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HORTICULTURE IN NEW ZEALAND

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ARTICLES

Front Cover Picture: A flowering shoot of *Leptospermum ×violipurpureum* 'Karo Spectrobay'. Photo: R. Lamberts. (See p. 3)

Future Direction for Institute Publications:
The New Zealand Garden Journal

I recently came across some 1962 copies of the Institute's Journal (at that time *New Zealand Plants and Gardens*). This quarterly publication was aimed at the serious gardener, and still makes fascinating reading. Articles in the June 1962 and September 1962 issues included 'Plant hunting in New Caledonia' by Lawrie Metcalf, 'Cycads of South Africa' by F.R. Lang, and notes from the various Botanic Gardens in New Zealand.

New Zealand is currently experiencing a phenomenal growth in the gardening 'industry,' and demand is increasing for a publication that will satisfy those people with a passion for plants – the more serious gardeners. The RNZIH needs to respond to these changes, and National Executive recently reviewed member publications in the light of the above trends and our strategy plan.

In November we are launching a new quarterly publication, *The New Zealand Garden Journal*, to replace the current newsletter and biannual journal *Horticulture in New Zealand*. This new journal too will be professionally produced, with contributing writers, A4 size, and eventually, we hope, in full colour. It will have an insert on RNZIH matters, and will have an emphasis on plants and gardens. Articles already commissioned include:

- 'Growing Rhododendrons, Deciduous Azaleas, and Viburnums,' by Derrick Rooney
- 'The Pleasure of Crocus,' by Charlie Challenger
- 'Arisaema – Subtle Beauties,' by Eric Walton

We have also developed a close working relationship with the *Australian Garden Journal*, and have the ability to publish some of their articles appropriate to our readership. The new *Journal* will be edited by myself and my wife, Sarah De Renzy.

The *New Zealand Garden Journal* will be at the forefront of our campaign to increase membership of the Institute, and so raise our profile as New Zealand's national horticultural society.

Many members will be saddened to see the demise of the present journal and newsletter, but it is no longer economic to produce two separate membership publications. There were overlaps developing between the two publications, and I'm sure the new publication will provide members with the in-depth articles they want, whilst keeping them up to date with Institute affairs.

I'd like to thank Dr Ron Davison, editor of *Horticulture in New Zealand* for the past five years, for his tremendous work. Ron has agreed to assist Dr Ross Ferguson as technical editor of the new *Journal*, so will continue his involvement with Institute publications.

So, what will members receive this year? This is the last issue of *Horticulture in New Zealand*, a larger than normal edition containing the proceedings of the Tree Symposium held in Rotorua in 1994. The first edition of *The New Zealand Garden Journal* will be produced in November. From then on it will be produced quarterly.

Mike Oates, Chairman, National Executive

Opportunities for *Leptospermum* Hybrid Ornamental Cultivars and a New Ornamental Cultivar – *Leptospermum ×violipurpureum* 'Karo Spectrobay'

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Introduction

In the course of research on New Zealand and Australian tea trees (Harris and Percy, 1988; Harris and Decourtye, 1991; Harris et al., 1992; Harris, 1993a, 1993b, 1994) a spontaneous hybrid was discovered (see front cover illustration) between the Australian species *Leptospermum spectabile* and *L. rotundifolium* 'Jervis Bay'. This article records the origin of the hybrid and formally names and describes it as an ornamental cultivar. The existence of this spontaneous hybrid highlights the considerable potential for further development of *Leptospermum* for ornamental use by purposeful interspecific hybridisation.

Most ornamental cultivars of *Leptospermum* have arisen from New Zealand *L. scoparium* (Harris, 1993a). *Leptospermum scoparium*, commonly known in New Zealand by its Maori name manuka, is the only species of *Leptospermum* that is indigenous to New Zealand, but it is also indigenous to Australia, where it occurs naturally in New South Wales, Victoria, and Tasmania. More than 100 ornamental cultivars of manuka have been named, whereas there are probably less than 30 named cultivars for all the other 78 species of *Leptospermum*. A detailed checklist of the ornamental cultivars of *Leptospermum* is in an advanced stage of preparation (M.I.D. and P.B.H.).

There is great potential to use interspecific hybridisation as a way to develop new ornamental cultivars of *Leptospermum*. Joy Thompson (1989) in her revision of the genus *Leptospermum* comments that interspecific sterility barriers do not seem to have had time to develop. Herbarium records, particularly for New South Wales, show many putative hybrids. Twelve mainly natural hybrid combinations are listed but not authenticated by Thompson. None of these hybrids involve either of the two species that are the parents of the interspecific hybrid described in this paper or *L. scoparium*.

Preparation of the checklist of cultivars of *Leptospermum* has uncovered several interspecific putative hybrids of *Leptospermum* that have been released as ornamentals. *L.* 'Pink Cascade'[1] is a hybrid raised in Australia between *L. polygalifolium* and a pink-flowered form of *L. scoparium* (Greig, 1987; Elliot and Jones, 1993). *L.* 'Green Eyes'[2] and *L.* 'Pink Surprise' are both *L. minutifolium* × *L. scoparium* hybrids raised in England at County Park Nursery, Essex (G. Hutchins, pers. comm. 1993; Lord, 1993, 1994). These are all spontaneous hybrids with poorly documented origins.

In addition to the interspecific hybrids referred to above, a natural intergeneric hybrid between the related genera *Kunzea* and *Leptospermum* has been reported in New Zealand. This cross, *Kunzea sinclairii* × *Leptospermum scoparium*, arose in cultivation from seed collected from *K. sinclairii* on Great Barrier Island (Harris et al., 1992), and has been named ×*Kunzspermum hirakimata* 'Karo Hobson Choice' (Harris, 1993b).

Flower Size and Colour Characteristics of the Parent Species

In their wild form *Leptospermum spectabile* and *L. rotundifolium* rank among the two most attractive species in the genus because of the large size and outstanding colour of their flowers. Analysis of the frequency distribution of flower size, from data given in Thompson's (1989) species descriptions, shows *L. spectabile* and *L. rotundifolium* to be in the top 10% (Fig. 1). *L. rotundifolium* has the largest flowers, to 30 mm or more in diameter, and *L. spectabile* has flowers 20 mm in diameter. By comparison, the flowers of wild *L. scoparium* are described by Thompson (loc. cit.) as being in the range 8–12 mm (occasionally larger), falling into the modal class for frequency distribution of the flower size of species in the genus.[3] Flower dimensions vary with environmental conditions, and measurements obtained from dried herbarium specimens that were probably the main source

Footnotes

[1] To avoid confusion with an earlier *L. scoparium* cultivar of that name, Australian *L.* 'Pink Cascade' is also known in New Zealand as *L.* 'Pink Beauty'.

[2] This English hybrid is different to the selection of an Australian species sold in New Zealand under the similar name of *L.* 'Green Eye'.

[3] However, the cultivars of New Zealand *L. scoparium* have been selected for their larger, showy flowers. Average flower diameter of these cultivars (measured from live material) is about 18 mm, ranging from 12 to 25 mm in individual cultivars (Metcalf, 1987).

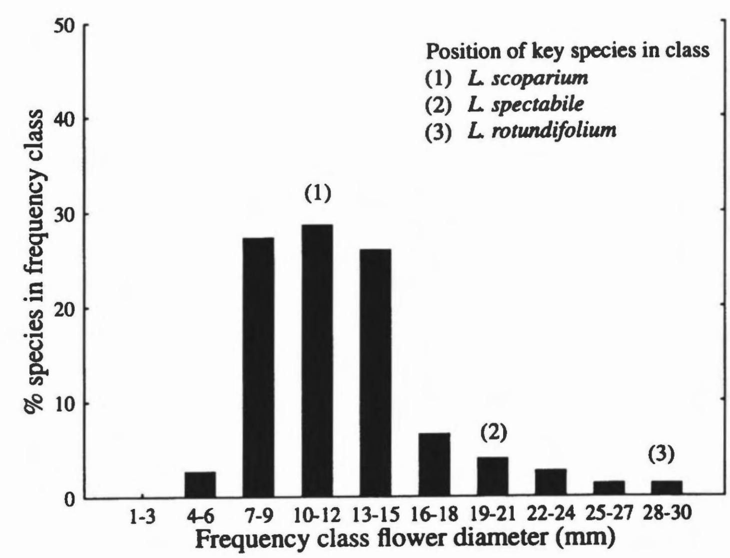

Fig. 1. Frequency distribution of flower diameters of 77 *Leptospermum* species. Data from descriptions in Thompson (1989).

Table 1. Comparison of leaf, flower, and capsule characteristics of *Leptospermum spectabile*, *L. rotundifolium*, and their putative hybrid. Standard errors are given where replicate measurements were made (n = 10).

	L. spectabile	Putative hybrid	*L. rotundifolium*
Leaf characteristics			
Leaf length (mm) – outdoors	27.2 ± 0.6	15.2 ± 0.4	12.2 ± 0.2
Leaf width (mm) – outdoors	4.6 ± 0.2	6.5 ± 0.1	7.3 ± 0.2
Leaf length:width – Ootdoors	6.1 ± 0.4	2.4 ± 0.1	1.7 ± 0.1
Leaf length (mm) – shaded	35.4 ± 1.0	19.6 ± 0.5	—
Leaf width (mm) – shaded	6.1 ± 0.3	7.3 ± 0.3	—
Leaf length:width – shaded	5.9 ± 0.2	2.8 ± 0.2	—
Leaf shape	narrow elliptic	elliptic	oval to orbicular
Flower characteristics			
Flower diameter (mm)	28.1 ± 0.4	27.9 ± 0.4	29.8 ± 0.5
Petal length (mm)	8.8 ± 0.1	8.9 ± 0.2	10.9 ± 0.3
Petal width (mm)	9.5 ± 0.1	9.9 ± 0.2	11.8 ± 0.2
Petal length:width	0.92 ± 0.02	0.91 ± 0.02	0.91 ± 0.01
Petal colour	R.H.S. 51A to 52A: rhodonite red to crimson	R.H.S. 80A: purple-violet group	R.H.S. 76A to 76D: lilac to white near receptacle rim
Receptacle disk diameter (mm)	11.4 ± 0.2	9.2 ± 0.1	8.7 ± 0.2
Petal length:receptacle disk	0.77 ± 0.02	0.97 ± 0.03	1.25 ± 0.04
Receptacle disk colour	R.H.S. 144A to 146A: green	R.H.S. 144A to 146A: green	R.H.S. 144A to 146A: green
Receptacle hairs	dense and conspicuously pubescent	pubescence of short hairs all over	slightly pubescent to glabrous in parts
Sepal length (mm)	7.6 ± 0.2	5.4 ± 0.1	5.9 ± 0.1
Sepal width (mm)	7.5 ± 0.2	5.1 ± 0.1	5.2 ± 0.1
Sepal length:width	1.01 ± 0.02	1.05 ± 0.02	1.11 ± 0.02
Sepal colour	green to white with pubescence	R.H.S. 145C: yellow green to pubescent white at margins	R.H.S. 53A: cardinal red and red near receptacle rim
Sepal hairs and glands	densely pubescent; gland cells not visible	circular gland cells visible through pubescence	pubescent around margins and tip; circular gland cells conspicuous in translucent tissue
Stamen filament colour, length	white to crimson near receptacle rim; 6-7 mm	white; 4.5-5 mm	white; 5 mm
Style colour and length	green; 5-6 mm	green; 4.5-5 mm	green; 4 mm
Capsule characteristics			
Diameter (mm)	10–12	14–16	11–13
Depth of base from rim (mm)	4	8	5
Height of valves above rim (mm)	3–4	6	6
Shape of base	broadly turbinate	turbinate	hemispherical
Sepals on mature capsules	conspicuous, partly reflexed, firmly attached	obvious and erect, readily detached	small and erect, usually shed
Opening of valves	opened within year of flowering	intact a year or more after flowering	can remain closed for several years

of Thompson's data are likely to differ from measurements made on living plants. Our flower diameter measurements on living material of *L. rotundifolium* (29.8 ± 0.5 mm) agree with Thompson's, but we record a larger flower diameter than Thompson (1989) for *L. spectabile* (28.1 ± 0.4 mm) (Table 1).

A comparison of the flower colour of *Leptospermum* species (Thompson 1989) shows that 48 are exclusively white, 18 have white or pink flowers, four have white or cream flowers, and one (*L. purpurascens*) has flowers described as white, sometimes flushed with red. Consequently white is the dominant flower colour for *Leptospermum* species. For the remaining eight species, the colour of two is unknown as Thompson's description is based on specimens without mature flowers. *Leptospermum sericeum*, a local species in the vicinity of Esperance, Western Australia, has exclusively pink flowers. *Leptospermum* *scoparium* is described by Thompson as having "white or, rarely, pink or red" flowers. Observations of wild populations of *L. scoparium* in New Zealand show that various degrees of pink shading of petals is not uncommon, and this points to the problem of determining flower colour from dried herbarium specimens in which subtle colour shades can be lost. Pink-flowered plants are characteristic of *L. scoparium* var. *incanum*, which is commonly encountered in the far north of the North Island. Red-flowered wild manuka is exceptionally rare. The origin of the carmine flower colour in most modern manuka cultivars can be traced back to *L. scoparium* 'Nichollsii', derived from a single wild plant with carmine flowers discovered near Kaiapoi, north of Christchurch, in 1898.

Thompson (1989) describes *Leptospermum spectabile* as having flowers that are exclusively "a rather dark red." Our observations, of plants raised from seed from the wild collection whose origin is described below, showed some petal colour variation from dark red to deep pink. Two other species closely related to *L. spectabile* are *L. macrocarpum*, which has "greenish white, pink or dark red" flowers, and *L. sphaerocarpum*, which has "rather greenish white or pink" flowers. Thompson includes these species in the same "putative natural subgroup" characterised by strongly woody seed capsule valves and retention of the sepals on the capsule.

Leptospermum rotundifolium is included by Thompson (1989) in the same subgroup as *L. scoparium*, and these species are characterised by strong woody seed capsule valves that do not retain their sepals. However, *L. rotundifolium* is unique among *Leptospermum* species in including purple coloration in its range of flower colour from "white to somewhat purplish pink."

Origin of the Parent Species and Hybrid

The natural habitat of *L. spectabile* is among sandstone boulders along the Colo River, a tributary of the Hawkesbury River in central eastern New South Wales not far north of Sydney. The interesting story of its discovery in 1957 is recounted by Harris and Percy (1988). Although publication of the formal name was delayed until 1989 (Thompson, 1989), horticultural interest in the species had reached New Zealand by the early 1980s.

Warwick Harris began his studies of the genetic variation of New Zealand tea trees with an experimental planting at the former Botany Division, DSIR, Lincoln in 1983 (Harris et al., 1992). At that time nine Australian *Leptospermum* species were included in the layout along with 72 provenances of New Zealand tea trees. Seed of *L. spectabile* was received from the Royal Botanic Garden, Sydney, as "*Leptospermum* sp. aff. *sphaerocarpum*, Colo River, below Boorai Ridge, (cc) NSW. 33°15´S, 150°32´E. Wallace 83003." Seed was sown in September 1983, and 24 plants were included in January 1984 in the experimental layout, where their growth and phenology were observed for several years. A further 35 plants from this sowing were retained in the nursery, and were planted in the field at Lincoln in June 1985. One of these plants (W. Harris reference number 81/23; Landcare Research Experimental Gardens accession number 45/95) was selected and named *Leptospermum* 'Christmas Star' (Harris and Percy, 1988). Now that the species is formally described (Thompson, 1989), the cultivar is correctly referred to as *L. spectabile* 'Christmas Star'.

Leptospermum rotundifolium occurs naturally in an area southward from Sydney on the tableland escarpment of central eastern New South Wales, and extends to the coast near Jervis Bay. Its usual habitat is in skeletal soils on sandstone. It was first named as a variety of *L. scoparium* in 1900, but was elevated to a species in 1919, and this status is supported in Thompson's (1989) revision of the genus.

L. rotundifolium is an extremely variable, very ornamental species widely cultivated in Australia (Elliot and Jones, 1993). Wrigley and Fagg (1979) commented that "*L. scoparium* var. *rotundifolium* ... must be regarded as Australia's best *Leptospermum* species and that with the most potential for hybridization." We have evaluated five provenances of *L. rotundifolium* at Lincoln since 1984, and the species shows very attractive variations. It is surprising that in comparison with New Zealand *L. scoparium* little attention has been given in the past to the selection of ornamental cultivars of this species. We are currently aware of four cultivars of *L. rotundifolium* – *L.* 'Jervis Bay', *L.* 'Julie Anne', *L.* 'Lavender Queen', and *L.* 'Williamsi', as listed by Elliot and Jones (1993). The cultivar epithet for *L.* 'Jervis Bay' suggests that this selection originated in the wild from that locality in New South Wales, the coastal part of the range of *L. rotundifolium*. However, we have not seen any references that confirm this suspicion. This cultivar may correspond with the "*L. scoparium* Jervis Bay form" listed in *The Plant Finder 1990/91* (Lord 1990), which is a plant directory of material grown in England. Subsequent editions of *The Plant Finder* do not list it. *L.* 'Julie Anne' was obtained from a wild prostrate form of *L. rotundifolium* from Beecroft Peninsula, near Jervis Bay (Elliot and Jones, 1993). *L.* 'Lavender Queen' (Harrison 1974) and *L.* 'Williamsi' are both early cultivars. It appears that *L.* 'Williamsi' is no longer known under this name (Elliot and Jones, 1993).

One plant of *L. rotundifolium* 'Jervis Bay' was purchased in January 1985 (accession G 15849; plant purchased from Portstone Nursery, Ferry Road, Christchurch) and planted in a block with other *Leptospermum* adjacent to the area where the 35 plants of the *L. spectabile* accession were planted.

Plants from the September 1983 sowing of *L. spectabile* first flowered in December 1986, and seed was collected from three of these and sown in July 1987. Three seedlings were raised from plant 81/21, which was closest in the planting layout (distance 3 m) to *L. rotundifolium* 'Jervis Bay', and one of these was noted to have leaf characteristics distinct from all the other seedlings. When this plant flowered in 1991 it was seen to have large and distinctively coloured flowers, different to the relatively slight variation of flower colour and form in *L. spectabile*. It was entered as Landcare Research experimental gardens accession number 596/91 in October 1991 and propagated from cuttings. The pollen parent plant of *L. rotundifolium* 'Jervis Bay' had died before this date, but the *L. spectabile* parent 81/21 remains alive.

Comparison of Hybrid and Parents

Leaf, flower, and capsule characteristics of the seed parent species, the putative pollen parent, and the hybrid were compared to confirm the hybrid's origin (Table 1). As the *L. spectabile* parent in the field (81/21) was in poor condition, and there was no equivalent plant of the hybrid in the field, measurements were made in November 1993 of ten flowers each of *L. spectabile* 'Christmas Star' (81/23) and the hybrid grown in a glasshouse. Cuttings of *L. rotundifolium* 'Jervis Bay' were acquired from Ken Davey of New Plymouth in April 1992 (accession 138/92), and a flowering glasshouse specimen from these cuttings was available for measurement in December 1994. In December 1994 length and width measurements were made for ten mature and characteristic leaves taken from single plants of *L.* 'Christmas Star', *L.* 'Jervis Bay', and the hybrid grown in planter bags on trickle irrigation outdoors. Also plants of *L.* 'Christmas Star' and the hybrid grown in a shadehouse were measured for comparison. A record of the silhouettes of these leaves was made (Fig. 2). A comparison was made of year-old capsules from the 1993 flowering for *L.* 'Christmas Star',

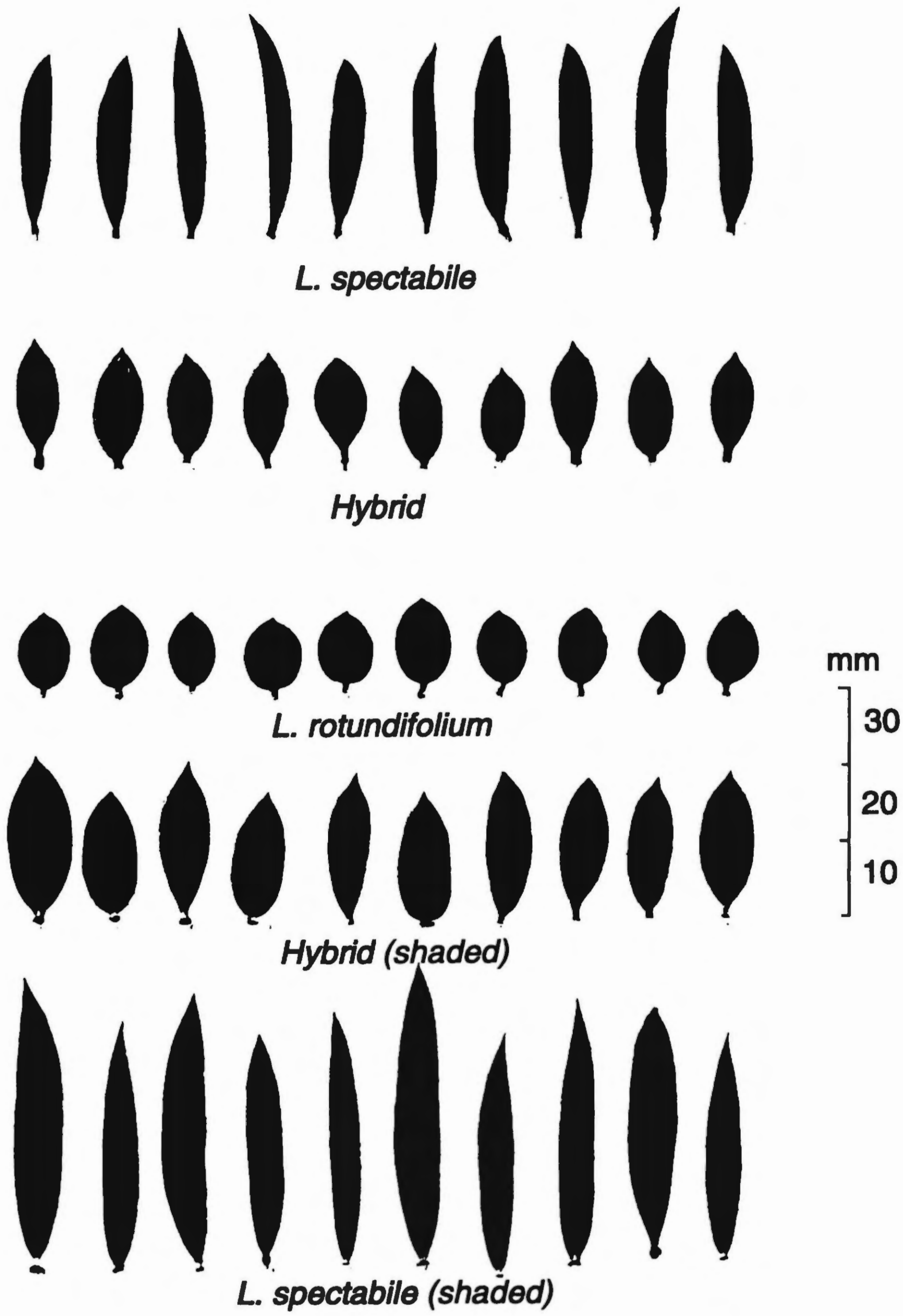

Fig. 2. Silhouettes of 10 characteristic mature leaves from plants of *Leptospermum spectabile* 'Christmas Star', *L. rotundifolium* 'Jervis Bay', and their hybrid grown in full daylight and in a shadehouse (shaded).

the hybrid, and wild provenances of *L. rotundifolium* as *L.* 'Jervis Bay' capsules were not available. Descriptions of colour are based on the 1966 Royal Horticultural Society Colour Chart (R.H.S.).

The leaf shape of the hybrid (Fig. 2) is intermediate between the distinctive shapes of the parents, but the leaf length and length-to-width ratios (Fig. 3; Table 1) are closer to the smaller-leaved *L. rotundifolium*. Interspecific hybrids with a leaf length and length-to-width ratio more similar to the smaller-leaved parent have also been recorded by Heenan (1994) for hybrids between the large-leaved *Hebe speciosa* and the smaller-leaved *H. pimeleoides* 'McEwanii' and *H. biggarii*. Leaf size is increased by shading, both *L. spectabile* and the hybrid becoming broader and longer-leaved under such conditions (Fig. 3; Table 1).

The parents and hybrid all have very large flowers for *Leptospermum*. The hybrid has a distinctive violet-purple coloration of the petals arising from the blending of the distinctive flower colours of the parents. Petal colour in *Leptospermum* is due to anthocyanins; cyanidin is responsible for the red petals of *L. spectabile*, and delphinidin, a purple pigment, occurs in *L. rotundifolium* 'Jervis Bay' petals (R. Bicknell, pers. comm. 1994). A feature that influences the attractiveness of the flowers is the relative size of the petals and green receptacle disk. *L. spectabile* has a particularly wide disk relative to the size of the petals. The size of the disk for the hybrid is similar to that of *L. rotundifolium* but it has petals of similar size to those of *L. spectabile* (Fig. 4; Table 1). This changed ratio is an improvement of the flower characteristic of the hybrid compared to that of *L. spectabile*.

A feature of the hybrid is that it has distinctly larger capsules than either of the parents (Table 1). This size difference is most apparent in the depth of the capsule below the rim. In *L. spectabile* this part of the capsule appears to diminish in size relative to valves as the capsule matures. For *L. spectabile* the valves had opened within a year of flowering, whereas *L. rotundifolium* capsules can remain intact for several years after they are formed. Capsules of the hybrid also seem to remain unopened for several years *in situ*, but open before those of *L. rotundifolium* when they are detached concurrently. Seed of the hybrid is viable.

Names and Descriptions

Leptospermum ×_violipurpureum_ W.Harris, M.I.Dawson _et_ Heenan notho-sp. nov.

Leptospermum ×violipurpureum is the collective epithet for *Leptospermum spectabile* (♂)×*L. rotundifolium* (♀). The epithet 'violipurpureum' refers to the colour of the petals, which is intermediate between violet and purple.

Diagnosis: Frutex ex hybridatione *Leptospermi spectabilis* et *L. rotundifolii* ortus; inter parentes intermedius; folis ellipticis; petalorum colore inter violam et purpuram intermedio.

Shrub, a hybrid of *Leptospermum spectabile* and *L. rotundifolium;* intermediate between parents; leaves elliptical; petal colour intermediate between violet and purple.

Holotype: CHR483436, W. Harris, 5 November 1993, Landcare Research Experimental Gardens, Lincoln, Canterbury, New Zealand.

The specimen was taken from a plant raised from a cutting of the original plant taken on 25 October 1991. The description given below is based on the same plant.

Parentage: Details of the origin of the hybrid are given above.

Distribution: Cultivated shrubs, in the Landcare Research Experimental Gardens, Lincoln, Canterbury. Clonal material has been distributed to commercial plant propagators for evaluation.

Description: Shrub broader than high; at 4 years from cutting grown in shadehouse 1.2 × 2.5 m; plants grown outdoors more compact and densely branched; habit open and weeping, with few main branches from base and with suppressed basal shoots. Branches tending horizontal from base before ascending, with higher-order branches and branchlets arched downwards. Mature bark firm, brown, and covered with a network of grey ridges; young bark light brown; stems near shoot tips with fine pubescence, orange-red. Leaves broad-elliptic to elliptic, green, incurved in cross-section, usually patent but young leaves usually erect near shoot tips and older leaves reflexed lower on stems, pleasantly aromatic when crushed, 15–20 × 6–7 mm; apex apiculate and slightly pungent; margin red, especially near apex; lamina surface glabrous, but with slight pubescence on margin and near base; petiole 1–2 mm long. Flowers usually borne singly on short terminal branches; terminal vegetative shoot extending above highest flowers, and new lateral shoots developing below mature capsules; flower buds surrounded by numerous golden-brown bracts which are shed after flowers are open. Sepals 5, triangular, hooded, yellow-green and white, pubescence showing petal colour on margins, visible through bracts in bud. Petals 5, broad-elliptic, violet-purple (R.H.S. 80A), slightly crumpled like crepe, especially at margins, 8–10 × 9–11 mm; fully open flower 26–30 mm diameter with petals well separated and sepals visible below. Stamen filaments 4–5 mm long, white, evenly distributed around receptacle. Style 4–5 mm long, green; stigma at about same level as anthers. Receptacle disk yellow-green (R.H.S. 144A), 9–10 mm diameter, remaining green after petals are shed. Capsule turbinate, strongly woody, grey-brown when mature, 14–16 mm diameter; rim distinct, and base deeper than height of valves. Flowering at Lincoln October to November. Capsules remain intact for a year or more.

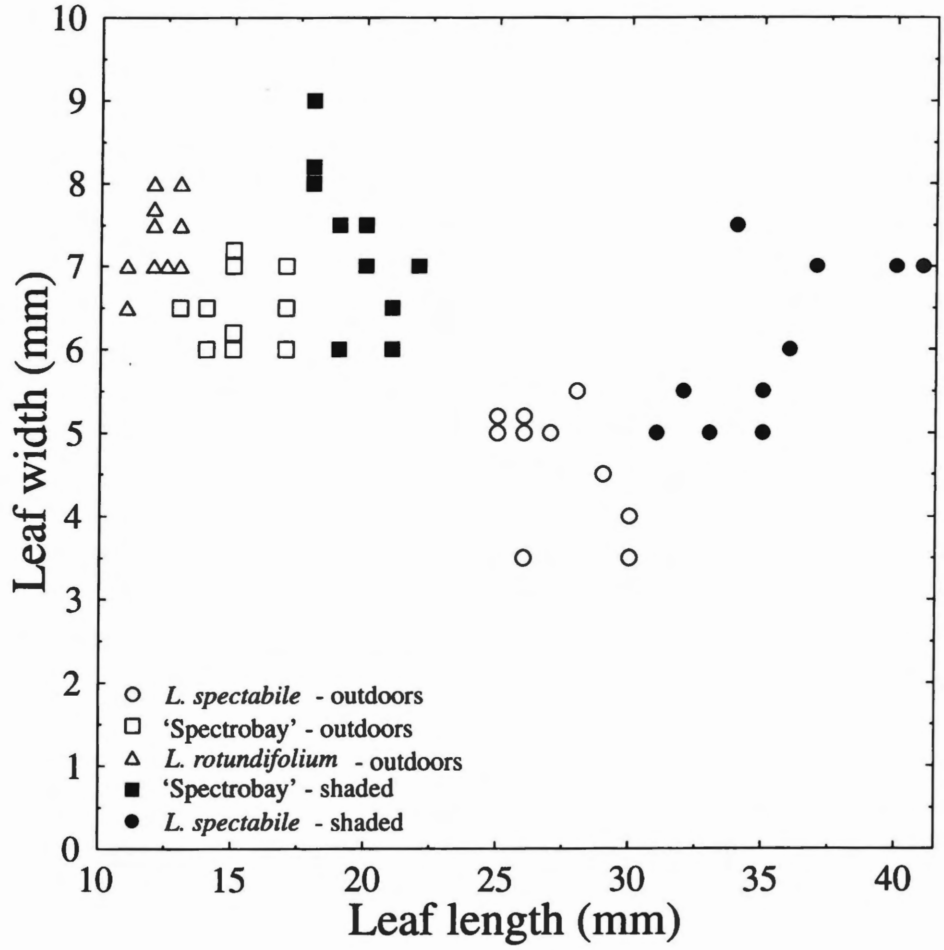

Fig. 3. Relationship between length and width of 10 characteristic mature leaves of *Leptospermum spectabile* 'Christmas Star', *L. rotundifolium* 'Jervis Bay', and their hybrid grown in full daylight and in a shadehouse.

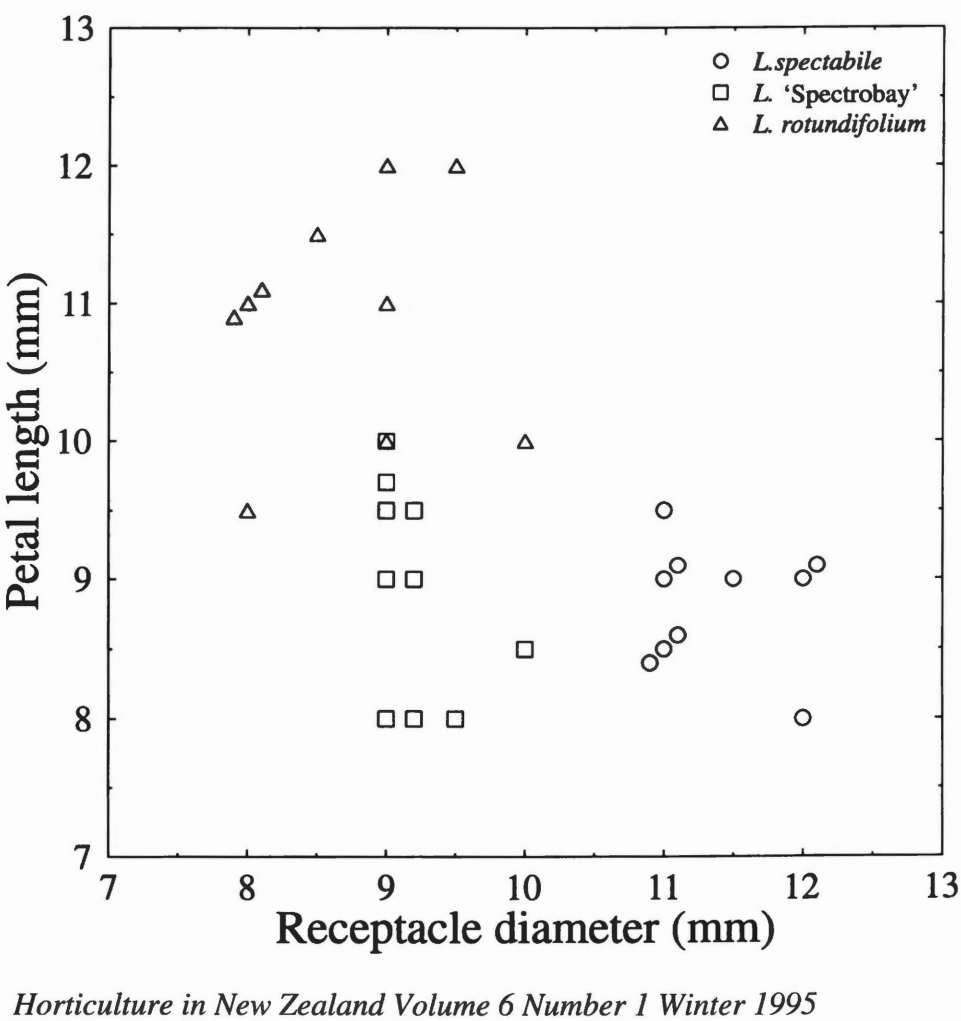

Fig. 4. Relationship between petal length and receptacle disk diameter for 10 flowers of *Leptospermum spectabile* 'Christmas Star', *L. rotundifolium* 'Jervis Bay', and their hybrid.

Leptospermum ×*violipurpureum* 'Karo Spectrobay' cult. nov.

As the hybrid has ornamental qualities and is desirable as a garden plant it is given a cultivar name. The cultivar epithet 'Karo' is an acronym of 'known and recorded origin', used to identify plants selected through research undertaken by Manaaki Whenua - Landcare Research (Heenan, 1992). The epithet 'Spectrobay' is derived from a combination of parts of the specific epithets of the parent species and the cultivar name of the putative male parent. The description and holotype specimen provided for *Leptospermum* ×*violipurpureum* apply to the cultivar.

Ornamental Characteristics

In addition to the evaluations at Lincoln the hybrid has been let out for commercial evaluation by Elliot's Wholesale Nursery, Amberley, Canterbury; Liner Plants New Zealand Ltd and Lyndale Nurseries Auckland Ltd, Whenuapai; and the Auckland Regional Botanic Gardens, Manurewa. The large, well proportioned, distinctive-coloured flower of the hybrid has been clearly recognised as an outstanding ornamental feature, and the foliage has been judged to be excellent.

Like the parents the hybrid is susceptible to manuka blight and leafroller caterpillars, but no more so than *L. scoparium* cultivars. Manuka blight can be controlled by spraying with an insecticide plus a summer oil or an all seasons oil after flowering. Carbaryl can be used to control leafroller during spring and summer. Plants of the hybrid have survived two winters in an open field at Lincoln, but immature foliage has been damaged by frosts, which have been as severe as –8°C. In common with most cultivars of *Leptospermum*, *L.* 'Karo Spectrobay' is likely to do best with a minimum of fertiliser, in free-draining soil in a sunny position. *Leptospermum spectabile* plants have become chlorotic with application of phosphorus-rich fertiliser, so the hybrid may have similar sensitivity.

