National pear breeding

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Project AP99007

Perfect Pears – the National Pear Breeding Program

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Media Summary

The National Pear Breeding Program commenced in 1992, and is managed by DPI-Victoria through its Knoxfield and Tatura sites, in collaboration with Horticulture Australia Limited, Apple and Pear Australia Limited (APAL), the Australian Nashi Growers Association and the Western Australian Department of Agriculture. Three years ago the program reached a population of over 52,000 seedling trees. These have now been culled to 37,000 trees, each of which is a unique individual seedling. The second phase of crossing has now commenced, using elite selections from the program as parents.

The breeding team describe their aim as "perfect pears", which will delight consumers. The first point of selection is therefore appearance. Only fruit with a smooth classical pear-shaped outline, smooth glossy skin, attractive colour, and absence of blemishes including russet, are acceptable. Several of the leading selections have an attractive red blush over a yellow background. Taste and texture must be equal or better than the leading commercial varieties for a seedling fruit to proceed to the second stage of selection, which involves growing the selections as orchard trees. Orchard trees are produced on several rootstocks, and managed on Open Tatura trellis, the current industry benchmark for good management practice. The program currently has over 80 selections managed as orchard trees. Most are less than two years old.

The second phase of the selection process is conducted by the pear industry through its variety improvement program, the Australian Pome Fruit Improvement Program, which is managed by APAL on behalf of fruit growers. DPI-Victoria has contracted APAL to conduct a multi-stage selection process on growers' properties, so that elite pear selections are subject to the same conditions as the growers' orchards. Seven pear selections were supplied to APAL in 2003, at the same time that they were established in an orchard at DPI-Tatura. This " fast tracking" trial will allow APAL and DPI-Victoria to test and fine-tune the commercial assessment process.

The ultimate aim of the program is to assist Australian pear growers to recapture export markets lost to countries with cheap labour, and to build a stronger domestic market through greater consumer satisfaction and orchard productivity.

Technical Summary

The National Pear Breeding Program (NPBP) was established by DPI-Victoria, Horticulture Australia Ltd, Apple and Pear Australia Ltd and the Australian Nashi Growers Association to develop distinctive new pear varieties which will give Australian producers a competitive advantage in export markets, and foster expansion of the domestic market, through greater productivity and consumer acceptance. The NSW Department of Agriculture and SARDI were active partners until 2001, and the Western Australian Department of Agriculture (WADA) remains an active partner.
Several ideotypes have been developed. These include:

- winter pears with the eating and storage qualities of Packham's Triumph, but with superior skin finish and a range of maturities;
- summer pears with a range of maturities, and extended storage life;
- canning pears based on WBC, with a range of maturities; and
- Asiatic hybrids which will allow expansion of the nashi market.

In addition, pear rootstocks are sought which will facilitate precocious, high density pedestrianised orchards. Disease resistance to *Venturia pirina* and fireblight is sought through putative resistant parents.

Approximately 53,000 seedlings were established by 2002, representing over 160 controlled crosses based on 50 parents. This population has now been reduced to 37,000 seedlings and will reduce further to a stable population of around 22,000 by winter 2007. Phase 1 crosses were based on existing cultivars; crosses made in spring 2003 and 2004 have included NPBP elite selections as parents since they represent more desirable phenotypes. Some of the crosses were produced in the USA and Canada through the collaborative efforts of Dr Richard Bell, USDA, Kearneysville West Virginia, and Dr David Hunter, MAF, Harrow, Ontario, Canada. Seedlings are grown on “own roots” in high density plantings, and are unpruned.

The selection procedure has been developed to efficiently identify those seedlings with commercially acceptable external fruit qualities, and only these proceed to assessment of internal characteristics, either fresh from the tree or following a structured storage procedure. Each seedling is assessed three times in its life. Development of a five-to nine point anchored hedonic scale has been a major achievement of the breeding team and has supported genetic analysis of the data captured, which in turn has more precisely identified those parents and crosses with better combining abilities.

Eighty two selections have progressed to the selection stage of establishment on rootstocks in an orchard planting. Selections are grown on two or three rootstocks and on east and west sides of an Open Tatura trellis. This stage of selection only commenced for *P. communis* selections in significant numbers in 2002, however preliminary observations indicate that seedling assessment at the Stage 1- seedling orchard stage- is a reliable performance indicator and that rootstocks do not substantially alter phenotype.

DPI-Victoria has entered a contract with the Australian Pome Fruit Improvement Program (APFIP) under which the commercial stages of the selection process will be conducted by APFIP on growers’ properties under good commercial practice. Seven selections have been “ fast tracked” into APFIP evaluation to allow APFIP and the breeding team to fine-tune the process. The same seven selections have been established at Manjimup Horticultural Research Station in WA by the WADA.

A range of seedlings have been assessed for their ability to strike roots from hardwood cuttings. Although the funding of rootstock breeding has been withdrawn by the Steering Committee, DPI-Victoria intends to progress those seedlings identified as capable of producing roots through a basic selection process to identify potential new rootstocks.

Details of the inception and development of this project are given in the previous Final Reports of project AP310 (1996) and AP96032 (1999).

Technical Report

Introduction

The perfect pear program was started in 1991 to address shortcomings manifest in current pear varieties, which leave Australian growers exposed to insurmountable competition in export markets, including:

- lack of distinctive varieties which allow product differentiation in export markets;
- lack of varieties which suit modern consumer preferences in all markets;
- lack of spread of harvest of varieties both for fresh fruit and canning markets, and
- a lack of appropriate management techniques suited to modern high-density, pedestrianised orchards and developed around the new pear selections.

All the above shortcomings have compounded to thwart market development, resulting in losses of export markets to countries with cheaper production costs (notably Chile and Argentina), a static and relatively small domestic market, and limits to cannery through-put.

The program is funded through DPI-Victoria, Horticulture Australia Ltd, Apple and Pear Australia Ltd and the Australian Nashi Growers Association.

Lack of distinctive varieties has come about through the successful development of Packham's Triumph plantings in Chile, South Africa and Argentina. The loss of Australia's own distinctive variety has deprived Australian growers of the opportunity for product differentiation and left us vulnerable to lower prices, based on cheap labour inputs. Australian growers need distinctive varieties upon which to build an export market which recognises both variety/varieties, and country of origin, and which offer consumers a better experience than they currently enjoy.

Modern consumers are not served well by melting flesh pears whose point of ripeness is a total mystery to them, as in Packham's Triumph. Melting flesh pears are not favoured by younger people nor most Asian consumers; these markets require pears which are eaten crisp like an apple or nashi, or at least firm and juicy. Such characters are found in some European pears, such as the early-season pears of northern Italy. Our challenge is to develop this character in varieties with an extended marketing period, through extended seasonal range and superior storage life. Melting flesh pears will continue to attract some consumer loyalty, but new melting flesh varieties will need to display clear maturity indices (such as the " ripe 'n' ready" Packham's sold in Australia and the UK) to achieve any market success.

Details of development of project objectives are included in the Final Report for 1996. Current objectives are to develop pear cultivars with superior fruit quality to Packham's Triumph, of compact form or moderate vigour, precocious, and with resistance to *Venturia pirina* and fireblight. These objectives are being sought in fruit with a range of maturities. Crisp flesh and tree ripening is preferred. The preferred shape is pyriform, and red blush is favoured for the fresh fruit market. The canning industry seeks pears with WBC processing characteristics, and a range of maturities.

