The 2007 Banks Memorial Lecture: 'Discovery and description' of the New Zealand flora: a contemporary perspective

Peter B. Heenan[1]

'Discovery and description'
New Zealand has a rich history of botanical discovery and description of its flora, with the first voyages made by Captain Cook including naturalists such as Joseph Banks, Daniel Solander, Johann Forster, and Georg Forster. Plants collected by these naturalists formed the backbone of the early floras of New Zealand, including *Florulae Insularum Australium Prodromus* by G. Forster and the *Handbook of the New Zealand Flora* by J.D. Hooker.

The more recent New Zealand floras have relied much more extensively on plant collections and research by botanists resident in New Zealand, including T. Kirk (*The Students' Flora of New Zealand and the Outlying Islands*), T.F. Cheeseman (*Manual of the New Zealand Flora*), and the authors of the five-volume *Flora of New Zealand* series published between 1961 and 2000 (Allan, 1961; Moore and Edgar, 1970; Healy and Edgar, 1980; Webb et al., 1988; Edgar and Connor, 2000). These are the vascular (so-called 'higher plant') floras (Fig. 1), but there are also floras on New Zealand desmids (a group of freshwater green algae; Croasdale and Flint, 1986, 1988; Croasdale et al., 1994) and lichens (Galloway, 1985, 2007). There are also moss and liverwort floras nearing completion.

Fig. 1 The five-volume *Flora of New Zealand* series.

All provide a wealth of information including detailed botanical descriptions, illustrations, and identification keys, which are used, for example, by students, farmers, and horticulturists for understanding New Zealand's biodiversity. Popular books such as those on garden plants or weeds also draw on the source information provided in these floras.

The flora treatments provide the latest information up to the time they are published. Subsequent fieldwork, plant collections, and detailed study of character variation and plant distributions provide new insights into relationships among plants (Fig. 2 A–E).

Therefore, taxonomic research on many groups of New Zealand plants is an ongoing process, and detailed taxonomic study of a particular genus or other well-defined group may be published as a monograph. The most notable monograph in recent years was made by David Glenny who studied the New Zealand gentians (Glenny, 2004). As a consequence of his work, new species were described, others were sunk into synonymy, and the New Zealand gentians were transferred from the genus *Gentiana* to *Gentianella*.

For other groups, such as the herbaceous *Cardamine* (bitter cress), *Craspedia* (woollyheads), and *Myosotis* (the forget-me-nots) genera, there are no comprehensive, modern and thorough taxonomic treatments. The 'discovery and description' of the New Zealand flora is very much incomplete, and although more than 2000 indigenous New Zealand plants have been named it is estimated that about another 15% (some 300 species) have yet to be formally named and described. Some of these unnamed species have been given informal 'tag names' but these have not been the subject of careful and rigorous scientific study which is required before a new species should be named.

Fig. 2 Plant taxonomists gather information using five major resources: **A**, fieldwork and plant collecting in the wild; **B**, growing plants on in the experimental nursery and grounds; **C**, laboratories for DNA sequencing and other work; **D**, herbaria where dried and pressed plants are deposited for permanent reference – the Allan Herbarium at Lincoln contains specimens dating back to the first collections made by Banks, Solander, and the Forsters; **E**, the research library, which contains specialist botanical literature.

---

[1] Landcare Research, PO Box 40, Lincoln 7640; heenanp@landcareresearch.co.nz

Since the early 1990s there has been a renaissance in flowering plant taxonomy and from this time more than 170 new species, subspecies, and varieties of New Zealand plants have been named. Much of this recent research has been on grasses, threatened species, and species-rich genera that lacked modern taxonomic treatments. Although many of the new species have been previously known by tag names, several are completely new discoveries that have been made by careful and detailed observation. From my research (and that of my collaborators) these include species such as *Sophora godleyi* (a new kowhai; Heenan et al., 2001), *Uncinia perplexa* (a new sedge; Heenan and de Lange, 2001), *Arthropodium bifurcatum* (a new renga lily; Heenan et al., 2004), *Myrsine umbricola* (a new matipo; Heenan and de Lange, 2004), *Olearia adenocarpa* (a new shrubby daisy; Heenan and Molloy, 2004), *Pseudowintera insperata* (a new horopito or pepper tree; Heenan and de Lange, 2006), *Ranunculus acraeus* (a new buttercup; Heenan et al., 2006), and *Lobelia carens* (Heenan et al., 2008).