The open spreading habit of the hybrid is regarded as not being desirable for container-grown plants or for meeting the demand for compact plants suited to small suburban gardens. Although readily propagated from cuttings, the growth of the main stem from these cuttings tends to be horizontal before becoming erect. This growth characteristic is shared by one parent, *L. spectabile* (81/21), surviving after 11 years in the field with a minimum of care. This plant is 0.9 × 1.8 m, sparsely branched and with the main branch running 0.2 m horizontally before becoming erect. We do not have a mature plant of *L. rotundifolium* 'Jervis Bay' for comparison of its growth form. According to Elliot and Jones (1993) *L.* 'Jervis Bay' grows to about 3 m tall, with upright habit.

One plant has been grown by Warwick Harris in his home garden at Lincoln on the north side of a trellis. In this sheltered position the hybrid has not been damaged by frost, has developed more branches and a greater density of foliage, and flowered prolifically in late October 1994. This indicates that *L.* ×*violipurpureum* 'Karo Spectrobay' is well suited for growing against a fence or trellis, and its branching arrangement would make it suitable for espaliering. The presence of suppressed basal shoots suggests that it should recover well from hard pruning, and this would encourage more branching and a more compact form. With the variation of shrub form in both *L. spectabile* and *L. rotundifolium* there is potential to plan crosses that would produce a compact and densely branched hybrid of these species.

Acknowledgments

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Observations on Cold Damage to New Zealand Plants Grown at Angers, France

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Abstract

Observations at Angers, France, on cold damage caused during four winters to provenances and cultivars of 75 New Zealand plant species and eight other Southern Hemisphere species are reported. Significant cold damage to 31 of the New Zealand species was recorded during the first three winters when temperatures were typical for the region and the severest frost was –9.1° C. Arctic air flow caused an extended cold period during the fourth winter, 1990–91, with 27 consecutive days of frost, the severest at –12.5° C. Sixty-three of the New Zealand species showed significant and, in many cases, severe damage and death as a result of this cold period. The cold damage observed corresponded well with results of freezing resistance studies using controlled temperature facilities and with the natural distribution of the species. Variation of cold damage among related species, provenances within species, and within provenances indicated the potential for selection to improve the cold resistance of New Zealand plants in order to extend the area in which they can be successfully grown. The results are discussed with reference to the species' ecological strategies and their use as ornamentals.

Key words *cold damage; ornamental plants; New Zealand; France; natural variation; selection; adaptation*

Introduction

Since the first introduction of New Zealand plants to Europe which followed Capt. James Cook's voyage of discovery in 1769, there has been interest in the use of these plants as ornamentals in the Northern Hemisphere (Brooker et al., 1988). Plant collections made by the botanists on Cook's voyage were from coastal regions of New Zealand. When grown in England, most were unable to survive the winter outdoors without damage, and were more suited to conservatory or glasshouse cultivation.

However, particularly in the south-western regions of the British Isles warmed by the Gulf Stream, favourable habitats were found where some New Zealand plants could grow in most years without serious damage from winter cold. Nelson (1989) gives a useful account of the history of introduction of New Zealand plants into gardens in Ireland. The treatise by Bean (1970, 1973, 1976, 1980) on trees and shrubs hardy in the British Isles makes reference to New Zealand species in about 40 of the genera dealt with. This work, largely built up from incidental observations on the hardiness of trees and shrubs grown in gardens, confirms that New Zealand species are best suited to the milder and moister parts of the British Isles but some are indicated to be more hardy. For example, Bean refers to the montane species *Hebe brachysiphon* as the most hardy of the New Zealand veronicas, recording that he had seen it killed by cold only in the winter of 1895.

Attempts to quantify cold hardiness of New Zealand plants began with an experiment by Cockayne (1898), who subjected alpine species in early summer to freezing in a chamber. Most were killed by minimum temperatures down to –6.7°C, but some species taken directly from their alpine habitat survived. Cockayne noted the limitations of his technique and commented that the results might have been different had the plants been dormant.

Recent experiments have subjected excised shoots or leaves or plants in pots to controlled freezing. These have shown the frost resistance thresholds of New Zealand native plants to be within the range –2°C for the Three Kings Island endemic *Elingamita johnsonii* (Bannister 1986, 1990) to –25°C for the subalpine *Halocarpus bidwillii* (syn. *Dacrydium bidwillii*) (Sakai and Wardle, 1978). Warrington and Stanley (1987) determined the freezing resistance of a range of ornamental New Zealand species and cultivars and showed the effects of seasonal hardening.

Most introductions of New Zealand plants into Europe have been via the British Isles. There is little published evidence of direct introduction of New Zealand plants into regions of southern Europe which are in latitudes (34° – 48°) similar to those of New Zealand. To meet the demand for new ornamental trees and shrubs for France and other regions of western Europe a collection of New Zealand plants was made in 1986, from both wild sources and gardens, and including both species and selected ornamental cultivars (Decourtye et al., 1991). This collection was assembled at the Laboratory for the Improvement of Ornamental Trees and Shrubs, National Institute of Agriculture, Angers, France. Plants raised from this collection were evaluated at this locality and, for part of the collection, at other sites in France for their suitability for use as ornamentals (Fig. 1). Evaluation of *Leptospermum scoparium* grown at Angers, Landerneau, and Fréjus showed differences of frost damage in the 1988–89 and 1990–91 winters that were correlated with the latitude and altitude of origin of the 37 provenances tested (Harris and Decourtye, 1991; Decourtye and Harris, 1992).

This paper reports observations made at Angers on cold damage during four winters to 75 New Zealand plant species and 8 from Australia, Lord Howe Island, and South America. Most of the species were trees and shrubs; the remainder were grasses and other monocotyledonous species. Cold damage to different provenances and cultivars of some of the species is also recorded.

Materials and Methods

The evaluation site was the Station d'Amélioration des Espèces Fruitières et Ornementales, Domaine de Bois l'Abbé, Beaucouzé, near Angers, France (47°28'N 00°36'W). The station has an altitude of 35–40 m above sea level.

Plants evaluated were raised from material collected by L. Decourtye in New Zealand during early 1986. Most were raised from seed obtained from wild (W) or garden (G) locations sown in October 1986, but some were rooted plants or were grown from cuttings imported from New Zealand. Plants were raised under nursery conditions until

Fig. 1. Part of one of the evaluation blocks of New Zealand plants at Angers, June 1989. Luc Decourtye is observing *Carmichaelia* species for flowering as part of their assessment for ornamental use.

they were planted in the field. The first and main planting took place in October 1987, but some accessions were not placed in the field until the following year. They were planted in rows at 1 m spacing and with 3 m between rows. Plantings were located in three blocks, with plants of each accession grown together in a row. Different accessions were represented by different numbers of plants according to the availability of propagated material for evaluation. Irrigation was applied to aid establishment in the field, and fertiliser was applied to support good growth. The overall objective was to determine the suitability of the plants for use in the region of the evaluation as ornamental specimens or hedges.

Plants were scored for cold damage on several dates according to the following scale:

(1) no damage or slight damage to shoot tips;
(2) dead leaves and twigs on up to 25% of branches;
(3) dead leaves and twigs on up to 50% of branches;
(4) dead leaves and twigs on up to 75% of branches;
5) severe damage, with most or all branches having dead leaves and twigs.

Plants scored as '1' characteristically had slight damage to late-season immature growth of the shoot tips, and showed quick recovery after winter. Most plants scored as '5' usually died, but some recovered from the base; this was noted where it occurred. Scoring was timed to relate to episodes of cold considered to have had the most influence on the ability of the plants to withstand damage and overwinter successfully. It was not possible to score all plants on all observation dates. Notes were made where damage or death was caused by factors other than cold.

The meterological station was located central to the three evaluation blocks, which were within a radius of 0.5 km. Automated recording provided summaries for 10-day intervals in each month, and these were used to describe the temperature patterns in each winter. Temperatures 'sous abri' and at 10 cm above ground level, closest to screen air temperatures and grass minimum temperatures defined for New Zealand meterological stations, were used to describe the temperature regime in each winter.

Results

Temperature regimes (Fig. 2)

Mean daily screen temperatures declined progressively from September to the end of November, and this would have induced hardening. Although light frosts occurred early in this period, in all years it was not until November that frosts harder than –5°C occurred.

In the 1987–88 winter the first frost occurred on 5 November (–1.0°C), the first significant frost on 9 December (–6.0°C), and the severest frost occurred the next day (–9.0°C), when the minimum screen temperature was –6.5°C. Scores of damage relevant to this episode of cold were made on 17 December 1987 and again at the end of the growth season in October 1988.

A –2.0°C frost on 31 October marked the beginning of the frost period in the 1988–89 winter, with the first significant frost on 2 November (–5.8°C) and the most severe frost on 22 November (–9.1°C); the lowest minimum screen temperature was recorded the next day

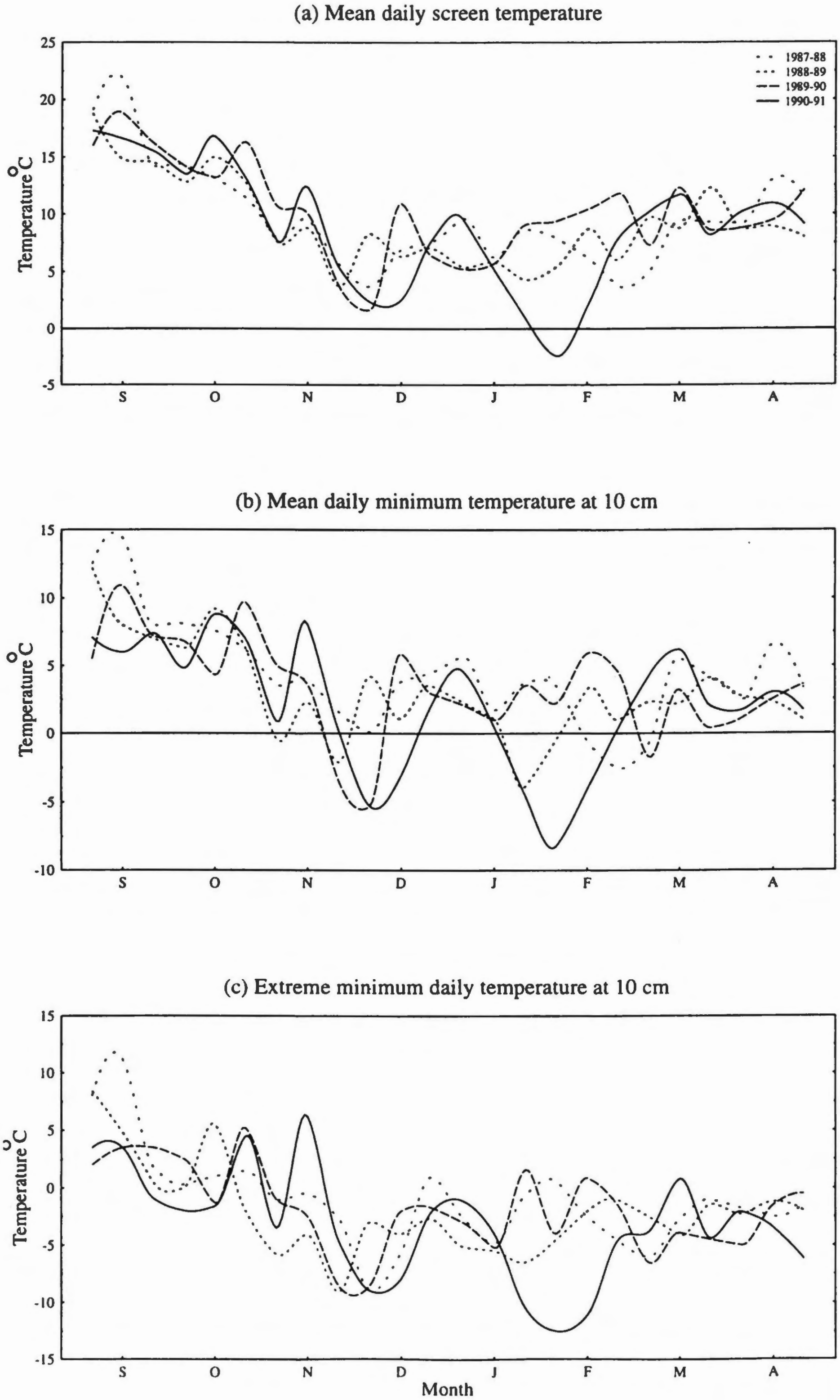

Fig. 2. Temperature patterns at 10-day intervals for the four winters of evaluation: (a) mean daily screen temperature; (b) mean daily minimum (frost) at 10 cm above ground level; (c) extreme daily minimum (frost) at 10 cm above ground level.

(–5.6°C). Damage scores relevant to this episode of cold were made on 30 January 1989.

The frost period for winter 1989–90 began on 16 October, with the first significant frost on 25 November (–7.1°C). This was during a 19-day period when both screen and 10 cm temperatures were below freezing. The extreme minimum 10 cm temperature for the winter occurred on 27 November (–8.6°C) and the screen minimum on 4 December (–5.6°C). Damage scores relevant to this episode of cold were made on 18 December 1989 in a mild period when the 10-day mean screen temperature was higher than 10°C, and in May 1990.

Winter 1990–91 began with a similar pattern to that of the previous winter. The first frost was on 28 September (–0.9°C), and a –5°C frost on 5 December was in a 20-day period when there were frosts on all days except one. The coldest day in this period was 9 December, when the 10 cm and screen minimum temperatures were –9.0°C and –4.7°C respectively. There was a relatively mild period in early January 1991, but commencing 20 January there were 27 consecutive days when frosts occurred, the severest (–12.5°C) on 8 February. The lowest screen minimum (–10.9°C) was on the previous day, and the 10-day mean screen temperature at that time was below zero. Observations on cold damage incurred during this winter were made in April 1991.

Frost occurred in all years until April, and as reported for *Leptospermum scoparium* accessions (Harris and Decourtye, 1991) active plant growth began in May, when mean daily screen temperatures were consistently above 10°C.

Cold damage

Because of different times of planting, the irregular timing of the observations, and the pattern of winter temperatures the results are presented as three groups of species according to whether they suffered no significant cold damage, suffered damage only in the last winter, or were damaged in earlier winters. Provenances from outside New Zealand that belong to genera indigenous in New Zealand are included in the Tables (p. 12ff.)

Exact coordinates for the sites of origin of the provenances were not recorded. The names of the localities of the collections and the information provided on the natural ranges of the species provides a general indication of the environments from which the provenances were obtained. Many of the garden plants had been raised from seed collected from wild locations in the region of the garden. Location of the garden collections is also useful in indicating areas of New Zealand where native species are acclimatised.

Where provenances of the same species or accessions from a provenance showed the same level of cold damage, results are combined. Plant names and notes on distribution are based on the *Flora of New Zealand* series (Allan, 1961; Moore and Edgar, 1970; Webb et al., 1988), Cheeseman (1925), Connor (1971), Connor and Edgar (1987), Metcalf (1987), and Zotov (1963), and a checklist of the grass flora (E. Edgar, pers. comm., 1990).

Table 1. Species not significantly damaged in any of the winters and that had a damage score of '1' after the 1990–91 winter (n, number of plants observed; W, wild accessions; G, garden accessions).

Family and species	Provenance	n	Distribution and typical habitat
Gymnospermae : Podocarpaceae			
Podocarpus nivalis	Kaikoura, Marlborough (G)	1	South of 36°50´S, subalpine scrub
Podocarpus lawrencei	Tasmania, Australia (G)	2	Tasmania, subalpine scrub
Podocarpus hallii	Mt Linton, Southland (W)	3	Lowland, montane and lower subalpine forest
Podocarpus 'Aurea'	Christchurch, Canterbury (G)	2	Garden selection
Angiospermae : Monocotyledons			
Phormiaceae			
Phormium cookianum	Arthur's Pass, Canterbury (W)	14	Coastal cliffs to subalpine mountain slopes
Arundineae			
Cortaderia selloana	France (G)	3	South American species (Argentina pampas grass) naturalised in New Zealand
Angiospermae : Dicotyledons			
Violaceae			
Melicytus alpinus syn. *Hymenanthera alpina*	6 provenances: Arthur's Pass, Waiau,and Lake Lyndon, Canterbury (W); Cromwell and Dunedin, Otago (G)	151	Lowland, montane to subalpine fellfield and rocky places, 40°30´ to 45°30´S
Malvaceae			
Plagianthus regius syn. *P. betulinus*	Dunedin, Otago (G)	39	Lowland and montane forest from 35° southwards Slight damage (mean score '1.5') in first winter
Plagianthus divaricatus	Dunedin, Otago (G)	25	Coastal, especially near salt swamp
Hoheria angustifolia	Kaituna Valley, Banks Peninsula, Canterbury (W)	5	Lowland forest margins from 39° southwards
Rhamnaceae			
Discaria toumatou	2 provenances: Dunedin (G); Porters Pass, Canterbury (W)	16	Coastal to montane on dunes, open and rocky places from 37° southward
Scrophulariaceae			
Hebe dieffenbachii	Invercargill, Southland (G)	2	Coastal, Chatham Island
Rubiaceae			
Coprosma ciliata	2 accessions: Mt Fyffe, Seaward Kaikoura Range, Marlborough (W)	20	Lowland to subalpine, forest and grassland
Coprosma propinqua	7 accessions: Cass (2), Waiau, Arthur's Pass (3), Canterbury; Mt Linton, Southland (W)	99	Coastal, lowland to about 1000 m in a variety of habitats including gravelly places, swamps, and forest

Table 2. Damage scores after the 1990–91 winter for species that did not show significant damage during the three preceding winters (n, number of plants observed; W, wild accession; G garden accession).

Family and species	Provenance	n	Damage score (and range)	Distribution and typical habitat
Angiospermae : Monocotyledons				
Asphodelaceae				
Cordyline australis	Winton, Southland (W)	4	4.5	Lowland and montane, forest margins, open places; abundant near swamps
	Manapouri, Southland (G)	15	5	
Cordyline indivisa	2 provenances: Dunedin, Otago; Invercargill, Southland (G)	25	5	Montane, well lit areas in higher-rainfall forest areas from 37° to 46°S
Cordyline pumilio	Waitara, Taranaki (G)	10	5	Under light forest and shrub north of 38°
Cordyline australis × *banksii*	Waitara, Taranaki (G)	6	5	Garden hybrid
Liliaceae				
Dianella nigra	Maitai Valley, Nelson (W)	15	4.5 (3–5)	Lowland and montane, forest floor, banks, and track edges
Iridaceae				
Libertia ixioides	Levin, Wellington (G)	10	5	Coastal to montane, stream edges, banks and rocks
Cyperaceae				
Gahnia pauciflora	Maitai Valley, Nelson (W)	14	5	Forest, sea level to 750 m north of 44°S
Poaceae : Arundineae				
Cortaderia rudiuscula	Lincoln, Canterbury (G)	28	2	South American species, Chile
Cortaderia richardii	2 accessions: Lincoln, Canterbury (G)	11	3 (2–5)	South Island, common on stream banks up to 600 m

Cortaderia toetoe	2 accessions: Lincoln, Canterbury (G)	17	3.6 (3–5)	Lowland swampy places north of 44°S
Cortaderia fulvida	2 accessions: Lincoln, Canterbury (G)	10	5	North Island, up to 600 m especially in hill country cleared of forest, near streams
Cortaderia splendens	2 accessions: Lincoln, Canterbury (G)	5	5	Coastal, north of 38°S
Angiospermae : Dicotyledons				
Leguminosae				
Chordospartium stevensonii	2 accessions: Lincoln and Halswell, Canterbury (G)	35	1.9 (1–4)	Alluvial soils near rivers and foothills, Kaikoura Ranges to 750 m, Marlborough, 42°S
Notospartium carmichaeliae	Dunedin, Otago (G)	28	2.8 (1–5)	Valleys and river terraces, Wairau and Awatere rivers, Marlborough
	Lincoln, Canterbury (G)	41	2.0 (1–3)	
Carmichaelia robusta	Port Hills, Banks Peninsula, Canterbury (W)	5	3.0	Lowland to higher montane grassland east of main divide, 42° to 45°S
	Prices Valley, Banks Peninsula, Canterbury (W)	27	3.0	
Carmichaelia appressa	Birdlings Flat, Canterbury (W)	20	3.5 (2–5)	Local, on shingle beaches near Lake Ellesmere, 44°S
Carmichaelia egmontiana	Waitara, Taranaki (G)	23	3.6 (3–5)	Local, montane to lower subalpine shrubland, streamsides and forest margins, Mt Taranaki (Egmont) and Pouakai Range
Notospartium torolosum	Lincoln, Canterbury (G)	28	3.9 (1–5)	Montane river valleys in foothills east of main divide, 42° to 44°S
Carmichaelia monroi agg.	Lincoln, Canterbury (G)	4	4.5 (2–5)	Lowland to higher montane gravelly and rocky places, 41° to 46°C
Carmichaelia aligera	Lincoln, Canterbury (G)	25	4.8 (4–5)	Coastal to lowland forest margins north of
39°S				
Cornaceae				
Corokia cotoneaster	Dunedin, Otago (G); Mt Linton, Southland (W)	24	1	Widespread in lowland to mid-altitude shrubland on river flats and rocky places
	Cass, Canterbury (W)	94	1	
	2 accessions: Waiau, Canterbury, calcareous soils (W)	9 13	1 1.3 (1–3)	
	Invercargill, Southland (G) (damage score '2' 1989–90)	12	2	
	Waiau, Canterbury, volcanic soils (W)	14	3	
Corokia macrocarpa	Otari, Wellington (G)	59	2.8 (1–5)	Chatham Island, forest and forest margin
Corokia × *virgata* 'Cherry Ripe'	Otari, Wellington (G)	17	1.4 (1–3)	Ornamental cultivar selected from *Corokia* ×*virgata* = *C. cotoneaster* × *buddleioides*
Corokia × *virgata* 'Frosted Chocolate'	Hamilton, S. Auckland (G) (damage score '2' 1989–90)	10	2.4 (1–3)	Ornamental cultivar selected from *Corokia* ×*virgata* = *C. cotoneaster* × *buddleioides*
Scrophulariaceae				
Hebe pauciramosa	Sheffield, Canterbury (G)	4	1.1 (1–2)	Widely distributed in wet ground in South Island mountains
Hebe pinguifolia	Sheffield, Canterbury (G)	2	1	South Island, alpine to 1500 m, east of main divide, 41° to 45°S
	Lake Lyndon, Canterbury (W)	14	1	
	Mt Arthur, Nelson (W)	7	1.4 (1–2)	
Hebe amplexicaulis	Sheffield, Canterbury (G)	21	1.2 (1–3)	Rangitata - Mt Peel mountains, Canterbury, on rocks in tussock grassland
Hebe albicans	Levin, Wellington (G)	21	1.7 (1–5)	Mountains of Nelson, 41°S
Rubiaceae				
Coprosma rhamnoides	Lewis Pass, Canterbury (W)	31	2.6 (1–5)	Lowland to lower montane forest and shrubland
Coprosma rotundifolia	Mt Linton, Southland (W)	7	3.5 (3–5)	Lowland forest on alluvial soils
Coprosma rugosa	Mt Linton, Southland (W)	6	3.2 (1–5)	Lowland to montane and lower subalpine grassland, shrubland, and forest margins south of 38°S
	Dunedin, Otago (G)	2	3.0 (1–5)	
Asteraceae				
Cassinia leptophylla syn. *C. vauvilliersii*	Whangamoa Valley, Nelson (W)	47	1.8 (1–5)	Lowland to montane to lower subalpine shrubland south of 37°
	Lake Pearson, Canterbury (W)	25	2.4 (2–4)	
	Lake Lyndon, Canterbury (W)	25	2.7 (1–5)	
	Dunedin, Otago (G)	25	3.0 (2–5)	
Olearia ilicifolia	Arthur's Pass, Canterbury, 2 accessions (W)	20 15	4.8 (3–5) 5	Lowland in far south to subalpine forest and scrub from 38°south
Olearia solandri 'Aurea'	Kerisnel Nursery, Britanny, France (G)	4	5	Coastal and occasionally inland north of 42°
Olearia virgata	Cromwell, Otago (G)	1	5	Lowland shrubland and boggy ground south of 37°

Table 3. Species that showed significant cold damage before the 1990–91 winter. Damage scores for the winters before 1990–91 and

			Cold damage		
			pre	post	
Family and species	Provenance	n	90–91	90–91	Distribution/typical habitat
Angiospermae : Monocotyledons					
Liliaceae					
Arthropodium cirratum	Christchurch Botanic Garden (G)	18	5, 87–88 respr.	5 died	Coastal, north of 43°S
Angiospermae : Dicotyledons					
Violaceae					
Melicytus ramiflorus	Kaituna Valley, Canterbury (W)	25	4.5 (4–5) 87–88	dead	Lowland to montane low forests and margins
Malvaceae					
Hoheria lyallii	Sheffield, Canterbury (G)	17	3.5 (3–4) 89–90	—	Montane to subalpine upper forest margins, east of main divide, 41° to 45°S
Elaeocarpaceae					
Aristotelia serrata	2 accessions: Winton, Southland (G)	29	3.1 (2–5) 89–90	dead	Lowland to montane forests, seral
	Mt Linton, Southland (W)	20	1.5, 89–90	4.9 (3–5)	
Pittosporaceae					
Pittosporum eugenioides	Christchurch, Canterbury (G)	12	2.8 (1–3) 89–90	5	Lowland to montane forest
	Winton, Southland (W)	34	1.9 (1–3) 89–90	4.8 (4–5)	
Pittosporum tenuifolium	Mt Linton, Southland (W)	5	1, 89–90	1.2 (1–2)	
	Manapouri, Southland (G)	30	1.1 (1–2)	1.3 (1–2)	
	Sheffield, Canterbury (W)	40	1, 89–90	1.5 (1–4)	
	Christchurch, Canterbury (G)	30	1.6 (1–3)	1.9 (1–3)	
Leguminosae *[cold damage scored for 1989–90 winter, no observation in 1991]*					
Sophora microphylla	Porter River, Canterbury (W)	20	1.0		Lowland and lower montane along rivers, forest outskirts, and open places
	Maruia Valley, Nelson (W)	65	1.4 (1–3)		
	Hanmer Springs, Canterbury (W)	27	1.6 (1–5)		
	Hanmer Springs, Canterbury (W)	81	1.8 (1–5)		
	Lake Wanaka, Otago (W)	25	1.9 (1–5)		
	Te Anau, Southland (W)	19	1.9 (1–4)		
	Invercargill, Southland (G)	17	4.0 (2–5)		
	cultivar 'Goldilocks'	1	4	died	Selection from seed collected at Chepu, Chiloe Island, Chile
	cultivar 'Earlygold'	1	4	died	Selection from seed collected Stephens Island, Cook Strait
Sophora prostrata	Marble Point, Waiau River, Canterbury (W)	27	2.7 (1–5)		Lowland and montane in grassland and rocky places, east of main divide, 41°
to					
	cultivar 'Little Baby'	1	3.0		45°S
	2 accessions Lincoln, Canterbury (G)	31 22	3.0 (1–5) 4.5 (2–5)		
Sophora prostrata × *tetraptera* F2	Lincoln, Canterbury (G)	89	2.4 (1–5)		*Sophora tetraptera* distributedfrom 38° to 41°S on lowlands
Sophora howinsula	cultivar 'Gnome'	1	4.5 (respr. from collar)	dead	Lord Howe Island
Fagaceae					
Nothofagus solandri var. *cliffortioides*	Manapouri, Southland (G)	29	1.3 (1–2)		Lowland to subalpine forest, 38° to 44°S
Onagraceae					
Fuchsia excorticata	Mt Linton, Southland (G)	20	5, 87–88	dead	Lowland to lower montane forest especially on margins
Myrtaceae					
Metrosideros umbellata	2 accessions: Arthur's Pass, Canterbury (W)	20	3.5 (2–5) 89–90	5	Lowland to subalpine forests south of 36°S
	Arthur's Pass, Canterbury (W)	26	5	—	

for 1990–91 are shown separately (n, number of plants observed; W, wild accessions; G, garden accessions; respr., resprouted).

Family and species	Provenance	n	Cold damage pre 90–91	Cold damage post 90–91	Distribution/typical habitat
Metrosideros excelsa	Paekakariki, Wellington (G)	20	5, 87–88	dead	Coastal forest north of 39°S
Cornaceae					
Griselinia littoralis	Sheffield, Canterbury (G)	29	2, 88–89	1.1	Lowland to subalpine forest
	Mt Fyffe, Marlborough (W)	2	2.5 (2–3) 89–90	2	
Araliaceae					
Pseudopanax ferox	Kaikoura, Marlborough (G)	1	2, 88–89	2	Lowland forest and scrub
	Otari, Wellington (G)	10	1.3, 87–88	3.5 (3–5)	
Pseudopanax crassifolius	Kaikoura, Marlborough (G)	1	3, 89–90	3	Lowland to lower montane forest, and as young plants in seral scrub
	Manapouri, Southland (G)	19	3, 89–90	3.7 (3–5)	
	New Plymouth, Taranaki (G)	5	1, 89–90	4	
Pseudopanax lessonii	Richmond, Nelson (G)	10	1.2, 87–88	5	Coastal forest and scrub north of 39°S
	cultivar 'Goldsplash'	2	3, 87–88	5	
Pseudopanax arboreus	Richmond ex Queen Charlotte Sound, Marlborough (G)	7	3, 87–88	5	Lowland forest to 45°S
Pseudopanax hybrid cultivars	'Purpureum' *P. lessonii* × *discolor*	2	1, 89–90	5	
	'Trident' *P. lessonii* × *crassifolius*	2	1, 89–90	5	
	'Sabre' *P. crassifolius* × *arboreus*	2	3, 89–90	5	
	'Cyril Watson' *P. lessonii* × *crassifolius*	1	5, 87–88	dead	
Scrophulariaceae					
Hebe salicifolia	Cass, Canterbury (W)	78	1.5 (1–3) 88–89	1.1 (1–2)	Throughout South Island and coastal Chile, lowland to lower subalpine
	Arthur's Pass, Canterbury (W)	23	1.2, 89–90	1.2 (1–2)	
	Lewis Pass, Canterbury (W)	31	1.1 (1–2)	1.1 (1–2)	
	Arthur's Pass, Canterbury (W)	9	1.4, 89–90	1.5 (1–3)	
Hebe traversii	Lake Lyndon, Canterbury (W)	56	2.3 (1–4) 89–90	1.3 (1–4)	Montane to subalpine east of main divide, from 42° to 44°S
Hebe stricta	Goose Bay, Marlborough (W)	28	2.2 (1–4) 89–90	1.4 (1–2)	Lowland and montane areas north of about 42°S
	Maitai Valley, Nelson (W)	20	2.3 (1–4) 89–90	1.7 (1–4)	
Hebe urvilleana	Whangamoa, Nelson (W)	33	1.1 (1–2) 89–90	1.9 (1–5)	D'Urville I. and adjacent mainland area on serpentine
Hebe subalpina	Arthur's Pass, Canterbury (W)	34	1 (1–2) 89–90	2.6 (1–5)	Southern Alps, subalpine from 750 m to 1200 m in higher-rainfall areas
Hebe barkeri	Chatham I. (W)	31	2.6 (1–4) 89–90	3.1 (1–5)	Chatham I., lowland and tableland forest
Hebe elliptica	Levin, Wellington (G)	36	2.9	3.7 (1–5)	Coastal, south of 39°S
Rubiaceae					
Coprosma robusta	not known	12	1.7, 89–90	—	Lowland to montane forest and shrubland north of 46°S
	2 accessions: Mt Fyffe, Seaward	25	2.5, 89–90	—	
	Kaikoura Ra., Marlborough (W)	12	1, 89–90	4.8 (4–5)	
	Kaituna Valley, Canterbury (W)	15	1, 89–90	5	
Coprosma areolata	Prices Valley, Banks Peninsula, Canterbury (W)	48	5, 87–88	dead	Lowland to lower montane forest
Coprosma crassifolia	Prices Valley, Banks Peninsula, Canterbury (W)	37	5, 87–88	dead	Rocky and sandy coasts; lowland to lower montane forest and shrubland
Asteraceae					
Olearia avicenniifolia	Arthur's Pass, Canterbury (W)	19	2.1 (2–3) 89–90	1.2 (1–2)	South Island, lowland to lower subalpine shrubland throughout
	Takaka Hill, Nelson (W)	7	2, 88–89	2.2 (1–3)	
	Manapouri, Southland (G)	8	2, 88–89	3.1 (2–4)	
	Dunedin, Otago (G)	1	4, 88–89	3	
Olearia traversii	Lincoln, Canterbury (G)	4	3, 89–90	5	Mostly coastal forest, Chatham I.
Olearia lacunosa	Mt Arthur, Nelson (W)	4	5, 89–90	dead	Subalpine scrub/low forest south of 40°S

Where species have limited latitudinal distributions these are given to the nearest °S, otherwise it can be taken that the species are widely distributed in New Zealand. The listing of related groups of species is in the order of least to most cold damage.

Fourteen species showed negligible cold damage during the full period of the evaluation (Table 1). Of the two overseas species, *Podocarpus lawrencei* is closely related to *P. nivalis*, and *Cortaderia selloana* from South America is related to several New Zealand *Cortaderia* species that showed significant damage in the 1990–91 winter. The New Zealand species, apart from the Chatham Island endemic *Hebe dieffenbachii*, have wide latitudinal distributions and — apart from *Plagianthus regius, P. divaricatus, Hoheria angustifolia*, and *Hebe dieffenbachii* — extend into montane and subalpine environments. *Plagianthus regius* is one of the few deciduous trees indigenous to New Zealand.

Thirty-two New Zealand species and *Cortaderia rudiuscula* from Chile were not significantly damaged by cold until the 1990–91 winter (Table 2). For some, such as the *Cordyline* and *Olearia* species, the damage in 1990–91 was severe, whereas provenances of *Corokia cotoneaster* and the four *Hebe* species showed little damage. The latitudinal and altitudinal distribution patterns of the species in this group vary, and these distribution patterns show relationships to the variation of cold damage. In particular the cold damage to *Cortaderia* species relates well to their latitudinal distributions.

Thirty-one New Zealand species and *Sophora howinsula* from Lord Howe Island showed noticeable cold damage before the 1990–91 winter (Table 3). For some species this damage was severe and killed plants, e.g., *Metrosideros excelsa* and *Fuchsia excorticata*, whereas in others it was slight, provenances of some having cold damage scores of '1', e.g., *Pittosporum tenuifolium* and *Sophora microphylla*. The *Sophora* provenances were not scored after the 1990–91 winter, but a general observation showed that the level and pattern of damage was similar to that in 1989–90, and most of the plants survived. Relationships between the level of cold damage and the geographical distribution of *Hebe* and *Olearia* species are indicated.

Examples of species for which provenances differed in cold damage and where within-provenance variation was marked are *Cassinia leptophylla* (Table 2), *Pittosporum tenuifolium, Sophora microphylla*, and various *Hebe* species (Table 3).

Species evaluated that did not survive or were severely damaged through factors other than cold, were:

Chionochloa rubra (Arundineae) – 2 accessions, Arthur's Pass, Canterbury (W);

Aciphylla squarrosa (Umbelliferae) – Otari, Wellington (G);

Heliohebe raoulii (Scrophulariaceae) – Arthur's Pass, Canterbury (W);

Parahebe lyallii (Scrophulariaceae) – Sheffield, Canterbury (G).

Cold damage scores for the 1990–91 winter for species from Tasmania of genera not indigenous to New Zealand were:

Acacia retinodes (Leguminosae) (G, n = 30) – local on Flinders I. and in South Australia and Victoria – 5;

Billardiera longiflora (Pittosporaceae) (G, n = 14) – widespread in Tasmania, Victoria and N.S.W. – 1.1;

Callistemon viridiflorus (Myrtaceae) (W, n = 46, Mt Alma) – Tasmanian endemic, montane in wet places – 1.1 (1–3);

Casuarina littoralis (Casuarinaceae), (W, n = 20, Mt Grey) – widespread, especially on dry hills, in Tasmania, Victoria, N.S.W, Queensland – 5.

Table 4. Comparison of rank of cold damage scores at Angers with measurements and rank of freezing resistance from controlled temperature studies.