Budgetary constraints have curtailed the rootstock breeding component of this program, however the *P. communis* selections identified to date will continue through a screening program to identify new rootstocks.

Materials and Methods

2.1 Controlled crosses and seedling orchard establishment.

Fruit crosses were initially made primarily in WA, and the seed sent to DPI Knoxfield. Now that stage 1 crossing of 25 parents in 130 combinations is almost complete, this activity has reduced. The initial intention was to replicate elite crosses and produce high numbers of seedlings, however this approach will now be limited to a reduced number of families, in order to make room for crosses derived from National Pear Breeding Program selections which provide greater potential for phenotypic improvement.

Crosses are produced by conventional emasculation of female parent flowers, bagging to exclude stray pollen, and manual pollination using selected male parents. Seed are removed from mature fruit, stratified and germinated. Seedlings are grown in pots and transferred to the seedling orchard either after one growing season, or where time has permitted, in the year of germination.

Trees are grown at DPI-Tatura.

DPI-Victoria has initiated a trial to examine the use of multi–mother trees, to increase effective planting density of seedlings, and to hopefully reduce the vegetative period before trees fruit.

2.2 Seedling orchard establishment and management

Orchard management at DPI- Tatura is based on high density plantings at 3.0 to 4.5 m x 0.5 m. Beyond trimming and pruning basal limbs, tree management is not practiced. Since trees are on "own roots", those orchard practices designed to sustain optimum yields of appropriate sizes of fruit do not apply at the seedling stage of assessment. Commercial management of trees on selected rootstocks is applied to selections from the original seedling population.

2.3 Fruit screening

Fruit are assessed for visual appearance in the seedling orchard and only those which meet selection criteria proceed to eating assessment. The breeding team has developed a protocol for semi-quantitative scoring of key fruit quality attributes.

Stage 1 assessment of every seedling is conducted for three successive years, and is characterised by presence or absence of fatal faults, as the most cost-effective form of evaluation. No further details are recorded in any one year once a fatal fault is observed.

Fruit which pass Stage 1 assessment are assessed at Stage 2 for eating quality directly from the tree, and also after maturation. Maturation involves storage for 6 weeks and 10 weeks at 2^{o}C, followed by 18^{o}C for 1 week, prior to taste testing. Eating quality was determined through selection criteria detailed in Appendix 1. Sensory assessment was carried out by a panel of at least 3 people. Both fruit appearance and eating quality were scored according to a 5-point inverse and a 9-point hedonic scale in 2002 and 2003, respectively.

2.4 Genetic analysis of fruit assessment data

The resemblance between parents and offspring is the foundation of plant breeding. Heritability and general combining ability (GCA) estimates are genetic parameters which quantify the degree of this resemblance; in other words, they are the measures of how parental genotypes transmit the attributes to offspring in breeding populations. Fruit breeders rely on phenotypic performance to process selection. When attributes have high heritability, genetic gain will be large by selection *per se*. Otherwise, for those with low heritability, genetic gain would be small in each breeding cycle, and obviously a persistent breeding effort and long time would be needed to achieve considerable genetic improvement. Analogously, the use of genotypes with high GCA's as parents in a crossing program would also improve genetic gain.

In order to understand these genetic parameters of fruit appearance and quality attributes in pear breeding populations of the National Pear Breeding Program, univariate analyses were conducted based on a mixed model as follows for 2002 and 2003, respectively:

$$y_{ijk}=\mu+b_i+g_j+g_k+s_{jk}+e_{ijk}\,,$$

where y_{ijk} is a given score for quality attributes of individual trees, b_i is a fixed effect for orchard block, i, g_j and g_k are GCA estimates for female and male genotypes, respectively, s_{jk} is the specific combining ability (SCA) estimates for the family derived from parents j and k, and e_{ijk} is the random residual effect. Both fruit appearance and eating quality attributes were sensorily assessed against five- to nine-point anchored hedonic scales. For trees with multiple harvest dates, the highest score was used in the analysis as it was most likely to represent genotypic potential.

The above model was fitted using ASReml statistical software, which is cooperatively developed by DPI-NSW and UK based VSN International Ltd., and extensively used in research of animal genetics (Gilmour et al., 2000). Narrow-sense heritability (h^2), GCA and SCA was estimated for both fruit appearance and eating quality attributes. Narrow-sense heritability (h^2) was calculated as follows:

$$h^2= 4\sigma^2_{gca}/(\sigma^2_{gca}+\sigma^2_{sca}+\sigma^2_e),$$

where $\sigma^2_{gca,}$ σ^2_{sca} and σ^2_e are estimated GCA, SCA and residual variance components, respectively.

Forty attributes were scored by a three-person panel (19 for fruit appearance, 4 for storage quality and 17 for eating quality). Details of the hedonic scale developed over the 2003 and 2004 seasons are given in appendix 1. The assessment was benchmarked against WBC and Beurre Bosc as minimal quality benchmarks for fruit appearance and eating quality, respectively.

2.5 Selection orchard establishment and management

Orchard trees of approximately 30 selections were produced each year by grafting to three rootstocks: D6, Quince A and B. Hardy / Quince A. Orchard trees were established on Open Tatura trellis and managed as a commercial orchard. Planting was randomised according to a split plot design to ensure that 3 trees were planted on each side of the trellis. Pest and disease management follows best local practice. A total of 82 selections are now established.

2.6 Regional assessment of selections

Promising selections were budded or grafted to two commercial rootstocks for further evaluation. DPI-Victoria and APFIP have established a contractual agreement whereby APFIP subjects pear selections to their assessment regime developed for imported cultivars, and results are reported to DPI-Victoria.

2.7 Screening for *Venturia pirina* resistance

Details of scab screening procedures have been reported in the Final Reports of 1996 and 1999.

A trial has been established to determine the accuracy of glass-house scab screening through a randomised block planting of 4 plots each of 20 replicates of each (resistant or susceptible) cross. Five crosses are represented. Drought conditions have severely limited symptom expression during the life of this project and results are pending. Seed received in 1999 and 2000 was subjected to glasshouse scab screening at DPI Knoxfield, but further scab screening has been deferred until the value of the glasshouse screening test, as a predictor of field response, has been evaluated.

2.8 Rootstock breeding

Hardwood cuttings from selected parent trees were inserted into sharp sand in cell trays, located in mist beds equipped with bottom heat and located in a glass-house to maintain day and night temperatures. Temperature at root growth level was maintained at 22 – 25^{o}C. Leaf wetness was controlled by Carbon block elements to optimise growth of willow (*Salix alba*) cuttings used as controls. The experiment was of Randomised Block design, with 5 blocks each of which occupied half a mist bed unit. Cuttings were established during full dormancy. Root growth was assessed in January after 3 – 4 months of growth.

Results

3.1 Controlled crosses and seedling orchard establishment

Crosses made to date are listed in Appendix 2. In the first stage of crossing, a wide range of parents has been utilised in order to evaluate their value as parents. Details of parent selection criteria are included in the Final Report of 1996 (project AP310). Controlled crossing of emasculated flowers has yielded an average of 4 seeds per flower in both WA and Victoria.

3.2 Seedling orchard establishment and management

One of the challenges facing this program is to minimise the resources required to maintain the seedling population, which in year 2000 reached 53,000 trees. The period of vegetative growth of a seedling tree varies with parents; interspecific hybrids which include an Asiatic parent usually fruit by year 4, however a proportion of late-season by late season European crosses fail to fruit within ten years. The proportion of non-fruiting trees (at year 10) can be over fifty per cent in some families. As the assessment process requires results from three fruiting seasons, the minimum age for removal of rows of trees (usually 100 trees of one family) is a minimum of seven years and ten is more common, given the focus on late x late European crosses which are the major source of long storage life. Seedling orchard tree numbers have now been reduced to 37,000 and this number will be further reduced over the winters of 2005 and 2006, to reach a constant population of approximately 22,000 seedling trees.