When studying plant groups (e.g., genera or species) for taxonomic research projects, many biological attributes are investigated in detail. Such attributes include, for example, leaf and wood anatomy, breeding systems, phenology (timing of different stages in the lifecycle such as growth initiation and flowering), hybridisation, chromosome number and DNA variation. This information is usually an essential and critical part of the taxonomic decision making process, but it is also invaluable for understanding other aspects of the group, such as conservation biology and evolutionary processes.

Two case studies are now discussed where general taxonomic information is utilised for the conservation of *Olearia adenocarpa* and in the development of *Pachycladon* as a model plant for understanding evolutionary processes.

Olearia adenocarpa: conservation

An unnamed *Olearia* from the Canterbury Plains was first recognised as distinct in August 2002 (Fig. 3 A–B).

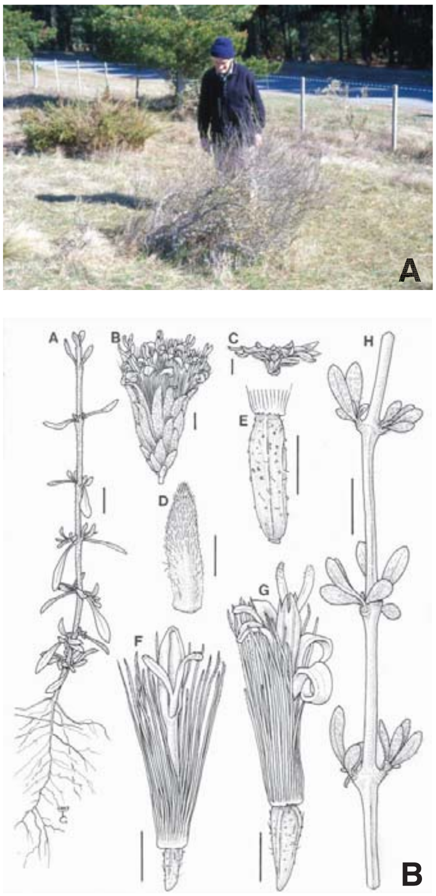

Fig. 3 *Olearia adenocarpa*: **A**, Dr Brian Molloy examines a mature plant in the field. Before conservation measures were implemented, there were only 11 mature plants capable of reproduction; **B**, botanical illustration of the new species.

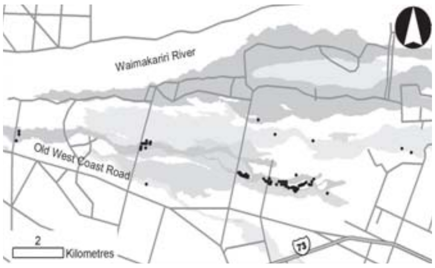

Fig. 4 Distribution of *Olearia adenocarpa* in the Waimakariri River floodplain.

Fig. 5 Dr Brian Molloy examines a severely browsed plant of *Olearia adenocarpa*.

This small-leaved shrubby member of the daisy family is known only from the lower reaches of two river systems – Great Island in the Rakaia River and an intermittent distribution along the Waimakariri River floodplain (Fig. 4). More than 600 plants are now known but the majority are severely browsed by cattle, sheep, hares, and rabbits (Fig. 5). This species was subsequently named as *O. adenocarpa* and a conservation assessment recommended it be listed as Nationally Critical (Heenan and Molloy, 2004).

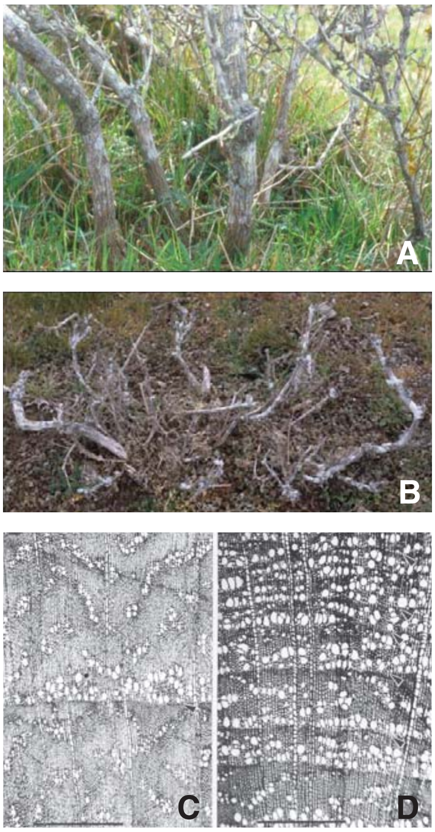

Fig. 6 *Olearia adenocarpa*: **A**, unbrowsed stems; **B**, browsed stems; **C**, cross section of an unbrowsed stem as seen through a microscope showing the widely spaced growth rings; **D**, cross section of a browsed stem.