Species ranked in order of damage at Angers	Damage scores, 1991 (pre 1991)	Freezing resistance (°C), leaf (bud)	Rank order
1. *Metrosideros excelsa*	5 (5)	–3.0 (–3)[a] –2.5 [b]	1
2. *Metrosideros umbellata*	5 (2–5)	–8 (–8)[a] –5 [b]	8
3. *Pseudopanax arboreus*	5 (3)	–6 [b]	4=
4. *Pittosporum eugenioides*	5 (1–3)	–3.0 (7)[a]	2
5. *Pseudopanax lessonii*	5 (1–2)	–6 [b]	4=
6. *Pseudopanax crassifolius*	3–4 (1–3)	–7 [b]	7
7. *Leptospermum scoparium*	2–5[c] (1–4)[d]	–7 (–7)[a] –6 [b]	6
8. *Olearia avicenniifolia*	1–4 (2–4)	–10 (–10)[a]	11
9. *Pittosporum tenuifolium*	1–4 (1–3)	–8 (–8)[a]	9
10. *Hebe salicifolia*	1–3 (1–3)	–5 [b]	3
11. *Griselinia littoralis*	1–2 (2–3)	–8 (–10)[a]	10
12. *Podocarpus nivalis*	1 (1)	–22 (–20)[a]	12

[a] Sakai and Wardle (1978); [b] Bannister (1986, 1990); [c] Decourtye and Harris (1992); [d] Harris and Decourtye (1991)

Discussion

The latitude of Angers, 47°N, is the same as that of Stewart Island, at 47°S the southernmost of New Zealand's three main islands. Thus all the provenances tested originated from latitudes lower than that of the evaluation site. However, the climate at Angers is significantly affected by continental climatic influences that are distinct from the maritime influences that characterise the New Zealand environment. Consequently, with the possible exception of a few of the species characteristic of inland higher-altitude parts of the South Island, the provenances were subjected to temperatures lower than they would encounter in their environment of origin. This was especially the case in the 1990–91 winter.

We were fortunate in the sequence of winter temperature regimes because, had the low temperatures of February 1991 occurred early in the evaluation period, much of the discrimination of cold damage observed would not have been obtained. The winter temperatures in the first 3 years of evaluation were of an order typical for Angers. However, temperatures as low as those of winter 1990–91 are not exceptional, and occur when flows of cold Arctic air overwhelm the latitudinal and maritime influences that normally dominate the climate of Angers (Harris and Decourtye, 1991). Winter temperatures as low as those of 1990–91 occurred in the three winters preceding the evaluation period, 1984–85, 1985–86, and 1986–87, when the extreme minimum screen temperatures were –14.6°, –15.0°, and –18.0° C re-

Fig. 3. An attractive flowering shrub in June 1989, *Olearia ilicifolia* was severely damaged by cold in the 1990–91 winter.

spectively, with lowest grass minimum temperature of −22°C occurring in January 1987. However temperatures as low as those of 1990–91 did not occur at Angers in the 30 winters before 1984.

There is a marked difference in the approach we used to measure cold damage compared to those using controlled temperature facilities (Bannister, 1986, 1990; Greer et al., 1991; Sakai and Wardle, 1978; Warrington and Stanley, 1987). A comparison of ranking of cold damage susceptibilities by ordering the scores after the 1990–91 winter and further discrimination of the order by reference to damage in previous winters is made with the ranking of cold resistance of 12 species observed in the investigations of Sakai and Wardle (1978) and Bannister (1986, 1990) (Table 4). This shows a good level of agreement between the studies, apart from *Metrosideros umbellata* and *Hebe salicifolia*. With these two species included the correlation coefficient was 0.637 ($P < 0.05$, 10 d.f.), and when excluded 0.925 ($P < 0.001$, 8 d.f.). The different response of *H. salicifolia* may arise from the provenances in our study coming from the colder part of the species' range, but the *M. umbellata* provenances tested were from a part of the species' range similar to that of material tested by Sakai and Wardle (1978).

As also shown by the results of Sakai and Wardle (1978), there was for most species correspondence between their distributions and the extent to which they were damaged by cold. For species that did not correspond, Sakai and Wardle (1978) offered as explanation ecotypic differences and the capability some species have for regrowth after cold damage. These aspects of cold adaptation are also revealed in our study. More information about them is required to improve understanding of the ecological strategies of New Zealand plants and realisation of their potential as ornamentals. With the latitudinal and maritime influences that determine New Zealand environments, plants are presented with the opportunities inherent in the alternative strategies of cold tolerance and correlated dormancy or the ability to gain competitive advantage by vegetative growth in the colder months of the year. This latter strategy carries the risk of plants losing significant biomass or suffering mortality through tissue damage caused by cold.

Growers of New Zealand plants in climates similar to that of Angers risk having significant cold damage to many of these plants in some years. This risk can be significantly reduced by the choice of species. The cold damage responses of the species observed (Tables 1–3) can be used as a guide to this choice. From our evaluation of *L. scoparium* we concluded that a damage score of '3' was the maximum acceptable for horticulture (Decourtye and Harris, 1992), but we suggest that for the larger range of species dealt with in this paper a more conservative score of '2' should be used.

The risk of damage can be balanced against the value of having attractive flowering or fruiting shrubs in typical years (Fig. 3) with the expectation that they will have to be replaced after the less frequent colder winters. Species with a good level of cold hardiness that also showed characteristics that indicate their potential for horticultural use in France include *Plagianthus regius*, *Hoheria angustifolia*, and *Pittosporum tenuifolium* for use as boundary hedges, *Plagianthus divaricatus*, *Cassinia leptophylla*, and *Olearia avicenniifolia* for low hedges, and *Sophora microphylla*, *Corokia cotoneaster*, several *Hebe* species, and *Coprosma propinqua* for their attractive habit, flowers, or fruits.

The use of the species as ornamentals will also take into account their ability

Fig. 4. Rows (from foreground to background) of *Cassinia leptophylla*, *Olearia avicenniifolia*, *Pittosporum eugenioides*, and *Pittosporum tenuifolium*. Healthy shrubs in June 1989, these species suffered differing levels of cold damage during the evaluation.

to recover from cold damage. Some provenances of *L. scoparium* had the ability to regrow from the collar after cold damage to the score of '3', and with appropriate pruning of damaged shoots these shrubs recovered fully in the summer (Decourtye and Harris, 1992). Many of the species showed the ability to recover healthy and attractive foliage in summer after moderate cold damage (Fig. 4). *Melicytus ramiflorus* provides an example of a species that has shoots particularly susceptible to cold damage, but which has the ability to resprout from the collar. But this species, as with *Arthropodium cirratum*, whose leaves are usually killed by winter frost but which recovers from its rhizome in spring, were killed by cold in the 1990–91 winter. This was the only winter when soil at 10 cm froze, and this was only to –0.6°C. *Sophora howinsula* 'Gnome' differed from the other *Sophora* provenances in its ability to resprout from a lignotuber (Heenan, 1992).

Selection of provenance or cultivar can further reduce the risk of cold damage. The examination of provenance and individual plant variation in *L. scoparium* after the 1990–91 winter showed cold damage scores from '2' to '5' related to latitude and altitude of origin, and a significant number of individual plants had damage scores of '1' (Decourtye and Harris, 1992). Variation of this kind is indicated for the *Corokia cotoneaster*, *Cassinia leptophylla*, *Pittosporum tenuifolium*, *Sophora microphylla*, and *Olearia avicenniifolia* provenances, and for more species by within-provenance variation of cold damage (Tables 2, 3). These results indicate the potential for significant enlargement of the areas in which New Zealand plants can be effectively grown as ornamentals by selection of the natural variation of their ability to resist cold damage.

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Résumé

Résistance au froid hivernal d'espèces ligneuses originaires de Nouvelle-Zélande cultivées à Angers.

La situation insulaire de la Nouvelle-Zélande a permis la différentiation au cours des temps géologiques d'une flore particulièrement originale. Néanmoins, celle-ci est fort peu représentée dans la pépinière ornementale européenne. Son utilisation est limitée à une frange littorale étroite en raison de la sensibilité au froid hivernal de la plupart des cultivars introduits jusqu'à maintenant. Pourtant, il existe en Nouvelle-Zélande, dans les zones les plus méridionales et à des altitudes élevées, des régions régulièrement soumises à des froids de –10°C à –15°C. Ces basses températures ont nécessairement favorisé l'émergence de génotypes plus résistants.

C'est cette hypothèse qui nous a guidés dans la collecte de près de 500 lots de graines, récoltées dans des sites favorables représentant une centaine d'espèces. Ces différentes provenances ont été cultivées à Angers, à raison de 10 à 50 individus, et observées au cours de quatre années (1987–1991) pour leur comportement hivernal.

Les trois premiers hivers d'observation peuvent être considérés, pour les conditions d'Angers, comme des hivers doux: les minima absolus au sol n'ont jamais atteint –10°C: –9°C le 10 décembre 1987, –9,1°C le 22 novembre 1988, –8,6°C le 27 novembre 1989 (fig. 2). L'hiver 1990 / 1991, sans être particulièrement rigoureux, est d'avantage représentatif d'un hiver normal, avec 27 jours de gel consécutifs et un minimum absolu de –12,5°C en février 1991. L'état de chaque plante a été évalué au cours de la saison de végétation suivante, selon une échelle de notation variant de 1 (aucun dégat) à 5 (brunissement et nécrose de la totalité des rameaux).

Les résultats obtenus figurent dans les tableaux 1–3. Le tableau 1 rassemble 14 espèces restées indemnes après les quatre hivers, dont les plus résistantes au froid. Le tableau 2 rassemble 32 espèces ayant bien résisté au cours des trois premiers hivers (–9°C) mais en partie endommagées par le dernier hiver (–12°C). Enfin, le tableau 3 recueille les 31 espèces en partie affectées dès –9°C et, plus encore, à –2,5°C mais pour lesquelles des individus indemnes subsistent dans la plupart des cas.

Une sélection pour la résistance au froid s'avère donc possible, des dégâts notés '2' restant acceptables. Parmi les espèces où se trouve un niveau de résistance suffisant, certaines ont des potentialités horticoles, telles que Plagianthus regius, Hoheria angustifolia, *ou* Pittosporum tenuifolium, *pour constituer des haies mitoyennes;* Plagianthus divaricatus, Cassinia leptophylla, *ou* Olearia avicenniifolia *pour des haies basses, et enfin* Sophora microphylla, Corokia cotoneaster, *plusieurs espèces d'*Hebe, *et* Coprosma propinqua *pour leur floraison, leur port, ou leur fructification.*

Ces résultats, mesurés dans des conditions naturelles, sont en bonne corrélation avec les études de laboratoire (tableau 4). Ils confirment l'intérêt de la collecte de graines dans des zones à climat rigoureux, au même titre que les résultats précédemment obtenus sur Leptospermum scoparium.

COLOUR KEY TO PEST ARMOURED SCALES IN NEW ZEALAND

Enclosed with this final issue of *Horticulture in New Zealand* is an insect identification guide, or LifeKey, recently published by Manaaki Whenua - Landcare Research. Funds for its preparation were provided as a grant by The Agricultural and Marketing Research and Development Trust.

This sample issue is distributed free to members of RNZIH with the request that it be tested 'in the field.' Feedback on its usefulness to horticulturists would be appreciated by the publisher.

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Ambrose Taylor 1826–1913: Curator, Botanic Gardens, Christchurch – the Early Years

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Ambrose Taylor was Head Gardener and then Curator of the Botanic Gardens, Christchurch, 1889–1907. He was the father of New Zealand's first landscape architect, Edgar Taylor (1886–1979).

The position of Head Gardener at the Gardens had been advertised after disagreements between the previous joint Curators, John and Joseph Armstrong, and the Domains Board. Previous accounts[1] suggest that Taylor was brought out from England to take up this position but this does not agree with the available evidence. In fact much of the published material and private accounts of the Taylors coming to New Zealand are full of contradictions. This situation has not been helped by some recent publications which have displayed a degree of uncritical use of evidence. Gardner has drawn attention to the historian's task "... to analyze what actually happened, and why it happened at that time ...", in the context of his work revising the traditional view of the sale of the Cheviot estate. The case of Cheviot is a warning, he has written, "...against accepting generalizations not based on all aspects, including chance elements in a situation ...", and an encouragement "... to look again at particular events or episodes in order to test or amend the received wisdom ..." [2] This article was begun while I was writing an essay on Edgar Taylor for the *Dictionary of New Zealand Biography*, Volume III, and reviews the evidence relating to his birth and background. A further article will follow on Ambrose Taylor's years at the Christchurch Botanic Gardens.

The earliest published account of Ambrose Taylor is contained in *The Cyclopedia of New Zealand – Volume 3, Canterbury* [p. 130], which describes him as the son of a gardener and forester in the service of the Duke of Bedford, born at Oakley, Bedfordshire, in the 1830s. Before coming to New Zealand:

> *... he was at Chatsworth and Kew Gardens, and manager of several properties in England, including the estate of Baron Rothschild, in whose service he continued for twenty years ... Mr Taylor was married in 1884 to a daughter of Mr Tomkinson, of London, and has three sons and one daughter.*

This account is followed in his obituary in *The Press* (14 March 1913) and in the Macdonald Dictionary of Biography,[3] which manages to correct the date of birth to 1827, presumably by using the age at death from his tombstone inscription. His birth is recorded in Parish records for Oakley as on 18 April 1826.[4] Otherwise the Macdonald Dictionary repeats the account from *The Cyclopedia of New Zealand*.

In *A Garden Century, a history of the Christchurch Botanic Gardens* [1963],[5] Barnett, Gilpin, and Metcalf describe Ambrose correctly as the son of a gardener and forester in the service of the Duke of Bedford, who entered the Royal Botanic Gardens, Kew, as a student gardener. They also drew attention to the period as Head Gardener and Estate Manager to Baron Rothschild.

Their next statement is more problematic. It is claimed that Taylor was Head Gardener at Chatsworth, the seat of the Duke of Devonshire. Challenger was unable to confirm this from sources at Chatsworth when researching the early history of gardening and nursery work in Canterbury, as no evidence could be found to support the assertion.[6] That Taylor did work at Chatsworth is supported by Taylor's own *curriculum vitae,* provided to the Domains Board at the time of his application to become Head Gardener (Fig. 1).[7] However, that is in itself problematic because while Sir Joseph Paxton may have been in charge nominally at this time, he may not even have known Taylor. The latter was probably more of a gardener in training than the Head Gardener.[8] Thus, surviving estate records might not have revealed a head gardener called Taylor because he did not reach that exalted position. Chatsworth archives have not permitted confirming Taylor's position, but it has been suggested that acquiring a knowledge of surveying was quite possible at Chatsworth at that time. A highly detailed series of surveys of Chatsworth was published in 1858 which would have necessitated several years of work to bring to fruition. Perhaps Ambrose was involved in them.[9] It might explain why, in his book collection, he had a copy of J.C. Loudon's *Self-Instruction for Young Gardeners, Foresters, Bailiffs, Land-Stewards and Farmers in Arithmetic and Book-Keeping, Geometry, Mensuration and Practical Trigonometry, Mechanics, Hydrostatics and Hydraulics, Land-Surveying, Levelling, Planning and Mapping, Architectural Drawing, and Isometrical Projection and Perspective: With Examples, showing their Application to Horticultural and Agricultural Purposes.*[10] It is inscribed Ambrose Taylor, Chatsworth, December 1st/65. The inscription is not entirely clear, but whether that means 1865 or not is a problem, as that date does not conform with the *curriculum vitae* either (Fig. 2).

This illustrates a further problem with Taylor's c.v., that Taylor himself appears to have been somewhat misleading in the way he presented his previous work history. This problem is described further below, but was magnified by the writings of his son, Edgar Taylor, which did nothing to dispel these myths. In *The City Beautiful*, in a series entitled 'The Gardens at the Turn of the Century', Taylor describes his father as "... head gardener at Chatsworth, where incidentally eight[y]-two gardeners were employed ..."[11]

There are three further problems with Ambrose Taylor's *c.v.*: first, the period of training at Kew Gardens; second, the sequence of dates offered; and, third, the period in the employment of Baron Rothschild.

It appears that Ambrose Taylor was accepted into Kew in September 1851 following letters of support from his father, backed up by one from the 7th Duke of Bedford, to Sir William Hooker, the Director of Kew, who had been a close friend of the 6th Duke.[12] He entered service there on 2 April 1852, when he was described as having "Not much knowledge of botany" and having "Arithmetic as far as mensuration. Can chain plans." When he left on 2 November 1852 to become foreman for Lord Harewood near Leeds, a note was added to his entry in the Kew lists "Will be a

Fig. 1 *(opposite page)*. Ambrose Taylor's curriculum vitae given in 1889 when applying for the Head Gardener's position in the Christchurch Domain. (Collection: Edgar Taylor jun.)

A. L. Taylors Statement
of His
Experience & Qualifications
for Head Gardener to the Domain Board
Christchurch

Oct 19th 1889

1st Under the tuition of His Father
Late Head Gardener and Forester
to the Duke of Bedford, Woburn.
and for a period on the same Estate
under Thos Bennett Esq on drainage
and Estate work. — up to the year 1853

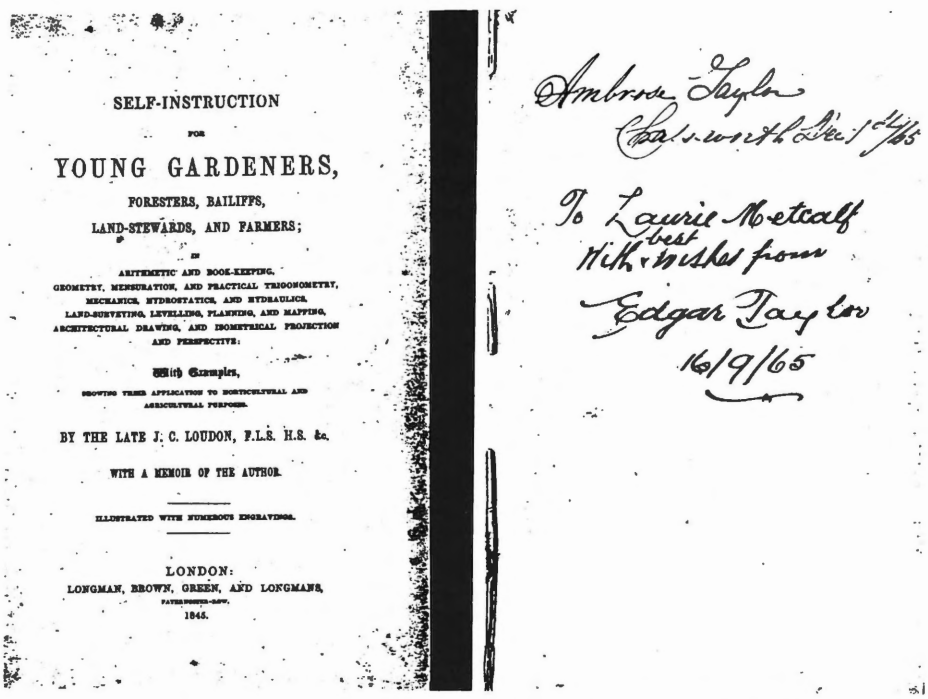
2ndly Under Sir Joseph Paxton
Duke of Devonshires, Chatsworth,
as improver, in the Gardens and
Ornamental Grounds —
acquired here, a practical
knowledge of Surveying, Levelling
& drawing - under the resident Surveyor, up to year 1854

3rdly At the Royal Botanic Gardens, Kew.
Two years probationary study
in Botany, Ornamental Gardening
and Arboriculture — up to — 1859

4thly The Earl of Harewoods. Yorkshire
as Terrace & pleasure Ground
Gardener for 2 years,
& Head Gardener 2 years } = 4 up to 1863

5thly Baron Lionel de Rothschilds
Superintendent of Woods
Formation of Ornamental and
Forest planting - Renovation of
Gardens - and Erection of Glass Houses
And further, appointed manager of
drainage and general Estate Work,
to which Testimonial alludes. up to 1883

Since the death of the Baron
practised - on own acct, Landscape
Gardening and otherwise advising.
Covering many Engagements up to 1889



SELF-INSTRUCTION

FOR

YOUNG GARDENERS,

FORESTERS, BAILIFFS,

LAND-STEWARDS, AND FARMERS;

IN

ARITHMETIC AND BOOK-KEEPING,
GEOMETRY, MENSURATION, AND PRACTICAL TRIGONOMETRY,
MECHANICS, HYDROSTATICS, AND HYDRAULICS,
LAND-SURVEYING, LEVELLING, PLANNING, AND MAPPING,
ARCHITECTURAL DRAWING, AND ISOMETRICAL PROJECTION
AND PERSPECTIVE:

With Examples,

SHOWING THEIR APPLICATION TO HORTICULTURAL AND
AGRICULTURAL PURPOSES.

BY THE LATE J. C. LOUDON, F.L.S. H.S. &c.

WITH A MEMOIR OF THE AUTHOR.

ILLUSTRATED WITH NUMEROUS ENGRAVINGS.

LONDON:
LONGMAN, BROWN, GREEN, AND LONGMANS,
PATERNOSTER-ROW.
1845.

Ambrose Taylor
Chatsworth Dec 1st/45

To Laurie Metcalf
best
with wishes from
Edgar Taylor
16/9/65

Fig. 2. Title page and inscription on Lawrie Metcalf's copy of Loudon's *Self-Instruction for Young Gardeners*. (Collection: L. Metcalf)

good gardener."[13] The dates given by Kew Gardens do not agree with those given by the Taylor *c.v.*, that two years probationary study was undertaken between 1857 and 1859 in Botany, Ornamental Gardening, and Arboriculture. Later in 1893 Ambrose Taylor joined the Kew Guild when it was formed.[14]

Employment with the Earl of Harewood does match with that listed in the *curriculum vitae*, although the dates are again uncertain. The subsequent employment with Baron Lionel de Rothschild is also problematic. Here several sources provide incompatible information, all of it fragmentary.

Barnett, Gilpin, and Metcalf's account seems to be accurate as far as it goes, and it agrees with the Taylor *c.v.* in that Taylor claims to have been Superintendent of Woods, and Manager of drainage and general estate work for Baron Lionel de Rothschild between 1863 and 1883. However, the Rothschild Archive and the Buckinghamshire Record Office have supplied data suggesting that Taylor was employed between 1863 and 1876 by Sir Anthony de Rothschild at Aston Clinton House (Fig. 3).[15] During most of this period he lived at Walton Villas (Fig. 4) on the Aston Clinton side of Aylesbury. In Kelly's Directories of the period he was listed, for 1863 and 1864, as resident at Temple Square, Aylesbury, and listed as Land Steward to Baron Rothschild. In 1869 and 1876 he is similarly listed, but resident at Walton. The 1871 Census of Population also has him listed as resident at Walton, aged 44, with his wife of the same age, Mary (*née* Wootton), and being described as a Land Agent and Surveyor (Fig. 5). During this period he was also on the Register of Electors for Aylesbury, being registered as resident at Walton Villas from 1872 to 1877 and entitled to vote by virtue of freehold land at Ardenham Hill. He is not listed before or after this date, nor is he listed in the 1881 Census of Population for Walton.[16]

The Rothschild Archivist could find no record of Taylor's employment after the death of Sir Anthony in January 1876. If Taylor did transfer his employment to Baron Lionel, the latter lived only to 1879, still four years short of the date, 1883, given in the Taylor *c.v.* Baron Lionel de Rothschild lived at Gunnersbury Park, Ealing, on the opposite side of the Thames to Kew Gardens. His death is reported in *The Gardener's Chronicle* for 21 February 1880, as he had been a "...kind and liberal benefactor..." of the Gardeners' Royal Benevolent Institution.[17] In an earlier issue there is an article on Gunnersbury Park, which seems to be the work of a writer focusing on the achievements of a new Head Gardener. There is no mention of Taylor as either Head Gardener or Land Steward.[18] John Newman is listed as Land Steward to Baron Lionel at Gunnersbury Park in 1878.[19] Baroness Charlotte, the late Baron Lionel's wife, lived on at Gunnersbury Park until 1884. Taylor may have worked there, although Baron Lionel also bought Tring Park, Buckinghamshire, for his son, Nathaniel Mayer, and he could have worked there.[20] However, Nathaniel and his wife, Emma, were renowned as some of the most beneficent of Victorian landlords and employers, and it seems unlikely that they would have cast off a long-serving senior staff member.[21] No reference to Taylor working for Baron Lionel has been found in the Kelly's directories of the period, or other horticultural directories.

One must presume that the testimonial, referred to in the *c.v.* against the entry for Baron Lionel, must have been undated and thus not have indicated to the selectors of a new Head Gardener for the Christchurch Domains Board the discrepancies described.

One further reference tends to confirm the period of employment with Sir Anthony de Rothschild. In one of Edgar Taylor's articles in *The City Beautiful*, 'The Gardens at the Turn of the Century', he refers to his father wanting him to enter Kew, as the son of a 'Kewite', and the help Sir Anthony Rothschild had given to his former Head Gardener with the application.[22] However, again this information could not have been correct because of Sir Anthony's death in 1876, ten years before Edgar was born.

The appointment of Ambrose as Head Gardener for the Domains Board, Christchurch, raises the question of whether he was brought from England for the job or came separately. Edgar Taylor suggested that his father was brought out for the position, but there is no evidence to support this contention.[23] The position from which the Armstrongs had resigned was advertised by the Chairman of the Domains Board in *The Star* once on 5 October 1889 and in the *Canterbury Times*.

The Christchurch Domains Board require a Head Gardener. Particulars may be seen at my office, South British Insurance Buildings, Hereford Street, where applications will be received until noon on 31 October.[24]

The particulars referred to were, in modern parlance, a job description. The salary was to be £120 *per annum* paid monthly with a cottage, to be entered by agreement. The duties were:

(1) To be a gardener in the Domain, and as such responsible to the chairman, and members of the Executive Committee, as representatives of the Board.
(2) To have charge of and be responsible for the labour done in the Domain.
(3) To keep written up the book 'Diary of the Head Gardener' recording the occupation of every gardener, with details sufficient to convey complete information for future reference.
(4) Monthly at meetings of the Executive Committee and of the Board to produce a programme of the work proposed to be done during the ensuing month.
(5) Written testimonials must be produced as [to] character and qualifications.[25]

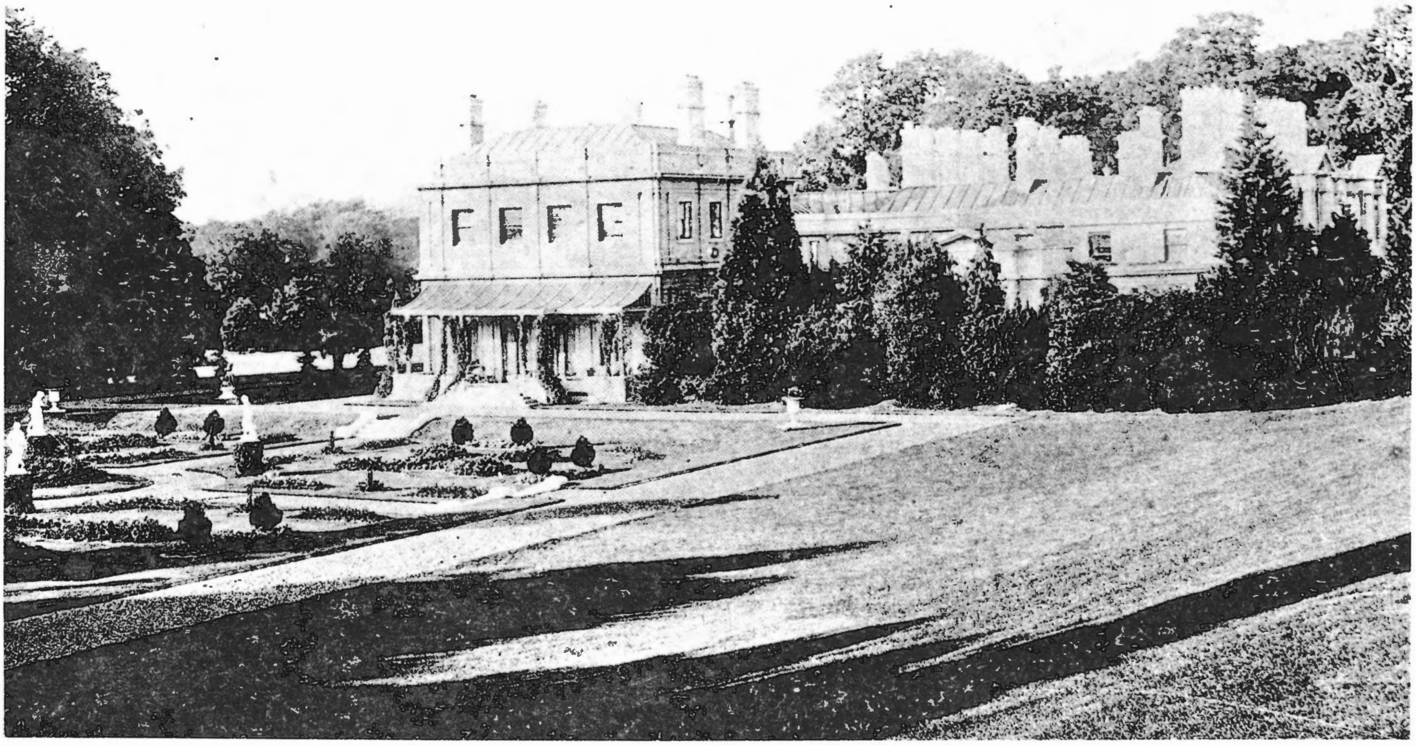


Fig. 3. Aston Clinton House. (Buckinghamshire County Archives)

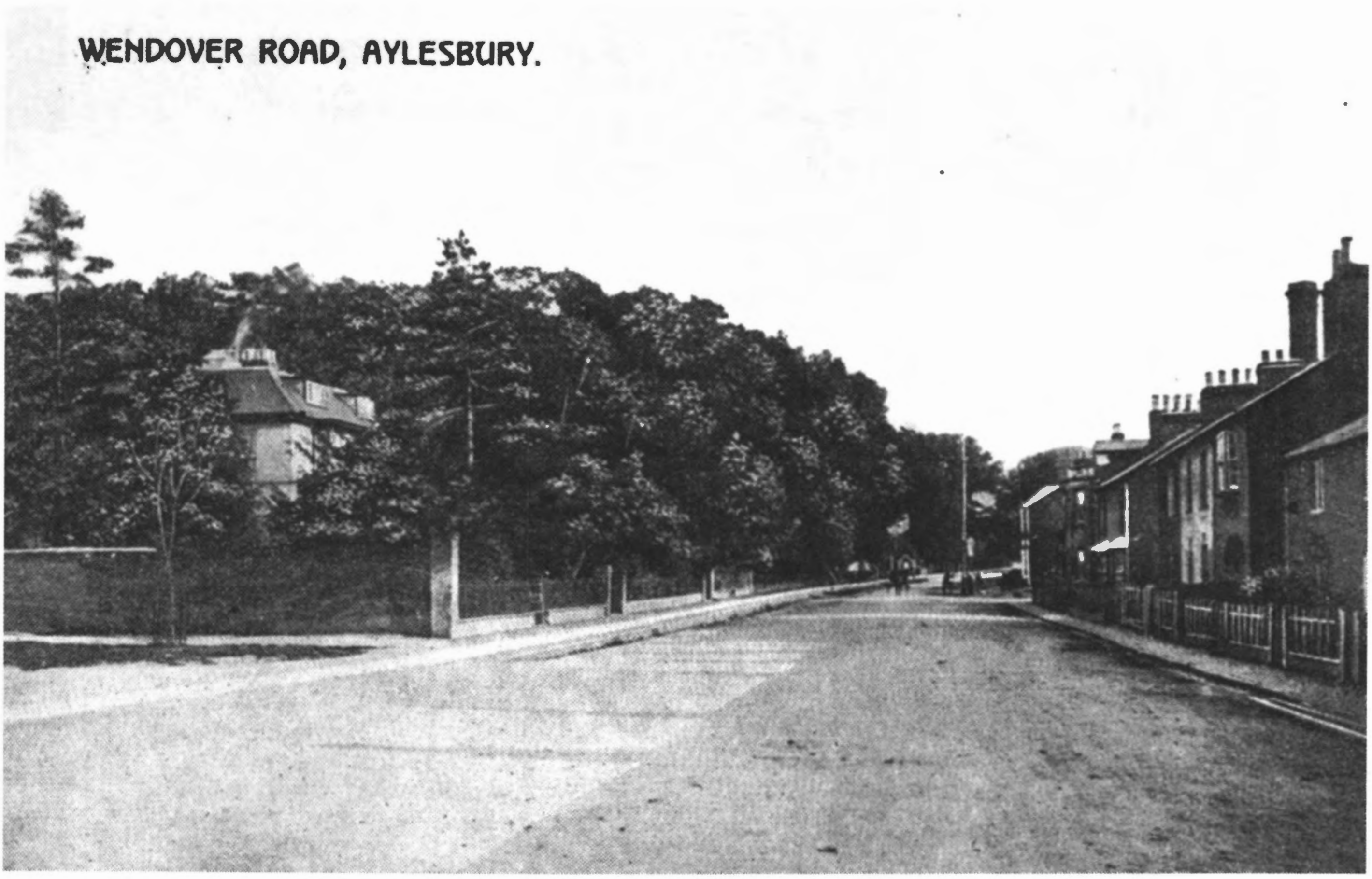


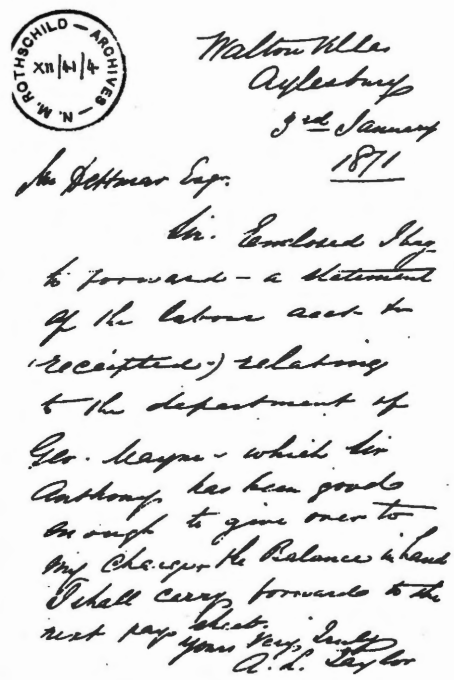
Fig. 4. Wendover Road, Aylesbury (Buckinghamshire County Archives). Walton Villas may be seen on the left. They are clearly identified on the 4.166 feet = 1 inch Ordnance Survey Map of Aylesbury of 1878.

Later in the *Letters Book - Outward Letters* is a reply to an application from Ambrose Taylor for the position of Head Gardener, which he was offered at £120 *p.a.*[26] A later entry in the Domains Board's Minute Book of the period states that Taylor was selected from 23 candidates, not 30 as given in the *Cyclopedia of New Zealand,*[27] and that he had been trained at Kew Gardens and had had other experience of the management of large gardens.[28]

This reply and job offer was addressed to St James Terrace, Carlton Mill Road. Consequently, Ambrose must have been in New Zealand already. Family tradition, supported by the *Cyclopedia of New Zealand* (Vol. 3, Canterbury), suggested that he and his family had arrived by the s.s. *Ruapehu*. No shipping lists exist for the period except for assisted immigrants, and the scheme had ceased in 1884. Checking the arrivals of the s.s. *Ruapehu* at Lyttelton revealed that it had docked on 30 May 1889 and 16 October 1889. The latter was after the job was advertised, and thus it seemed unlikely that Ambrose had arrived on that sailing. When the passenger list for the May arrival was checked in the *Lyttelton Times* a Mr and Mrs Taylor had arrived in the Steerage accommodation accompanied by three children.[29] The three children were Master T. Taylor, Master Edgar Taylor, and Miss Jessie Taylor, an infant. These data match the family of Ambrose and his second wife, Sarah. Why they had come to New Zealand is a mystery, but a number of suggestions may be made.

The period after Ambrose Taylor left Rothschild employment before the move to New Zealand is also problematic. In his *c.v.* Taylor suggested that he had "... practised on his own account, Landscape Gardening and otherwise advising, covering many engagements." No supporting evidence is offered of any of these activities. Perhaps no individual engagement was associated with a 'big' name to compare with his previous employers. The late nineteenth century was a period when the owners of big houses and country estates, so typical of the late Georgian and early Victorian era, experienced severe economic difficulties associated with the depression being endured by the agricultural sector and therefore lower levels of rents.[30] Consequently not many new large gardens were being created, and employment for an experienced gardener in his sixties may not have been easy to find.