3.3 Seedling Fruit Assessment.

Results of seedling fruit assessment are shown in appendix 3.

In 1999, the majority of fruiting trees represented two families, namely Corella x Ya Li and Packham’s x Ya Li. Three seedlings were selected but have not progressed due to inferior storage quality.

In year 2000, four families fruited of which one only was solely of *P. communis* derivation, and one selection has been retained. The other three families included Packham's Triumph x Hood. Hood has proved to be a very poor parent and no selections have been retained.

In year 2001, 2000 seedlings of *P. communis* origin fruited and forty were identified as commercially acceptable at visual (orchard) assessment. A further 2700 hybrid seedlings fruited, of which 46 were visually acceptable; most were from OP Florida selections.

Sixty nine selections were identified in season 2002, from 35 families. Details are given in appendix 3 Notable inclusions are from crosses made by Dr Jill Campbell at the USDA pear breeding program in

1996 in collaboration with Dr Richard Bell, and also in 1996 with Dr David Hunter of AgCanada, Harrow, Ontario.

Season 2003 yielded 35 selections, and a further 34 were identified in 2004, as listed in appendix 3.

The rate of sequential culling is demonstrated by the results from season 2004, given below in Table 1.

Table 1. The number of retained seedling trees for each cross after visual selection, selection for edible fruit flesh and selection for commercially acceptable fruit quality (from Liu et al, 2005)

Cross	Season planted	No. of trees retained after selection for:				
		Visual appearance in orchard	Edible fruit flesh	Acceptable appearance post storage	Acceptable eating quality	Acceptable for appearance & eating quality
Comice x BPM	1995	26	16	8	7	4
Guyot x Beurre Bosc	1997	40	8	0	3	0
Guyot x Corella	1996	149	51	23	16	7
Guyot x Hood	1996	83	22	11	1	1
Guyot x Howell	1996	35	9	0	3	0
Guyot x Rogue Red	1999	122	64	4	14	2
Eldorado x BPM	1999	24	2	0	0	0
WBC x BPM	1997	53	21	13	10	7
WBC x Corella	1997	31	8	5	0	0
WBC x Howell	1995	31	13	1	3	0

'BPM'='Butirra Precoce Morettini'; 'WBC'='Williams' Bon Chretien'.

3.4 Genetic evaluation of seedlings.

Of the fruiting families assessed in 2004, 1 in 135 showed commercially acceptable appearance., 1 in 16 were edible, and 1 in 450 showed both qualities. This analysis indicates that a seedling population of 500 individuals is required to adequately express the potential of selected parents to produce a seedling with commercial potential, although success with specific combinations of better parents can be achieved at lesser populations.

3.5 Selection orchard establishment and management

A total of 82 selections have been established as orchard trees, each on at least 2 rootstocks and with both east and west orientation. Data available are only preliminary, given the age of trees, however there are no indications that seedling selection misses important phenotypic traits, or that growth and management on rootstocks produces any undesired traits.

3.6 Screening for *Venturia pirina* resistance

Results of scab screening tests are detailed in appendix 4. As all screened families were of *P. communis* origin, susceptible seedlings have been retained and planted.

3.7 Rootstock breeding.

Results of investigations of callus and root formation by hardwood cuttings of Pyrus seedlings are shown in Table 2.

Most families show a low ability to produce roots, and the variation between two Guyot x Packham's crosses is a year x year variation in the experiments. The high success rate of the Guyot x Hood seedlings reflects the hybrid nature of the Hood parent.

Table 2. The ability of hardwood Pyrus cuttings to produce roots. Data are collated over four years. Five hardwood cuttings per seedling tree were tested for their ability to produce roots. The number of trees with roots indicates the number of individual trees of that family which produced any roots under experimental conditions.

Rootstocks: collated data 2000, 2001, 2002 and 2003					
Female	**Male**	**CrossID**	**Number of trees tested**	**No.trees with Roots**	**Percent rooted**
BPM	Corella	93-01	31	0	0
Guyot	Comice	94-01R	149	3	2
Corella	Comice	94-14	31	1	3
Comice	Corella	95-17	199	10	5
Comice	Guyot	94-01	128	7	5
Josephine	Corella	94-18	364	21	6
Guyot	Corella	95-22	121	7	6
Corella	Packham's T	95-05	17	1	6
Packham's T	Corella	93-03	31	2	6
Guyot	Packham's T	93-10	28	2	7
Guyot	Packham's T	95-25	63	9	14
Guyot	Hood	95-23	29	22	76
		total =	**1191**		

Discussion

4.1 Controlled crosses and seedling orchard establishment

The opportunity presented to use NBPP selections as parents became obvious in season 2002 when several selections were identified with appearance traits clearly superior to existing parents. Where possible, these selections have been used as pollen parents, in order to maximise the use of germplasm and still leave flowers available for fruit formation and subsequent assessment.

DPI-Victoria is investigating the use of multi-mother trees on Open Tatura trellis, to reduce the period of vegetative growth, to increase effective planting density and to reduce establishment and removal costs. Initial assessment of multi-mother trees grown as central leaders showed strong within-tree position effects and this technique was not pursued, however it does not present in the current trial. Details will be publicised once conclusive results are available.

4.2 Seedling Fruit Assessment

The development of an anchored 7 to 9-point hedonic scale for fruit quality attributes has given the breeding team a powerful tool to maximise throughput of seedling fruit and represents a significant technical advance in the program.

As trees have matured and aged, the mix of fruit types has changed from 1999, when only asiatic hybrids fruited, to an increasing percentage of *P. communis* fruit, and within *P. communis* to include an increased percentage of fruit of late x late crosses. The late x late crosses are of particular interest to the export business as they are most likely to produce selections which mature late. This characteristic is usually associated with long storage life- ie; pears with a long storage life are usually later maturing cultivars such as Packham's Triumph, Beurre Bosc and Winter Nelis.

Unfortunately the late x late crosses have not yielded any selections to date. Most selections represent early x early, early x mid-season families, or interspecific hybrids (nashi types). The late x late families are characterised by poor appearance. Of the late maturing parents, Corella and Comice have both been produced selections in combination with specific parents, however the eating qualities of some Corella progeny require further examination. The flesh texture of Corella suggests that it is an interspecific hybrid pear as it does not mature to a buttery smooth texture (but remains crunchy), nor does it develop a distinctive flavour; its progeny frequently suffer from this characteristic.

Seedling trees frequently produce only small crops of fruit, and detailed analysis of optimal harvest and storage times are not available for seedlings. This stage of the selection process will become available as stage 1 selections mature as orchard trees (see section 4.5 below).

4.2 Genetic evaluation of seedlings

Identifying desirable seedlings is a critical phase in a breeding project. The retention result of sequential culling, which was conducted in our breeding strategy last season, demonstrated that most seedlings (about 95%) in most families had no potential in regard to our breeding objectives, and can be rapidly eliminated by simply inspecting fruit visual appearance in the seedling orchard and by selection of edible flesh post cool-store maturation. When only a small number of potential seedlings were retained after culling, assessment of fruit quality could be done in great detail and selection could be based on quantified fruit quality attributes. This strategy not only improved the efficiency of the selection process, but also ensured that only seedlings with commercial potential enter the next phase of evaluation. The retention rate also provides us with valuable data from which we can estimate the optimal size of the breeding population needed in pear breeding. Therefore, it is of significance for both improving the effectiveness of the breeding strategy, and also optimising resource input to the breeding operation.