The scientific paper describing this *Olearia* included information of relevance to its conservation biology, including plant growth habit, age (growth ring counts; Fig. 6 A–D, Fig. 7), height, stem number, wood anatomy, and phenology. Furthermore, detailed description of its habitats and distribution was presented, as well as issues and opportunities for conservation management.

At the time of its discovery, only 11 mature plants of *O. adenocarpa* were thought to be capable of sexual reproduction and therefore research on its breeding system was considered to be critically important to its long-term survival.

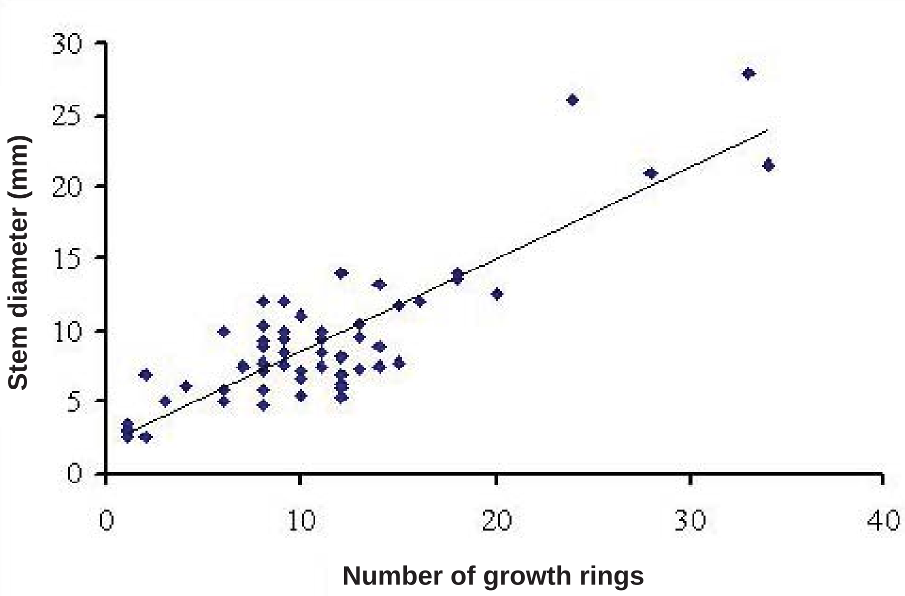

Fig. 7 Graph of the number of growth rings plotted against the stem diameter of *Olearia adenocarpa*.

This research was undertaken and the species has been shown to have a mixed breeding system that includes self-incompatible and some self-compatible plants (Heenan et al., 2005). The self-compatible plants probably arose recently through the loss of self-incompatibility due to extreme selection pressure within the small populations. The progeny of self-compatible plants have been shown to suffer from inbreeding depression (a decrease in vigour or fitness as a result of inbreeding), as about 33% of the selfed offspring were runts (Fig. 8).

Fig. 8 Controlled self-pollinations of *Olearia adenocarpa*. Plants on the left-hand side show evidence of inbreeding depression. All plants are 6 months old and the offspring of self-compatible genotype C.

Since *O. adenocarpa* is probably naturally self-incompatible, populations comprising large numbers of plants (at least 50 individuals) are required to ensure successful outcrossing (Fig. 9).

Once the breeding systems were resolved it became possible to initiate conservation measures for *O. adenocarpa*. Two areas comprising about 36 hectares and including about 250 plants have been fenced with stock- and rabbit/hare-proof fencing. Since the fence was completed in August 2004, plants have had several growing seasons and their recovery has been very successful. New shoots have emerged from at and below ground level; plants that were once severely browsed to only 2–3 cm high are now 30–50 cm high, and now flowering and fruiting regularly.