Sometime after Sir Anthony's death in 1876 Ambrose left Aston Clinton. Between then and 1879–80 he may have worked for Baron Lionel, who gave him an employment reference, if that reference was genuine. Then in 1879–80 he began work as an independent/consulting landscape gardener. In 1880 an Ambrose Lloyd Tayler was listed in the Commercial and Trades sections of *Kelly's Post Office Directory for London* as a Landscape Gardener operating from 13 Great George Street, Westminster, close to Parliament. He had chambers alongside a terra cotta manufacturer, civil engineers, a barrister, a company secretary, a general agent, and parliamentary and legal stenographers.[31] Perhaps Parliament was a potential source of clients; certainly the Rothschilds were represented there, in both Houses.[32] But independent consulting did not last, and by 1883 there is no mention of Tayler at 13 Great George Street. No trace of Taylor's activity has been found in the columns of *The Gardener's Chronicle*. There are no advertisements there, as there are for other landscape gardeners, nor in any other journal of the period held in the Lindley Library of the Royal Horticultural Society. Two other observations may be made from reading *The Gardener's Chronicle* of the period. First, not many landscape gardeners were advertising, and those that did tended to highlight some specific achievement such as a successful tender for the design and layout of a public park.[33] Secondly, each issue contains sections for gardeners wanted and wanting jobs. There were always more wanting jobs than wanted, and those offering their services were generally in their 30s and only occasionally in their 40s. They also tended to highlight the fact that they were childless. Ambrose would have been older, and after 1884 with children.


N.M. ROTHSCHILD ARCHIVES XII/41/4

Walton Villa
Aylesbury
3rd January
1871

Mr Dettmar Esq.

Sir. Enclosed I beg to forward – a statement of the labour acct (receipted) relating to the department of Geo. Mayne – which Sir Anthony has been good enough to give over to my charge. The Balance in hand I shall carry forward to the next pay sheet.

Yours very truly
A. L. Taylor

Fig. 5. Letter from Ambrose Taylor to John Dettmar, the accountant at the Rothschild Bank. (N.M. Rothschild Archives)

The next trace of Ambrose is as a provision merchant at Harlesden, Middlesex, about four miles from Westminster, in 1884. It may have been at this time that he met Sarah Tomkinson, by whom he had three children before emigration in 1889. It was suggested in *The Cyclopedia of New Zealand* that they married in 1884. In fact Ambrose remarried in 1889, shortly before emigrating. Presumably his first wife had died by then, but no death of a Mary Taylor of the right age could be found in the right area among the many Mary Taylors in the Registry of Births, Marriages, and Deaths at St Catherine's House. Birth certificates have not been found either for any of Ambrose and Sarah's children born before their emigration. Edgar's and Jesse's dates of birth were given at the time of their baptism in New Zealand in 1892, but no details of their elder brother's have been able to be found.[34]

At the time of his remarriage he and his new wife gave their address as 2 Mozart Street in the Queen's Park Estate, which is adjacent to Kensal Green, to the west of Paddington. They were married at the Registry Office, Paddington. This area is described in Charles Booth's famous social survey of London poverty, *Labour and life of the people*:

> *The Queen's Park Estate hardly needs any description. Houses and roads neat and clean. People sober and steady, and mostly in good regular work as artisans, clerks or railway men.*[35]

It contrasted with the other part of what was described as Kensal New Town, which was one of the six areas of Western London identified by Booth as "poor districts." However, Mozart Street had no residents recording their addresses in the 1889 *Kelly's Paddington, Bayswater and Kensal Green Directory*. Several factors may explain this deficiency. First, Mozart Street may have had no residential accommodation; or none of the residents may have been willing to have their addresses and particulars recorded; or the residents may have all been living in short-term rental accommodation and not have had the security suggested by the quote from Booth given above. The latter appears to be most likely, as plans of the day suggest that there was residential accommodation in Mozart Street, and short-term tenants were not listed in directories.[36] Perhaps the Taylors had gone progressively downhill in economic terms after the period in Rothschild employment.

Other details on the marriage certificate were also incorrect. The ages given for Ambrose and Sarah were inaccurate: Ambrose was listed as being 54 and Sarah as 28. Ambrose must have been nearly 63, from a comparison of his birth and second marriage details. Sarah was

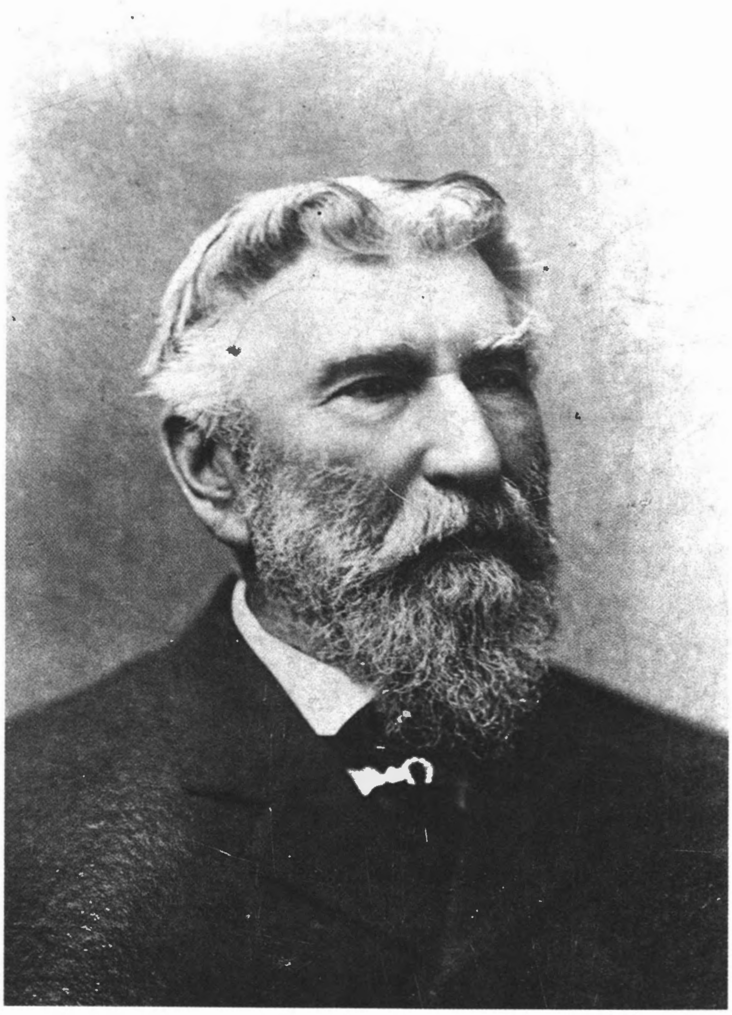


Fig. 6 *(left)*. Ambrose Lloyd Taylor; date uncertain. (Collection: Edgar Taylor jun.)

Fig. 7 *(right)*. Sarah Taylor, née Tomkinson; date uncertain. (Collection: Edgar Taylor jun.)

aged 67 at her death in 1934, which gives a date of birth in 1867, making her about 22 at the time of marriage to Ambrose.

The most likely reasons for the move to New Zealand appear to be a family connection with Christchurch and the search for employment. On 20 January 1889 a Henry Taylor, born in Oakley, Bedfordshire, aged 60, died and was buried in Linwood cemetery. He was Ambrose's younger brother.[37] Henry appears to have married a second time too, as his first wife is recorded as Elizabeth (née Beaumont) of Ampthill, but he is buried with Sophia Ann (née Allen), who was 15 years younger.[38] His testamentary records suggest that he must have been reasonably successful as a hotelier at the Clarendon Hotel, Christchurch. He left his American-born wife, his sole legatee, some £600 net. There were no surviving children of the marriage. They had married in New Jersey in 1872, and had been in New Zealand for ten years.[39] She survived him and lived until 1899.[40]

A letter announcing the demise of his brother could have reached Ambrose in time for him to decide to take his chance in New Zealand. New Zealand too was in the depths of the 'Long Depression'. It may have been seen as a land of opportunity in an era of extensive emigration from Britain, validated by the personal family experience. Although unemployment was improving in Britain in 1888–89, Malchow has drawn attention to the lag factor in related booms in emigration, which ran at a gross level of over 200,000 persons per year throughout the late 1880s.[41] Whether or not there was a connection, Ambrose and his family were in Christchurch in time for him to apply successfully for the Head Gardener's job at the Botanic Gardens in October 1889.

Ambrose was employed at the Botanic Gardens, Christchurch, for the remaining years of his working life. He did not retire until 1907, when he was well into his eighties. By that time his family had grown up in the Curator's House at the Gardens and Edgar, the prospective landscape architect, was already showing horticultural prowess in his employment.[42]

Why the family came to New Zealand remains something of a mystery. After leaving Rothschild employment Ambrose had had a declining work career. In an era when pensions were only just beginning, the availability of paid work would have been a major concern for an elderly parent such as Ambrose. Only when Edgar had obtained a stable job might he have felt free to retire. Edgar began his twenty-year period of employment with A.W. Buxton Limited, the landscape gardeners, in 1906 as the draughtsman of their landscape plans.[43] His elder brother, Master T. Taylor (in the notice of their arrival in *The Lyttelton Times*) disappeared at some stage early in the family's sojourn in New Zealand, was never talked about,[44] and appears unlikely to have been the source of this support. In the later years of his life economic survival for himself, his wife, and family seems to have been the driving force in Ambrose Taylor's life. Only when those pressures were reduced did he retire.

Acknowledgment

Research conducted in England in 1994–95 took place while I was on study leave from Lincoln University. I wish to record my appreciation to the University for the time off from normal academic duties and for the Study Leave Grant which I received.

Endnotes

1. Taylor, J.O. 'Edgar Taylor A.H.R.N.Z.I.H. – The Father of Landscape Architecture in New Zealand', *R.N.Z.I.H. Annual Journal*, no. 6, p. 70. See also M.J. Barnett, H.G. Gilpin, and L.J. Metcalf *A Garden Century*, Christchurch City Council, 1963. They imply Taylor's appointment before his arrival in New Zealand. This myth is also reproduced in '"Horticulture is in his blood", says Planner', *The Christchurch Star*, 15 December 1965, p. 4; and 'Noted Landscaper dies', *The Press*, 3 August 1979, p. 16.
2. Gardner, W.J. *A Pastoral Kingdom Divided: Cheviot 1889–1894*. Bridget Williams Books, with assistance from the Historical Publications Branch, Department of Internal Affairs, Wellington, 1992.
3. Macdonald Dictionary of Biographies, Canterbury Museum Library. Entry T.41.
4. Letter from Mrs S.D. Banks, Bedfordshire County Record Office, to Rhys Taylor, 27 Centaurus Road, Christchurch, 6 March 1989.
5. Barnett et al., pp. 46–47 [note 1].
6. Personal communication with the author.
7. Manuscript in the possession of the Taylor family, photocopied by the author.
8. See R. Tipples *Colonial Landscape Gardener – Alfred Buxton of Christchurch, New Zealand 1872–1950*, Lincoln College, 1989, pp. 40 and 157.
9. Letter from Michael Pearman, Librarian and Archivist to the Trustees of the Chatsworth Settlement – Devonshire Collections, 26 May 1993.
10. Published by Longman, Brown, Green and Longman, Paternoster Row, London in 1845. The book was given by Edgar Taylor to Lawrie Metcalf on the 16 September 1965 and is held in his personal library.
11. *Op. cit.*, 1972, November, p. 21.
12. Blakiston, Georgiana, *Woburn and the Russells*, Constable, London, 1986, pp. 190–193.
13. Letter from D.M. Short, Assistant Librarian, Royal Botanic Gardens, Kew, to Rhys Taylor, 27 Centaurus Road, Christchurch, 10 March 1989.
14. Letter from Short, 10 March 1989 [note 13].
15. Letter from Simone Mace, Archivist, The Rothschild Archive, New Court, St Swithin's Lane, London EC4P 4DU, to Rhys Taylor, 27 Centaurus Road, Christchurch, 3 March 1989.
16. Letter to the author from H.A. Hanley, Buckinghamshire County Archivist, 30 March 1993.
17. *The Gardener's Chronicle*, 1880, p. 244.
18. *The Gardener's Chronicle*, 1880, pp. 145–147.
19. *Kelly's Post Office Directory for Middlesex*, 1878, London.
20. Tipples, R., p. 40 may be incorrect on this point [note 8].
21. Wilson, D., *Rothschild: a Story of Wealth and Power*, André Deutsch, London, p. 256.
22. 'The Gardens at the Turn of the Century', *The City Beautiful*, 54, No. 2, April 1973, pp. 21–22.
23. J.O. Taylor, *op. cit.* [note 1].
24. Canterbury Public Domains Board, *Letter Book – Outward Letters* [undated], p. 90. Held by the Information Centre, Christchurch Botanic Gardens.
25. *Ibid.*, p. 94.
26. *Ibid.*, p. 98. Letter dated 13 November 1889 to Ambrose Taylor, St James Terrace, Carlton Mill Road.
27. *Op. cit.*, p. 130.
28. Christchurch Domain Board *Minute Book*, p. 208. Minutes of meeting 11 December 1889.
29. Comber Index of Shipping, arrivals; *Lyttelton Times*, 31 May 1889; National Archives Official Transcript, Reference SS 1/26, of passenger list for the *Ruapehu* arriving Lyttelton, 30 May 1889.
30. Franklin, Jill 'The Victorian Country House', Chapter 29 (particularly pp. 410–411) in G.E. Mingay (ed.) *The Victorian Countryside*, Routledge and Kegan Paul, London, 1981.
31. *Ibid.*, p. 1276. The changed spelling may have been accidental. No other Ambrose Lloyd Taylor or Ambrose Lloyd Tayler has been found either in Directories or in searches of the Registry of Births, Marriages, and Deaths at St Catherine's House, London.
32. Davies, Richard [1983] *The English Rothschilds*, William Collins and Sons Ltd, London.
33. *The Gardener's Chronicle*, 1880, p. 482.
34. *Church Register of Baptisms*, St Michael's Church, Christchurch, Diocese of New Zealand. Baptisms – numbers 77 and 78, 9 October 1892.
35. Louise Buckingham of the staff of the *Directory of New Zealand Biography* obtained a copy of the original Marriage Certificate for me when I was writing about Edgar Taylor for the *Dictionary* in 1993.
36. *Loc. cit.*, Appendix to Volume 2, Maps etc., p. 9, Williams and Norgate, Covent Garden, London, 1891.
37. Whitehead, Jack [1989] *The growth of St Marylebone and Paddington: From Hyde Park to Queen's Park*, J. Whitehead, London.
38. Henry Taylor, fourth son of John and Elizabeth Taylor of Oakley, was born on 21 August 1828, making him 60 at his death in January 1889. Source: family tree and census records provided by Mrs S.D. Banks, Bedfordshire County Record Office to Rhys Taylor, 27 Centaurus Road, 6 March 1989.
39. Letter from Bedfordshire Record Office, *op. cit.*
40. Probate records for the will of Henry Taylor, died 20 January 1889, held by National Archives, Department of Internal Affairs, Peterborough Street, Christchurch, and Death Certificate.
41. Headstone of Henry and Sophia Ann Taylor, buried in Linwood Cemetery, Christchurch. No death certificate has been able to be traced.
42. Malchow, Howard L. *Population Pressures: Emigration and Government in Late Nineteenth Century Britain*, S.P.O.S.S. Inc., Palo Alto, California, pp. 8–10.
43. Tipples, *op. cit.*, pp. 40 and 43 [note 8].
44. Tipples, *loc. cit.*, pp. 40 and 43 [note 8].
45. Edgar Taylor jun. told me that his father, Edgar sen., would never talk about his 'lost' brother. No records of him have been found.

Proceedings of the First
NEW ZEALAND TREE SYMPOSIUM
Rotorua, 11–15 August 1994

Interspecific Hybrids in the Cypresses

M.H. Bannister
P.D.C. Lake Okareka, Rotorua, New Zealand

Summary

Since 1950 several individuals of putative F_1 Cupressus macrocarpa × lusitanica *have been found in the North Island of New Zealand, and descendants of this combination have been studied to the third generation.*

There are indications, especially from the South Island, that spontaneous hybridisation, segregation, and back-crossing may have taken place between C. macrocarpa *and* C. arizonica *and possibly* C. sempervirens.

A primitive backyard programme of artificial selection, beginning in 1982 with a second-generation segregate of C. lusitanica × macrocarpa *open-pollinated to* C. lusitanica, *has resulted in one or two hybrid clones that look promising for plantation forestry.*

It is suggested that a well planned programme of artificial selection, able to draw on the genetic variation of two, three, or even more species as its basic genetic reservoir, would have the potential to generate valuable new hybrid genotypes. On suitable sites these might be able to out-perform the original species.

Introduction

In their natural habitats the cypresses (i.e., those species usually included in the genera *Cupressus* and *Chamaecyparis*) are confined to the Northern Hemisphere, in Africa, Europe, Asia, and North America. Present estimates of the total number of species vary between about twenty and thirty. For the most part these are genetically isolated from each other, the distances between them so great that physical isolation alone would preclude any natural hybridisation. Within several of the species, also, one finds the same effective barrier preventing cross-fertilisation between small, isolated populations. The isolation seen today has probably been in effect for many generations, so that seed collected from a natural source, as distinct from a cultivated one, is not only likely to be inbred, it may also have evolved into a separate entity, genetically distinct from all others, and possibly divergent from them in one or more morphological characters. This phenomenon lies at the heart of some persistent taxonomic problems in the cypresses. The question arises repeatedly: Is a certain provenance or isolated population a local race, or is it a variety, a subspecies, or even a distinct species?

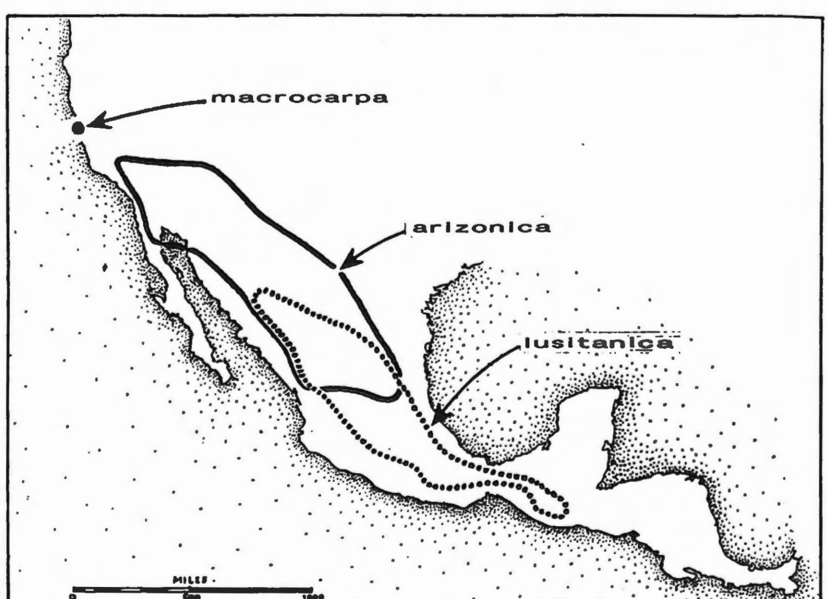
The studies reported here deal with three species in particular:

(1) *C. macrocarpa.* So familiar in the New Zealand countryside that it scarcely needs introduction, this is native to a very small area on the coast of California (Fig. 1). The population of the species in its natural state has been estimated at only 10 000 individuals.

(2) *C. arizonica.* As interpreted by some modern botanists, this is a series of populations, most of them widely separated from one another, and including entities that have had bestowed on them the names *C. arizonica, C. glabra, C. nevadensis, C. stephensonii,* and *C. montana* (Fig. 1). In the north-east and north it occurs, far flung, in Texas, Arizona, Nevada, California, and Baja California. It appears to be more common to the south, in Mexico, but as scattered trees or groups rather than in continuous stands. Like any species fragmented and scattered over such a vast area and such a wide range of habitats, *C. arizonica* can be expected to have a complex pattern of genetic variation.

(3) *C. lusitanica.* Although there may still be a few dissenters, it is generally accepted nowadays that this species incorporates all the cypresses variously

Fig. 1. South-western North America, showing the outer limits of the natural distribution of three *Cupressus* species.



described as *C. lusitanica, C. lindleyi,* and *C. benthamii.* It is native to the highlands of Mexico and Guatemala (Fig. 1). There are countless discontinuities in its distribution, so that inbreeding and 'genetic drift' have probably played an important part in the evolution of local races. At any rate, its morphological variation is wide, bewildering, and the despair of typologists.

Spontaneous Hybrids

C. arizonica × *macrocarpa*

My first introduction to interspecific cypress hybrids was in 1954. During the following five years or so my attention was concentrated mainly on *C. macrocarpa* and *C. lusitanica,* because they seemed to be the two species involved. But during that period the initial problem was complicated by a series of samples from shelterbelts in Southland, sent to me by K.W. Allison (then Senior Forest Ranger in Dunedin and a highly respected botanist), who asked me to determine their species. I had to reply that I certainly could not refer any of them to a species, but suggested very tentatively that they might represent one or more hybrid swarms involving *C. macrocarpa* and *C. arizonica.* This I was unable to pursue with proper morphological and experimental work; but I did note also, in North Auckland, another unusual shelterbelt which possibly incorporated hybrids between these species.

Fig. 2 *(right).* A conspicuous tree, tentatively assigned to *C. arizonica* × *macrocarpa,* in a shelterbelt near Ruawai, North Auckland, showing signs of hybridism.

Its most conspicuous features were that the trees were nearly all of short, bushy habit and soft green in colour, but varied greatly in the details of foliage and cones, while a few were much taller and dark green. Close examination of one of these (Fig. 2) showed that, although it seemed to have an affinity to *C. macrocarpa,* it also seemed to be outside the range of morphological variation for that species.

Most of what I know about this subject is only superficial, but there is experimental evidence that the two species can produce an F_1. That was the work of my colleague J. McGuffog. He had a specimen of *C. arizonica* in his garden in Marguerita Street, Rotorua, and successfully bagged and pollinated female

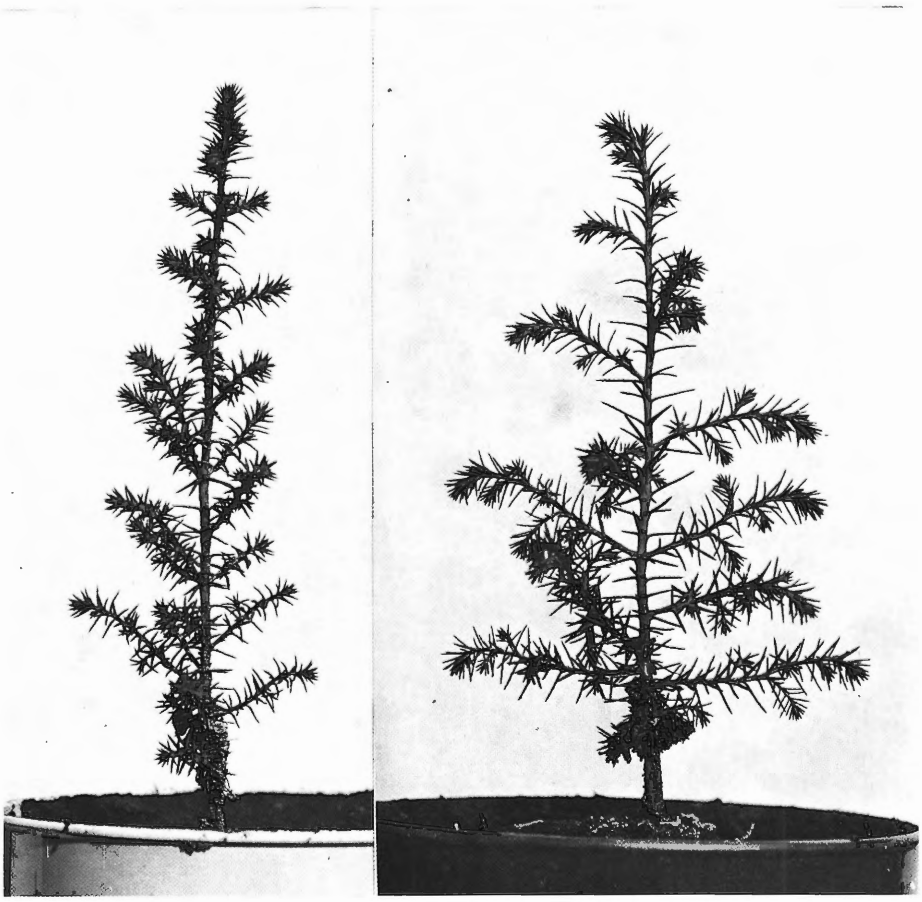


Fig. 3. Year-old seedlings of *C. macrocarpa* (left) and *C. lusitanica* (right). Photographs: W.J. Wilson.

conelets with *C. macrocarpa* pollen about 1957. There can be no doubt that he succeeded in producing an artificial F_1 of *C. arizonica* × *macrocarpa:* there are five robust trees in the arboretum for all to see, out of seven originally planted.

C. arizonica and *C. lusitanica*

There appears to be no experimental evidence for the existence of hybrids, past or present, between these two species. Circumstantial evidence, however (Martinez, 1947; Dyson, 1973) suggests very strongly that where their distributions overlap in Mexico (Fig. 1) natural hybridisation has taken place on such a scale that it has largely blurred the distinction between them in that region. It has even been suggested, more than once, that these two species form a continuum, and that Arizona cypress would be best classified as a variant of *C. lusitanica.*

Whether or not one accepts that concept, one may feel confident that it would be easy to produce artificial F_1 and later generations of hybrids between these two.

C. lusitanica × *macrocarpa*

Putative spontaneous hybrids of this origin were described by Gomes and da Costa (1943) in Portugal. The first F_1 to be recognised and convincingly determined in New Zealand was also of spontaneous origin, having germinated as an adventive on the farm of F.W. Bartlett near Silverdale about 1924. All the evidence – circumstantial, historical, and morphological – pointed to *C. lusitanica* and *C. macrocarpa* as the parent species, but the most telling evidence came from the segregation pattern revealed by its open-pollinated progeny. Although this may well have included some backcrosses it had all the hallmarks of an F_2.

Fortunately for the observer, the parent species are visibly quite different, even in the seedling stage (Fig. 3). *C. macrocarpa* has a stiff, erect stem, a narrow conical habit, generally very subordinate and stiff, somewhat ascending branches, and an intense green colour overall. *C. lusitanica,* despite wide variation, characteristically has a diffuse or 'fluffy' look; the apex of the stem curves away from vertical, and the lateral apices curve downwards; and the colour is a soft bluish green, often tinged with mauve or pink.

One-year-old seedlings from the Bartlett hybrid showed the expected range of variation, with various combinations of characters from the two species. The display was even more impressive when the two-year-old progeny was planted in the arboretum: among all the unfamiliar forms and colours one could single out one or two young trees that would easily have passed inspection as 'good *C. macrocarpa*', and one or two others that would have passed just as easily as 'genuine *C. lusitanica*'.

Fig. 4. A second-generation hybrid of *C. lusitanica* × *macrocarpa*. At 35 years of age this had attained a height of 41.4 m and had a breast-height diameter of 90 cm.

About 14 of these second-generation hybrids have survived and are now 35 years old. There has been no control whatsoever over their parentage. Their mother was a tree of most undesirable form, and they have had no silviculture other than low pruning; yet even so some have produced raw material that a timber merchant would consider well worth sawing. Of special interest is one individual that has shown an extraordinary growth rate and now towers above its half-sib neighbours (Fig. 4).

In addition to the Bartlett hybrid, other putative F_1s of spontaneous origin were found in the North Island. Forty years ago G.H. Hocking (a Senior Forester then based in Palmerston North) knew of two or more; J. Cox (a Forest Biology Observer based in North Auckland) found another near Kerikeri; and I have noted at least one more on the Bartlett farm, and as many as six within a ten-mile radius of Rotorua.

But that was only a beginning. There is every indication that any individual tree of the F_1 combining these two species is highly fertile. Consequently seed collected from it – and also seed collected from others within range of its pollen – may be raised as one species or the other by mistake. I have no doubt that this expectation has been realised repeatedly in the North Island, where in several districts (Warkworth, Whangarei, Tamahere, and the Hauraki Plain) I have seen shelterbelts that seemed to be hybrid swarms. At Rotorua *ca* 1981 I even saw a big bed of about 10 000 seedlings which showed all the combinations of size, habit, colour, and smell imaginable for a *C. lusitanica* × *macrocarpa* F_2

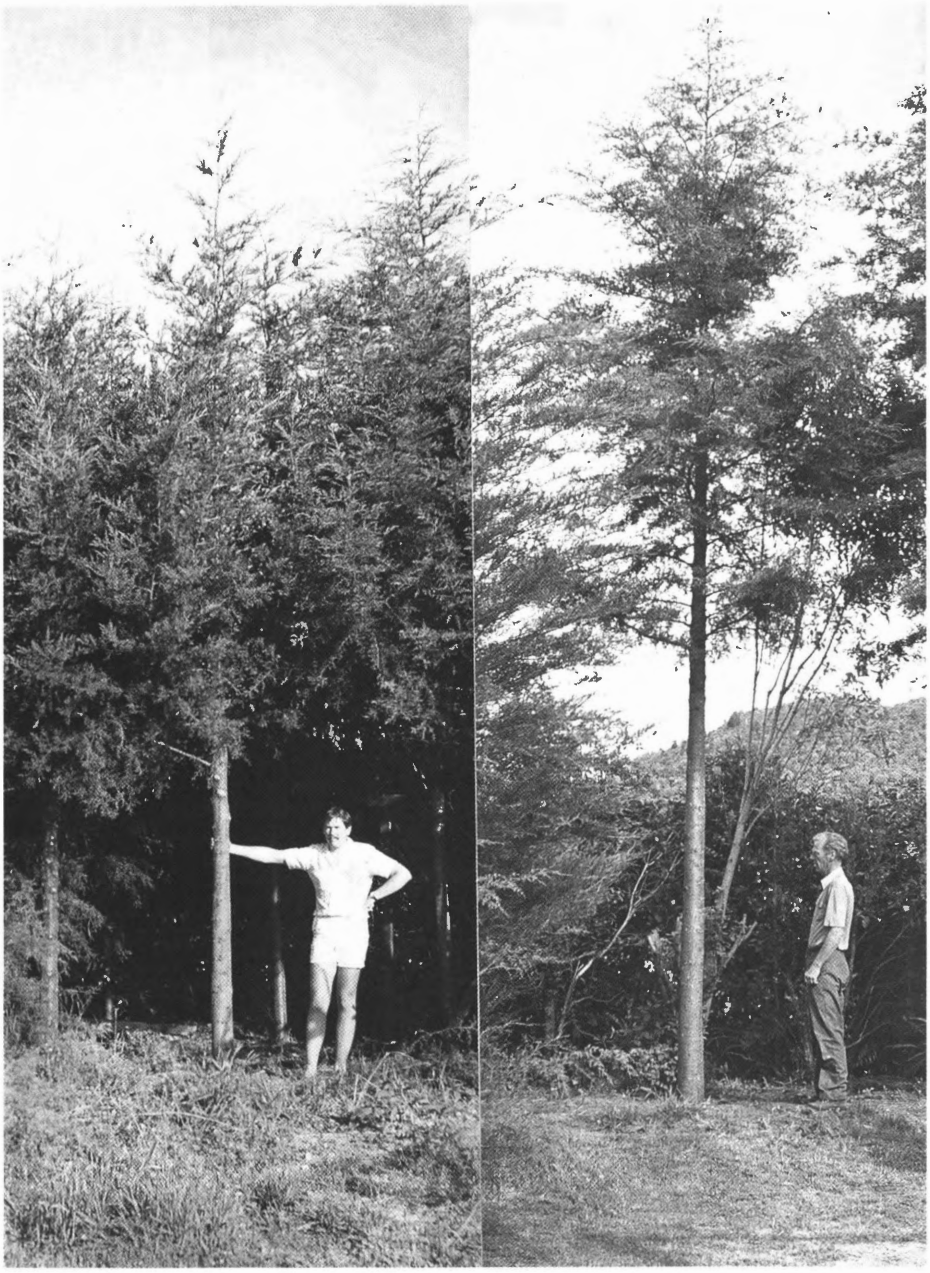


Fig. 5. Two selected hybrids of *C. lusitanica* × *macrocarpa* believed to be the result of two generations of back-crossing to *C. lusitanica.*

or hybrid swarm; yet they bore a label proclaiming that they were a single species, and carried a seedlot number registered in the Head Office of the New Zealand Forest Service.

Even the Forest Research Institute in Rotorua has had the experience of spontaneous hybrids, almost certainly second generation.

C. lusitanica × *macrocarpa* hybrids showed up unexpectedly in a seedlot that was supposed to be *C. lusitanica.* How this happened cannot be explained, but they offered an opportunity for further study of hybridism and, at the same time, a chance to see whether a backyard programme of artificial selection could produce individual hybrids with silvicultural potential.

First, the most outstanding hybrid was felled. Knowing the virtues of the two parent species when converted into timber, and having had some experience of them both for boat building, I took its butt log home. It was only 20 years old but produced excellent material, which was very pleasant to work.

At the same time I saved all its seed, and, having confirmed its hybridity by testing its progeny for segregation, selected 20 of them – presumably backcrosses to *C. lusitanica* and hybrids of at least the third generation – and grew them in my garden.

Soon they grew too big and had to be destroyed, but some of them had already shown promise as saplings (Fig. 5), and their genotypes are conserved as clones.

Conclusion

This report has presented only three species as capable of hybridising one with another, but experience in other parts of the world has shown that other species of cypress hybridise too. Adding them to the first three, we may draw up a list of combinations, each of which may be regarded as a fait accompli:

C. macrocarpa × *arizonica*
C. macrocarpa × *lusitanica*
C. macrocarpa × *Chamaecyparis nootkatensis*
C. arizonica × *Chamaecyparis nootkatensis*
C. lusitanica × *Chamaecyparis nootkatensis*
C. arizonica × *C. torulosa* (L.D. Pryor, pers. comm.)

To these may be added other known or putative hybrids:

C. macnabiana × *sargentii*
C. arizonica × *sempervirens* (Piskoric, 1962)
Chamaecyparis pisifera × *obtusa*

Finally, there appear to be grounds for believing that *C. macrocarpa* × *sempervirens* has arisen spontaneously in the South Island, and possibly in the Northern Hemisphere too.

Some of the hybrids of today are being used to good effect: one has only to see how Leyland cypress is superseding *C. macrocarpa* as a favourite for shelterbelts and hedges. Some of those of yesteryear have, according to Dyson (1973), provided a transfusion of genes from *C. macrocarpa* into *C. lusitanica,* probably contributing thereby to the great success of *C. lusitanica* in East Africa. Hybrids of the future may facilitate the synthesis and selection of new and highly valued cypresses, which would most likely be propagated as clones. The reservoir of genetic variability must be enormous.

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The Eastwoodhill Arboretum

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Introduction

For the last nine years I have had the privilege of living at and working as the Curator of Eastwoodhill Arboretum for the Eastwoodhill Trust Board. We have there some of the finest autumn colour scenes in New Zealand, but I fear we are in for some competition. With over 10 000 acorns of our scarlet oaks disposed of annually to three major New Zealand nurseries for the past six years, I think we will have some very colourful parts of New Zealand in another 40 years during the April and May period.

This address glosses over a lot of the details of various people's involvement and situations, covered in other publications relating to Eastwoodhill.

Botanic Garden or Arboretum ?

In this country we have two options when we want to do some serious exotic botanising: we can visit a Botanic Garden or an Arboretum. The three Botanic Gardens located in Dunedin, Christchurch, and Wellington are the ones I traditionally think of, Christchurch Botanic Garden being the source of my own inspiration. More recently the Auckland Regional Botanic Gardens have become a positive force to be reckoned with, especially with its active Friends organisation, but are not yet a place to study larger trees.

Many Botanic Gardens have an arboretum, but an arboretum is not in itself an alternative to a Botanic Garden. What, then, is an arboretum ?

An arboretum is a tree collection or a tree garden. The origin of the word is Latin, and I have seen it written that it comes from gardens of trees grown to support the vines that produced the grapes for the wine. Although we do attempt to grow grapes up some trees at Eastwoodhill, regrettably *Vitis coignetiae, V. amurensis, V. riparia,* and *V. betulifolia* have no reputation for any alcoholic products.

Most of the world's arboreta are attached either to a Botanic Garden or to a teaching institution, normally a university. One of the world's most notable is the Arnold Arboretum at Harvard, funded and supported by that University and the various foundations associated with it. In New Zealand most have been privately established and have begun in a farm setting.