There was no genetic barrier to recombination between fruit appearance and eating quality attributes because of the lack of any adverse relationship between them. Heritability estimates of fruit attributes were low (<0.10), but reasonable genetic gain can be expected *per se* for fruit appearance if genotypes with high GCA estimates are chosen as parents in the crossing program. With data aggregation from fruit assessment in future seasons, we should be able to differentiate breeding values of pear cultivars currently used as parents and also those just selected from breeding populations. With this information, we will be able to choose more desirable parents at the planning stage to derive more potential crosses in the future, so that genetic gain will be maximised in return.

4.4 Selection orchard establishment and management

Most of the stage 2 trees (selected seedling scions on rootstocks, managed as orchard trees on open Tatura trellis) were only established in the orchard block in 2002 and 2003, and have not yet yielded any fruit. Those few stage 1 selections established prior to 2002 have borne some fruit and are included in the selection process each year.

The main conclusion to be drawn so far is that none of the selections has presented unexpected traits when trained as an orchard tree on a rootstock. Fruit appearance on seedling trees appears to be replicated on orchard trees. This observation extends to variable appearance traits which can downgrade a selection, both as a seedling tree and as an orchard tree. This weakness is exemplified by selection A-04-29, which showed acceptable appearance at the first crop (1999) but suffered from a tapering neck thereafter, both as a seedling tree and as an orchard tree.

4.5 Screening for *Venturia pirina* resistance

Efforts to correlate glasshouse – based resistance with field resistance to *V. pirina* have been frustrated by lack of field symptoms for the past 5 years, however conditions in the current season have favoured *V. pirina* expression and data will be assembled during 2005. Discussion of results is included in appendix 4.

4.6 Rootstock breeding

Pyrus communis does not readily strike roots from hardwood cuttings, and few rootstocks have been commercially produced worldwide. Notable successes are the South African series of BP1 and BP2, the USDA Old Home x Farmingdale series, the German Pyrodwarf, and the French Pyriam.

P. communis rootstocks remain an attractive breeding objective because incompatibility problems are less likely than with other species, a range of vigour is achievable (eg the OH x F series), and clonal propagation supports orchard uniformity. Given that incompatibility between rootstock and scion can take several years to express, the safety perceived in *P. communis* rootstocks is clear.

The seedling families selected for rootstock screening all include one parent noted in the literature for the ability to produce some roots on hardwood cuttings. Results have been very low, with one exception; the high success rate of the Guyot x Hood seedlings reflects the hybrid nature of the Hood parent. It is recognised that this family may present black end problems due to Hood's ancestry (which includes Asiatic germplasm; the pedigree is unknown). Asiatic hybrid rootstocks are sometimes associated with a physiological disorder called Black End, due to the protruding black calyx which characterises the disorder. The problem is believed to be caused by water imbalance in the trees; uneven irrigation during the growing season can exacerbate the development of black end.

Although the funding of rootstock breeding has been withdrawn by the Steering Committee, DPI-Victoria intends to progress the seedlings identified as capable of producing roots through a basic selection process to identify potential new rootstocks.

Recommendations

The success of the National Pear Breeding program will ultimately lie beyond the control of the program. Once selections are identified which fulfil the program's broad selection criteria, their success beyond that point will depend on marketing. It is imperative that APAL, representing industry ownership in the program, constructs or directs an entity capable of successfully identifying, developing and exploiting market opportunities for future pear varieties. This exercise will require market research; pears are a diverse fruit, and the reasons behind the success or failure of varieties need careful understanding to ensure that the investments of all stakeholders achieve success.

Technology Transfer

The major technology transfer activities of the National Pear Breeding Program include articles in Pome Fruit Australia, the NVFA Newsletter, and reports to the Annual Steering Committee meeting. These reports focus on progress rather than the transfer of new technologies *per se*, as no cultivars have yet been identified.

Publications

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Dr Eleanor Melvin-Carter continues to represent WA Dept of Agriculture on the program and has managed the production of most of the seed received since 2001.

We gratefully acknowledge the valuable contributions of the Steering Committee at its Annual General Meeting and subsequent discussions.

Appendix 1. Fruit Quality descriptors and anchored hedonic scales

Term	Definition	Type of scale	Reference standards	Literature
Texture				
Firmness	The force required to compress the samples between the back teeth	1 to 7 just right scale	1=wet 2=very soft, banana 3=moderately soft, Kraft cheese 4=slight soft, soft apple 5=neutral, Fuji apple 6=slightly hard, Pink lady 7=moderately hard, celery 8=hard, carrot	Jaeger, Lund, and Harker, 2003; Kappel, Fisher-Fleming, and Hogue, 1995; Hampson et al., 2000; Lawless and Heymann, 1999
Juiciness	The amount of juice perceived from the sample during the 1^{st} 3 chews	1 to 9 intensive scale	1=very dry, banana 3=dry 5=neither dry nor juicy 7=juicy 9=very juicy, canned pineapple chunks or mandarin segment	Jaeger, Lund, and Harker, 2003; Kappel, Fisher-Fleming, and Hogue, 1995; Lawless and Heymann, 1999; Hampson et al., 2000; Blake and Van der Zwet, 1979
Fineness	Degree to which the flesh breaks down into a mass containing soft particles (similar to fine porridge)	1 to 9 intensive scale	1=very coarse 3=coarse 5=neither coarse nor fine 7=fine, ¼ cup Semolina in 2 ¼ water 9=very fine	Jaeger, Lund, and Harker, 2003; Blake and Van der Zwet, 1979
Grittiness	The presence of stone cells in the flesh	1 to 9 intensive scale	1=extra heavy 2=very heavy 3=heavy 4=moderately heavy, cv. Kieffer 5=medium 6=moderately light 7=light, commercial acceptable 8=very light, cv. Williams' 9=extra light/none	Blake and Van der Zwet, 1979; Thompson, Zwet T, and Oitto, 1974
		1to 4 intensive scale		
	Location		0=none 1=under skin 2=core layer only 3=1+2 4=everywhere	
		1 to 3 intensive scale		

Term	Definition	Type of scale	Reference standards	Literature
Texture				
	Size		1=large 2=medium 3=small	
Flesh	Colour	1 to 3 categorical scale	1=white 2=cream 3=yellow	
	Quality	1 to 4 intensive scale	1=none 2=slightly prominent 3=prominent 4=very prominent	
Crispness	The amount and pitch of sound generated when sample is first bitten with the front teeth	1 to 9 intensive scale	1=not crisp at all, banana 3=slightly crisp, cucumber 5=moderately crisp 7=crisp, canned water chestnut 9=very crisp, celery	Jaeger, Lund, and Harker, 2003; Hampson, Quamme, et al. 2000
Crunchiness	The amount of noise generated when chewing with the back teeth	1 to 5 intensive scale	1=not crunch at all, banana 3=moderately crunch 5=crunch, carrot	Jaeger, Lund, and Harker, 2003
Skin thickness	The taste of skin	Nominal scale for taste	1=none 2=astringent 3=bitter	Blake and Van der Zwet, 1979; Jaeger, Lund, and Harker, 2003
	The amount of chewing required to cut through and breakdown the skin with the back teeth	1 to 7 intensive scale	1=tough 3=thick 5=medium, cv. Granny Smith apple 7=thin	