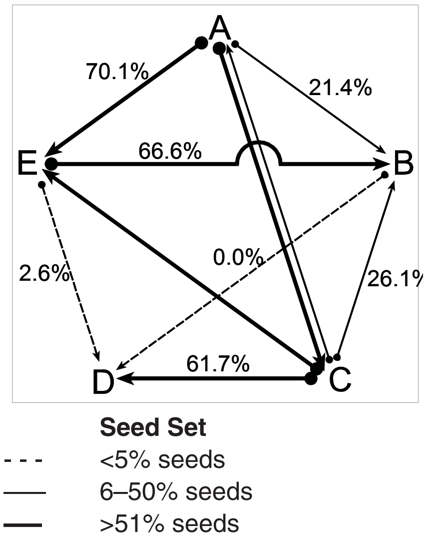

Fig. 9 Controlled cross-pollinations and seed set of five *Olearia adenocarpa* genotypes (A–E).

Fig. 10 The Canterbury Botanical Society planting out nursery-raised plants of *Olearia adenocarpa*.

Replanting inside the fenced areas with one-year-old nursery-raised plants was undertaken in August 2004 and July 2005 by the Canterbury Botanical Society (Fig. 10). This has only been partially successful, with about 10% of the plants surviving. To address this problem research is planned on the suitability of different potting mixes for nursery-raised plants, particularly in regard to growth and establishment after being planted out. Further research is also planned on the ecophysiology of *O. adenocarpa*, including water stress, photosynthesis, and respiration responses.

Pachycladon: investigating a New Zealand genus for understanding plant species and adaptive radiations

New Zealand has several indigenous members of the Brassicaceae (a family also known as the mustard or cabbage family, or the crucifers). Genus and species relationships have traditionally been based on morphological characters that are now known to exhibit considerable convergent evolution. Convergent evolution is where plant groups may look similar due to a shared environment but are actually more distantly related than it would seem.

Therefore, in 1998 we began a molecular study using DNA sequence data (from a region called ITS) to further understand relationships of the New Zealand species. All genera and most indigenous Brassicaceae species from New Zealand were sequenced (Mitchell and Heenan, 2000). The outcome of this phylogenetic (evolutionary) research and subsequent reappraisal of genus-level boundaries is that New Zealand has five genera and about 30 indigenous species that belong to the family. *Lepidium*, *Rorippa*, and *Cardamine* (a genus now including *Iti*; see Heenan, 2002), are cosmopolitan genera with mostly endemic New Zealand species. *Notothlapsi* is a New Zealand endemic alpine genus with two species, and *Pachycladon* occurs in New Zealand and Tasmania. On the basis of our phylogenetic research and a reassessment of morphological characters, *Pachycladon* was recircumscribed to include the genera *Cheesemania* and *Ischnocarpus*. This enlarged genus now comprises eight

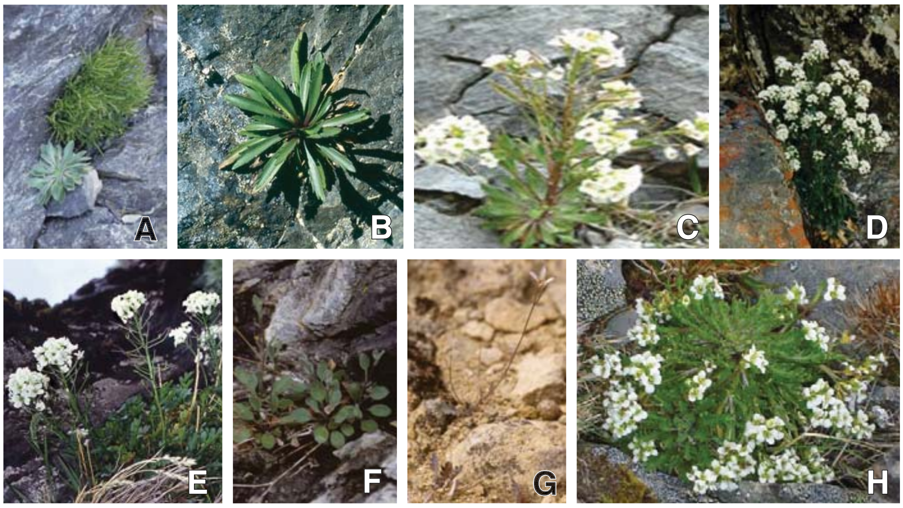

Fig. 11 New Zealand species of a recircumscribed *Pachycladon*: **A**, *P. enysii* (was *Cheesemania enysii*); **B**, *P. fastigiata* (was *C. fastigiata*); **C**, *P. latisiliqua* (was *C. gibbsii*); **D**, *P. stellata* (was *C. stellata*); **E**, *P. wallii* (was *C. wallii*); **F**, *P. cheesemanii* (was *Ischnocarpus novae-zelandiae*); **G**, *P. exilis* (was *I. exilis*); **H**, *P. novae-zelandiae*.