The various botanic gardens in New Zealand have been long established from an initial vision of the city's founders, with the financial backing of their local Council. Over time they have become such a focal point in their district that even the most critical cost-cutting Council would have severe reservations about holding the knife too tightly above its Botanic Garden.

The various arboreta in New Zealand are the result of an individual vision followed by a time-consuming passion to collect, create, find more, and plant. The personal desire to accumulate a serious collection is more easily realised than is convincing a committee to do likewise. Moreover, the ability to plant in whatever chosen manner, often with many idiosyncrasies, is tolerated when done by an individual. Try doing that with a committee and a consensus decision. Standard 'landscaping practices' are often not considered, and this *can* lead to problems later. However, if we regard Mother Nature herself, who casts out many thousands of individuals on the way to the climax forest, most private collections can be transformed over time through judicious use of a chainsaw. Eastwoodhill today, highly regarded by many, is the result of much considered reworking of the planting through removal of old shelter belts, thinning of some plantings, and arboriculture work.

Arboreta seem to be dedicated labours of love, but destined for 'the public good'. They have proved to be very important sites in the preservation and understanding of exotic flora in this country. Funding for their establishment has been restricted to what could be drawn from the personal fortunes of their planters; public or official funding is almost unknown. Future management and tenure of the plantings is most often not initially secure, and requires consideration later on.

New Zealand Arboreta

The main arboreta in New Zealand are 'McLaren Falls' near Tauranga, 'Hackfalls' at Tiniroto near Gisborne, 'Orton Bradley Park' near Diamond Harbour, in the Christchurch area, and 'Eastwoodhill'. Others of note, though smaller, are 'Torwood', the species conifer collection of Ian McKean at Rangiwahia, the Pinetum at Lake Coleridge, and the remnants of the Adams's collection 'Greenbank' near Rakaia. The latter was once a fine collection but has deteriorated badly. All these arboreta were established with dedicated amateur enthusiasm and, in all but Orton Bradley and McLaren Falls, through the energies of a *single* individual. The resulting collections are admirable, their extent is a tribute to what unbridled and lustful enthusiasm can generate. For example, Bob Berry at Hackfalls has collected over 190 different species, hybrids, and cultivars of oak alone.

McLaren Falls has recently begun writing a management plan. This was initiated through the Tauranga District Council, which is now well involved in its future management. So although the collection was set up by voluntary means, through the Bay of Plenty Tree Society, the district has recognised its worth and is attempting to put something together to secure its future directions.

Hackfalls Arboretum, although protected under a QEII Covenant, is still privately owned and operated. Concern for the future has also motivated owners Bob and Anne Berry to set up a charitable trust, and to seek funding to enable the collection to be adequately maintained for the future. Even if there is no further expansion, there is still ongoing work that will need to be done to keep this premier collection in good heart.

Eastwoodhill has become a main tourist attraction for the Gisborne district, and is the premier botanical park for local people's recreation. However, the Council provides no funding for it apart from a remission of rates. Gate receipts (limited), special project grants, donations pursued by the Friends of Eastwoodhill, and interest from the endowment fund are the means by which Eastwoodhill keeps itself going. Those, and a generous Chairman whose family trusts are often called upon to meet the deficit. Staff levels are restricted by an inability to pay for any more than its present two workers.

Eastwoodhill and Douglas Cook's Story

Eastwoodhill as a major garden and collection was established from 1918 onwards when its creator William Douglas Cook was 34 years old. By 1923 he had stated his intention that it was going to become a major garden for New Zealanders. His creation was bedded in a love of horticulture that went back to his school days. While recuperating from war wounds received in France in 1917, Cook became in awe of the great gardens surrounding the stately homes of both his Scottish relations and their friends. The seed that was planted, to become the treasure of today, was sourced from Scotland.

Impressed, he later wrote "*... that I too could have lovely surroundings, even if I could never have a fine home and live as they did. That was the start of the park. A dignified park to drive through to my home, – whatever its size. Set your heart at an objective and believe in your heart you'll achieve it and you will. Where most ... fail is in lack of faith in themselves.*"

The name Eastwoodhill, though well suited to the now wooded hilly terrain on Gisborne's East Coast, has its actual origins in his mother's family home in Thornliebank near Glasgow.

Incidentally, at this time he visited Kew, and from Arthur Hill – later Sir Arthur, who become the Kew Director – received a plant each of the red and variegated cabbage tree which he brought back to New Zealand in his pack, thereby introducing these varieties into this country.

A Cook family quotation reads: *"He who would do some great thing in this short life must apply himself to work with such concentration of his forces as, to idle spectators, who live only to amuse themselves, looks like insanity"*(from Parkman).

Douglas Cook's dedication to his task was almost total. His enthusiasm meant growing isolation from many of his neighbours. Some aspects of his lifestyle were at variance with the local norm. Let's face it, working naked about your property was rather bold in the era between the 1920s and 1950s. But I wonder if planting such large areas of trees – and then those not even plantation trees – was even stranger and more of a nonsense to those pastoral farmers. The level of understanding and forgiveness was so much less then than it is now.

Douglas Cook planted a garden, not an arboretum. He did not see that there was any need to separate the classes of plant material. The strength was trees and shrubs. But in those early days, while the soil was not yet ramified by tree roots, the bulbs, perennials, and smaller shrubs found homes beside paths where the soil had been dug out and laid to give a greater depth. As the years passed the growing shade changed the mixture but, even today in our 'Cedar garden', remnant spring crocus still bloom some 60 years after their first planting.

Cook purchased plant material widely from within New Zealand until 1936, when he decided he had acquired all that New Zealand had to offer. The time was then ripe for an overseas trip. He went to Kew and met with the Director, Sir Edward Salisbury, and curators Campbell and Pierce. They took him to many places and gave him an open letter of introduction to the owners of any garden he wished to visit. As he returned home he filled out the order sheets accompanying the nursery catalogues he had collected. The material began to arrive, halted temporarily by the Second World War. It grew in numbers when the wild-collected material from China was still available. The Cold War of the mid 50s caused him some concern, and he pushed ahead even more strongly to collect all that was deemed good and would grow in his garden. He also tried many plants that would not grow so well, but all of this was so that in the event of a nuclear war in Europe, material would be safe and would be able to be returned there at a later date.

Planting continued up to his death at the age of 84 in 1967. As the years progressed he was unable to maintain the grounds, apart from mowing the main tracks for access. However, even at the age of 79 he still expanded the plantings by taking in a further 25 acres. The vision for the garden still continued. He knew he was not planting for himself. He was planting for future New Zealanders. At the time of his death he had planted 160 acres in over 5000 different species, hybrids, and cultivars. He had also spent a fortune.

RNZIH Involvement

In the early 1960s the Royal New Zealand Institute of Horticulture almost found itself the owner of Eastwoodhill. Douglas Cook was endeavouring to donate, through the Executive of the time, not only the garden but the house and all its contents including fine antique furniture, artworks, Persian carpets, Georgian silver, and his library. He was prepared to give it all to secure Eastwoodhill's future. However, the Executive of the RNZIH appreciated the crunch item that pertains to maintaining any great garden ... *funding*. That stopped the RNZIH from taking the garden, caused great anguish and finally bitterness to Douglas Cook, and left Eastwoodhill in a precarious position. What to do with this collection? What of its future? Douglas Cook now was really in despair.

Private Purchase and Formation of Trust Board

Fortunately for Eastwoodhill and New Zealand, the best of all possibilities happened. Eastwoodhill was purchased privately in 1965 by Mr H.B. Williams. Probably he alone was able to draw all things together so that Eastwoodhill was protected from any damage through cattle browsing or wanton milling. He then held it in limbo until permanent protection was found, namely the privately introduced Act of Parliament of 1975 that established the Eastwoodhill Trust Board, and then the establishment of an endowment fund by Mr Williams's mother.

The income from the Arboretum today covers about 20% of our annual costs. We depend on the income from the now enlarged Endowment fund, and on special project grants generated by the activities of the Friends Association to cover the rest.

With a growing financial backing, the Trust Board then moved to begin the tidy-up process, using whatever labour various service groups could muster, as well as Periodic Detention and PEP work schemes. In 1985 a Friends organisation was formed to raise finance and promote the arboretum. That group is now an essential part of the life of Eastwoodhill. With additional finance becoming available through donations from various trusts, the QEII National Trust, and the Lotteries Commission, who funded some specified projects, the Trust Board could then begin further works, and the tidying up was pushed ahead. At the same time new planting was again able to take place.

International Dendrology Society Involvement

When the International Dendrology Society visited New Zealand in 1976, it was itself in the process of urging action to save 'La Mortola', an Italian garden of note that had suffered from the ravages of the Second World War and subsequent neglect. Noted garden author Hugh Johnson, known to RHS Garden readers as Tradescant, suggested that a plaque for arboreta deserving special recognition be instigated. In 1977 the International Dendrology Society conferred the Society's first Award of Merit upon Eastwoodhill.

The Society visited Eastwoodhill the year after it became the property of the Trust Board. At that stage, overgrowth and undergrowth covered much of the area, and dead and fallen trees lay all about. An air of neglect and senescence pervaded, and yet through this the competent botanists who made up that visiting group saw the wealth of a strong and unique collection.

It was stated subsequently that Eastwoodhill Arboretum, in the mid 1970s, was thought to have contained the largest collection of Northern Hemisphere trees and shrubs in the Southern Hemisphere. The status of that claim is today probably rather more tenuous. There has been a real surge of interest in the planting of exotic material in both New Zealand and Australia in the last two decades. In private and public gardens, with the growing availability of plant material from East Asia and Central and South America, a resurgence has occurred in the planting of premier woody plant material, with species not seen since before the Second World War. At the time that the collection at Eastwoodhill was going through its initial assembly from 1928 to 1965, very few gardeners were making collections of the same nature and scale.

In Australia, for example, the collection of plant material differed in its composition from that being assembled in New Zealand. In the late 1980s Peter Cave was exporting grafted plants to an Australian nursery as first introductions to Australia of material imported into New Zealand through Eastwoodhill as early as the 1940s. Such is the result of the work of the eager enthusiast and collector.

Expanding the Plant Collection

Today at Eastwoodhill we are again expanding the collection. If Douglas Cook were alive today, he would relish the variety of exotic plant material available courtesy of some very avid plant collectors, such as Stephan Halloy in Argentina and Bob Berry in Mexico. Let us note also the opening up of the wealth of China's flora with Ron Gordon and Pukeiti, the many excursions into the Himalaya with Alan Jellyman, and good introductions from Korea through the Chollipo Arboretum. Then the private importations through Peter Cave, Glyn Church, and Michael Hudson, not forgetting the conifers through Ian McKean, Don Tantrum, and Noeline Sampson. Appleton's and Top Trees complete a strong circle of dedicated plant enthusiasts who have made a tremendous impact on the new collection at Eastwoodhill.

Our involvement with members of the International Dendrology Society has resulted in about 90% of all our new plant material being gifted. The frequent comment has been, "Eastwoodhill has contributed so much to New Zealanders, it is only proper that we return something." Douglas Cook purchased over 90% of all his planted material. He was worried that people would forget what he was doing. How thrilled he would be to see how people regard his creation today.

In 1984 Eastwoodhill contained 340 genera comprising over 3000 species, hybrids, and cultivars. Today we have over 500 genera of woody species, and I have not yet counted the individual unique species. But for example, the pine collection in 1984 was 28 species, today it is over 100; oaks were then about 84, today 120; alders then 11, now 37 ... and so it continues. Out there in our community are some very eager individuals who have made the ornamental horticulture scene in New Zealand so much richer – and I don't mean in money for their pocket. They are dedicated plantspeople who are continually seeking new species and adding to their knowledge of those plants and the situations in which they grow. They are also very interested in the nature of the country and the peoples of those areas. Sadly, recent regulations regarding seed importation will alter many aspects of this understanding of the world's flora.

The planted area of Eastwoodhill has grown from 160 acres in 1984 to just under 200 acres today. The general public are still led only through the established collection, as this is mostly what they wish to relate to.

One of the difficulties for us at Eastwoodhill has been to keep up, as well as possible, with this flood of plant material and all the work that it involves. At the same time, and with limited labour, we need to translate Eastwoodhill into a public attraction of a sort that Douglas Cook did not have to cope with under his private ownership.

Difficulties of Interpretation Facing Eastwoodhill and Other Arboreta in New Zealand

All of the arboreta in New Zealand are largely administered by concerned amateurs. They all face the same problems in dealing with public attention, and all, except perhaps Orton Bradley, have had to face problems dealing with public access long after the arboretum has been planted. From Eastwoodhill's perspective I now will deal with some of the various problems that have faced us.

We cover a large area, 160 acres plus, with many well graded tracks covering the property; this can confuse visitors as to direction. We found many returning on the same track to and from the ponds, so that they did not get lost. Frequently placed maps and track names were not enough. A track network, with five colour codes all marked from the carpark, was established to give ease of access to large parts of the property. Once this was completed we noticed immediate use of all these tracks; grass-surfaced tracks suddenly got worn out.

Acknowledgments go to the Whakarewarewa Forest Park, here at Rotorua, for giving me the initial concept of a track marking system that I could use at Eastwoodhill. We found that the Gisborne Taxi Bus Company's route markers were well suited to our purpose, with a 20 × 20 centimetre square steel plate covered with a coloured plastic coating and a white direction arrow, all on a half-round post. No more having to explain the way. It is a joy to see children leaving parents back at the carpark and running the route, feeling safe and confident to explore on their own.

Tidying the grounds was a major job, but it improves the public's awareness that the property is being cared for, and also reduces the summer fire risk. This was a major task that took many years. It required clear-ups and huge fires over many months, use of the chipper, and then subsequent grazing. It is now largely in order, with minimal on-going effort.

Then there was the need to address the arboriculture work, removing the many flaws and problems of the 60-plus years of growth. Mr Cook believed in letting a tree take its own form. I still hold with that but it is imperative to make sure that unsafe branching habits are corrected, remedied, or prevented. It has been a thrill to have the attention of each year's intake of the Waikato Polytechnic's arboriculture course. So much work has been done with their assistance. We could still cater for a full-time arborist on the staff.

It has also been highly necessary to enlarge on the catalogue to produce an arboretum-held database, enabling identification of each and every tree in the collection. Major work was done in the past by Bob Berry on establishing a grid system, locating and identifying the collection from his own knowledge and using Mr Cook's plant purchase notebooks to identify some 3000 different trees, shrubs, and climbers. His work was followed by Marion MacKay, who took the whole catalogue into map form, thus permitting identification of material not already noted and giving the basis for a future computer mapping system. Hours and hours of data entry has followed for me, plus field checking, and reference to plant purchase records to tie a plant on the ground with a possible date of purchase, to finally giving each tree its unique accession number. I have encouraged knowledgeable visitors so as to check identification, sources, and personal knowledge of certain plant material.

An interesting moment was when I found that a certain *Prunus kanzakura rubra* was in reality another form of *Prunus campanulata* (sold through a major New Zealand nursery in the 40s). It differed enough from the normal form being sold for a new name to be invented to sell the line. Bill Sykes, Marion MacKay, and I laboured a long time over the identity of this tree, referring to library books, checking cherry lists throughout the world, and Bill writing to various noted authorities on cherries ... until the mystery was suddenly disposed of in an offhand comment by a visiting former staff member of that nursery.

Following on from this inventory comes the task of progressively labelling the entire collection with easy-to-read labels on every tree on a main track, and smaller labels hanging from a branch in other parts. We will have to allow eventually for over 6000 labels. While catalogues are essential and useful tools for the enthusiast, the public need the name right there on the tree that interests them.

Because of our limited staff and volunteers, we are not able to personally give directions or information to visitors. We have begun the task of producing interpretive material to enable the public to enjoy and understand aspects of the collection and arboretum at different levels. This has begun, but is far from completion. Only two of seven guides to selected walks are as yet available. At this point there is only one person able to write them, the curator. A difficulty comes in having no permanently manned point of sale. There is a great need to generate material on information boards around the arboretum. People do want to be informed. It is a pleasure to deal with knowledgeable and interested people, and even people who are simply enthusiastic are worth spending time with. Time is at a premium when staff levels are so low.

With about a thousand primary and intermediate school children visiting each year we must have educational material for primary school children available. Some funds have recently been granted, but not as yet the time or skill to put something together. It is imperative that this be done, as in these enquiring young minds is such potential for the community's future attitudes. Many school visits use their time for writing poems, stories, and literary appreciation. We have much to teach, and must assist in the moulding of young minds regarding tree consciousness and all its associated values.

Lastly in this list, but by no means the last of our problems, is gaining access to considered advice and guidance for various aspects of the collection. With able assistance from a group of horticulturists from various disciplines, we now have a Plant Advisory Committee that meets annually. Over time the knowledge of this group can be applied to specific and general problems that we have. A list of key genera has been established, so directing the focus of the collection into those species thought to be better suited for the region of New Zealand in which we are located. For example we have selected *Cupressus, Callitris*, and *Widdringtonia* rather than *Abies* and *Picea*, except where there are species in those last two genera that are from similar climatic regions – Mexico or Spain, not Alaska or Siberia. We are attempting to turn this tree garden around, and to reform it as a scientifically and educationally valid arboretum.

If only we had many more staff or labour units ! Presentation of the Arboretum has been affected by our low staff level. It depended on the involvement of service groups in the early days, and more recently on Justice Department Periodic Detention detainees. An article in the RHS 'Garden' stated that at Kew they employed one person per quarter acre, and at Sheffield Park one person per 8 acres. At that rate Eastwoodhill should have 640 people if we aimed at a Kew presentation or research level. But as Sheffield Park is the type of presentation we are aiming at, we would have 24. We have about six labour units working at Eastwoodhill, made up of the two permanent staff (myself and my assistant), a voluntary women's garden group, and the P.D. detainees; six labour units on nearly 200 acres, with 100,000 visitors and over 1000 school children visiting each year.

Eastwoodhill Today

We are located in the Ngatapa country district of Gisborne, half an hour's drive and 35 km by road north-west of Gisborne.

Although we are not on a main through route, the hill that forms our backdrop was an important Maori foot access to the Urewera country from Turanganui-a-Kiwa (the Gisborne of today). Te Kooti, Major Ropata, and Col. Whitmore trod our boundary. Today, though, it is the massive flocks of starlings who use our valley as their main flightpath, flying daily into the rural hinterland of the district from their night-time roosts in the palms near the Gisborne Courthouse.

Our soil is not easy. We are sited on sedimentary sandstone and mudstone bases, but from the Rotorua district successive volcanic eruptions over the last 54 000 years have top-dressed us with up to 1.5 metres of ash from Okataina, and in the last 4000 years two major pumice showers from Taupo. The Okataina ash can be rock-hard in the summer dry and porridge sloppy in winter. The black Taupo pumice topsoil looks fantastic in winter when it is damp, dark and friable, but in summer it is but a water-resisting grey powder. Deep layers of brown pumice exist, completely unmodified by any organic staining, although it is 4000 years since it arrived by air. However, the underlying sandstone is the best parent material we could wish for. Even in a drought this layer contains moisture, and soil weathered from it is a sure guarantee of excellent growth. Also, once the deeper-rooted material is able to penetrate the ash layer in particular, there is little to limit its growth. Shallow-rooted subjects such as Mr Cook's beloved rhododendrons, though, are almost surely doomed to failure except in the most favoured of sites.

Our annual rainfall is on average about 1000 mm. Summer drought is a regular occurrence, though since 1988 to date that has not been the case. In Eastwoodhill's early days the sole water source was a stream passing through the lower reaches of the property that seasonally dried up. The 15 ponds throughout the place today give access to water in the summer, but were created only 5 years before Mr Cook ceased his planting. Watering to him was an onerous task, and only that amount needed to keep a new plant alive was given; two years is what he aimed at, and then nothing. There were too many new plants to care for without watering the hundreds from previous seasons. In this way he made his plants work hard, and slow growth ensued for many. But given the fickle nature of this climate, no plant was lured into thinking that life was easy here. The roots had to work, seeking and reaching down to the sandstone and its moisture, and only then was top growth assured.

A series of steep ridges lifts the north and west winds, protecting the bulk of the area planted during Douglas Cook's time. Douglas fir planted on these ridges further shelters the arboretum. However, I am not so lucky because the new areas I have to plant are on mudstone and open to these same strong winds, the only prospect of shelter being the planted conifers, which are small at the moment.

When I arrived at Eastwoodhill, for the first few years so many people said "If only he [Cook] had chosen a better site for planting trees." Today I can point to Lombardy poplars at 132 feet, 8 feet taller than those Bob Burstall had measured elsewhere as the tallest in the country; narrow Atlantic cedars that rise to 120 feet; a photinia which at 85 feet is 20 feet taller than that claimed by Hugh Johnson as the tallest in the world; and an American oak that is 45 years of age, 120 feet in width, 85 feet tall, and 4 feet in diameter. Various tree lovers then exclaim, "You have no wind." "Why so?" I ask. "Look, your liquidambars still have their tops." I mind all these and many more, and realise that Eastwoodhill is well sited. It has survived the droughts, the floods, the landslides, and the strong winds that we do get, though they are not constant winds. Douglas Cook planted everything that he could get his hands on, that he thought might grow. His garden was where *he* was – that is how so many great things happen, is it not?

An arboretum can be regarded as a testing place, a tree garden where you go to see what is relevant for the area. In any arboretum, especially those planted by the amateur who aggregates everything new, time produces an array of survivors of the given conditions. The enthusiast's natural interest makes each of the resulting collections unique.

Visitor numbers were low in the early days of the Trust Board's tenure, gradually rising with time, following occasional publicity through *Woman's Weekly*, National Radio's *Roundabout*, and various newspaper articles. And then our turn on television: *Sunday Magazine* barely elicited a response, catering for about 4% of the viewing numbers, *Living Earth* a few more, but from both of those absolutely no written correspondence.

Our feature on *Palmer's Garden Show* was a major event, though, with a deluge of mail, increased attendances, and doubled gate takings for that year over the previous best. Incredibly, some people flew from Auckland or Wellington and hired cars to drive out to Eastwoodhill.

Our formal garden area has been vastly improved and upgraded over the last 10 years by our dedicated group of lady volunteers. However, as it does so the potential for criticism grows, with greater expectations from some members of the public. I venture to suggest that the most vocal critics have at home a pocket handkerchief garden immaculately maintained.

We are a small and largely amateur group of people who are attempting, somewhat successfully, to take Eastwoodhill from a large private tree garden into the next century as a relevant, progressive, interpreted, educational arboretum, assisting in the process that most of us here are already involved in – educating New Zealanders as to the benefits of trees, and a care for the landscape. We have depended on various people's goodwill, time (and lots of that), and so much energy.

So for arboreta in New Zealand maybe the future looks as if we will still need that original raw, unbridled enthusiasm. Difficulty of finance does hinder; but then, we are not faced with cruel funding cuts, as we have never had those funds in the first place. Also, we are not subject to the whims of a change of Council policy. However, with the growing interest in trees and landscape it does behove all arboreta to address the public access in some form or other. Similarly the scientific criteria to validate the collection.

The Eastwoodhill experience is only one small part of what is possible. The native plants must be given much more weight in the New Zealand landscape as a whole. It is the essential structure on which our uniqueness is based. Eastwoodhill is not trying to address that need except in a small way, where it relates to collecting native plant material of the immediate ecological district, making a limited Gondwana collection, and collecting a specialised local filiramulate collection. We are a collection of a different sort, we have our own unique part to play, and we will seek to maintain that for both the New Zealand and international scenes.

Ornamental Plantings

Gordon Collier

Titoki Point, Taihape R.D. 1, New Zealand

After a lifetime in ornamental horticulture gardening for myself and for other people, talking about it, doing it, and advising about it, I do have some opinions on this very wide subject. Some of these opinions may be forthright, but these are easy to hold when you are self-employed with a staff of one – my wife. Of course our business could not operate without our team effort, but as I often say about gardens, 'big is not necessarily beautiful'.

Usually I speak to groups about particular aspects of ornamental horticulture such as 'Plants for problem places', 'Gardening in the shade', 'Maintaining your garden', or a lecture I particularly enjoy called 'Creative plant pruning'. My activities in this area especially over the last ten years have clearly shown that there is a great thirst for knowledge about all aspects of ornamental horticulture.

To begin, I should tell you how I first became seriously involved in gardening. In my last year at High School the Careers Master handed me a slim, red-covered booklet entitled, I think, 'Careers in Horticulture' with the by-line RNZIH. As a result of this fortuitous happening, I completed the two-year full-time Diploma in Horticulture at Massey College, studying under people like John Yates, Ella Campbell, Paul Yalden, and Jack Forno. These were halcyon days at Massey, when students had almost one-on-one tuition, when students knew everyone by their first name, and the Principal, Prof. Peren, out walking his dog would doff his hat to passers-by.

Our time was divided equally into academic work and to practical horticulture taught on campus. There were weekly lectures on plant identification, and over the two years we learnt the names and details of a wide range of plants. I was severely bitten by the plant bug! This was a great learning experience, and in retrospect the only element lacking from a rounded education was formal tuition in design. I tell you this because it is still relevant in my work today, and plants and design are two subjects I want to talk about later.

After Massey I spent a year at 'Tupare' near New Plymouth, the great garden belonging to the Matthews family and now managed by the QEII Trust. In its day Tupare was unique in its concept, its design, and in the execution of its ornamental plantings. It was this country's number one garden, and attracted great public interest when occasionally it was opened to the public.

On the other side of the North Island there was a further garden called 'Eastwoodhill', owned by W.D. Cook. Eastwoodhill is now one of the great arboreta of the world. The owners of these two properties collaborated briefly, sometimes with fiery results, to launch the Pukeiti Rhododendron Trust, which from a very modest beginning has surpassed all expectations. My year at Tupare exposed me to these wonderful plant enthusiasts, and explains why I spent the next 35 years of my life creating my own ornamental plantings at 'Titoki Point' and how, in time, it became possible to turn this into a viable business from which we now earn our living. This would not have been possible 30 years ago. For one thing it would have been socially unacceptable to charge people to see your garden. Public interest in ornamental horticulture has in that time grown immeasurably, and is today our second most popular leisure activity.

In New Zealand, with its excellent climate ranging from subtropical to temperate, and never approaching that of continental U.S.A. or Europe, we have the opportunity to create gardens and ornamental plantings without the constraints that a severe climate imposes. This allows us to exploit an ever-increasing range of plants from which to select those best suited to our particular requirements. Understandably, the gardener is often confused by this wealth of material and ends up using one of everything available from the local garden centre. A horticultural fruit cake is the inevitable result. Plants have become merchandise, marketing is paramount, and dissemination of knowledge about a plant's requirements has become of secondary importance.

It takes skill and experience and/or guidance to choose the right plants for the right situation. For me this is one of the most satisfying aspects of the job. On the steep, sunny hillside we call Titoki Point there are still places that defy me.

When at last you have the right plant for a particular situation, it suddenly looks 'right'. To arrive at this point many factors will have been considered – soil, climate, aspect, drainage, height, leaf form, colour, texture, and perhaps colour of flower. But then the correct choice of plant is not the only factor in a successful design.

A good scheme will also have form and line, colour and texture. Usually, and especially in New Zealand, where buildings tend to play a smaller part than in counterpart English designs, the only way height can be expressed is with trees, and this is where many otherwise successful designs come unstuck, for these elevations consist of living material that alters as it grows in height and width. This is when we should practise our creative pruning or, if it is a bigger exercise, call in an arborist. Too often at this juncture along comes the good Kiwi bloke well endowed with his pioneer forebears' urge to destroy everything in his path – if it moves, shoot it, if it grows, chop it down.

I am reminded of the quote: "The tree which moves some to tears of joy is in the eyes of others only a green thing that stands in the way."

Regrettably the axe and the chainsaw go hand-in-hand with the moron and the ignoramus. This was revealed recently – a design project I executed 15 or so years ago in a small town near where I live had reached splendid maturity. It consisted of a planting around the courtyard of a small shopping centre. The lacy softening effect achieved by the use of sugar maples, honey locusts, and one or two carefully chosen trees was particularly pleasing. Not surprisingly after all those years, the line of sight between a certain shopkeeper's counter and the street became obscured. There was a complaint. Although only a phone call away I was not consulted, and not only the offending tree but all its neighbours came crashing down. A little creative pruning could have satisfied everyone, but as so often happens, ignorance of trees and their basic requirements prevailed.

There is another classic case of ignorance not too far from where I live, in this instance a row of mature silver birch truncated at shoulder height because they obscured the view of the nearby lake. Of course these trees were unsuitable from the beginning, and betula should never be hard-pruned. Although one of the most beautiful of deciduous trees they often suffer like this, doomed because of their availability and ease of culture. Such ignorance. It takes time for a tree to grow to full beauty and height, and even in this day and age, it is fortunate to be allowed to grow so long.

Earlier I spoke about my lack of formal design training. This lack of skill is also evident in most gardens I am asked to advise on; indeed, most gardeners, while strong on plants, are short on design. If we have trouble with our pipes and drains we call in a plumber; if our wiring packs up we consult an electrician. Similarly an attack of pleurisy has us rushing headlong to the doctor. This is as it should be. If we are short on a skill, we should buy the services of someone who has it. But we are 'Kiwi blokes' and 'we can do it ourselves' – and we usually do. No wonder so many gardens are a bewildering maze of paths, home to an assorted array of plants from all over the globe – frequently there is one of everything. Sometimes shrubs are dotted all over otherwise beautiful lawns like some adolescent with acne. Worst of all, choice trees are planted cheek by jowl, leaving Buckley's choice for the next generation of gardeners.

Humphrey Repton, a famous designer, said in 1816 "The art of landscape gardening is the only art which everyone professes to understand without having studied its rudiments. No man supposes he can paint a landscape, or play an instrument without some knowledge of painting and music but everyone thinks himself competent to lay out grounds ...". So we have a situation where amateurs are legion, successful but lacking design skills. Their gardens are now often open to the public, but the more discerning are not always willing to pay to see mistakes that remind them of their own.

On the other hand professional landscapers could be said to have a chink in their armour too. While design is their forte, their knowledge of plants is not always wide. Last month I saw in the South Island a town garden designed by an eminent landscape architect: an expensive new house in an expensive new subdivision. A very short distance from the house a rounded bank or berm had been constructed – good so far, visually pleasing, blocking out some traffic noise and preventing passers-by from looking in. This berm was sparsely planted with tussock grass, fitting to a commercial site but not very imaginative in a domestic situation. Not so bad, you say, but wait on; along the top was a newly planted row of Douglas firs already 2 m high. (I have photographs.)

Trees, shrubs, and perennials are to people who work with the landscape as paints, pencils, and chisels are to artists and sculptors. It mystifies me that students from polytechnics and universities, whether diploma or degree, should remain largely untutored in this essential discipline; or, for that matter, that a degree in horticulture is not a prerequisite for landscape studies. Professional landscape practitioners could add so much to their craft by having a little more than a basic knowledge of plants. Just as the amateurs' efforts can be compared to a fruit cake, the professionals can sometimes seem like madeira – bland and a little unexciting.

So much for design. One of the other considerations looming is that of colour. Have you noticed how horticulturists and gardeners – 'horticulturists' not 'horticulturalists' – are influenced by fashion? Those older among us will recall the craze for dwarf conifers, and that of the pebble garden – all that flapping black plastic weighed down by stones. Remember, this was ornamental planting! Other fashions have included that for cottage gardens, and more lately that of colour carried to extremes. Have you noticed a plague of clipped box (*Buxus*, that is) and an outbreak of trellis? Doesn't every garden now have a gazebo?

Enduring enthusiasms have developed for the rhododendron and camellia. These plants have been given lasting impetus by the formation of specialist societies in the forties and fifties. New Zealand seems to be overburdened with specialist societies in whatever plant family you can name. While these are excellent for the dissemination of knowledge about particular plants, new gardeners entering their ranks may become devotees of that genus at the expense of other plants, which are patronisingly labelled 'companions'. We need more broad-based horticultural societies such as that at Hamilton, and for that matter, at Taihape. So deeply are rhododendrons and camellias ingrained in the psyche of gardeners that the public perception is focused on the spring, "when the rhodees are out."

Good ornamental plantings last through summer and autumn, and should put up an effort in winter also. Camellias and rhododendrons are wonderful shrubs, but they are evergreen, like conifers, and my plantings aim to have at least 60% deciduous content. Take notice of plantings that please you, and see what they are composed of. Serried ranks of evergreen shrubs out of flower, no matter how rare or special, have little to recommend them.

Not long ago the 'white garden' was the pinnacle of fashion – shades of Sissinghurst. In a certain suburb in a certain city you still see Iceberg roses, *Primula malacoides* (white form), trellis, and green box. Now, it seems, white has been overtaken by yellow and blue – or is it orange, yellow, and black? But fashion is fun, and we always try new ideas. We shouldn't take them too seriously. Unfortunately it is much easier to follow than to create!

Colour in the broader sense is another matter, and in particular where an unspoiled landscape presents itself. The New Zealand landscape school follows the dogma of the English, in that "trees with variegated foliage and those with purple tones cannot be used without giving an exotic effect" (Graham Stuart Thomas). One local graduate goes further, advising removal of existing trees with golden or variegated foliage.

The gentle English landscape, where the light is soft and muted, is the opposite to the clear blue skies, high temperatures, and rounded landforms that prevail in my part of New Zealand. There I find the exuberant golden forms provided by tall standards of the elm now called *Ulmus glabra* 'Lutescens' quite acceptable. Cheap, available, vigorous, drought resistant, wind resistant, and on high standards – perfect for the large picture I was painting. I like yellow! This dislike of the colour yellow is fashionable too, but we should not follow such edicts too closely. Where would art be without the brilliant use of colours by artists such as Van Gogh and the French Impressionists?

The perfect ornamental planting as I see it can be likened to a third kind of cake – the layer cake. It has trees to provide architecture and dimension, shrubs to provide a background at ground level, and bulbs and perennials as an underplanting. To orchestrate all this plant material successfully within the dictates of a firm but imaginative design is what makes a good ornamental planting. To achieve this you need dedication over a number of years, knowledge of plants and their propagation, perseverance, and above all the ability to choose the right plant for the right position. A dash of flair would not go amiss either.

There seem to be three or four types of planters:

(1) Plantsmen (and women). Knowledgeable people who love plants for their own sake. These are often tree planters who keep meticulous records of provenance, planting dates, and the rest. One of these people I know from my membership of the International Dendrology Society gets more pleasure from the records she keeps than from the trees themselves. 'Plantsman' is not a term you give yourself, other people give it to you – a bit like the Honours system, though self-awarded knighthoods are not unknown.

(2) Flower Gardeners. To these people the flower is everything; they are not interested in the plants, just the mass display they provide. The public like colour, and the more vulgar the better. This accounts for the popularity of public displays of bedding plants, often garish schemes worked out using a colour wheel to get opposite colours together. The famous Butchart garden at Victoria, Canada embodies this concept. Butchart's use of colour is awful, but the public love it. Most people start off liking flowers and lots of colour. These people seldom get to appreciate form and texture.

(3) Designers. Their knowledge of plants is sometimes inadequate, but their design skills are highly developed. They tend to use plants just to flesh out the design.

These are sweeping statements, of course, but the successful ornamental planter is probably an amalgamation of all three types. If you haven't got these skills you will be disadvantaged.

Over the forty years that I have been planting there have been many changes in ornamental or 'amenity' horticulture, as we should now call it. The biggest change has been in peoples' attitude. I well remember when I announced I was going to Massey to study horticulture my grandmother saying "What is there to learn about gardening?" She would be astonished to learn how far I have to go even today. Then, when I started my garden – in territory where manly pursuits were confined to the farming round, and leisure hours to rugby and golf – my activities were definitely suspect. Now there is scarcely a farmer within cooee who hasn't called me in to advise on some aspect of homestead or farm planting. Ornamental plantings used to be confined to the strict boundaries of the house. Today they are much more ambitious.

On a national scene, gardening has increased to become this country's No. 2 recreational activity; where big business now controls one of our biggest horticultural outlets, and where television gardening programmes, scorned for so long, now screen at peak viewing times, indicating that gardening has reached an all-time high. This all spells 'SUCCESS', but yet I feel that ornamental horticulture is the Cinderella on the national scene. We lack a system whereby enough young people can gain sound practical training such as is available in private gardens, National Trust gardens, or at Wisley or Kew, to name just two institutions in England, or in America where they have a system at top institutions they call 'internship'.

My own daughter, a recent graduate from Massey, has just returned from such a four-month programme at Filoli, that magnificent garden out of San Francisco. There she worked in each department under trained staff, earning a reasonable wage over a period. Could not our leading colleges, parks, and gardens offer a facility like this? Students from overseas jump at the chance to work with us and further their experience.