Flavours				
Sweetness	The basic taste on the tongue stimulated by sugar and high potency sweeteners	1 to 9 intensive scale	1=not detectable, dH_2O 3=slightly sweet, 20 g sucrose/l dH_2O 5=moderately sweet 7=sweet, 60g sucrose/l dH_2O 9=sweet extremely	Jaeger, Lund, and Harker, 2003; Hampson, Quamme, et al. 2000
Acid	The basic taste of the tongue stimulated by acids	1 to 9 intensive scale	1=not detectable, dH_2O 3=slightly acid 5=moderately acid, 0.5 g malic acid/l dH_2O 7=acid 9=extremely acid	Jaeger, Lund, and Harker, 2003
Sugar/acid ratio	The response of the tongue to sugar and acid balance	1 to 7 just right scale	1=too acid, high acid:low sugar 2=moderately too acid 3=slightly too acid 4=just right 5=slightly too sweet 6=moderately too sweet 7=too sweet, low acid:high sugar	
Aromatics	The basic response of the phenolic/polyphenolic compounds	1 to 9 liking scale	1=dislike extremely 3=dislike moderately 5=neither dislike nor like 7=like moderately 9=like extremely	Hampson, Quamme, et al. 2000

Appearance			
Fruit size	1 to 7 just right scale	1=too small 2=moderately too small 3=slightly too small 4=just right 5=slightly too large 6=moderately too large 7=too large	Hampson and Quamme, 2000; Kappel, Fisher-Fleming, and Hogue, 1996; Kappel, Fisher-Fleming, and Hogue, 1995
Fruit shape	Nominal scale	1=round 2=round ovate 3=ovate 4=ovate-pyriform 5=pyriform 6=round pyriform 7=long pyriform 8=oblate 9=other	Blake and Van der Zwet, 1979; Hampson and Quamme, 2000; Kappel, Fisher-Fleming, and Hogue, 1995
	1 to 9 liking scale	1=dislike very much 3=dislike moderately 5=neither dislike nor like 7=like moderately 9=like very much	

Skin colour	Nominal scale	1=green 2=yellow green 3=yellow 4=orange 5=red 6=olive 7=tan 8=brown 9=other	Blake and Van der Zwet, 1979; Kappel, Fisher-Fleming, and Hogue, 1995
	1 to 9 liking scale	1=dislike very much 3=dislike moderately 5=neither dislike nor like 7=like moderately 9=like very much	
Blush colour	Nominal scale	1=green 2=brown 3=tan 4=orange 5=pink 6=red 7=other	Blake and Van der Zwet, 1979
	1 to 9 liking scale	1=dislike very much 3=dislike moderately 5=neither dislike nor like 7=like moderately 9=like very much	
Russet	Nominal scale for colour	1=grey 2=green 3=brown 4=tan 5=olive 6=yellow 7=orange 8=pink 9=red	Blake and Van der Zwet, 1979

		10=other	
	1 to 9 intensive scale for the degree of smoothness	1=very rough 3=rough 5=neither rough nor smooth 7=smooth 9=very smooth	
	1 to 9 liking scale for visual response	1=dislike very much 3=dislike moderately 5=neither dislike nor like 7=like moderately 9=like very much	

Storage quality			
Scald*	1 to 6 intensive scale	1=none 2=light, ≤10% of surface coverage 3=moderate, >10%≤25% 4=slightly heavy, >25%≤50% 5=moderately heavy, >50%≤80% 6=very heavy, >80%	
Internal breakdown	1 to 9 intensive scale	1=none 2=light core 3=medium core 4=heavy core 5=light flesh 6=medium flesh 7=heavy flesh 8=vascular bundle 9=whole	Blake and Van der Zwet, 1979

Others			
Core size*	1 to 4 intensive scale	1=very small, <1/10 the ratio of core/fruit max. width in the cross section 2=small, >1/10≤1/4 3=large, >1/4≤1/2 4=very large, >1/2	Blake and Van der Zwet, 1979
Lenticels	Nominal scale	0=not prominent 1=prominent	
Stem length	1 to 7 intensive scale	1=very long 3=long 5=medium, Williams' 7=short 9=very short	Blake and Van der Zwet, 1979
Stem thickness & angle	1 to 4 intensive scale for thickness	1=thick 2=medium, Williams' 3=thin 4=fleshy	Blake and Van der Zwet, 1979
	Nominal scale for angle	0=upright, Williams' 1=oblique, any angles except 90° & 180°	

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Appendix 2. Crosses made during seasons 1999 – 2003.

Code	Female Parent	Male parent	Year
99-01	Concord	Eldorado	1999
99-02	Eldorado	BPM	1999
99-03	Eldorado	Concord	1999
99-04	Eldorado	Corella	1999
99-05	Eldorado	Vicar Winkfield	1999
99-05R	Vicar Winkfield	Eldorado	1999
99-06	William Compat	Vicar Winkfield	1999
99-07	Moonglow	Forelle	1999
99-08	Rogue Red	Forelle	1999
99-09	Red Sensation	Forelle	1999
99-10	BPM	Forelle	1999
99-11	Forelle	Abate Fetele	1999
99-12	Beurre Bosc	Conference	1999
99-13	Beurre Bosc	Vicar Winkfield	1999
99-14	Dr Jules Guyot	Rogue Red	1999
99-14R	Rogue Red	Dr Jules Guyot	1999
99-15	Dr Jules Guyot	Vicar Winkfield	1999
99-16	Eldorado	Packham's Triumph	1999
99-17	Josephine	Rogue Red	1999
99-17R	Rogue Red	Josephine	1999
99-18	Packham's Triumph	BPM	1999
99-18R	BPM	Packham's Triumph	1999
99-19	Rogue Red	Eldorado	1999
99-20	Rogue Red	20th Century	1999
99-21	Rogue Red	Ya Li	1999
99-22	Red Sensation	20th Century	1999
99-23	Eldorado	Conference	1999
00-01	WBC x Concord	Concord	2000
00-02	BPM	Forelle	2000
00-03	Concord	BPM	2000
00-04	Josephine	Forelle	2000
00-05	Josephine	Corella	2000
00-06	Josephine	Concord	2000
00-07	Josephine	Guyot	2000
00-08	Packham's Triumph	Dr Julies Guyot	2000
00-09	WBC	Forelle	2000
00-10	Concord	BPM	2000
00-11	Vicar Winkfield	Dr Julies Guyot	2000
00-12	Concord	Eldorado	2000
00-13	Eldorado	BPM	2000
00-14	Eldorado	Concord	2000
00-15	Eldorado	Corella	2000
00-16	WBC	Forelle	2000
00-17	WBC	Concord	2000
00-18	Packham's Triumph	Dr Jules Guyot	2000
00-19	Josephine	Forelle	2000
00-20	Josephine	Dr Jules Guyot	2000
00-21	Josephine	Corella	2000
00-22	Josephine	Concord	2000
00-23	Concord	BPM	2000
01-01	WBC	Concord	2001
01-02	BPM	Forelle	2001
01-03	Concord	BPM	2001
01-04	Josephine	Forelle	2001
01-05	Josephine	Corella	2001
01-06	Josephine	Concord	2001
01-07	Josephine	Dr Jules Guyot	2001
01-08	Packham	Dr Jules Guyot	2001
01-09	WBC	Forelle	2001
01-10	Concord	BPM	2001
01-11	Vicar of Winkfield	Dr Jules Guyot	2001
02-01	Concord	Josephine	2002
02-02	Corella	Dr Julies Guyot	2002
02-03	Vicar of Winkfield	Corella	2002
03-01	B19-10	F11-82	2003
03-02	B19-10	C31-42	2003
03-03	B19-10	Packham's T. SO	2003
03-04	B19-10	Packham's T. SC	2003
03-05	B14-40	F11-82	2003
03-06	C31-42	C01-49	2003
03-07	C31-42	C53-75	2003
03-08	C53-75	C01-49	2003
03-09	Comice	F11-82	2003
03-10	Comice	Precoce di Fiorana	2003
03-11	Comice	Packham's T. SO	2003
03-12	Comice	Packham's T. SC	2003
03-13	Comice	C31-42	2003
03-14	Eldorado	Precoce di Fiorana	2003
03-15	Eldorado	C31-42	2003
03-16	E16-40	F18-71	2003
03-17	F02-85	C26-38	2003
03-18	F11-82	C32-42	2003
03-19	F18-71	F11-82	2003
03-20	F42-31	F11-82	2003
03-21	Harrow Delight	Packham's T. SO + SC	2003
03-23	Precoce di Fiorana	F11-82	2003
03-24	Precoce di Fiorana	C31-42	2003
03-25	Precoce di Fiorana	C26-38	2003