endemic South Island species (Fig. 11 A–H), with one additional species in Tasmania (Heenan et al., 2002).

Species of *Pachycladon* show little DNA sequence divergence and are considered to have evolved relatively recently, only in the last 1.0–3.5 million years (Heenan et al., 2002). It is now generally accepted that virtually the entire New Zealand flora has originated from long-distance dispersal[2] (e.g., Pole, 1994), and in the case of *Pachycladon* the closest relatives are the Northern Hemisphere genera *Transberingia* and *Crucihimalaya* (Fig. 12; Heenan et al., 2002).

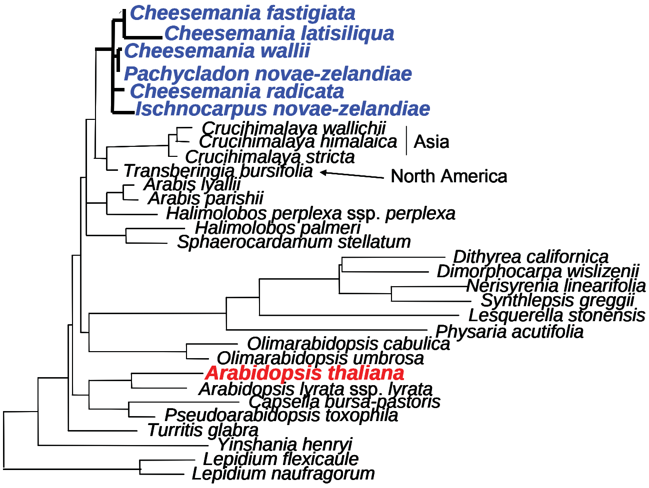

Fig. 12 Phylogenetic (evolutionary) tree (ITS maximum likelihood) of *Pachycladon* and related genera. In this tree, the previous names for the New Zealand species are used. This tree shows that *Cheesemania*, *Ischnocarpus*, and *Pachycladon* are intermixed (i.e., they do not form separate groups) and as a consequence they have now been combined under the one genus, *Pachycladon*.

Comparative research of morphological, molecular, and genetic data for these three genera could test the origin, establishment, and species radiation of *Pachycladon* in New Zealand, and its subsequent dispersal to Tasmania. In New Zealand the geological and climatic prehistory has been dominated by two phenomena. Firstly, the uplift of the Southern Alps of the South Island during the Pliocene and, secondly, by Pleistocene glaciation. Both events have had a major impact on the evolution and distribution of the indigenous New Zealand flora. For example, centres of endemism in the southern and northern South Island have been considered to be either glacial refugia or tectonically stable areas. Species of *Pachycladon* occur in these regions and have distribution patterns that are typical of other species radiations in New Zealand, and are therefore suited to testing these hypotheses.

An intriguing aspect of the phylogenetic research is that *Pachycladon* is also related to the well-known thale cress *Arabidopsis thaliana* (Fig. 12; Mitchell and Heenan, 2000; Heenan et al., 2002). *Arabidopsis thaliana* is indigenous to Europe, Asia, and north-western Africa. Significantly, it is one of the few model organisms used for studying plant biology and was the first plant to have its entire genome sequenced. Therefore it is a powerful tool for understanding the molecular biology of many different plant traits, including flower development. The monophyly[3] of the *Pachycladon* complex and its relationship to *Arabidopsis* has subsequently been confirmed by the analysis of additional molecular markers (McBreen and Heenan, 2006). Based on the close relationship between *Pachycladon* and *Arabidopsis*, the existing *Arabidopsis* genetic and molecular resources are likely to be well-suited to being used on *Pachycladon*. These high-end molecular and genetic resources make *Pachycladon* an ideal model genus for gaining a wider understanding of the evolution of morphological characters, how species and adaptive plant radiations work, and to test biogeographic hypotheses in a New Zealand setting.