Another great change in horticulture has been the freer availability of plant material. Plant quarantine regulations have tightened considerably, but it is still financially feasible to import. One is left in doubt about the intentions of the impending major changes governing the importation of seed. It would seem that, whereas before the system allowed us to import seed not specifically banned, the new system bans everything not specifically allowed. The proposed changes may cause frustrations downstream, with illicit importing resulting, and the drying up of sources of interesting new plants. For all that, far more plants are available than when I started out.

The best news about ornamental plantings has been saved for my conclusion. The training of young people as arborists has already had a major impact on gardens, parks, and arboreta throughout New Zealand. Their skill in looking after our trees is greatly appreciated. Over the past few years one of these graduates, James Ballard, has cared for the trees at Titoki Point and has transformed the appearance of the garden. Money is very well spent on an arborist.

Ladies and gentlemen, thank you for your attention. Gardening does not keep us sane. It merely allows us to be insane in a dignified and polite manner.

Botany of Rotorua

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The Rotorua Lakes Ecological District is one of the most distinctive in the country. Its unique geothermal features have made it a mecca for tourists since the earliest days of European settlement.

Some of the special plants and interesting botanical features of the Rotorua district were featured in the book titled *Botany of Rotorua*, compiled by Bruce D. Clarkson, Mark C. Smale, and Chris E. Ecroyd and published by the Forest Research Institute.

The district is entirely volcanic in origin, and consists of 17 lakes set amidst plateaus and rolling hills.

When the Maori people first settled around Rotorua about 600 years ago nearly all the land was covered with native forest, much of it dense podocarp-broadleaved forest with rimu, tawa, mangeao, and northern rata predominant. Although less rich in species than some forest areas in New Zealand, it commonly contained a luxuriant growth of epiphytes or perching plants, including large perching lilies, a wealth of ferns, and attractive climbing ratas. Today less than 15% of the district is covered in native forest. On swampy ground around the lake shores kahikatea forest was predominant, but only a few small remnants still exist. The best stand, consisting of young trees, is at Te Ngae near the Rotorua Airport, and there is another beside Lake Rotoma.

Over the centuries the Maori people cleared land for living areas and cultivation and to encourage bracken, whose rhizomes were a staple food, so that 150 years ago much of the land around the lakes was open country covered by bracken or low scrub. Gradually, land suitable for pastoral agriculture has been developed, although this has occurred much later than elsewhere in New Zealand because of the widespread occurrence of 'bush sickness' in sheep and cattle, recognised only in the late 1930s as cobalt deficiency.

Man-made exotic forest is now a significant feature of the district, covering at least one-third of the land area. Whakarewarewa, covering approximately 5000 hectares, was the first exotic forest of any consequence established in the North Island. It was planted between 1899 and 1918; the first plantings were largely experimental, and some 170 species were included. This forest is now managed for recreation as well as production, and the variety of species in its composition – including larches, eucalyptus, Douglas fir, sweet chestnut, Australian blackwood, and several pine species – has greatly added to its attractiveness. Native ferns, including large tree ferns, are a conspicuous feature of the understorey. The well known Redwood Grove featuring the coastal redwood is one of the most popular parts of the forest. Planted in 1901, some of these majestic trees are now over 55 m high.

Mt Tarawera provides a majestic backdrop for much of the district. In a catastrophic eruption on 10 June 1886, all the vegetation on the mountain top was destroyed and that on the lower slopes was buried or badly damaged. Gradually, over the last one hundred years, vegetation has begun to re-establish. Forest is creeping up the lower slopes. At higher elevations such as the Plateau Dome mosses, mat plants, and small shrubs are helping to bind the scoria, allowing patches of shrubs, especially tutu, to establish. On the upper slopes close to the craters, woolly moss and small mats of vegetation are spreading over the formerly barren landscape. Species recorded there by the early botanist Thomas Kirk, before the eruption, such as small-leaved rata, karamu, and akepiro, have re-established.

The vegetation around the margins of the lakes is diverse, and includes wetlands, native forests, and scrub on headlands and steep slopes, and pasture. The shallow water around the lake margins, and many of the streams and rivers, are regions of abundant plant life, from emergent tall reeds to underwater 'turf plants' and pondweeds. In recent years introduced aquatic plants, including oxygen weeds, have replaced much of the native flora in some of these situations, and caused a major interference with recreational activities.

An interesting feature of the local flora is the number of coastal species which occur inland here. In all, 18 have been recorded, but nearly half of these have not been seen recently and may have disappeared altogether. Habitat loss by land development, and competition from introduced weeds, are the most likely reasons for their disappearance. Still surviving around the lakes are species such as pohutukawa, which is very attractive in flower at Christmas time, and the rengarenga lily, a species which clings to rock cliffs on a few lake shores in the district.

There is a variety of wetland sites in the district, most but not all in low-lying land near lakes. In some there is a sequence of conditions from open water to swampy or boggy ground. The mire at Hinehopu is a place few people would choose to visit, but it is very old and rich in plant life, a very significant and irreplaceable botanical site containing many species not found anywhere else in the district. One example of the many botanical taonga or treasures in this swamp is the attractive pink-flowered orchid called lady's tresses, *Spiranthes*. These plants would disappear from the district if this swamp were drained or drastically altered – a clear example of the vulnerability of our native flora.

The Rotorua–Taupo area has the greatest concentration of geothermal sites in New Zealand. Thousands of tourists view the geysers and mudpools here at Whakarewarewa each year but only glance at the distinctive vegetation surrounding them as they admire these attractions. A special prostrate variety of kanuka is common around these thermal areas, well adapted with its low habit and spreading root system to surviving in the top few centimetres of cooler soil. A very close look at some of the kanuka may reveal the diminutive mistletoe *Korthalsella salicornioides*.

At Waimangu, where the hot water is less acid, displays of micro-algae enhance the beauty of the area with vivid splashes of contrasting colours. These colours, such as those on Warbrick Terrace, are caused by millions of tiny algae and bacteria, some living as cells no more than a few thousandths of a millimetre long or wide, others assembled into threads or colonies visible to the naked eye.

The margins of springs and streams in thermal areas carry a specialised flora where the ground is warm. Some are tropical species which can survive here only because of the geothermal heat.

The ladder fern which borders hot streams and fumaroles in Waimangu Scenic Reserve is found in New Zealand only around these thermal areas. Similarly, a species of *Christella* – another fern – is also found in New Zealand only around thermal activity.

Several orchid species grow in the disturbed acid soils around the Rotorua thermal areas, a few of which are very rare. The only plants of the duck orchid, *Caleana minor*, known in New Zealand are found here. These orchids have very light, wind-dispersed seed, and the Rotorua colony probably started from seed blown over the Tasman Sea more than a hundred years ago.

Other threatened species are known from the forests and lake shores of the district. The wood rose, *Dactylanthus taylorii*, is an endangered endemic species of Gondwanaland origins. Recently one small clump, possibly consisting of a single plant, was found in this district.

Many of the district's outstanding botanical features are included in areas managed for the recreational and aesthetic pleasure of residents and the multitude of visitors from within New Zealand and from overseas. Conservation areas have been set aside where representative examples of the landscape are kept as far as possible in their natural state, with special protection of rare and endangered plants and of the native birds that greatly assist pollination of flowers and dispersal of seed. Excluding the effects of large-scale geothermal activity, major future changes to the present pattern of farmlands, exotic forests, and the near-natural remnants of the native vegetation are unlikely. Species of introduced plants will continue to establish in the wild, but only the smallest pockets of native vegetation may be expected to be completely overwhelmed. In the long term, the most profound change envisaged is an eventual recrowning of Mt Tarawera with montane native forest like that which covers the nearby Makatiti Dome.

Botany of Rotorua was produced in conjunction with the Rotorua Botanical Society, members of which contributed most of the chapters, in the hope that it will enhance public understanding of the plant life of Rotorua District, instil appreciation of its values, and stimulate enthusiasm for its conservation. The book covers aspects of the district's native, naturalised, and cultivated vegetation, including aquatic vegetation and micro-algae of thermal areas, mosses, liverworts, and fungi, and has chapters on the history of the vegetation, records of the changes on Mt Tarawera, threatened plants, and traditional uses of wild plants. It is available for $39.95 from the Publications Officer, New Zealand Forest Research Institute, Private Bag 3020, Rotorua.

The Wood Rose and Bats: the Link between Two Unique Endangered New Zealand Species

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Introduction

New Zealand's flora and fauna have developed over the last 80 million years in relative isolation on a landmass of continental origins. The absence of terrestrial mammals, except bats, until the arrival of man about 1000 years ago had considerable influence on the evolution of the flora and fauna. New Zealand has a high percentage of endemic species, and two of the more unusual with ancient lineages are the root parasite *Dactylanthus taylorii* and the lesser short-tailed bat, *Mystacina tuberculata*.

The Wood Rose

Dactylanthus taylorii is New Zealand's only fully parasitic native angiosperm. A member of the largely tropical family Balanophoraceae and a monotypic endemic genus, it consists mainly of a swollen underground stem up to 50 cm in diameter which grows on the root of a host tree or shrub. It has no roots, and the leaves are reduced to non-photosynthetic floral bracts lacking stomata. The inflorescences with their bracts emerge 2–4 cm above ground level. At least 30 species from 15 angiosperm families are hosts.

The *Dactylanthus* plant moulds the attachment area of the host root into a fluted rose shape, hence the common name, wood rose. Through this placenta-like attachment area the *Dactylanthus* plant obtains all its nutrients from the host. The attractive 'wood rose' is valued as a curio, and collectors have dug up thousands of *Dactylanthus* plants.

Dactylanthus occurs in small colonies at widely scattered sites in the North Island and on Little Barrier Island. Its distribution has decreased this century, and probably only a few thousand plants remain. A book on threatened plants of New Zealand (Wilson and Given, 1989) classified the species as 'vulnerable', and the factors causing its decline were considered to be collectors of the wood rose and habitat destruction.

Dactylanthus is dioecious, that is, having separate male and female plants. The minute flowers are clustered in a capitulum 2–4 cm in diameter. Each consists of 15–20 spadices on the end of a leafy shoot surrounded by floral bracts. The male inflorescence with white stamens is easily distinguished from a female inflorescence with its dark stigmas. The bracts are usually dull purplish to yellow-brown, but sometimes greenish, and very occasionally bright yellow or red. The flowering season is long, starting about mid February and extending into May.

Bats

The only native terrestrial mammals in New Zealand are two species of bats, the lesser short-tailed bat, *Mystacina tuberculata,* which feeds on fruit, nectar, and insects, and the insectivorous long-tailed bat, *Chalinolobus tuberculatus*. The lesser short-tailed bat is the sole surviving species in an endemic family whose ancestors were separated from other bats about 35 million years ago. It is the size of a small mouse and weighs 12–15 g, with a wingspan of 28–29 cm. With comparatively strong hind legs, and a unique way of folding its wings into pouches, it is much more agile on the ground than other bat species. The adaptation to feeding on the ground reflects the lack of mammalian predators in New Zealand.

Found only on Little Barrier Island, Codfish Island, and a few North Island sites the lesser short-tailed bat is listed as vulnerable (Williams and Given, 1981). Predation by introduced mammals, competition for food, and habitat destruction are likely to be contributing to its decline, but the exact causes are unknown. Domestic cats prey on these bats, and feral cats, rats, and mustelids are likely to be predators.

Introduced Mammals

Among the introduced mammals now pests in New Zealand is the Australian brush-tailed possum (*Trichosurus vulpecula*). First introduced about 1840, it now costs millions of dollars a year, spreading bovine Tb among cattle, damaging forests, farms, and gardens, and requiring resources for control and research.

The Polynesian rat or kiore (*Rattus exulans*) was brought to New Zealand by the Maori, and although previously found throughout the country it is now restricted to remote parts of the South Island and offshore islands. The ship rat (*Rattus rattus*) has spread rapidly since the 1860s, and is now the commonest rat species.

Possums and *Dactylanthus*

A study of the ecology of *Dactylanthus* was begun in 1989 after extensive browsing damage to flowers was observed. Possums or rats were suspected, and protection of the plants with wire netting resulted in unbrowsed flowers.

Possum faecal pellets, scratching, and bite marks were commonly found around the browsed *Dactylanthus* plants, and the remains of flowers were found in the stomach of a trapped possum, indicating that possums were destroying the *Dactylanthus* flowers.

Exclosures have proven the most cost-effective means of protecting the plants from possums. Reduction of possum numbers using aerial applications of 1080 poison or ground control using traps, cyanide, or Talon® poison have been more expensive or not very effective.

Dactylanthus, Bats, and Rats

Before routinely using wire netting to protect plants it was essential to confirm that pollinators of the *Dactylanthus* flowers were not being excluded.

Earlier studies (Moore, 1940) had suggested that *Dactylanthus* was pollinated by small flies, but flies were not commonly seen at the flowers and the inflorescences seemed too large. Close observations of inflorescences and measurements also revealed a pool of up to 1.5 ml of sweet, musky-smelling nectar in each, and an inflorescence produced on average 5 ml of nectar in ten days. No significant difference was found in nectar flow during the day and at night.

Larger moths, wetas, lizards, birds, and bats are the only native fauna which could be possible pollinators of flowers producing such large quantities of nectar. Overseas studies (Wyatt, 1983) provided information showing that the large, robust, dull-coloured and bowl-shaped inflorescences are more typical of bat-pollinated flowers than those pollinated by birds or moths. Comparison with other studies (Opler, 1983) also showed that the quantity of nectar in the *Dactylanthus* inflorescence was well above the range for plants pollinated by birds, moths, and other insects but just above average for bat-pollinated plants.

The flowers were observed during the day and at night, insect traps were set up, and a footprint recording system was used. Introduced wasps were the most common insect visitor, and rat, mouse, and weta tracks were recorded.

A review of the literature on bats revealed that *Dactylanthus* pollen had been found in the guano of a short-tailed bat. Either this bat had visited the flowers or it had eaten insects which had visited the flowers.

A time-lapse video security system fitted with infra-red lighting, adapted for monitoring bird nests, was then used in an attempt to establish whether bats were pollinators of the *Dactylanthus* flowers. The equipment was trialed at two mainland *Dactylanthus* sites, and the resulting tape showed both possums and ship rats visiting the *Dactylanthus* plants. Possums browsed any accessible inflorescences, while the rats appeared to consume only nectar, leaving the flowers intact.

The video system was then set up to monitor *Dactylanthus* plants on Little Barrier Island, the only site known where short-tailed bats existed and *Dactylanthus* plants could also be located. The results were unexpected – Polynesian rats were filmed destroying the inflorescences. There were no visits by bats. With these rats browsing the flowers on the only possum-free *Dactylanthus* site, the future survival of *Dactylanthus* was definitely under threat.

The video equipment was used again on the mainland, to further monitor ship rats visiting the flowers. In one night there were twelve visits by ship rats, but between these visits a short-tailed bat often appeared, entered the exclosure, and fed from the *Dactylanthus* inflorescences. There were 40 visits by a bat in just one night, providing evidence that the short-tailed bat was an important pollinator of *Dactylanthus*. The site was also a new location for these bats, and it was obvious that monitoring flowering *Dactylanthus* could help locate them at other sites.

In the absence of short-tailed bats, ship rats are probably the most important pollinators. These rats are frequent visitors to *Dactylanthus* inflorescences, and abundant seed set has been observed on plants they have visited. However, monitoring has also shown that ship rats sometimes destroy the flowers, possibly owing to high numbers of rats and a shortage of food. It may be necessary to reduce rat numbers by trapping or poisoning where they are a problem.

An alternative is to move *Dactylanthus* to a possum-free and rat-free site, but to do this the plants must be cultivated in some way. Most root parasites require a chemical stimulant from the host root for the seed to germinate, and are difficult to grow artificially.

To simulate natural conditions, seed was sown close to young roots of two host species in a large planter box covered with glass on one side, allowing the roots to be observed. After three years a few small *Dactylanthus* plants were found, and a study of the cell structure of one plant confirmed its identity. Two small *Dactylanthus* plants attached to their hosts were successfully moved, indicating that *Dactylanthus* could be transferred to a possum- and rat-free site.

Future Survival of the Short-tailed Bat and *Dactylanthus*: the Role of the Community

Both *Dactylanthus taylorii* and the short-tailed bat are classified by the New Zealand Department of Conservation (Molloy and Davis, 1992) in the highest priority category of threatened species, and draft recovery plans have recently been written. These plans set out aims and objectives for research and management with the basic goal of ensuring survival of these species. As part of this work the Department of Conservation is planning to eradicate the Polynesian rat from Little Barrier Island, which if successful will be a major step towards achieving this goal.

The general public has provided information on new *Dactylanthus* localities, and volunteers have assisted in protecting them by erecting exclosures and reducing possum numbers. Recent publicity arising from this research project has educated people on the significance of *Dactylanthus* and discouraged many previous collectors of wood roses.

There is a large research effort being put into possum control and a breakthrough would assist the survival of many native species.

Conclusion

Owing to their isolation from mammalian predators and browsers *Dactylanthus taylorii* and short-tailed bats have evolved an unusual relationship. *Dactylanthus taylorii* is the only known bat-pollinated plant species in the world flowering at ground level. However, the existence of these two species is now threatened by mammalian browsers and predators, habitat destruction, and, for *Dactylanthus*, curio collectors.

None of the sites on which *Dactylanthus* occurs is free of both possums and rats, and consequently there is nowhere it can be considered secure. Protecting *Dactylanthus* plants from possums with exclosures has proved effective, allowing plants to set seed without preventing access by bats. However, exclosures can alert wood rose collectors to the plants' location, and rat damage is a possibility. For full protection, cultivation on island sites inhabited by bats but free of both possums and rats – and, hopefully, curio collectors – may be the only solution.

Less is known about the threats to the short-tailed bat, and more research is needed to identify the major factors causing its decline.

A human network consisting of the Department of Conservation, research contractors, funding organisations, and the general public is essential to the long-term survival of two of New Zealand's most interesting and unique species, the link between which has become increasingly tenuous owing largely to the activities of possums, rats, and man.

Acknowledgments

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New Zealand Law and the Urban Tree

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Urban tree cover varies from city to city, but we can mention the likes of the Auckland Domain, the Wellington Town Belt, and Hagley Park in Christchurch as being substantial populations of urban forest. However, the urban tree is under pressure.

Trees under Threat

In New Zealand our trees are threatened by many forces, such as disease and urban development.

There are people who like trees as long as they are not within their property and cause them no immediate problem. The phrase NIMBY has been coined in the U.K.; it is an acronym for Not in My Back Yard. They love trees, but ... !

Hazard trees, trees at hazard

Big trees in any proximity to residential buildings are perceived to be dangerous. In some instances they are.

There are many well meaning 'experts' who do not have the training or experience to make correct recommendations. The professional requires the latest in technology, such as the Metriguard stress wave timer, to assist in the practice of defensive consultancy.

By far the major threat to older established trees is change in land use. Rezoning of city areas has reduced the space given over to the urban tree, and this has increased the need for prudent control of the removal of such trees and/or alteration of their shape for the benefit of the community.

Arborists often have to advise clients on their rights, and this area is difficult to understand; it sometimes requires the assistance of a lawyer.

Tree Protection Legislation

The Resource Management Act and Reserve Act is legislation which covers large areas; this presentation concentrates on the residential situation. I will attempt to inform you of the difficult situations that might arise when visiting a well treed urban garden.

There are two major divisions of law, the Act of Parliament and the Law of Precedent (common law), which is based on responsibility and probability. Despite the increasing output of Acts of Parliament, New Zealand law still remains embodied in decisions of the courts (common law) and probability.

Over the years decisions that have been made by the courts have established that a tree is an integral part of the land on which it is growing. They have also accepted that although the owner has the right to the air above and the ground below his property, it is not an offence for a tree to overhang and encroach on the neighbouring property. The courts also say that the landowner should abide by any judgement that is made with pleasantness and harmony, so there should be a balance between rights and responsibilities.

Finally the courts recommend that the tree owner have a knowledge greater than a layman might have.

We will now look at the two types of law and see how they relate to the problems that arborists have to contend with: boundaries, and damage and liability.

Statute Law

Three Acts that influence certain aspects of responsibility are the Property Law Amendment Act 1952, the Trespass Act 1980, and the Criminal Law Act 1970.

Under the Property Law Amendment Act trees cannot be planted on boundaries without the written consent of the adjoining occupier. The District Court is also empowered by the Act

(1) to order an occupier of land to remove or prune any tree growing or standing on that land, if it satisfied that the tree is causing or is likely to cause loss of or injury or damage to the applicant's life, health, or property, or the life or health of any other person residing with the applicant; or

(2) to take action for damages against the trespasser; or

(3) to take criminal proceedings.

Certain people, such as building inspectors, are given statutory authority to enter a property, but not arborists.

The Criminal Law Act concerns the theft of trees and their destruction. It also includes poisoning of trees and removal of flowers or firewood.

Common Law

Trees on boundaries

There is no obligation at common law to cut a hedge or a tree on the boundary of a property, however much the neighbouring landowner may object to it. An adjoining landowner may not cut his neighbour's trees. However, the adjoining landowner may in law cut off any branch which overhangs his land without notice to the owner of the tree. But he may not go onto the land of the owner of the tree to do this. Branches which are cut off, and any fruit growing on branches, and fallen fruit still belong to the owner of the tree and, if they are not returned to him, he could sue the neighbour who cut them for their value. It is not permitted to prune branches as a precaution before they overhang neighbouring land. If fruit from a tree falls on neighbouring land the owner of the tree may enter the other land to take his fruit provided that he does not stay on the land longer than necessary and does not do any damage by doing so. There is no right to enter a neighbour's land in order to prune a tree. There is no legal right to poison the encroaching roots of a tree. If roots are damaged and the neighbour's tree is consequently injured the landowner using the weedkiller or other chemical will be liable for damages.

Roots on boundaries

Tree roots may spread considerable distances. On clay soils this can lead to shrinkage, and subsequent settlement of buildings. Should a large percentage of the root be removed, or perhaps the entire tree close to foundations, soil heave can occur. Complex engineering problems can occur which constitute further discussion beyond this subject. An owner has the same right to cut the roots of any tree which encroaches from the land of a neighbour onto his own land as he has to cut hanging branches.

Liability for encroaching roots and branches

If encroaching roots or branches actually injure property, then an action may be brought for the damage caused. This action is not for trespass but for nuisance, and there must be proof of actual damage. If there are more contributory causes of the damage the court will not hold the tree owner liable merely because its roots are found under the foundations. In one case where the foundations of a house were inadequate and one of the drains was leaking these factors were held to be the primary cause of the damage, although the roots from the neighbour's *Platanus* × *hispanica* were growing near the foundations.

Where the branches of some trees overhung adjoining land and damaged an orchard by taking away sun and water, damages were awarded to the owner of the orchard and an injunction was given by the court to prevent the continuance of the nuisance. Damages have been awarded for a creeper growing on to an adjacent house and obstructing gutters.

Damage - and Liability for It

Dangerous trees

A landowner with a tree in a state which is dangerous to occupiers of adjoining land or to persons lawfully using a highway (which includes any pedestrian walkway) is liable for any damage which it causes. The owner of the trees will also be liable for damage caused by falling trees, even if he does not know that the tree is dangerous; he must, however, be shown to have been negligent.

A highway authority which plants trees along or near highways owes the same duty of care to the users of the highway as do owners of land adjoining the highway.

Generally speaking, the owner or occupier of property is under a duty to act as a good steward. This means inspecting and pruning the trees in an appropriate manner. A tree may be dangerous because of some form of defect, for example basal rot. The test is whether a prudent landowner should know of the danger which would have been revealed by proper inspections.

A prudent owner should ensure that his trees are regularly inspected for signs of danger. Annual inspection of large, mature species in confined spaces is to be advised. Inspection should be carried out by properly qualified and experienced arborists.

If a tree or a branch is in imminent danger of falling onto adjoining land the owner of the land could obtain an injunction ordering the owner to remove it. If a branch falls on to a passer-by this is not in itself proof of negligence.

Overhanging branches

There is no liability for merely allowing a tree to overhang the highway, provided that no damage is done to anyone. However, if actual damage is caused to a person lawfully using the highway, the tree owner may be liable. If overhanging branches create a nuisance without causing danger to the public, generally the occupier of the land may be liable for a public nuisance.

Arborists should command a good knowledge of the law and in doing so provide a more professional approach to community education. Many of the problems that occur with trees in confined places can be dealt with at the planning stage, whether it be protection or the right tree for the right site.

A Survey of Exotic Tree Collections in New Zealand

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Summary

Management of plant resources in collections is an important aspect of landscape management. Plant resources are part of the 'natural capital' of a country, and their conservation is justified by the economic notion of option value. If collections are to be used as sites for conserving such resources, then they must be properly managed using internationally accepted practices. In other countries this has been done under the auspices of a plant collections scheme. The first step is the development of an inventory of the collections. This will be the basis for future management decisions.

This paper presents the results of a survey of selected exotic woody tree genera in plant collections in New Zealand. Twenty-nine genera were recorded in 56 collections, comprising a total of 2242 different types of trees. The largest genera were Acer, Juniperus, Quercus, Prunus, *and* Magnolia. *The results show that certain genera are 'at risk' in New Zealand, and that the majority of important collections in New Zealand are owned by private individuals.*

Introduction

Plant diversity and landscape management

A diverse range of ornamental horticultural plants are found in gardens and landscapes. Over 50 000 types of plants are in cultivation in Britain (Lord, 1991). The first Australian Plantfinder (a source book) lists 9000 different plants (Hutchison, 1993). Is there a similar level of diversity in New Zealand? If so, where might we find a particular species or cultivar? Should we conserve these plants? How? This paper considers management of the landscape plant resource and reports on the range and frequency of selected exotic tree genera in plant collections in New Zealand.

Plants are part of the 'natural capital' of a country and provide a variety of benefits to the community (McNeely, 1988). We are familiar with the direct benefits of plants, the products which we consume as food, clothing, and shelter. There are also important indirect benefits such as life support and life quality (McNeely, 1988). Plants provide oxygen, remove pollutants from air, reduce soil erosion, control noise, ensure a clean water supply, enhance human health, and improve the visual quality of environments (Coughlin, 1991; McNeely, 1988; Relf, 1992). Yet these benefits can be enjoyed only if suitable plants are available. Indeed, McNeely (1988) argues that future productivity depends on a stock of 'natural capital', making access to biodiversity a prerequisite for economic development (McNeely, 1988; WWF and IUCN, 1989).

Plants represent opportunities for nurserymen, landscapers, plant breeders, soil conservators, and others who gain from the products and benefits of plant material. Yet the plant resource is diminishing as ecosystems are destroyed, and species and cultivated plants become extinct (Brickell and Sharman, 1986; WWF and IUCN, 1989).

Safeguarding the potential of plants justifies conservation as a management goal (Groombridge, 1992). This rationale is based upon the economic notion of option value, i.e., retaining something now so that we may have access to it in the future (Groombridge, 1992; McNeely, 1988). The World Conservation Strategy follows this theme and aims to 'maintain essential ecological processes and life-support systems', and to 'preserve genetic diversity' (WWF and IUCN, 1989).

Priorities for science in New Zealand reflect a similar view. Output 31 (Land use, flora and fauna) of the Ministry of Research, Science and Technology has a major focus on biodiversity, including introduced flora, and 'research to improve the integrity of databases and collections' (Lee, 1993).

It is accepted that the ideal place to manage wild species is in their natural habitat. Sometimes this is not possible; the habitat may have been destroyed or is likely to be destroyed. In such instances ex-situ methods must be used, where species are cultivated in botanic gardens, arboreta, and plant collections. Of the 1500 botanic gardens world wide, 800 are involved in conservation work (Groombridge, 1992; WWF and IUCN, 1989).

What is the significance of garden plants and plant collections to the long-term management of plant resources? Many garden plants are closely related to the wild types, and indeed many collections contain wild source material. Although garden forms are often physically different from their wild parents, they still contain part of the genetic make-up of the species, and ultimately it is a representative gene pool that must be conserved. There is another important reason for conserving garden plants, however – their human value. Garden plants are a component of culture in the same manner as art, architecture, or literature (Brickell and Sharman, 1986). They are the foundation of historic gardens and the living components of landscape design (Marquis-Kyle et al., 1992; Sales, 1990).

Plant Collections and their Management

What are the principles and practices for conserving garden plants? A botanic garden is a place for the collection, study, and culture of plants for scientific purposes (Byrd, 1989). A plant collection is a group of plants which represents a genus or a part genus (Lowe, 1991). The British plant collections scheme has 500 collections of 400 genera, which conserve 50 000 plants (NCCPG, 1991). A similar scheme has recently been initiated in Australia (Cross, 1990). New Zealand does not have a collections scheme in operation, but the Royal New Zealand Institute of Horticulture (RNZIH) has initiated the work needed to develop such a scheme (RNZIH, 1990).

There are precise requirements for the management of plant collections. These follow accepted management principles and emphasise the importance of data, planning, good decision making, and strategy formulation when managing an important resource (Bromley, 1990). These principles ensure that decisions have a rational and defensible basis, and are based on correct information. Guidelines developed by Botanic Gardens Conservation International (BGCI) and Plant Collections Schemes show how these principles are applied to plant collections (Cross, 1990; Sales, 1990; Sanecki, 1989; Stungo, 1982; WWF and IUCN, 1989). First, an enterprise must develop a Mission statement and adopt more professional standards of management (WWF and IUCN, 1989). The Mission is a critical step, as it sets parameters for all later decisions.

Second, development of an inventory is essential as data are a prerequisite for any management process (Ashton, 1989; Cullen et al., 1985; Lowe, 1989; Sales, 1990; Zander, 1980). Plant collections must be mapped, and the plants accurately identified and catalogued (Cross, 1990; Sales, 1990; Sanecki, 1989; Stungo, 1982). The botanic garden record is a recommended method for recording plant collections. These records must be taxonomically precise and able to deal with a scientific name of many parts (Walter, 1989). Synonyms, common names, and changes of name must be accommodated (Walter, 1989). The record must be able to track provenance, propagation history, and maintenance history (Given, 1984). There must be a precise and unambiguous link between a record and the plant in the ground (Michener, 1989). These requirements underpin the international specification (the International Transfer Format) for botanic garden records.

While inventory is essential, it does not constitute a management plan. An inventory does not indicate which species and collections are important, which should be given priority for conservation, and how priorities should be assigned (Lowe, 1989; WWF and IUCN, 1989). The remaining steps in the management process are used to develop the management programme. The next step should be an evaluation of the resource. For plant collections this might include an analysis of factors such as number, age, condition, and rarity of plants, and assessment of visitor numbers and preferences. In this project rarity was used, as shown by frequency of each species in collections. The number of rare species in a collection will give an indication of the importance of that collection. Finally, after the evaluation the planning steps of the management process can be initiated. These include development of objectives and strategies. These steps are beyond the scope of this paper, and will not be discussed here.

To focus on inventory, BGCI calls for improved documentation of collections (WWF and IUCN, 1989). Unfortunately, the standard of data collection and management in botanic gardens world wide is often poor (Given, 1986). The capacity of New Zealand gardens to manage collections is inhibited by inappropriate management, including poor documentation (Given, 1986). In general there is a low level of inventory, and most collections do not have a catalogue (MacKay, 1990, 1993). New Zealand does not have a Plantfinder, although an initial survey suggests that there is a wide range of material available in trade (MacKay, unpublished). Nevertheless, several groups have been recording various categories of plants, such as herb collections (Herb Federation, 1991), tree fruits and nuts (Denton, 1991), production horticultural plants (Halloy, 1993), trees (MacKay, 1990), and notable trees (Flook, 1984, 1993). Several databases also exist, e.g., the Landcare Research database at Lincoln. Thus some plant groups are well known, but they tend to be those associated with production species.

Although it is useful to know of the presence of a species in New Zealand, this does not secure its future. The purpose of a plant collections scheme is to form a series of dedicated homes for plants which will ensure managed perpetuation of important species. Various commentators have called for a plant collections scheme, a national strategy, and coordination of plant management and recording schemes (Given, 1986; Heenan, 1985; Jollife and Oates, 1988; Paterson, 1987). In 1991 the Royal New Zealand Institute of Horticulture initiated a plant collections scheme to bring groups and information together into a national body. The stated Mission of the scheme was to 'participate in a global strategy for conserving plant genetic diversity by monitoring, preserving, and enhancing the resource in New Zealand' (RNZIH, 1990). Given the size of the overall project, the initial focus was on data gathering to achieve the first goal of the scheme, i.e., 'to establish which plants exist in New Zealand and to establish a common system of documentation and plant recording' (RNZIH, 1990). The intention was not to repeat work that had already been done, but to co-ordinate the information that was available and to develop the additional information that would be needed to form a collections scheme. The first phase of the RNZIH project revealed a wide range of collections throughout New Zealand (Hammett, 1993). Although Hammett's study revealed few tree collections, my previous studies suggested that there was an extensive range of exotic trees in this country (MacKay, 1989, 1990, and unpublished).

Survey of Collections

Method

As effective management depends upon data, the first phase of a project must be inventory. If plant collections are not documented, the easiest way of obtaining data is to conduct a survey (Lowe, 1989). In October 1993 a survey of 91 tree collections was carried out. Twenty-nine exotic woody genera were studied (Table 1). These genera were selected on the basis of previous work which suggested that they are present in significant numbers in New Zealand (MacKay, 1989, 1990, and unpublished). The collections targeted for this survey included private individuals (65%), local authorities (15%), universities (5%), and botanic gardens and other plant collections (15%). The minimum data required for recording collections includes name and source (Cullen et al., 1985). Participants were asked to indicate the species in their collection, and the age and source of each one, if known.

Fifty-six of the 91 collections surveyed replied within the time limit set for the completion of the survey. The data were collated to show where each species occurred. Next, a summary was generated which showed number of species and cultivars found, number of plants in three or less collections, and the collections with the largest range of that genus. The 'three or less collections' is a benchmark used by the British to describe risk (Lowe, 1989). It is difficult to define what constitutes an 'important' collection as there are no set standards, except the notion of 'representativeness' used in Australian and British collections (Anon., 1991; Lowe, 1991). In the absence of a suitable guideline an arbitrary threshold of '50% of the types in the survey' was selected to indicate significant collections for the genera in this survey. Collections with '30% to 50% of the types in the survey' were put into a second category for significance. Any collection with less than 30% of the types in the survey was classified as not significant, unless it was within the five largest collections for that genus.

Table 1. Summary of genus information; data taken from MacKay (1993).

Genus	Number of spp.	Number of cvs	Total	Largest collections*
Abies	59	9	68	55, 65 / 63, 13, 47, 121, 134 /
Acer	103	126	229	13 / 63, 06, —/ 22, 121
Aesculus	18	11	29	13 / 104, 121, 09 / 06
Alnus	35	3	38	06, 13 / 121 / 111
Betula	59	11	71	06, 121 / 13, 63 / 104
Buddleia	30	21	51	13, 46 / 121, 118, 14, 128 /
Carpinus	16	1	17	13 / 27, 06 /
Cedrus	7	21	28	47 / 22, 128, 63, 13, 55 /
Crataegus	41	17	58	13 / 121 / 118, 22
Cupressus	30	51	81	—/ 55, 47, 128 / 13, 134, 123, 39
Euonymus	28	28	56	—/ 121 / 13, 128, 05
Fagus	7	23	30	13, 104 / 63, 22, 19, 16 /
Fraxinus	36	11	49	13, 121 / 06 / 128, 63
Gleditsia	9	8	17	13 / 121, 104, 128 / 131, 120
Ilex	41	32	73	—/ 121 / 13, 06, 128, 26, 63
Juniperus	42	136	178	47, 134 / 55, 133, 128 /
Magnolia	40	124	164	120, 63 / 129, 31, 114, 13 /
Malus	44	60	104	13 / 121 / 129, 06, 128, 118
Nothofagus	18	1	19	121, 06, 128 / 30, 103, 63, 13 /
Picea	40	32	72	55 / 47, 63, 65, 22 / 13
Pinus	129	11	140	65, 55, 13 / 47, 121, 123 /
Podocarpus	30	11	41	121 / 128, 47, 13, 63 /
Populus	36	42	78	06 /—/ 13, 39, 22
Prunus	57	107	164	13 / 103, 121 / 128, 131
Pyrus	13	3	16	06 / 128 / 13
Quercus	146	25	172	06, 13 /—/ 63, 121, 53, 128
Sorbus	64	34	98	—/ 13, 06 / 27, 132, 121
Tilia	21	5	26	13 / 106, 121, 19 /
Viburnum	44	33	77	—/ 121, 39, 13, 128 / 27 120

*Collections are shown thus: Collections with more than 50% of the range in N.Z. / collections with more than 30% of the range in N.Z. / collections with less than 30% of the range in N.Z. but still in the top five. Collections are shown by number, as many owners wish to remain anonymous. Interested persons should contact the author for identifying information.