Appendix 3. Selections noted in seasons 2002, 2003 and 2004.

Season 2002

Selections season 2002

No.	Cross	Type	Female	Male parent
1	93-1	W	BPM	Corella
2	93-11	W	Josephine	Packham's Triumph
3	93-2	W	Packham's Triumph	Comice
4	93-5	W	Packham's Triumph	Josephine
5	93-5	W	Packham's Triumph	Josephine
6	93-5	W	Packham's Triumph	Josephine
7	93-6	G	Packham's Triumph	Howell
8	93-6	W	Packham's Triumph	Howell
9	93-7	G	Potomac	Packham's Triumph
10	93-7	S	Potomac	Packham's Triumph
11	94-14	G	Corella	Comice
12	94-14	G	Corella	Comice
13	94-15	G	Guyot	Dawn
14	94-15	W	Guyot	Dawn
15	94-15	W	Guyot	Dawn
16	94-15	W	Guyot	Dawn
17	94-17	G	L'inconnu	Corella
18	94-19	N	Fla 58-45 OP	
19	94-19	N	Fla 58-45 OP	
20	94-19	S	Fla 58-45 OP	
21	94-19	S	Fla 58-45 OP	
22	94-19	S	Fla 58-45 OP	
23	94-1R	W	Corella	BPMorettini
24	94-1R	W	Guyot	Comice
25	94-21	S	Fla-57-75 OP	
26	94-3	W	Eldorado	Comice
27	94-4R	W	Comice	BPMorettini
28	94-5	W	Howell	Comice
29	94-6	S	WBC	Ya Li
30	95-1	G	BPM	Corella
31	95-1	G	BPM	Corella
32	95-1	G	BPM	Corella
33	95-1	G	BPM	Corella
34	95-1	S	BPM	Corella
35	95-1	S	BPM	Corella
36	95-1	S	BPM	Corella
37	95-1	W	BPM	Corella
38	95-10	G	Packham's Triumph	Corella
39	95-13	W	WBC	Eldorado
40	95-2	G	BPM	Dawn
41	95-2	W	BPM	Dawn
42	95-22	S	Guyot	Corella
43	95-23	G	WBC	Eldorado
44	95-23	S	Guyot	Hood
45	95-23	S	Guyot	Hood
46	95-24	G	Guyot	Howell
47	95-24	G	Guyot	Howell
48	95-24	S	Guyot	Howell

Selections season 2002

No.	Cross	Type	Female	Male parent
49	95-24	W	Guyot	Howell
50	95-24	W	Guyot	Howell
51	95-24	W	Guyot	Howell
52	95-25	G	Guyot	Packham's Triumph
53	95-4	N	comice	Ya Li
54	95-5	W	Corella	Packham's Triumph
55	96-11	W	Eldorado	Guyot
56	96-15	S	Guyot	Dawn
57	96-20	G	Harvest Queen	Packham's Triumph
58	96-21	G	Hw606	Packham's Triumph
59	96-21	W	Hw606	Packham's Triumph
60	96-21	W	Hw606	Packham's Triumph
61	96-22	W	Hw610	Packham's Triumph
62	96-23	W	Hw614	Packham's Triumph
63	96-25	W	Ill-13B-83	Packham's Triumph
64	96-25	W	Ill-13B-83	Packham's Triumph
65	96-25	W	Ill-13B-83	Packham's Triumph
66	96-25	W	Ill-13B-83	Packham's Triumph
67	96-25	W	Ill-13B-83	Packham's Triumph
68	96-37	W	WBC	BPMorettini
69	96-9	G	Dawn	Packham's Triumph
69 selections				
	36 families		G = edible off the tree and capable of post-storage maturation	

W = winter pear-requires maturation
S = only edible directly from tree (summer pear)
N = nashi type

Season 2003

Selections, season 2003

CrossCode	Female	Male Parent	Number of Selections
93-1	BPM	Corella	1
94-14	WBC	Howell	1
94-15	WBC	Howell	7
94-4	BPM	Comice	2
94-4R	Comice	BPM	2
94-5R	Comice	Howell	2
95-1	BPM	Corella	3
95-16	Winter Cole	Packham's Triumph	1
95-22	Guyot	Corella	7
95-24	Guyot	Howell	1
95-25	Guyot	Packham's Triumph	1
96-11	Eldorado	Guyot	1
96-15	Guyot	Dawn	1
96-17	Harrow Del	Packham's Triumph	2
96-21	Hw606	Packham's Triumph	1
96-37	WBC	BPM	1
96-48	Ya Li	Eldorado	1
17 families			35

Number of fruited, selected trees and desirable trees identified after fruit assessment in 88 crosses assessed in 2004 season.

Code	Cross ID	Pedigree		No Fruited trees	No trees selected for assessment	No desirable trees selected after assessment
		Female	Male			
1	93-11	Josephine	Packham's T	245	3	
2	94-01	Comice	Guyot	242	53	
3	94-01R	Guyot	Comice	351	92	5
4	94-02	Comice	Vicar	43	1	
5	94-03	Eldorado	Comice	400	43	
6	94-04	BPM	Comice	42	3	
7	94-04R	Comice	BPM	179	23	6
8	94-05	Howell	Comice	316	58	1
9	94-05R	Comice	Howell	540	90	
10	94-06	WBC	Ya Li	12	1	
11	94-11	Packham's T	Hood	43	3	
12	94-14	Corella	Comice	164	13	
13	94-15	WBC	Howell	428	31	
14	94-18	Josephine	Corella	194	74	
15	95-16	Winter Cole	Packham's T	783	12	
16	95-17	Comice	Corella	468	26	
17	95-18	Comice	Josephine	653	19	
18	95-19	Comice	Nicholas	519	13	
19	95-20	Comice	Packham's T	800	31	
20	95-21	Comice	Winter Cole	866	18	
21	95-22	Guyot	Corella	913	149	9
22	95-23	Guyot	Hood	1026	83	1
23	95-24	Guyot	Howell	443	35	
24	95-25	Guyot	Packham's T	429	31	
25	95-26	Guyot	Vicar	28	4	
26	95-27	Eldorado	Comice	230	8	
27	95-28	Hood	Comice	3	1	
28	95-30	Josephine	Comice	562	6	
29	95-31	Harrington	Packham's T	37	1	
30	96-01	Bosc	Comice	177	2	
31	96-02	Bosc	Guyot	45	3	
32	96-05	BPM	Ya Li	236	24	
33	96-06	Corella	Ya Li	94	3	
34	96-07	Dawn	Eldorado	64	2	
35	96-08	Dawn	Guyot	268	12	
36	96-09	Dawn	Packham's T	245	2	
37	96-10	Eldorado	Dawn	118	2	
38	96-11	Eldorado	Guyot	219	3	
39	96-13	Eldorado	Ya Li	161	5	
40	96-14	Guyot	Bosc	999	40	
41	96-15	Guyot	Dawn	211	20	
42	96-16	H7632-V-6 Harrow	Packham's T	25	1	
43	96-17	Delight	Packham's T	107	15	
44	96-19	Harrow Sweet	Packham's T	37	1	
45	96-20	Harvest Queen	Packham's T	36	2	
46	96-21	HW606	Packham's T	169	14	