In addition to the phylogenetic DNA sequencing work there is a large body of other research on *Pachycladon* that further highlights its usefulness as a model genus.

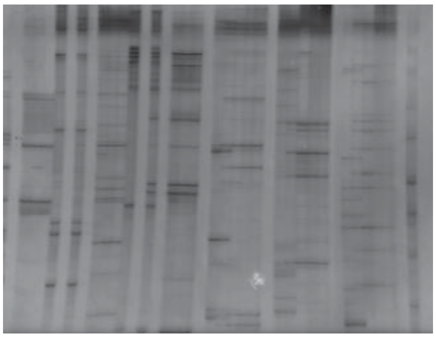

Fig. 13 DNA 'fingerprinting' (AFLP) plate of *Pachycladon* species. Each vertical lane represents a separate plant.

These studies include seed anatomy and morphology (Garnock-Jones, 1991a), breeding systems (Garnock-Jones, 1991b; Heenan and Garnock-Jones, 1999; Bicknell et al., unpubl. data), embryology (Luo et al., 2003), and DNA fingerprinting (Mitchell and Heenan, 2002). The DNA fingerprinting study used amplified

---

[2] See the article by Dawson and Winkworth (pp. 19–23).

[3] A monophyletic group is a 'natural' group or lineage. See the article by Glenny et al. (pp. 8–9).

fragment length polymorphism data (abbreviated AFLP) for most species of *Pachycladon*, and indicated that greater genetic variation was found among populations and within species than within populations (Fig. 13; Mitchell and Heenan, 2002). Artificial interspecific F_1, and some F_2, hybrids have also been generated between species previously assigned to the genera *Cheesemania*, *Ischnocarpus*, and *Pachycladon* (Heenan, 1999; Fig. 14, 15).

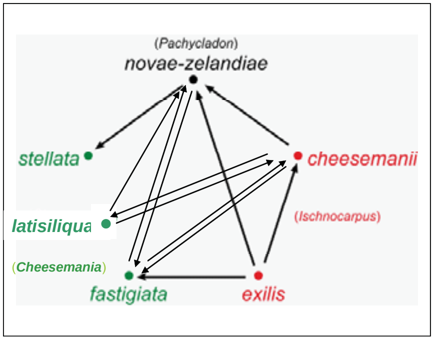

Fig. 14 Interspecific hybrid combinations of species now assigned to *Pachycladon*.

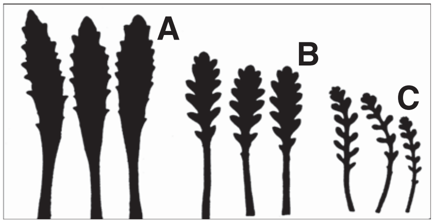

Fig. 15 Leaf size and shape of the parents and an intermediate F_1 hybrid: **A**, *P. stellata*; **B**, F_1 hybrid; **C**, *P. novae-zelandiae*.

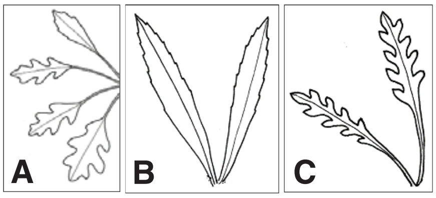

Fig. 16 Leaf types in *Pachycladon*: **A**, heteroblastic (two or more different leaf types on the same plant); **B**, serrated; **C**, lobed.

Species of *Pachycladon* comprise several distinct morphological characters including, for example, leaf types (heteroblastic, serrated, and lobed; Fig. 16 A–C), growth habit (monocarpic or polycarpic), fruit (laterally compressed and the seeds biseriate or terete and the seeds uniseriate), and seeds (winged or wingless; Fig. 17 A–B).

Pachycladon species mainly grow on shaded south-facing rock bluffs, but they grow in soils derived from different parent material rock types (Heenan and Mitchell, 2003). There are three groups of *Pachycladon* with different distributional and substrate preferences. These include species that are restricted to either schist (e.g., *P. novae-zelandiae*) or greywacke (e.g., *P. enysii*), and others that are generalists (e.g., *P. cheesemanii*), occurring on a wide range of substrates such as schist, greywacke, marble, limestone, and basalt. Many of the adaptive plant radiations in New Zealand have utilised the diversity of habitats that are available on these different parent materials. We can use these differences to test whether environmental factors are important drivers for speciation and if they are imposing selection.

