Quarantine, and Fruit Breeding

Australia's vigorous quarantine against fire blight has been completely effective in holding this disease at bay. However, some aspects of AQIS policy have made it very difficult to develop a full-scale breeding program for apples resistant to this disease. Recognizing that eventually the quarantine barrier will be breached and that the Australian apple and pear industries will be attacked by fire blight, it is imperative that procedures be developed to expedite the development of fire blight-resistant varieties by the Australian breeding programs.

Fire blight-resistance breeding programs are quite active in Geneva, NY and Kearneysville, WV, USA; at Harrow, Ontario, Canada; at Angers, France; and at Dresden-Pillnitz, Germany. It is possible, but not highly likely, that output from these programs will be directly useable by the Australian fruit industry, but some of the varieties developed overseas will be highly useful in the Australian breeding efforts.

To that end, we propose to bring through quarantine a group of new varieties, advanced selections, and rootstocks for research and breeding purposes. Should any of these introductions prove suitable for later commercial deployment in Australia, appropriate financial arrangements would be required of the nurseries concerned. The major thrust of this introduction scheme, though, will be to provide a more suitable base of germplasm for the breeding programs than is now available.

After clearance from quarantine, *Malus* and *Pyrus* taxons so obtained would remain under direct control of the Australian fruit breeding team, subject to appropriate agreements with foreign patent-holders. Although the primary objective is to broaden the base of the fire blight-resistant germplasm in the breeders' working collection, the varieties and rootstocks would also be entered into suitability trials. Any subsequent release to industry would be carried out in full compliance with quarantine restrictions and patentholders' requirements.

Appendix 6: OVERSEAS FRUIT BREEDERS

Disease Resistant Apples

Dr. Yves Lespinasse
INRA Sta. d'Amel. des Especes Fruitieres
Beaucouze, F-49000 Angers

Dr. Anisio Camilo
EMPASC
Casador, SC, Brazil

Dr. Roberto Hauagge
IAPAR, Caixa 2301,
Curitiba, Parana, Brazil 80001

Dr. Susan K. Brown
NYSAES
Geneva, NY 14456 USA

Dr. Jules Janick
Dept. of Horticulture
Purdue University
W. Lafayette, IN 47907

Dr. Frank Alston
Inst. of Hort. Research
East Malling

Dr. Hanna Schmidt
Institute for Plant Breeding
Bornkampsweg 31
D-W-2070 Ahrensburg, Germany

Dr. Christa Fischer
Dresden Pillnitz

Fire Blight-Resistant Pear Breeding

Dr. Richard Bell
USDA Appalachian Fruit Research Station
Kearneysville, WV 25430

Dr. Jacques Huet & Dr. Elizabeth Chevreau
INRA Sta. d'Amel. des Especes Fruitieres
Beaucouze, F-49000 Angers

Classical Apple Breeding

Dr. David Lane
Agriculture Canada Research Station
Summerland, BC

Dr. Curt Rom
Dept. of Horticulture
University of Arkansas
Fayetteville, AR 72701 USA

PROFESSOR JAMES CUMMINS

James N Cummins was born in 1925 onto a fruit farm in central Illinois. His initial study at the University of Illinois was interupted by active service in Western Europe, 1943-46. Completing his Bachelor's degree in 1947 he returned to the family farm, marrying Cindy in 1948. He saw additional service as an officer going to Korea in 1950. Returning in 1952 he and Cindy established their own orchard. Bad seasons and hail saw Jim teaching high school science in the late 1950s and reviewing a Master of Science Education in 1960 after part time study. Winning a fellowship to the University of Wisconsin, he was awarded a Masters degree in Botany in 1961 and was appointed Assistant Professor at the University of Southern Illinois. Whilst working full time he pursued a PhD from that University in his spare time, graduating in 1964.

By now a father of five children, 1967 saw Jim and Cindy move north to Cornell University at Geneva, New York. Today he holds the position of Professor of Pomology there.

An active member of many professional associations he was the President of the American Pomological Society 1988-90.

Professional travel has taken him to Israel, the Netherlands and England in 1970, Poland and Germany in 1974, France in 1979, Germany and Italy for six months in 1983 and Spain in 1990. Since leaving Australia in February 1992 he has visited the New Zealand and South American industries.

A recipient of many professional honours he has published over 70 papers and has many Bulletins, Conference Proceedings and Book Chapters to his credit.

His teaching and research activities have included nursery management, orchard management, plant propagation, tissue culture, fruit tree viruses, chilling requirements of trees, and the breeding, genetics and evaluation of fruit tree rootstocks.

Apple rootstock breeding may prove to be his most enduring achievement. Releases from the breeding program initiated over 20 years ago by Jim and Plant Pathologist Dr Herb Aldwinkle are now being released. These dwarfing rootstocks resistant to root-rots and fireblight will have application in every production district in the world.

Jim had his 67th birthday in Australia but has no immediate plans to retire. His children are involved in horticultural research, orcharding and tree nursery operations and will ensure an ongoing interest in the industry.

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