Code	Cross ID	Pedigree		No Fruited trees	No trees selected for assessment	No desirable trees selected after assessment
		Female	Male			
47	96-22	HW610	Packham's T	37	5	
48	96-23	HW614	Packham's T	55	6	
49	96-24	HW622	Packham's T	27	5	
50	96-25	I11-13B-83	Packham's T	284	13	
51	96-29	Packham's T	Dawn	118	4	
52	96-30	Potomac	Packham's T	138	3	
53	96-31	Red Sensation	Ya Li	153	7	
54	96-34	US 56112-146	Packham's T	33	3	1
55	96-35	US 65063-044	Packham's T	75	3	
56	96-36	Vicar	Dawn	12	1	
57	96-37	WBC	BPM	654	53	7
58	96-38	WBC	Corella	541	31	
59	96-39	WBC	Dawn	326	20	
60	96-40	WBC	Packham's T	453	15	
61	96-44	Eldorado	Kosui	294	12	
62	96-45	Packham's T	Tsu Li	5	1	
63	96-48	Ya Li	Eldorado	322	1	
64	97-01	Bosc	Guyot	840	22	1
65	97-03	Comice	Dawn	1105	16	
66	97-05	Dawn	Packham's T	101	3	
67	97-07	Eldorado	Rogue Red	341	6	
68	97-08	Guyot	Corella	1178	50	1
69	97-12	Packham's T	Comice	1405	39	
70	97-13	Packham's T	Dawn	589	35	
71	97-16	Corella	Dawn	441	27	
72	97-18	Eldorado	BPM	91	8	
73	97-19	Eldorado	Corella	85	1	
74	97-20	Eldorado	Dawn	68	1	
75	97-21	Eldorado	Packham's T	73	1	
76	97-22	Packham's T	June Gold	6	1	
77	97-23	Rogue Red	Eldorado	179	3	
78	97-24	Rogue Red	WBC	727	21	
79	97-25	Vicar	Comice	106	1	
80	97-27	Winter Nelis	BP1	9	1	
81	97-28	Winter Nelis	BP3	31	1	
82	97-30	Eldorado	Vicar	8	1	
83	98-11	Rogue Red	Josephine	257	2	
84	98-13	Rogue Red	Ya Li	86	8	
85	98-16	Guyot	Rogue Red	1512	107	2
86	98-17	Rogue Red	Guyot	345	15	
87	98-19	Eldorado	BPM	994	24	
			Total	**28274**	**1653**	**34**

Appendix 4: Scab screening

Report on pear scab screening during 1999

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IHD Knoxfield

1. Scab screening of 1998-99 crosses

A total of 5887 pear seedlings, from a total of 8149 seed, were screened for their reaction to pear scab during 1999. These seedlings represented 10 crosses derived from 8 cultivars which were considered to have some potential for resistance to pear scab. They were a proportion of the total number of seedlings produced in this season. Two inoculations were carried out in August and September 1999, with assessments being made about three weeks after inoculation. The last assessment was made on 29 September 1999. Scab inoculum was from WBC pears from northern Victoria, which was frozen and then bulked up by inoculation onto Packham seedlings.

Results of the inoculations are shown in Table 1. Seedlings assessed as having reactions 0,1 or 2 were considered resistant, while the remainder, which showed limited or abundant sporulation, were considered susceptible. See "Report on pear scab screening in 1994" for details of the assessment methods. The proportion of seedlings rated as resistant to scab ranged from 0-37.3%. Control infection levels were 100% for both Packham and WBC seedlings which were used as indicators of suitable infection conditions for each inoculation (Table 1). The crosses between Rogue Red and 20th Century, Ya Li and Guyot all gave moderately high proportions of resistant seedlings, ranging from 24.2 to 37.3%.

2. Susceptibility of pear cultivars and species to infection by pear scab, caused by *Venturia pirina.*

Replicated field plantings of 19 pear cultivars and species were made in winter 1998 at both Knoxfield and Tatura as part of the above investigation. These plantings do not receive any fungicide sprays and thus scab incidence on different cultivars will indicate their relative susceptibility to scab in the two locations. The first observations are shown in Table 2 and Figure 1. As these plants are in only their second season of growth in the field, few fruit were present (on some trees at Tatura only), and further observations are required before definite conclusions can be drawn. This study will continue over a number of seasons.

Due to staff movement and changing priorities the detailed study to examine variation of the scab fungus which was outlined last year has ceased. Narelle Kita, who had begun work at Knoxfield on this subject as part of a post graduate degree in association with Melbourne University Institute of Land and Food, has stopped her post graduate studies in this area and is moving into another area of work at DPI-Knoxfield.

Table 1. Results of scab screening from selected crosses made in 1998-99 (screened with *Venturia pirina* in August and September 1999)

Cross	Date inoculated	No. seed sown	No. plants tested	% seed germination	No. of seedlings in each scab infection rating category[A] 0	1	2	4	% resistant	% susceptible	% control infection[B]
Guyot x Rogue Red	30/8/99	2009	1691	84.2	17	0	0	1674	1.0	99.0	100
Guyot x Rogue Red	1/9/99	399	330	82.7	1	0	0	329	0.3	99.7	100
Vicar x Eldorado	1/9/99	966	242	25.1	2	0	0	240	0.8	99.2	100
Rogue Red x Josephine	1/9/99	603	532	88.2	0	0	0	532	0	100	100
Josephine x Rogue Red	6/9/99	2016	1012	50.2	47	20	3	942	6.9	93.1	100
Rogue Red x 20th Century	8/9/99	462	227	49.1	31	14	10	172	24.2	75.8	100
Rogue Red x Ya Li	8/9/99	790	702	88.9	206	43	13	440	37.3	62.7	100
Rogue Red x Guyot	8/9/99	632	591	93.5	110	47	25	409	30.8	69.2	100
WBC x Vicar	8/9/99	20	15	75	1	2	1	11	26.7	73.3	100
Eldorado x Vicar	8/9/99	31	27	87.1	0	1	3	23	14.8	85.2	100
Guyot x Vicar	8/9/99	42	39	92.9	2	3	1	33	15.4	84.6	100
Total		8149	5887								

[A] Number of seedlings in each category. Scab infection ratings: 0= no macroscopic evidence of infection; 1= fine pits, no sporulation; 2= chlorotic or necrotic lesions, sometimes crinkled aspect, no sporulation and 4= limited and abundant sporulation.
[B] Percentage infection in open-pollinated Packham and WBC seedlings used as controls.