Next, the data were combined on the basis of overall number to find out which collections were the most extensive. This was done by allocating three points if a collection had 50% or more of the range in the survey, 2 points for 30–50% of the range, and 1 point if the collection had less than 30% but was still in the top five. The resulting points were summed for each collection to give a collection total.

A weakness of this survey was that the identity of the plants could not be verified by the author. It is possible that incorrectly identified plants were reported. Ideally subsequent projects should investigate plant verification. This will be needed if national collections are to be developed (Michener, 1989; Stungo, 1982).

Results

A complete set of survey results, including plant lists for each genus, is found in MacKay (1993). The survey revealed a total of 2242 different types of woody plants from the 29 genera studied (Table 1). Of these, 1243 were species and forms of species, and 999 were cultivars and hybrids. Fifty-two percent of the total were found in three or fewer collections. The largest genera were, in descending order, *Acer, Juniperus, Quercus, Prunus,* and *Magnolia*. Some genera comprised a majority of species, namely *Abies, Aesculus, Alnus, Betula, Carpinus, Crataegus, Fraxinus, Nothofagus, Pinus, Podocarpus, Pyrus,*

Table 2. The degree of risk of each genus, as shown by the percentage available in three or fewer collections. Data taken from MacKay (1993).

Genus	Percentage in three or fewer collections
Euonymus	75
Crataegus	75
Malus	73
Populus	71
Quercus	69
Pyrus	68
Sorbus	65
Aesculus	62
Tilia	61
Ilex	60
Carpinus	59
Acer	55
Prunus	53
Betula	52
Fraxinus	51
Alnus	47
Fagus	43
Juniperus	43
Nothofagus	42
Gleditsia	41
Viburnum	41
Podocarpus	41
Cupressus	40
Magnolia	40
Buddleia	39
Cedrus	39
Picea	37
Pinus	36
Abies	27

Table 3. The top three collections – identified by code number – for each genus. Data taken from MacKay (1993).

	Collection rank		
Genus	1	2	3
Abies	55	65	63
Acer	13	63	06
Aesculus	13	104	121
Alnus	06	13	121
Betula	06	121	13, 63
Buddleia	13	46	121
Carpinus	13	27, 06	—
Cedrus	47	22	128
			63, 13
Crataegus	13	121	118
Cupressus	55	47	128
Euonymus	121	13	128
Fagus	13, 104	63, 22	19, 16
Fraxinus	13	121	06
Gleditsia	13	121	104, 128
Ilex	121	13, 06	128
Juniperus	47	134	55
Magnolia	120	63	129
Malus	13	121	06, 129
Nothofagus	121	06	128
Picea	55	47	63
Pinus	65	55	13
Podocarpus	121	128	47
Populus	06	13	39
Prunus	13	103, 121	128
Pyrus	06	128	13
Quercus	06	13	63
Sorbus	13	06	27
Tilia	13	106, 121	128
Viburnum	121	39, 13	128

Quercus, Sorbus, and *Tilia*. Other genera comprised a majority of cultivars: *Cedrus, Cupressus, Fagus, Juniperus, Magnolia, Malus,* and *Prunus*. Some had similar proportions of each, namely *Acer, Buddleia, Euonymus, Gleditsia, Ilex, Picea, Populus,* and *Viburnum*.

The genera were ranked for degree of risk, following the 'three or less collections' benchmark (Table 2). The ten genera most at risk were *Euonymus, Crataegus, Malus, Populus, Quercus, Pyrus, Sorbus, Aesculus, Tilia,* and *Ilex*. Unfortunately this survey did not include the collection at the Aokautere Plant Material Centre; inclusion of that data would likely change the position of *Populus* in the ranking. The genera most secure in collections were *Abies, Pinus, Picea, Cedrus, Buddleia, Magnolia, Cupressus, Podocarpus, Viburnum,* and *Gleditsia*.

Table 3 shows collections having the largest groupings of each genus (listed in descending order). When genera are considered individually it is clear that a number of collections are important. For example, collection 65 focuses specifically on coniferous species. It does not have the breadth of genera found in some collections, but it is a leading collection for *Abies* and *Pinus*. There are several collections with this type of narrow but highly significant focus. Although they do not spread over many genera they are still important to the overall resource. On the other hand, some collections appear regularly in the top three positions. When the data were collated for frequency of important genus collections, the important collections were (in descending order) numbers 13, 121 (restricted), 06, 128, and 63. Clearly these collections have a broader range of genera, and therefore a greater volume than the narrow focus collections. The previous ranking is subjective, as it assumes that the value of a collection is based upon diversity and volume of different plants. Indeed a ranking based upon number in a single genus may be equally valid. Moreover, collection owners may value other criteria more highly.

Although the inventory revealed a wide range of plant material, it represents the situation at one point in time. As collections acquire new material or lose existing plants there will be minor repositioning amongst the largest collections for any one genus. Major shifts in the position of a collection will occur if the manager is implementing a focused accessions policy for particular genera. For example, the *Magnolia* in collections 120 and 129 are relatively recent developments. Major changes will also occur if suitable propagation and replacement policies are not used at key sites. For example, important species may be lost if a mature collection is not replaced when it declines.

Discussion

The survey results have important implications for those managing plant collections. In the national interest there is clearly a need for managers who hold the 'at risk' collections to take steps to ensure the long-term viability of those collections. Plans for propagation, replacement, and dispersal are needed to ensure that species are not lost. Similarly, those planning the future content of their collection can use these data to decide how to position their collection in relation to other collections. For example, in the long term a balance of collections is needed so that no genus is at serious risk, but at the same time the individual character of collections must be allowed to develop.

The majority of important collections were privately owned. Of the top ten collections, only three were maintained by institutions. Private collections are the property of the owner, and their development and utilisation are the prerogative of the individual. This has implications for access to germplasm for the public good, and, conversely, for funding assistance by government for the preservation and management of these important resources. For example, species from the rose family feature strongly in the 'at risk' genera. Given the relationship between these genera and the fruit production industry, the apparent precariousness of these genera is a cause for concern. If the germplasm contained in plant collections is of national importance, these types of issues must be addressed.

This inventory forms a database for the decisions necessary to manage the resource. Analysis of the inventory will identify those collections which are likely candidates for national collections. Similarly those collections which are complementary and/or parallel can be identified (Stungo, 1982). Although the results of this survey identify possible national collections, by highlighting the largest collections, they do not establish value. A collection which is in poor condition is less valuable than one in good condition. A collection which is in a flowering but vigorous growth phase is more valuable than one which is in decline. A rigorous evaluation of collections must be made to establish priorities. Then we can identify which species, cultivars, and collections should be conserved, and in what order.

Analyses underpin the development of operating strategies. First, the content of a collection must be managed with a coherent accessions policy (WWF and IUCN, 1989). This should take account of the plants in other collections (WWF and IUCN, 1989). To meet this goal effective data exchange between institutions is needed (WWF and IUCN, 1989). This is a key purpose of the BGCI database system. Further to an accessions policy, BGCI recommends that each collection develop ex-situ and in-situ conservation policies (WWF and IUCN, 1989).

Evaluation and strategy development are, however, management steps that belong in subsequent projects. Meanwhile another inventory issue must be addressed – management of the inventory information itself. The vast amount of data involved calls for a computerised recording method, with manual options for those without access to a computer. The development of an appropriate format is a task which must be addressed. Which information will be necessary? How will data be collected and verified? Policies for overall management of the data will be needed. The RNZIH plant collections group is currently addressing some of these issues.

Finally, there are more collections to be recorded. There are known collections of *Acer, Magnolia,* and *Ilex* which for various reasons were not included in the survey. Similarly there are general collections which were not included. In several instances the omission occurred because the owners were unable to reply to the survey at this time. It is likely that a future survey will include those collections. From a broader perspective there are other woody genera still to be investigated, as well as the wide range of herbaceous material.

Conclusion

The development of a plant collections scheme, with a series of dedicated collections, will be an important contribution to the management of plant resources in New Zealand. The economic notion of option value underpins the development of this scheme and other similar initiatives. The science priorities for New Zealand also support the rationale of the scheme. Data presented in this paper usefully contribute to the development of a plant collections scheme. Much remains to be done, however, before one can claim to be fully managing the ornamental plant resource in collections. Unrecorded collections must be added to the inventory. The resource must be evaluated, and appropriate policies and strategies developed.

Managing the plant resource, however, involves more than just inventory and evaluation. Achievement of conservation goals (or any other goal) requires conscious management activity. We must be prepared, informed, and actively monitoring the resource. In other words we must be systematic managers, otherwise we will have crisis management, adhoc operations, and uninformed decisions. If we should discover a taxol, or be invaded by gypsy moth, could we quickly and effectively find plant material relevant to the crisis, or would we simply generate much heat and no solution? Management is about recognising the decisions that *need* to be made, and thinking ahead in advance of potential problems.

Successful plant resource management is about biological skills, plant species, and their locations. It is also about the management skills we use in planning and decision making for the enterprise. We must be able to anticipate the decisions that need to be made. This is possible only if we have the necessary data. Only then will we be rigorous and effective managers.

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Biotechnology and Forestry: Where to Now?

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Summary

A tree breeding programme now provides sufficient improved 'orchard' seed for all of the New Zealand radiata pine planting programme. A higher level of gain is available from use of control-pollinated seed. However, this seed is expensive and still in short supply. Vegetative propagation by cuttings is enabling a greater area of forest to be planted that is derived from this scarce seed.

Propagation techniques for clonal forestry are also being developed. Both micropropagation and embryogenesis are technologies which have the potential for high multiplication of individual genotypes, while also allowing storage of material in a juvenile state by cold storage or cryopreservation during the clonal testing phase. An extra multiplication step by cuttings is also possible.

Molecular biology techniques are now being researched for forestry applications. Fingerprinting of clones is now possible, and marker-aided selection is promising. Gene transformation appears to have been achieved for radiata pine embryogenic tissue, using a GUS marker gene, and it is likely that herbicide resistance will be the first commercial application of this technology.

Integration of programmes for tree improvement, propagation, and molecular biology will continue to yield increased gains for forestry as New Zealand advances towards clonal forestry with radiata pine.

Introduction

The word 'biotechnology' conjures up different images for different people, from a narrow sense of genetic engineering or molecular biology to a wider industrial application of biological processes. I use the word 'biotechnology' to broadly describe the delivery of genetically and physiologically improved planting stock to the forest industry. This research area was started at the N.Z. Forest Research Institute (NZFRI) in the 1950s, with genetic improvement of *Pinus radiata* D. Don by tree breeding, together with improved nursery practices. In the 1970s and 1980s this was expanded to include vegetative propagation by cuttings, micropropagation, and embryogenesis. More recently, in the 1990s, molecular biology has been included.

In this paper I would like to discuss where we have come from, and what the future may hold.

Tree Breeding and Seed Orchards for Radiata Pine

Early forest establishment in New Zealand was carried out with bulk seed, or seed collected by climbing or felling selected trees. Intensive tree breeding started in New Zealand in the early 1950s with intensive selection of superior trees for the establishment of open-pollinated (OP) seed orchards using grafts. The emphasis of this selection was on growth rate, tree form (straight bole and light, wide-angled branching), and lack of stem cones on the lower stem. Seed from these orchards started becoming available in the early 1970s.

A further selection of superior trees was made in the late 1960s. This was a less intensive selection from northern Kaingaroa Forest. Open-pollinated progeny trials were planted and used to select the best clones for planting in open-pollinated seed orchards. Later progeny trial information was used to reduce the number of clones. These orchards started coming into production in the mid 1980s.

However, there are a number of limitations with open-pollinated orchards (Carson, 1992), particularly pollen contamination from outside the orchard diluting genetic gain. A solution to this problem was the introduction of control-pollinated (CP) orchards, which are now in commercial seed production (Carson, 1992). The trees are kept hedged, and are pruned to optimise female cone production. Each year, just before female flowers become receptive, shoots bearing the flowers are bagged with cellulose bags. Pollen from selected parents is injected into the bag several times while the flowers are receptive. Bags are removed once the flowers are no longer receptive. Control-pollination allows both parents to be selected, and this gives far higher levels of genetic gain, and also allows specific traits to be bred for. The main production breed is for

Table 1. Comparison of the performance of some typical seedlots from various seedlot classes with that of 'bulk' seed (Forest Research Institute, 1987).

Breed/seedlot class	Percentage gain in volume	Percentage of acceptable stems	Improvement rating for growth and form*
Growth and form breed			
Bulk	—	45	1
Climbing select	5–10	50	7
1st OP orchard	13–18	65	14
2nd OP orchard,	15–20	70	16
and top 16 clones	19–23	70	19
Control-pollinated orchard	27–32	80	23

*Average improvement ratings will vary considerably within seedlot classes.

growth and form, but other special breeds include long internode and *Dothistroma* needle blight resistance (Forest Research Institute, 1987).

A new concept under development since 1988 is that of a meadow (CP) orchard where 2000 or more grafted trees per hectare are established. Early flowering is encouraged by crown management. Further developments are continuing to increase female flower and cone production and to effect pollination without the use of isolation bags (Sweet, 1992). These developments should lead to a significant reduction in the cost of CP seed in the future.

The demand for radiata pine seed was expected to stabilise at about 5000 kg (Wilcox, 1981), although there was a demand of only 2400 kg in 1989. About 7000 kg of GF 16 and 17 seed and about 600 kg of GF 18 and above seed was collected in 1993 (Vincent, 1993).

There have been progressive gains in volume and the percentage of acceptable stems as the tree improvement programme has progressed (Table 1), with approximately 1% gain in volume for each year of operation of the programme. This gain has been sufficient to require current growth models to be adjusted for level of genetic improvement.

Higher quality levels of genetically improved seed are also more expensive, and typical costs in 1993 were \$50–60/kg for bulk seed, \$200–520/kg for OP seed, and more than \$7500/kg for CP seed. CP seed is also in short supply, and so some form of vegetative propagation by cuttings or tissue culture is often used to allow a greater forest area to be planted with plant material derived from this superior seed.

Nursery and Tree Handling Practice

Seedling quality is critical for successful establishment. Seedlings must not only survive after transplanting, they must also have optimum and uniform early growth. The key seedling quality attributes are described by the morphological and physiological characteristics of the plants. These are determined by the methods used to grow plants in the nursery, and how the plants are handled before planting in the field.

The main morphological characteristics are height, diameter at the root collar, and sturdiness. Physiological characteristics include root growth potential, food reserves (mineral nutrients and carbohydrates), water reserves, and frost tolerance. Typical radiata pine seedling specifications and the critical nursery operations to achieve these specifications are described by Menzies (1988).

The two most critical aspects affecting seedling quality of nursery-grown plants are spacing in the nursery bed and conditioning by root pruning. Nursery machinery has been developed in New Zealand to ensure that high-quality plants can be reliably produced (Menzies et al., 1985a). Spacing is controlled by use of a precision vacuum-drum seed sower, while root conditioning is done with an undercutter/wrencher and a lateral root pruner. The undercutter/wrencher is used to cleanly sever the taproots in summer at a depth of 10 cm. This encourages lateral root growth while slowing down top growth. A wide tilted blade on the undercutter/wrencher is used subsequently at monthly intervals to break off any sinker roots growing down below the undercutting depth, as well as aerating the soil. Lateral roots growing across the rows are severed by the rolling coulters of a lateral root pruner once or twice during the wrenching period. This conditioning concentrates new root growth close to the seedling root collar and results in a balanced seedling in terms of root/shoot ratio.

Other machinery includes equipment for distributing solid fertiliser accurately between the rows of seedlings and boom sprayers for application of liquid fertilisers, weedicides, fungicides, and insecticides. This mechanisation means that all nursery operations can be done from the back of a tractor except for the final lifting operation, where hand lifting is preferred.

Lifting and handling practices now include careful hand lifting to minimise root damage, and trimming of lateral roots to 10 cm long. Roots are kept moist by spraying or dipping. Seedlings are packed into rigid containers on the nursery bed, rather than in a packing house, to avoid prolonged exposure. Packing seedlings on their sides prevents taproot damage. The cardboard containers act both as storage containers and also as planting boxes out in the field, so the seedlings are not exposed from the time of lifting until they are planted. Seedlings should be stored for no more than 72 hours, at cool temperatures (2–4°C).

Following these procedures means that high-quality seedlings are produced in the nursery, and their quality is maintained throughout handling to planting in the field.

Propagation Technology

A range of propagation technologies is now either available or being researched to bulk up scarce control-pollinated seed trees from the tree breeding programme. The method used depends on the multiplication rate required and the time available. Options include cuttings, tissue culture (or micropropagation), and embryogenesis.

Cuttings

Cuttings are widely used in New Zealand to bulk up seed trees of CP families. Identity of the families is often kept separate, allowing for plantations of individual families to be harvested in the future. Cuttings are produced on stock plants in the nursery. The stock plants are trimmed each summer to allow production of shoots for setting as cuttings. Cuttings are set directly into raised beds in winter, and grown on a similar regime as seedlings. They form roots in late spring, and are ready for planting out the following winter. Stool beds can be maintained for at least four years (Faulds and Dibley, 1989).

Another method of obtaining cuttings is to collect branch tips from genetically improved trees in young plantations. These are more expensive to produce, because of the travel involved between the nursery and the site and also the travel between trees. However, cuttings from field collections have demonstrated advantages, particularly on fertile farm sites, of improved form over juvenile stool bed cuttings, owing to physiological age effects and selection of cuttings from the best plantation trees (Menzies et al., 1985b).

The time taken for a tree to grow from seed is its 'chronological age'. A tree's chronological age can be different from its 'physiological age', which is the apparent age of the tree. A number of factors affect the physiological age, including the tree's genotype and the site where it is growing, e.g., trees age more quickly on fertile warm coastal sites, where they grow more rapidly (Menzies et al., 1988). Some of the effects of a more mature state are positive, such as improved form, while other effects, particularly slower early growth rates, are negative.

Micropropagation

Micropropagation is a technology which offers a far higher potential multiplication rate than is available from cuttings, and offers the opportunity to multiply superior clones from within top CP families. Embryos from CP seed are usually used as a starting material for micropropagation. There are several stages involved, including shoot initiation, shoot elongation, shoot multiplication, and rooting. Tissue is kept sterile through all the stages except the last, and is grown in containers on an agar medium containing all the necessary nutrients, hormones, and other substances to support growth. The containers are kept in a controlled environment with artificial lighting. When shoots are large enough, they are given a hormone treatment to stimulate rooting and set as small cuttings in containers in a greenhouse to form roots. After rooting, they can be lined out in a nursery bed and grown on like seedlings or cuttings (Menzies et al., 1985b).

Tissue-cultured plantlets are currently expensive to produce, because of all the manual stages of transfers and the need for growing in sterile controlled conditions.

Embryogenesis

Another propagation technology which is being developed is embryogenesis. Embryogenic cell lines are established from immature seed, and millions of immature embryos of individual genotypes can be multiplied from each seed. These embryos will develop and mature under appropriate conditions and then can be germinated like natural embryos. The efficiency of this process needs further improvement, but the technology has the potential to produce unlimited quantities of embryos of desirable genotypes at costs cheaper than current CP seed prices.

Future Directions

Clonal forestry

Clonal forestry offers a number of potential advantages over use of CP families, including greater genetic gains for particular traits and improved crop uniformity. However, these benefits need to be proven.

One of the problems to be resolved is selection of which clones are superior. At present, trees need to be at least eight years old before growth rate and stem form can be reliably selected, and even older for some wood property traits. During this time, all clones need to be kept juvenile to avoid problems of physiological aging. Cold storage or cryogenic storage are potential methods for this, but probably 95% of the clones stored like this will not be used. Early selection methods offer some potential to avoid storing clones for too long.

Another option is to develop methods to rejuvenate trees, and this is being actively researched. This would allow the best trees to be selected in trials and propagated in large numbers after rejuvenation. This would avoid the costs of placing material in storage.

It still needs to be evaluated whether the gains from selecting the best clones within top families will give more gain than could be achieved in the same time by turning over another breeding generation. However, clones may offer a better opportunity to select trees for specific sites or trees with specific traits, such as high growth rate and high wood density (since these traits are inversely correlated, and gains in both are difficult to achieve with conventional tree breeding).

Molecular biology

Molecular biology has tremendous long-term potential as a tool to assist tree breeding in the two areas of gene mapping and transformation (or genetic engineering). Molecular biology involves working with the basic building blocks of life, DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). DNA is the active genetic material of chromosomes in cells, controlling inheritance, while RNA carries messages from the DNA to other parts of cells to regulate and participate in the synthesis of amino acids and proteins and control all plant functions.

Gene mapping

Purified DNA from cells can be cut into different-sized fragments by the use of restriction enzymes, which cut the DNA at a specific place, depending on the restriction enzyme used. The DNA fragments can then be separated by electrophoresis, as the smaller fragments travel further along the gel. The DNA bands generated are specific for the genotype and the restriction enzyme used. This provides a powerful tool for distinguishing between genotypes, i.e., fingerprinting. Vegetatively propagated plants of a given clone will have the same bands on a gel, and so clones can be differentiated from each other. This has already proved useful in distinguishing between seed orchard clones where mistakes in clonal identity were suspected.

These bands also have the potential to be used as markers for particular traits, such as wood quality or disease resistance. An example of this is being tried at NZFRI, using the cross 850.55 × 850.96, where 850.55 has low wood density as a parent, and 850.96 has higher wood density. The offspring have a range of wood densities between those of the parents. Some of these offspring have been selected at the high or low wood density end of the spectrum, and their DNA is being mapped using different restriction enzymes. It is hoped that bands related to either low or high wood density will be discovered. If this technique is successful, a given trait could be identified while the plant was being propagated, allowing early selection for the trait. This 'marker-aided selection' (MAS) has the potential to improve traits more quickly and efficiently than can be achieved through use of conventional tree breeding methods.

Gene transformation

Gene transformation or genetic engineering is the insertion of foreign genes into the genome of a plant. This is achieved by inserting the foreign gene into small pieces of tissue growing in a tissue culture or embryogenesis system so that the gene is expressed in the tissue. Plants are then regenerated from the transformed tissue. Several methods are used to achieve transformation, including the use of *Agrobacterium* or a 'gene gun'. A number of steps must be achieved for successful transformation, including:

- Obtaining the required genes. These may be 'off-the-shelf' constructs such as for herbicide resistance, genes isolated from radiata pine, or genes isolated from other species.
- Obtaining a suitable promoter. A gene promoter is required to obtain expression of the gene in the desired tissue at the desired time.
- Developing a suitable transformation system to introduce the gene into the plant tissue.
- Developing a suitable propagation system to be able to regenerate plants from the transformed tissue.
- Field testing of the transformed plants to ensure that the gene is expressed as required.

Early research has involved the use of marker genes for antibiotic resistance and GUS. Use of antibiotic resistance allows screening of tissue after attempted transformation, as only transformed tissue should survive. The GUS gene is used as a visible marker. When transformed tissue is fixed with chemical reagents, any tissue expressing the GUS gene will turn blue. Embryogenic tissue appears to have been successfully transformed with an antibiotic gene and the GUS gene, and germinated somatic embryos have been recovered from this tissue. The next phase of research will probably include resistance to herbicides, such as glyphosate (Roundup®). Any other genes available 'off the shelf' will also be able to be used. In the longer term, traits of interest could include male or female sterility, wood properties, wood durability, and disease resistance. Successful alteration of these traits involves a far greater understanding of the biochemistry and mechanisms of gene regulation for these traits, requiring further research.

Conclusions

Advances in tree breeding have allowed significant gains to be made in the value of radiata pine plantation forests, particularly because of increased wood volume and quality, as well as improvement in other traits such as branching habit and disease resistance. Improvements in nursery and propagation technologies have allowed greater forest areas to be planted with the improved seed. Molecular biology techniques are now also being developed, and these will assist in increasing the gains even further, as New Zealand forestry advances towards clonal forestry with radiata pine.

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Alternative Species

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Introduction

When asked to speak on 'alternative species', I decided first to interpret this as meaning species considered as alternatives to radiata pine, and second to include only exotic species, despite the fact that our New Zealand native species may also be rightly considered as alternatives. Third, I decided to attempt an overview of the subject rather than to concentrate on a single specialised aspect of it, despite the knowledge that by so doing my account would inevitably have to be a most cursory one.

Already in previous approaches to the subject at Forest Research Institute we had encountered difficulty in marshalling and arranging information about alternative species. As a result of this experience it seems best to follow through the concept of use and purpose for growing, as the basis for a short talk.

We can perhaps distinguish three broad categories: contingency species; species for non-radiata sites; and special purposes, e.g., timber, industrial, shelter, soil conservation, amenity. Obviously these are not watertight categories; some species can appear in one or more categories.

We will consider the categories in turn, and assign to each the various species which appear most suited to it.

Contingency Species: Nature and Requirements

The 'contingency' here implied is that which could arise were radiata pine in New Zealand to suffer some severe setback, from pathological or other causes, affecting its present position as our paramount commercial softwood.

A point to consider is that despite its susceptibility in relatively recent times to needle-cast fungi including *Dothistroma pini* and *Cyclaneusma minus*, and over a longer period to other fungal diseases such as *Diplodia, Phomopsis,* and *Armillaria*, radiata pine maintains a relatively healthy presence, even in extensive monoculture.

Radiata pathologists tend to be either optimists or pessimists. Optimists say that the national investment in the species is so great that we can afford to pay for research necessary to get and keep us out of trouble should it arise. Thus, as an example, tree-breeding could provide within a few years resistant material with which to counteract any threats arising. Pessimists, on the other hand, may point across the sea to the lands which harbour diseases which have yet to appear in New Zealand, and which could affect radiata, like western gall-rust, *Endocronartium harknessii;* or they may cite other examples of pathogens which have suddenly and seriously upset the efforts of foresters to grow important exotic and native species alike. The fate of cypresses in Kenya, where macrocarpa succumbed to *Seiridium* fungi, or of lusitanica to *Cinara* aphids, the ravages of Dutch elm disease, or the reverses caused by the root rot *Phytophthora lateralis* in mature stands of Lawson cypress come to mind.

In addition to pathogenic threats we also have the possibility of climatic change due to the increase in atmosphere of so-called 'greenhouse gases' including carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. Rising temperatures have been predicted, but also more extremes of windier, wetter, or drier weather depending on geographic location within New Zealand.

Irrespective of one's persuasion in the matter, it would seem prudent to take out some sort of insurance policy on any species representing a large investment, and the cheapest and most obvious of these would be in the form of knowledge of, or preparedness to use, species which could be rapidly and effectively substituted for the mainline one in the event of serious trouble.

What, then, are the qualifications one should look for in a contingency species?

- Wood uses comparable to radiata pine
- Good health
- High productivity
- High site adaptability
- Provenance variation

It may be said of these requirements:
(i) wood must be suitable for a role as a general utility softwood;
(ii) good health is mandatory;
(iii) productivity must be high enough to provide industrial needs within an accepted timespan and within the forest area which could be made available.
(iv) site adaptability should cover a wide range of soils within a large altitudinal range, e.g., sea level to 500–600 m;
(v) a wide spectrum of provenance variation is also apt to reflect increased site adaptability.

There are very few species which qualify well. Among those whose merits are worthy of discussion are *Pinus muricata, P. pinaster, P. patula, P. contorta, P. taeda, P. pseudostrobus; Pseudotsuga menziesii; Abies grandis; Sequoia sempervirens;* and *Eucalyptus nitens.*

Of this list, the pine species may be regarded as the only direct substitutes. Other species are included on the grounds that they may relate to *Pinus radiata* in a complementary way rather than directly. Thus Douglas fir is the most valuable species which can complement radiata on more exposed sites. *Abies grandis,* though producing rather soft and light wood, can nevertheless function as a general purpose utility species. *Eucalyptus nitens* has potential as a pulping species which can grow on a wide range of sites, and *Sequoia sempervirens,* once established, is capable of realising large volumes of valuable, if rather purpose-specific timber.

Pinus muricata – muricata pine

Wood properties. Muricata pine has higher wood density near the pith than radiata pine, so up to middle age (30 years approx.) it could be expected to have high whole-tree density. Strength properties are about the same as radiata when wet, better when dry. Resin content is a little higher, but not affecting the timber over short rotations. The uninodal habit of muricata pine suits finger-jointing procedures. Seasoning behaviour is similar, as is groundwood pulping quality. Wood properties are thus quite satisfactory.

Health. Muricata passes through the juvenile stage of susceptibility to *Dothistroma* slightly faster than radiata pine; otherwise resistance is similar. It suffers from no other major pests, although it has been attacked by *Sirex* and by *Armillaria.* Muricata is more frost-resistant than radiata.

Productivity. Volume, at similar stockings, is 85% that of radiata pine. 'Blue' muricata can be 17–28% better than radiata pine at higher sites. Volume at 250 stems/ha at 45 years (m^3/ha):

Green muricata – 610 (54%)
Blue muricata – 950 (85%)
Radiata pine – 1120 (100%)

Site adaptability. Muricata pine is able to grow on all sites that suit radiata pine, and furthermore can extend its good performance onto sites beyond radiata's optimal range, e.g., at higher altitudes and onto phosphate-deficient soils.

At sites of higher elevation less malformation has been recorded for muricata than for radiata:

Altitude (m)	Forked stems (%) radi.	Forked stems (%) muric.	Age (yrs)
630	84	64	40
690	66	28	6

Provenance variation. Muricata pine has a wide natural distribution in coastal California, spanning 13° of latitude. It shows marked varietal differentiation, expressed in differing chemical composition (turpentines). The northerly chemical variety is known as 'blue' muricata, on account of its distinguishing foliage colour, while the southern varieties comprise 'green' muricata. In general the blue varieties grow better in New Zealand, although one of the 'greens' from Sonoma County at the point of change-over (lat. 38°42′ N) is proving to be quite vigorous and well adapted in New Zealand.

Summary. Muricata pine is probably the most promising contingency species. Its continuing good health should be monitored with interest, therefore.

Pinus pinaster – maritime pine

Pinus pinaster has been established in New Zealand for longer than most exotic species. In 1830 it was considered to be an indigenous species, and was given the name *Pinus novazelandii.*

Wood properties. Compares very favourably with radiata pine. Maritime pine timber has higher density and superior strength. It has higher resin content, and shows less longitudinal shrinkage than radiata pine. It satisfies a wide range of applications in its European homelands, as sawn timber, panelling, poles and piling, railway sleepers, pulpwood, plywood, fence posts, etc.

Health. In this country it is a healthy species, having no major insect predators. Moderately susceptible to *Dothistroma.*

Productivity. Compares unfavourably with radiata pine in both growth rate and form. Height growth is about 70–100 cm per annum, and average volume production is about half of what may be expected from radiata pine. The tree generally is likely to be coarse-crowned and heavy-branched, and to show frequent stem sweep and pronounced taper.

Site adaptability. Grows over a wide range of sites in most parts of the country. Prefers low altitudes where summers are hot. Tolerant of a wide range of soil types, including those of low nutrient status, e.g., phosphate-deficient podzolised gumland clays. Grows well on sandy foredunes by the sea. Frost tolerant, and tolerates exposure well.

Provenance variation. Shows considerable variation over its wide natural distribution in the Mediterranean and in North Africa:
(i) Atlantic provenance group – Southwest France, north coast of Spain, Portuguese coast (vigorous);
(ii) Mediterranean group – inland Spain, Morocco, northern Italy, French Mediterranean coast;
(iii) Corsican group – island of Corsica (good form).

Summary. Hybrids have been made between Portuguese and Corsican provenances to combine vigour and straightness.

Pinus pinaster could be used as a substitute for radiata pine, more especially in warmer parts of the country, but the species would need intensive breeding to improve form, and generally slower growth rates than radiata pine would have to be accepted.

Pinus contorta – contorta pine

Pinus contorta is at present prescribed as a weed species owing to its notorious tendency to spread across open country. However, it possesses qualities which demand its inclusion as a contingency species relative to radiata pine.

Wood properties. Similar to radiata pine in many aspects, and fulfils functions as a general utility softwood in North America. The many differences between contorta pine and radiata pine are in piece size, a great proportion of heartwood in contorta pine, and the presence of nodal swellings. Contorta pine is suitable for both kraft and mechanical pulping.

Health. A healthy species. Attacks by *Dothistroma, Armillaria,* and *Diplodia* are neither widespread nor serious.

Productivity. Yields on average or better-quality sites have ranged from 270 to 680 m³/ha at age 35, about half to three-quarters of what might be expected from radiata pine.

Site adaptability. Very wide range indeed, from coastal dunes to the upper limits of tree growth in the mountains. Tolerates most soils over this large range.

Provenance variation. Very wide provenance variation linked to an extensive natural distribution in North America, from the Alaskan border to Bahia California and from the Pacific coast to South Dakota. Occurs as four subspecies.

Summary. Contorta pine could handle all radiata pine sites, and could be planted in addition well beyond radiata's present range in New Zealand. The most obvious difference would be in productivity, although rotation length would remain short (30 years approx.) in this fast-growing species.

Although a highly speculative concept, contorta pine is a species which could probably continue to function in the event of greatly reduced mean temperatures, as might be associated with a 'nuclear winter'.

Pinus taeda - loblolly pine, *P. patula* - patula pine, and *P. pseudostrobus*

Wood properties. These three species broadly resemble radiata pine in wood properties. *P. taeda* has denser, stronger wood; *P. patula* is slightly less dense. *P. pseudostrobus* has distinct, regular nodal branching (could provide long, clear internodes).

Health. Generally healthy species, less susceptible to *Dothistroma* than radiata pine.

Productivity. Yields compare well with those which might be expected from radiata pine on an average site. Recorded examples are:

P. patula total M.A.I. – 23 m³/ha at age 42

P. taeda total M.A.I. – 22 m³/ha at age 25

P. radiata total M.A.I. – 23 m³/ha at age 40

Site adaptability. *P. taeda* is capable of growing well over much of the North Island. *P. patula* is suitable for high summer rainfall areas in the North Island and in the milder parts of the South Island. *P. pseudostrobus* also is a North Island prospect.

Provenance variation. *Pinus taeda* is widely distributed to south-eastern U.S.A., and provenance variation has been reported from New Zealand and South Africa. Coastal and southern provenances have grown faster than northern and western ones. The straightest provenances, however, have been from Arkansas and the south-western quarter of the species' natural distribution.

Pinus patula has shown little provenance variation in New Zealand, the best origin being a New Zealand lot from Rotoehu, a locally adapted seed source, probably from the northern part of the species' natural range in central Mexico.

Pinus pseudostrobus has also shown a small amount of provenance variation. The best origin in trials was from Vera Cruz state in south-eastern Mexico.

Summary. Although all three species are capable of growing well on certain sites, and could be improved by selection and breeding if applied, they lack the broad site tolerance of radiata pine. Also, growth rates and form are generally lower than for radiata pine, and their potential as contingency species is affected accordingly.

Species for non-Radiata Sites

Difficult sites for radiata pine are usually those which are frosty or at high elevations, or those having unusual or poor soils. Applications of these species can be summarised as follows:

Frosty/high elevations – *Pinus muricata, P. nigra, P. ponderosa, P. sylvestris, P. contorta, Larix, Pseudotsuga.*

Difficult soils – *P. muricata, P. pinaster, P. monticola, P. strobus.*

P. muricata. Better frost resistance than radiata pine. Better form at higher elevations. Tolerates soils deficient in phosphate better than radiata pine.

P. nigra. In areas where *Dothistroma* is not a problem (e.g., dry inland areas, Mackenzie country) *P. nigra* is a reliable species with very low rates of malformation. The New Zealand race, descended from trees of Corsican ancestry, is of very good form. Not a fast-growing species, but can yield high volumes (e.g., 240 m³/ha by 30 years).

P. ponderosa. Grows well in inland, southern sites where *Dothistroma* is not a problem.

P. sylvestris, P. contorta. Very hardy species, on frosty, high-elevation sites.

Larix spp. *L. decidua*, European larch, can grow well at high elevations and on frosty sites. It requires sufficient moisture in spring, however, to develop and sustain its new foliage. Its golden autumn colours give the species amenity value. *L. kaempferi,* Japanese larch, is better suited to upland sites in the North Island.