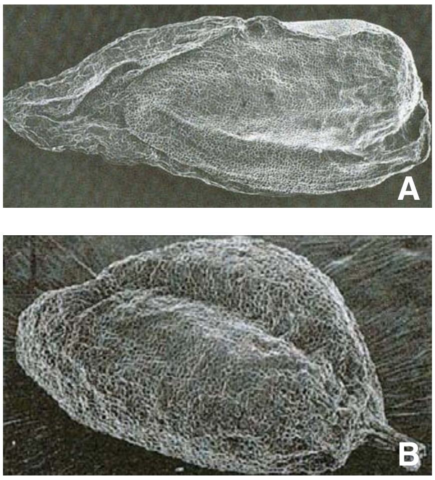

Fig. 17 Scanning electron micrographs of seed types in *Pachycladon*: **A**, winged seeds, e.g., *P. latisiliqua*; **B**, wingless seeds, e.g., *P. novae-zelandiae*.

The case studies presented here for *Olearia* and *Pachycladon* show that taxonomic research in New Zealand has come a long way since the pioneering days of the botanists on Captain Cook's first voyages. While some of the original methods remain unchanged, such as the careful examination of plant characters and the production of floras, there is also a vast array of new tools and ways of applying the basic taxonomic information into a much wider context.

Acknowledgements

I wish to thank my co-authors listed below and others for their support and collaboration over the years. Thanks also to the *New Zealand Journal of Botany* for their permission to reproduce some of the figures used in this article.

References

Allan, H.H. (1961). Flora of New Zealand. Vol. 1. Government Printer, Wellington.

Croasdale, H. and Flint, E.A. (1986). Flora of New Zealand Desmids, Vol. 1. Manaaki Whenua Press, Lincoln.

Croasdale, H. and Flint, E.A. (1988). Flora of New Zealand Desmids, Vol. 2. Manaaki Whenua Press, Lincoln.

Croasdale, H.; Flint, E.A.; Racine, M.M. (1994). Flora of New Zealand Desmids, Vol. 3. Manaaki Whenua Press, Lincoln.

Edgar, E. and Connor, H.E. (2000). Flora of New Zealand, Vol. 5. Manaaki Whenua Press, Lincoln.

Galloway, D.J. (1985). Flora of New Zealand Lichens. Manaaki Whenua Press, Lincoln.

Galloway, D.J. (2007). Flora of New Zealand Lichens, Revised Second Edition: Including lichen-forming and lichenicolous fungi. Manaaki Whenua Press, Lincoln.

Garnock-Jones, P.J. (1991a). Seed morphology and anatomy of the New Zealand genera *Cheesemania*, *Ischnocarpus*, *Iti*, *Notothlaspi*, and *Pachycladon* (Brassicaceae). *New Zealand Journal of Botany 29*: 71–82.

Garnock-Jones, P.J. (1991b). Gender dimorphism in *Cheesemania wallii* (Brassicaceae). *New Zealand Journal of Botany 29*: 87–90.

Glenny, D. (2004). A revision of the genus *Gentianella* in New Zealand. *New Zealand Journal of Botany 42*: 361–530.

Healy, A. and Edgar, E. (1980). Flora of New Zealand, Vol. 3. Government Printer, Wellington.

Heenan, P.B. (1999). Artificial intergeneric hybrids between the New Zealand endemic *Ischnocarpus* and *Pachycladon* (Brassicaceae). *New Zealand Journal of Botany 37*: 595–601.

Heenan, P.B. (2002). *Cardamine lacustris*, a new combination replacing *Iti lacustris* (Brassicaceae). *New Zealand Journal of Botany 40*: 563–569.

Heenan, P.B. and de Lange, P.J. (2001). A new, dodecaploid species of *Uncinia* (Cyperaceae) from ultramafic rocks, Surville Cliffs, Northland, New Zealand. *New Zealand Journal of Botany 39*: 373–380.

Heenan, P.B. and de Lange, P.J. (2004). *Myrsine aquilonia* and *M. umbricola* (Myrsinaceae), two new species from New Zealand. *New Zealand Journal of Botany 42*: 753–769.

Heenan, P.B. and de Lange, P.J. (2006). *Pseudowintera insperata* (Winteraceae), an overlooked and rare new species from northern New Zealand. *New Zealand Journal of Botany 44*: 89–98.