Table 1. Incidence of leaf and fruit scab (%) on 19 cultivars of pear over the 1999/2000 season. (Assessed on 1/12/99 at IHD and on 15/2/00 at ISIA)

Cultivar	**Leaf Scab (IHD)**	**Leaf Scab (ISIA)**	**Fruit Scab (ISIA)**
Beurre Bosc	27.7	17.0	50.0
Clapp's	11.7	10.0	10.0
Conference	10.4	2.0	
Josephine	8.8	0.4	0
Packham	6.2	2.3	26.7
Red Sensation	4.6	11.3	100
Howell	4.1	11.2	
Eldorado	2.2	5.4	0
WBC	1.2	7.4	100
Pound	0.5	0	33.3
Corella	0.2	0	
FlordaHome	0	0	
Hood	0	0	
Comice	0	0	0
Pyrus calleryana D6	0	0	
Tsu Li	0	0	0
Ya Li	0	0	0
Hosui	0	0	0
20th Century	0	0	0
l.s.d (P=0.05)	(6.8)		

Report on pear scab screening during 2000

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1. Scab screening of 1999-00 crosses

A total of 1306 pear seedlings were screened for their reaction to pear scab during 2000. These seedlings represented 6 crosses derived from 6 cultivars which were considered to have some potential for resistance to pear scab. They were a proportion of the total number of seedlings produced in this season. Inoculations were carried out in August 2000, with assessments being made in September, about three weeks after inoculation. Scab inoculum was from WBC pears from northern Victoria, which was frozen and then bulked up by inoculation onto Packham seedlings.

Results of the inoculations are shown in Table 1. Seedlings assessed as having reactions 0,1 or 2 were considered resistant, while the remainder, which showed limited or abundant sporulation, were considered susceptible. See "Report on pear scab screening in 1994" for details of the assessment methods. The proportion of seedlings rated as resistant to scab ranged from 15.9-68 %, if the three tests with low numbers of plants (8 or less) tested were excluded. Control infection levels ranged from 95-100% (Table 1).

Table 1. Results of scab screening from selected crosses made in 2000 (screened with *Venturia pirina* in August and September 2000)

Cross	Date assessed	No. seed sown	No. plants tested	% seed germination	No. of seedlings in each scab infection rating category [A]				% resistant	% susceptible	% control infection (Packham)	% control infection (WBC)[B]
					0	1	2	4				
Eldorado x Concord	5/9/00	58	50	86.2	28	0	6	16	68	32	95.2	100
Concord x Eldorado	5/9/00	8	8	100	7	0	0	1	87.5	12.5	95.2	100
Eldorado x Vicar of Winkfield	5/9/00	10	7	70	5	0	0	2	71.4	28.6	95.2	100
Williams Cpt X Vicar of Winkfield	5/9/00	1	1	100	1	0	0	1	100	0	95.2	100
Eldorado x Corella	5/9/00	535	474	88.6	95	0	55	323	31.6	68.4	95.2	100
Eldorado x BPM	5/9/00	840	766	91.2	69	15	38	644	15.9	84.1	95.2	100
Total		1452	1306		205	15	99	987				

[A] Number of seedlings in each category. Scab infection ratings: 0= no macroscopic evidence of infection; 1= fine pits, no sporulation; 2= chlorotic or necrotic lesions, sometimes crinkled aspect, no sporulation and 4= limited and abundant sporulation.
[B] Percentage infection in open-pollinated Packham seedlings used as controls.

2. Susceptibility of pear cultivars and species to infection by pear scab, caused by *Venturia pirina.*

Two field plantings of pear species and cultivars have been established, one at Tatura and the other at Knoxfield to study the relative susceptibility of a range of pear cultivars to scab. Results to date are summarised below in an abstract presented to the Australasian Plant Pathology Society Biennial Conference in 2001.

FIELD SUSCEPTIBILITY OF PEAR CULTIVARS TO SCAB IN VICTORIA, AUSTRALIA

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Introduction

Scab (caused by *Venturia pirina* Aderh.) is the major fungal disease affecting European pear (*Pyrus communis* L.) production in Australia (1). It is routinely controlled on all commercial cultivars of European pear by fungicide sprays applied during the growing season. In Australia a program to breed new cultivars of pear began in 1992 which included the aim of breeding for scab resistance (2). As there is little information on the susceptibility of pear cultivars to scab in Australia, a study was conducted to compare the susceptibility of 18 pear cultivars and one *Pyrus* species to natural infection with scab.

Materials and methods

Eighteen cultivars (including European and Asian pears) and one species of pear (Table 1) were planted in duplicate blocks, one at the Institute for Horticultural Development, Knoxfield, and the other at the Institute for Sustainable and Irrigated Agriculture, Tatura, in winter 1998. Dormant trees were planted in a randomised block design with five single tree replicates of each cultivar. No disease control measures were applied to the block for the duration of the trial. For each of two seasons, the incidence of pear scab on leaves was recorded in late spring or summer. All leaves on each of five shoots/ tree, and all fruit/ tree, were examined and scored for the presence of scab.

Results and Discussion

Scab incidence increased over the two seasons, as inoculum built up at each site. The incidence of scabbed leaves at Knoxfield was highest on cultivars Buerre Bosc (average of 43.3% infection over two years), Red Sensation (20.8%), Clapp's (19.1%) and William's Bon Chretien (WBC) (18.6%) (Table 1). At Tatura, the incidence of leaf scab was highest on cultivars WBC (27.8%), Buerre Bosc (23.9%), Howell (22.4%) and Red Sensation (22.1%). All the Chinese pear cultivars (*P. ussuriensis*): Tsu Li, Ya Li, the Japanese pear cultivars (*P. pyrifolia* var. *culta*): Hosui and 20th Century, *P. calleryana*, or cultivars with Asian pear ancestry: FlordaHome and Hood, were highly resistant to leaf infection, with no lesions observed at either site in either season. Interestingly, the two most important commercial cultivars WBC and Packham's showed similar susceptibility at Knoxfield, but WBC was far more susceptible than Packham's at Tatura (Table 1). Fruit scab observations were generally consistent with observations of leaf scab, although fruit numbers were low and variable.

Table 1. Incidence of leaf scab (%) on pear cultivars over two seasons at Knoxfield and Tatura

Cultivar	Knoxfield	Tatura
	2-yr mean	2-yr mean
Beurre Bosc	43.3	23.9
Red Sensation	20.8	22.1
Clapp's	19.1	17.4
WBC	18.6	27.8
Packham's Triumph	16.4	7.9
Josephine	16.3	6.7
Doyenne du Comice	15.7	11.2
Eldorado	15.4	9.4
Corella	15.1	7.9
Conference	14.1	6.4
Howell	12.8	22.4
Pound	7.3	0.3
FlordaHome	0	0
Hood	0	0
P. calleryana	0	0
Tsu Li	0	0
Ya Li	0	0
Hosui	0	0
20th Century	0	0
l.s.d. ($p = 0.05$)	8.4	8.9

This ongoing study has already provided information about the susceptibility of a range of pear cultivars to scab, which should be useful in planning pear breeding crosses to produce scab resistant progeny. Information about the relative susceptibility of cultivars should also assist integrated pest and disease programs in Victoria. Further data are required to confirm the fruit scab observations, and studies are required to establish the existence of physiological strains or races of scab.

Acknowledgments
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Figure 1. Scab on unsprayed pear trees at ISIA Tatura and IHD Knoxfield