Heenan, P.B. and Garnock-Jones, P.J. (1999). A new species combination in *Cheesemania* (Brassicaceae) from New Zealand. *New Zealand Journal of Botany 37*: 235–241.

Heenan, P.B. and Mitchell, A.D. (2003). Phylogeny, biogeography, and adaptive radiation of *Pachycladon* (Brassicaceae) in the mountains of South Island, New Zealand. *Journal of Biogeography 30*: 1737–1749.

Heenan, P.B. and Molloy, B.P.J. (2004). Taxonomy and conservation of *Olearia adenocarpa* (Asteraceae), a new species from braided riverbeds in Canterbury, New Zealand. *New Zealand Journal of Botany 42*: 21–36.

Heenan, P.B.; de Lange, P.J.; Wilton, A.D. (2001). *Sophora* (Fabaceae) in New Zealand: taxonomy, distribution, and biogeography. *New Zealand Journal of Botany 39*: 17–53.

Heenan, P.B.; Mitchell, A.D.; Koch, M. (2002). Molecular systematics of the New Zealand *Pachycladon* (Brassicaceae) complex: generic circumscription and relationships to *Arabidopsis* s.l. and *Arabis* s.l. *New Zealand Journal of Botany 40*: 543–562.

Heenan, P.B.; Mitchell, A.D.; de Lange, P.J. (2004). *Arthropodium bifurcatum* (Asparagaceae), a new species from northern New Zealand. *New Zealand Journal of Botany 42*: 233–246.

Heenan, P.B.; Smissen, R.D.; Dawson, M.I. (2005). Self-incompatibility in the threatened shrub *Olearia adenocarpa* (Asteraceae). *New Zealand Journal of Botany 43*: 831–841.

Heenan, P.B.; Lockhart, P.J.; Kirkham, N.; McBreen, K.; Havell, D. (2006). Relationships in the alpine *Ranunculus haastii* (Ranunculaceae) complex and recognition of *R. piliferus* and *R. acraeus* from southern New Zealand. *New Zealand Journal of Botany 44*: 425–441.

Heenan, P.B.; Knox, E.B.; Courtney S.P.; Johnson, P.N.; Dawson, M.I. (2008). Generic placement in *Lobelia* and revised taxonomy for New Zealand species previously in *Hypsela* and *Isotoma* (Lobeliaceae). *New Zealand Journal of Botany 46*: 87–100.

Luo, C.; Bicknell, R.A.; Heenan, P.B. (2003). Embryology of two threatened species of *Pachycladon* (Brassicaceae). *New Zealand Journal of Botany 41*: 171–178.

McBreen, K. and Heenan, P.B. (2006). Phylogenetic relationships of *Pachycladon* (Brassicaceae) species based on three nuclear and two chloroplast DNA markers. *New Zealand Journal of Botany 44*: 377–386.

Mitchell, A.D. and Heenan, P.B. (2000). Systematic relationships of New Zealand endemic Brassicaceae inferred from nrDNA ITS sequence data. *Systematic Botany 25*: 98–105.

Mitchell, A.D. and Heenan, P.B. (2002). Genetic variation within the *Pachycladon* (Brassicaceae) complex based on fluorescent AFLP data. *Journal of the Royal Society of New Zealand 32*: 427–443.

Moore, L.B. and Edgar, E. (1970). Flora of New Zealand, Vol. 2. Government Printer, Wellington.

Pole, M. (1994). The New Zealand flora – entirely long-distance dispersal? *Journal of Biogeography 21*: 625–635.

Webb, C.J.; Sykes, W.R.; Garnock-Jones, P.J. (1988). Flora of New Zealand, Vol. 4. Botany Division, DSIR, Christchurch.

Dr Peter Heenan began a horticultural career at the Dunedin and then Christchurch botanic gardens, gaining a National Diploma of Horticulture. In 1989, he took a position at Landcare Research, Lincoln, in charge of the gardens and experimental nursery. He launched his botanical career at Landcare Research soon afterwards, gaining an MSc at Missouri and then a PhD through Canterbury University.

Peter Heenan is now one of New Zealand's foremost contemporary botanists. He has published more than 100 papers, described some 60 plant species, and continues the tradition of botanical discovery and description of New Zealand's flora.