Douglas fir. The most productive species for higher-elevation sites (i.e., 600–800 m in the South Island). It suffers less snow damage than radiata pine, tending to shed snow rather than suffer branch breakage

P. pinaster. Can withstand exposure to salt winds better than radiata pine, and thus can be planted as a seaward species on foredunes. Can also tolerate phosphate-deficient soils better than radiata pine.

P. monticola. Can tolerate some soil clays or impeded drainage better than radiata pine.

P. strobus. Can survive on some poor, dry soils which are unsuitable for radiata pine.

Some hybrid species which as yet have been inadequately tested may have potential to extend the productivity of radiata beyond it present limits.

Pinus attenuata × *P. radiata* hybrids (known as KMX in America) appear to grow well on very cold and dry sites, taking their vigour from the radiata parent and the cold-hardiness and drought tolerance from the *P. attenuata.*

Special Purposes

Though alternative species are always grown 'for a purpose,' these purposes can be broadly categorised somewhat further:

Timber – Douglas fir, eucalypts, cypresses, acacias, *Sequoia, Juglans, Paulownia, Larix, Robinia.*

Industrial – eucalypts, poplars, willows, *(Picea).*

Shelter – cypresses, poplars, willows, *Cedrus, P. muricata, Thuja, Cryptomeria, Ps. menziesii.*

Soil conservation – *Pinus mugo*, poplars, willows.

Amenity – Douglas fir, cypresses, *Sequoia, Abies, Picea, Paulownia, Cedrus,* hardwoods, etc.

Timber

Much attention has been concentrated on the actual products, on articles which have been made from alternative timbers. However, emphasis may equally be placed upon the natural desire for variety and enrichment which a diversity of species introduces. Alternative woods usually feel, look, weigh, and smell different to radiata, and even though the latter may be functionally adequate in the role concerned, the environment is enhanced through the experience of a variety of woods.

Douglas fir. Structural timber. Staff, tough, and stable. Excellent for beams and for bold-pattern panelling.

Eucalypts. The ash-group includes *Eucalyptus delegatensis, E. fastigata, E. obliqua, E. regnans, E. fraxinoides, E. sieberi,* and others (the gum *E. nitens* is usually associated as well).

Species in the group are difficult to process and require special techniques for sawing and drying, but once dried produce medium-density, pale brown wood with good working and finishing properties, suitable for use in furniture, veneers, turnery, and panelling. The Eastern blue gums *E. saligna* and *E. botryoides*, and the stringy barks *E. muelleriana, E. pilularis,* and *E.*

globoidea are more frost-tender than the ash eucalypts, but produce timber of higher density and strength that can be used for furniture, turnery, and veneers but also structurally for framing, cross-arms, and decking. They are less susceptible than the ash-group species to collapse and internal checking, but again require careful sawing and drying according to special techniques.

Cypresses. The main species in New Zealand are:
Cupressus macrocarpa – 'Macrocarpa';
C. lusitanica – 'Lusitanica';
×*Cupressocyparis leylandii* – 'Leyland cypress' (hybrids between *Cupressus macrocarpa* and *Chamaecyparis nootkatensis*);
Chamaecyparis lawsoniana – Lawson cypress.

The cypresses produce very similar light-coloured, medium to low density wood with an attractive grain. The woods are naturally durable, stable, and have low shrinkage. They are suitable for use in exterior joinery, weatherboards, and boat building. Furniture can also be made, although the low surface hardness of cypress wood is a constraint.

Acacias. The most important acacia timber to be considered to date in New Zealand is Australian blackwood, *Acacia melanoxylon*, although future use may be made of other acacias ultimately, and these could include *A. dealbata* and *A. mearnsii*.

Acacia melanoxylon has an attractive, variable brown colour and grain. It is of medium density and can be finely worked, making it suitable for a range of high-quality uses including furniture, cabinets, veneers, and panelling.

A. dealbata has not been widely used as yet, but it is a stable, easily sawn, variably coloured wood from which attractive panelling can be made.

A. mearnsii is widely grown in South Africa, but has not been promoted so far in New Zealand.

In addition to other uses in furniture and joinery, all three species provide very good slow-burning firewood

Black walnut *(Juglans nigra)*. Provides a heavy, hard, sturdy, very stable wood for cabinet making, quality furniture, veneers, turnery, and gun stocks.

Coastal redwood *(Sequoia sempervirens)*, sierra redwood *(Sequoiadendron giganteum)*. Produces high volumes of soft, straight-grained, easily worked timber suitable for weatherboard, decks, panelling, sashes and doors, exterior joinery, and furbishing work.

Paulownia spp. *(P. tomentosa, P. elongata, P. fagesii, P. catalpafolia, P. fortunei)*. Low-density, soft, durable woods. Established utility timber in Asia. Furniture, packaging, boxes, turnery.

Larix spp. (European larch, *Larix decidua;* Japanese larch, *L. kaempferi;* hybrid larch, *L. eurolepis*). Larches are New Zealand's strongest softwoods. Like Douglas fir, larch timbers have a pronounced figure which can be accumulated by sandblasting to produce decorative panelling.

Robinia *(Robinia pseudoacacia)*. A hard, strong, impact-resistant timber from which high-quality tool handles can be made.

Industrial purposes

In the central North Island *Eucalyptus regnans* (7000 ha) and in the South Island *E. nitens* (approx. 1800 ha) are being grown as a source of short-fibre pulpwood, for which the species are eminently suitable.

Shelter

A great many species are used for planting as shelter. In the present brief opportunity it may be helpful to consider some of the desirable attributes by which candidate species may be compared.

Longevity. Everyone wants 'quick' shelter, but often the really fast-growing species may suffer from lack of crown density, or may be short-lived. (Bamboo, to give but one instance, is an excellent shelter within the limits of its height, but dies suddenly once it has flowered.) Choose long-lived, steady-growing species, therefore.

Uniformity. Uniformity is always an asset in a shelter belt or hedge, even where regular trimming is a requirement. Clonal material is more uniform than seedling material. The Leyland cypress, *Cryptomeria*, poplars, and willows are available as clones, and a high degree of uniformity can be expected. By contrast, hybrid plants of seedling origin are *not* recommended, as variability may be extreme. Hybrid cypress seedlings, once supplied under the name 'Bentham's cypress', are a case in point.

Branch retention. Eucalypts, which may self-prune later, are of use for upper shelter, but may not provide the same degree of protection near the ground.

'Clippability'. Only certain species respond to clipping by thickening their foliage. Norfolk pine would be one of the more difficult species in this respect.

Health. Like uniformity, health is a paramount requirement in a shelter species, for not only will mortality impair the project, but also species which will fall prey to pruning and topping damage may fail the objective. Find out beforehand what species are likely to be healthy or unhealthy in a given district (e.g., in areas where canker is a problem *Thuja plicata* may be an alternative to cypress species for this reason).

Soil conservation

Poplars have long been the leading species in New Zealand for stabilising slips and gullies, and willows for holding river banks.

Many of the poplars now recommended for soil conservation purposes also have the capacity to serve as timber species. In recent years the main advances have been in the production of rust-resistance clones. Also, unpalatability to possums is a desired feature.

The commonest representations in New Zealand are hybrid black and balsam poplars, the well known Lombardy poplar *Populus nigra* 'italica', cottonwood *P. deltoides,* and Yunnan poplar *P. yunnanensis.*

The willows recommended for soil conservation purposes include hybrid clones of *Salix matsudana,* while possum-resistant others include *S. purpurea* 'Booth' and *S. viminalis.*

In the mountains up to the limits of tree growth (1800 m a.s.l.) *Pinus mugo*, dwarf mountain pine, has been used for pioneer establishment on depleted, exposed, or erosion-prone sites. In steep country this species has also been used for roadside stabilisation.

Green alder *(Alnus viridis)* is capable of growth at high altitudes, its low, branching habit assisting accumulation of leaf-litter on stony and sterile soils.

Amenity

The range of amenity species is too extensive to present at this time. However, criteria in their successful use are colour and shape, of which the latter is independent of seasonal changes in the more enduring examples. The impact of tree shape is well made in genera such as *Abies, Picea, Sequoia,* and *Araucaria* which are tall and spire-like in maturity, and hardwoods such as *Quercus, Fagus, Castanea,* and *Aesculus,* which can be broad and spreading.

In applying tree shapes in a landscape, the available skyline is often as suggestive or definitive as the trees themselves, and should be included with great care as a 'baseline' or 'backdrop' to the general work.

Finally, tree growers should be aware of the role that they themselves can play in preserving and enhancing the heritage of alternative species which has developed over the past 150 years.

The most positive action to be taken is, firstly, to recognise superior or outstanding examples of the species concerned in all categories mentioned, especially where they occur in groups or stands from which genetically broad seed collections may be made.

Thereafter it is up to individual initiative to ensure that worthy material is collected, recorded, and perpetuated. The Forest Research Institute is committed to using its technical experience to advance the use of alternative species where appropriate.

Trees in the Urban Environment

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Abstract

Modern arboricultural practice always begins with proper planning, which includes appropriate tree selection, correct planting technique, and a consideration of the environment around the tree. Furthermore, an understanding of tree anatomy and physiology allows the implementation of management practices which not only recognise the tree's capacity to deal with stress and disease, but which also minimise interference with its natural defence mechanisms.

Unlike earlier arboricultural practices, the modern approach is based on a minimum of intervention and interference. Trees are sophisticated living organisms that can cope with most of the stresses and diseases that come their way, and if the basic requirements for a full and healthy life are provided then intervention may never be necessary. Modern arboricultural practice aims to minimise the need for expensive management techniques, but also attempts to reduce the causes of major problems.

If intervention involving tree surgery techniques is required, then wounding should be minimised. The techniques used must complement the tree's complex response and defence systems and should facilitate a rapid growing over of the wounded or diseased tissues.

Introduction

Before considering issues associated with hazardous trees, it must be emphasised that the role of planning cannot be ignored. Complex and expensive maintenance problems – even tree mortality requiring removal – result from inappropriate tree selection or poor planting techniques years earlier.

In Australia, and in many other countries, little work has been done on selecting and breeding trees from our native flora for specific urban use. Our trees have been exploited and exported, but rarely have they been properly developed. They are a great and valuable asset, and with proper research trees that meet specific urban, park, and roadside requirements could be bred.

If appropriate material is available, the next problem is to make a selection that suits the planting site. This can be done in many ways, but the development of a checklist (Table 1) is simple and effective (Moore, 1991). No checklist is ever perfect, but it may cause people to think. Aspects of the site should also be checklisted (Table 2) to ensure that the selected tree and its site are really compatible. If these steps are done properly, progress towards hazard reduction has already been made.

Not only must trees be propagated so that they possess a well developed root system, but they must be planted correctly as well (May, 1991). When a tree is purchased, the most important part of the buy – given that the tree is of the right species and is alive – is the root system. It is amazing how many professional horticulturists buy and plant trees without inspecting the root system.

Trees with kinked and circled roots from various causes (Table 3) can struggle on for years, moving in the ground, showing symptoms of die-back, and then falling when height and weight make them extremely hazardous (Moore, 1985). The 'Burnley test' (Fig. 1), which involves rocking the tree back-and-forth and checking for movement below the ground, has proved both simple and effective in diagnosing such tree root problems (Moore, 1990).

Table 1. Tree selection criteria (Moore, 1990).

Height (as a mature tree) – metres	
Width (as a mature tree) – metres	
Shape:	juvenile
	adult
Canopy:	spread – metres
	density
Lifespan:	long – years
	short – years
Foliage texture:	fine
	coarse
Foliage colour:	usual
	autumnal
Bark:	texture
	colour
Flowers:	season
	colour
	fragrance
	size – centimetres
Fruits:	size – centimetres
	colour
	season
	edibility
Roots: (mature)	spread – metres
	depth – metres
Habit:	evergreen
	deciduous
Form:	stable
	unstable

Table 2. Site checklist (from Moore, 1990).

Aspect of site:	characteristic
Space:	for foliage
	for roots
	among other plants
Soil:	waterlogged
	too dry
	fertility
Irrigation/ watering:	type
	installation
Mulch:	is it needed?
	what type?
	what depth?
Slope:	too steep?
	flat
Garden:	effect of other plants
	effect on other plants
	shading

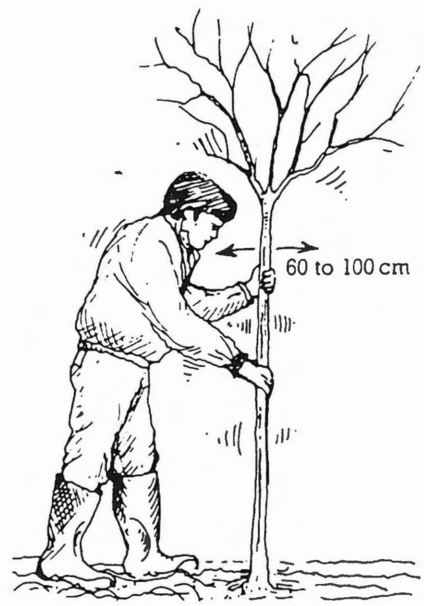

Fig. 1. The Burnley test of tree root structure (after Moore, 1990).

With a young plant, grab the trunk about 60 cm to 1 metre above the soil surface and try to rock the tree back and forth. If the trunk bends but the tree is firmly anchored, all is well. However, if the tree appears to be rocking at or below the soil surface, you will find that the root system is deformed. In such a case it is worth pulling out the tree to inspect the problem. It is always worth checking the roots of young trees.

The test has been done with trees up to 18 metres in height, planted years earlier, but which were toppling over. In most cases the deformities were traced to pot-bound material attributable to poor plant propagation techniques.

Table 3. Causes of tree root deformities (from Moore 1985).

Procedure	Aspect of procedure causing deformity	Kinking	Circling
Propagation	Depth of germination tray	•	
	Pot: shape		•
	diameter		•
	depth	•	•
	Pricking out	•	
	Potting out	•	•
Planting	Hole: shape		•
	diameter		•
	depth	•	•
	Twisting as planting		•
	Depth of planting	•	

Table 4. Requirements for healthy tree growth.

Space:	above ground
	below ground
Light:	quantity
	quality
Air/oxygen:	above ground
	in soil pore space
Water:	quality
	quantity
Nutrients:	quality
	quantity

The importance of a healthy and vigorous root system to the development of healthy trees cannot be over-emphasised. Problems that become evident even ten or twenty years after planting can often be traced back to a tree's poor root system, due either to errors in propagation technique in the nursery or to poor planting practices.

A Simple Perspective on Tree Requirements in Urban Areas

The requirements for healthy tree growth are relatively simple (Table 4), but are too easily overlooked. Trees need space to grow! Being large and long-lived perennials, their requirement for space increases as they mature. The space they need above the ground is usually obvious, but their needs below the ground are just as great. Massive trees have massive root systems, and both the above-ground and the below-ground parts of the tree have to be managed. The 'out of sight, out of mind' syndrome associated with roots changes rapidly when property damage becomes apparent.

Healthy, vigorous tree growth requires high levels of photosynthesis, which depends upon good illumination. Furthermore, if branch distortion or angled trunks are to be avoided then a direct or even source of light is often an essential. Light is often the forgotten ingredient of good growth and tree form, and trees struggling in low levels of light or bending at acute angles towards the few rays that fall between tall buildings are prone to poor vigour, disease, or deformity, and will not only create hazard but need greater levels of maintenance.

Water and nutrients must be available if trees are to grow and mature. The soil volume that is available for the roots to exploit should be appropriate, but irrigation and fertilising can overcome minor deficiencies if the tree is managed properly. Similarly, trees require good-quality air, which can be a serious problem for trees growing on busy city streets or on the edge of freeways, where pollution damage can be quite severe. However, the most common problem is the quality of the air supplied to the roots, and too often trees face difficulties of compaction, paved surfaces, waterlogging, or even gas leaks.

Often hazardous trees develop because managers fail to recognise the tree's basic requirements. Trees are planted in places where the availability of space is insufficient, where they come into contact with hard structures, and where water, light, oxygen, and nutrients are in short supply. Furthermore, sometimes trees are placed in well designed and engineered positions, but they are alive, change over time, and respond to the environment. Trees are not entirely predictable, and if we want trees that are uniform and predictable and which lack roots we can have them – they are called posts!

Trees in urban areas face problems that plants growing in forests never confront. Failure to follow the old, basic rule of 'Right tree in the right place, at the right time' can give rise to major planning problems, which may be exacerbated by the unforeseen effects of microclimate. Local wind patterns, compaction, and reflective surfaces can all affect the growth rates of trees and ruin the uniformity of mass plantings.

Changes to the water regime are not at all uncommon, and are another example of a microclimatic change. Old trees often die when subterranean water flows are diverted from their root systems by the construction of a nearby building. Furthermore, any excavation work that damages a significant part of a tree's root system must be managed. The risks to the tree must be assessed, and the tree may have to be replaced if the risks are great, or pruned to reduce the canopy if the time of the year means that water balance is the main priority, or left intact if water is available and a high rate of photosynthetic activity can give more rapid regeneration of the root system by the transfer of photosynthate to the roots.

The issue of trees and power lines is still causing concern, and it should not be. Given the massive numbers of trees and the sums of money involved, the problem should be tackled and resolved. Underground cabling may well prove the cheapest option if full and proper costings are done. This issue gains importance with the impending arrival of cable television. Surely these cables will be placed underground? Proper planning, proper specifications, and full costings must be done to eliminate this as a cause of concern.

Arboricultural practices have changed dramatically in the past decade. All treatments must be based on the concepts of compartmentalisation, our knowledge of branch attachment, and the use of the collar and branch bark ridge concepts. Trees are major community assets, and an appropriate budget should be made available for their maintenance and management. Staff must be professional in their approach, familiar with safe work practices, and when necessary seek specialist expertise.

Roots a Top Priority

The root systems of mature trees are poorly understood, not only by members of the general public but by many horticulturists as well. The common view that big trees have large tap roots is a misconception. Tap roots are usually a juvenile phenomenon that allow the young tree to firmly anchor and establish itself in the first decade or so of life. The tap root then normally rots away. The mature tree is supported by a large and often shallow network of lateral roots, from which occasional sinker or vertical roots descend (Fig. 2). The importance of the lateral roots in providing support for the tree is easily forgotten, but these roots should be cut only with great reluctance.

Because roots are relatively shallow and spreading, then the holes we plant them into should also be shallow and wide (Whitcomb, 1987). The roots will grow along the lines of least resistance, which are often along old trenches and sewers or along house foundations. Roots

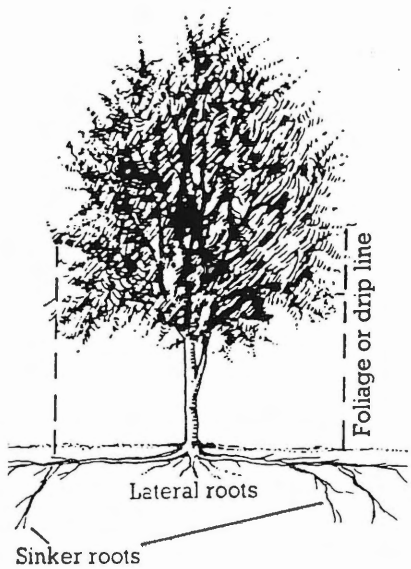

Fig. 2 Typical tree root structure (from Moore, 1990).

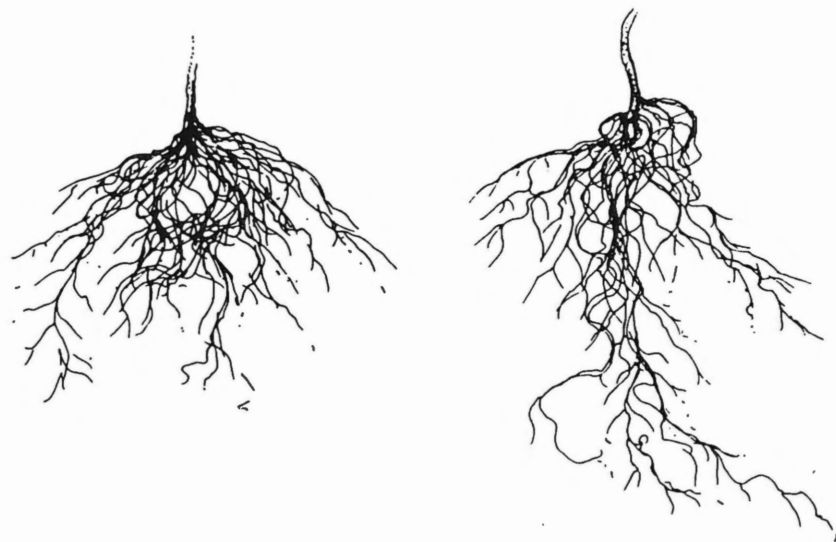

Fig. 3 Tree root structure can be manipulated. The root on the left has had occasional watering, but that on the right has been frequently irrigated.

do not – contrary to a view popular among engineers – go on search-and-destroy missions against their lovingly constructed foundations or pipelines. But fine roots can penetrate small cracks, and then as the roots grow significant damage can result, because roots will proliferate in moist, nutrient-rich environments.

In Melbourne at present there is considerable concern about the damage that tree roots can cause to paths, fences, and house foundations. There are two basic types of damage that tree roots cause to property:
(1) direct damage due to direct contact with a root, which can shift and damage property when the root expands through secondary growth;
(2) indirect damage due to the roots removing water from reactive clays, which exacerbates the shrinkage and expansion typical of clay soils.
The first type is relatively easy to detect, and is not a common cause of damage if pipelines and footings are properly engineered. The second type of damage is more difficult to detect and to verify, and it requires a more sophisticated approach to tree root management.

In Australia several local councils have been sued for damage to residences caused by street or park trees (Barley, 1990). Frequently the damage could be attributed to other factors such as poorly constructed footings or even faulty plumbing. Yet the trees were blamed. This caused an over-reaction in some places, where trees were removed not because they were causing damage, but because they had the potential to do so. It is ironic that at a time when Australia is greening and when the value of vegetation is at last being recognised, trees are facing a great threat from the ignorance of legal interpretation. It seems to be a case of 'it is all right to be green as long as it doesn't cost'.

Furthermore, the suggestion made by CSIRO (Cameron, 1985) that trees be planted no closer than 1.5 times their projected mature height to constructed structures is a recipe for the creation of an urban desert, and is not an acceptable approach to tree management. Root systems must be managed as part of urban tree management, but this requires subtlety and an understanding of tree root development.

Root system development can be altered by the watering regime, whereby frequent watering gives a shallow fibrous root system, whereas infrequent watering gives extensive and spreading roots (Fig. 3). Although compaction is more usually raised as a problem for urban trees, it can be used to manage root growth. By compacting soils around structures the soil oxygen level can be reduced and the growth or penetration of roots impeded.

It is also interesting to note that the large woody roots of mature trees display the same compartmentalisation biology as the stems and branches. These compartments have major effects on how disease and decay affect root tissues. There is a proper method of pruning roots, and there is probably the equivalent of the branch bark ridge. Certainly roots should not be simply hacked off, as is so often the case today.

Modern Tree Management

Arboricultural practices have changed dramatically in recent years. Flush cutting is now the subject of derision, and the absurdity of scraping and draining cavities has become clear. Much of this change is attributed to an improved knowledge of the anatomical implications of wood structure in the response to disease and decay through the model of compartmentalisation (Shigo, 1986). The nature of branch attachment was also explained (Harris, 1991). Pruning according to the presence of a collar or the branch bark ridge, and working with the trees' methods of compartmentalisation, are the basis of good pruning practice.

Tree management begins in the trees' earliest years, when formative pruning can provide the desired branching framework and eliminate the development of V-crotches, which are inherently weak. Cabling may help to stabilise an old tree that is V-crotched, but prevention is always better than cure. Young trees are remarkably tolerant of mistreatment, especially if healthy and vigorous, but old trees have a reduced tolerance of mistreatment, and the guidelines should be followed at all times.

Management practices were also changed by the knowledge that plants have complex physiological and biochemical responses to wounding and disease. The role of the abscission zone of leaves, fruits, and flowers has been well known for decades. However, the antibiotic properties of the polyphenols when oxidised have only recently come to light. This response shows the sophistication of the trees' response mechanisms and the strength of the protection provided by the antibiotics. Furthermore, the role of a new group of plant-protecting chemicals called phytoalexins in tree response to infection is barely known. These chemicals are highly specific, and attack disease-causing micro-organisms with great efficiency. Their potential as arboricultural 'tools' looks to be impressive. These natural mechanisms reinforce the importance of pruning according to the guidelines.

In recent years the quality and diversity of the equipment available to the arborist has increased rapidly. There are excellent high-tech drills and augers which permit effective sampling and inspection of woody tissues. The Shigometer and the Australian-made PIRM allow detection of decay and measurement of vigour, and sap flow can be measured using modern heat-pulse sensing apparatus. Such equipment brings together new knowledge about the anatomy and physiology of trees and modern technology. Practising arborists must be prepared for these products of research, and use them where practical.

Trees in the Real World

In most developed societies the language that everybody speaks is 'dollar'. Money is the currency of the decision-making process. Accordingly, trees – which have been referred to as assets on several occasions in this paper – must be treated as assets and given a monetary value. There are many methods of amenity tree evaluation available (McGarry and Moore, 1988) and choosing one that is appropriate is not all that easy, but the trees must be valued. Only when trees have this monetary value can they compete for the attention of engineers, accountants, councillors, and politicians against footpaths, roads, and buildings.

Often decisions are made assuming a nil value of standing trees. This is patently absurd, and represents very poor management of public assets. Furthermore the problem is compounded by a lack of proper, computer-based tree inventories that provide information on what is there. The attitudes of people at all sorts of levels can change dramatically when it is pointed out that the trees they are making decisions about have a real value of perhaps $15–20 000 each. Lateral thinking and other options suddenly become the order of the day.

There are relatively few instances of proper specifications and standards being set for the propagation and establishment of trees. When dealing with expensive advanced trees, detailed specifications on what is required, how it should be planted, and how it should be managed post-planting would seem to be in everyone's interest (May, 1991). The Standards Association of Australia is currently considering an Australian pruning standard. Given an increase in expenditure and greater accountability, it is inevitable that proper professional standards and codes of practice must be developed by arboriculturists. Indeed, modern tendering practices will demand it.

Many professions make important decisions about trees, but their knowledge base is often founded more on the experiences of a home gardener than on relevant modern tree biology. The real danger is that they don't even realise what they don't know. Arboriculture is a profession, and it is time that these other professions sought proper advice and updated their approaches to urban trees. Decisions made in magistrates and higher courts, or by insurance companies, that limit the proximity of trees to dwellings could result in an urban environmental disaster.

Conclusion

As the largest and most long-lived components of our landscapes, trees are well worth investing in, because they can set the ambiance of a landscape for years to come. Planning is the key to the successful interface of trees and the created urban environment. The view of 'Trees at any cost' is not, and has never been, professionally tenable, but it must be recognised that we have to pay for their presence, and that being 'green' does not come cheap. Yet few people have thought of the long-term costs of planting trees.

With the massive increase in tree planting over recent years, proper tree planning and maintenance schedules must be assured. In Australia alone there has been a pledge to plant one billion trees by the year 2000. These efforts are laudable, but in twenty or thirty years the maintenance costs will be enormous. It augurs well for the future of arboriculture as an industry and as a profession, but it surely also emphasises the need for planning and for cost-effective maintenance of our trees.

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Trees and the Hard Landscape

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Abstract

Trees are an essential part of any landscape, and their interface with the hard components of an urban environment is often poorly understood. Frequently, trees are blamed for problems that arise in urban situations that are really the fault of poor planning, inadequate design, or poorly engineered construction. Such responses to these problems as removal of trees, expensive litigation, or selection of shrubs to replace trees can often be minimised by a better understanding of tree biology and development of specifications that recognise both the biological and engineering requirements of the landscape. It is possible to manipulate tree growth by managing both the above-ground and below-ground components of the tree.

Introduction

A civilised society values the contribution that horticulture makes to the created landscape, and it is ironic that, over the past few years, trees growing in urban areas have been removed because they have no monetary value placed upon them. They have often fallen victim to urban upheavals such as road widening, historic site redevelopment, and the usual urban renewal. In the decision-making process it is easy to undervalue trees, which leads to their removal or to poor treatment that may be lethal. In Melbourne the threat of Dutch elm disease has received much publicity, but the biggest cause of death of mature elms has been road widening and major site works.

The role of the horticulturist in the decision-making process at this interface has reduced over the past few decades, with a consequent increase in the risk to vegetation. Damage to plants in the landscape results not from malice, but from ignorance of those factors that are important to the survival of specimen plants or plant associations.

Issues concerning trees are products of both the environment and the social context in which decisions must be made. Some of these issues (Table 1) are of recent origin, and need to be considered (Moore, 1994). Ignorance amongst the legal profession about the biology of trees and their root systems has led to many strange and unacceptable decisions in court.

The trend towards compulsory competitive tendering poses an interesting set of problems that must be considered, and which could pose grave risks to the proper maintenance of vegetation in the future.

Compulsory Competitive Tendering (CCT)

One of the most significant issues impacting upon trees at the present time has nothing to do with tree biology. Compulsory competitive tendering is rapidly establishing itself as the norm within local government throughout Australia. It must be made clear that there is nothing wrong with CCT, and it may provide improved quality of service at reduced cost, which is its aim. The trend towards adopting CCT has followed the English experience, and recent information from England (Hitchmough, 1994) suggests that savings of 10–15% can be made.

However, while acknowledging the benefits that CCT can confer, these will be obtained in full only if potential problems are identified early, and then properly and professionally addressed (Yau, 1993; Moore, 1994). The concerns about CCT (Table 2) need to be recognised and managed if the financial benefits are to be obtained whilst the improved qualities of service are achieved. A major concern with CCT is that tender documentation must be of the highest quality, and must include sound biological risk assessment and management detail. Furthermore, there is the risk that specified minima become the standard to which work is done. If this happens there is an overall lowering of the quality of arboricultural care.

The risk is that a standard CCT documentation will be developed for services relating to trees. It is likely that documents developed by the large councils will be seen as models by smaller organisations and used without modification.

Table 1. Issues confronting arboriculture in 1995.

Compulsory Competitive Tendering (CCT)
Litigation, especially about root damage
Poor planning in urban areas
Increased scale of plantings
Need to reduce maintenance costs
Implementation of new arboricultural practices
Tree valuation methods
Increased transplanting opportunities
More relevant tree selection criteria
Trees, disasters, and management
More cables near trees – cable TV

Table 2. Concerns about Compulsory Competitive Tendering (CCT).

Reduced quality of service

Loss of 'free' professional advice

Fierce competition between public and private sectors

Adoption of model tender documentation, which could lead to:
- reduced species diversity
- adoption of inappropriate common practices
- increased weed potential
- overuse of exotic species
- overuse of native species
- minimum standard becomes *the* standard

Loss of local control of arboricultural services to overseas organisations owing to the large size of some tenders, which could lead to:
- reduced species diversity
- adoption of inappropriate common practices
- increased weed potential
- overuse of exotic species

Such a situation would be disastrous, as it would fail to recognise the local ecological and climatic variations that impact so strongly on plant growth. There is, furthermore, the risk of reduced biological diversity. In specifying suitable plants for roads, streets, parks, and gardens the CCT documentation may opt for those common species for which we have full growth and cultural data.

Many private-sector arborists have welcomed the advent of CCT. They have seen it as an opportunity to enter areas previously reserved for local government workers, and which offers the prospect of lucrative contracts. This indeed may be the case; however, many local government groups that have been corporatised will in fact win such contracts and be free to compete with the private sector for other work. This will cause substantial disruption to the industry, and it is inevitable that many private contractors will face stiff competition from large, previously local government-based groups that have specialist equipment, expertise, and a substantial capital base.

Inevitably there will be some conflict between arborists from the two sectors as a result of these changes. Many in the private sector will consider the competition to be unfair, and that the corporatised groups will have made use of internal contacts that provide an unfair advantage. There is also the loss of advice to the private sector and the general public that once came free from the public sector. There will be accusations of unethical and unfair behaviour as the public sector re-organises.

The situation could be further compounded by the fact that under CCT, many of the tasks associated with tree planting and care may fall to the control of overseas companies. This situation becomes all the more likely because, in many countries, arboricultural companies are relatively small, but the tenders for the large municipal arboricultural services will be very large. Accordingly, tenders may be won by companies based in the United States and Europe that have substantial assets of capital and labour.

The tendency to copy what has been done in the Northern Hemisphere has led to a situation whereby unsuitable practices are adopted for an Australian context. Cavity filling is rarely required in Australia, where winters are mild, but may be essential in the Northern Hemisphere. Pruning guidelines for trees growing near power lines have often failed to take into account the prodigious growth rate of epicormic shoots. Furthermore, the longer growing season in Australia and its subsequent effect on plant growth rates, root growth, and canopy spread has led to many inappropriate plantings.

In succumbing to the temptation to adopt uniform tender specifications, along with a reduction in planting diversity, and the displacement of native by exotic species, there could be a potential for the proliferation of 'weed' species. It is also possible that the relatively few native species of trees for which we have full and detailed cultural information could be widely planted regardless of their weed potential, and where there are still local populations, interbreeding between the two could put the local, possibly remnant, population at risk.

Trees and the Hard Landscape

When designing hard structures in the landscape, it is clear that they must be engineered to cope with the presence of trees and other vegetation. Too often in the past, when hard structures such as services, fences, paving, footpaths, roads, or even building foundations have been damaged, the nearest tree has been identified as the culprit. The blame is often misplaced, and the 'cause and effect' relationship is not established. It is rare that appropriate plantings in properly designed and constructed landscapes cause damage to hard structures.

The response to trees supposedly having an adverse impact on hard structures has been three-fold:

• an increase in litigation, with the trees' owners being held liable for damage (Whiteside, 1991);
• the recommendation that trees not be planted closer than 1.5 times their projected mature height to hard structures, especially buildings;
• the suggestion that trees be replaced by shrubs and/or other vegetation.

None of these are satisfactory responses. The first is expensive and does not resolve any of the issues raised, while the latter two are totally unacceptable as they bring about major changes to the landscape, which would lead to an unacceptable loss of vegetation or an inappropriate scale of planting.

It is clear that trees are a necessary feature of the landscape. In both public open space and in private gardens there are a variety of reasons for the presence of trees – social, cultural, aesthetic, recreational, and environmental needs, amongst others.

Clearly, if trees are the necessity that horticulturists believe them to be, then hard structures in the landscape must be designed and engineered to cope with their presence. This is not a simple request for stronger and larger structures, but a request that in designing engineering standards the biological reality of tree growth and development be taken into account.

Tree Root Growth: an End to Mythology

Understanding of how roots grow has been widely researched, but many still believe the myths associated with root growth (Moore, 1994). It has been known for a long time that tree roots do not go on 'search and destroy missions' against sewers or stormwater pipes. Tree roots tend to grow along lines of least resistance (Yau, 1991) and to proliferate in the direction of moisture gradients. Such gradients are likely to be found in the vicinity of cracked, poorly laid, or leaking pipes. Properly laid and joined pipework enormously reduces the risk of service damage.

In private homes the use of plastic plumbing with properly welded joints should see the elimination of much root damage to plumbing. Moreover, trenching provides a fractured soil profile along which easy root growth is possible. It is essential that such trenches be properly backfilled and compacted. At the present time the opposite usually applies, with all sorts of building debris being used to fill trenches and pipelines.

To prevent damage to house foundations, especially where footings have been constructed, it is important that the footings be properly engineered, with appropriate standards for depth, width, reinforcing, and concrete specifications. However, the treatment around the filling after construction may be poorly specified, and it is essential that it be backfilled and compacted.

The soil profile around a foundation has been shattered, and on completion the site may be backfilled with building rubble, usually with a high organic content from sawdust or wood. This is ideal for the growth and proliferation of tree roots. However, risks can be minimised by backfilling with clean, compacted fill. Compaction reduces soil oxygen levels and water penetration, and increases physical resistance to root growth.

The potential to manipulate plant growth, both above and below the ground, by altering soil, oxygen, water, nutrition, and resistance properties must be recognised. Compaction can be used to deter root growth, while reduced water penetration with subsequent drying of the soil is an added root deterrent. These general principles can be applied to most situations where tree roots and hard landscape structures interface.

Similarly, in dealing with paving, proper compaction of the substrate before application of the finished surface can reduce the impact of tree root damage. However, the possibility of direct damage by tree roots to paving, particularly where space is limited, has to be acknowledged. Under such conditions it may be necessary to review the materials used. Often concrete paving is specified for low-use areas where flexible materials would provide a more suitable surface over a longer period of time.

If damage to hard surfaces occurs, it may be necessary to specify the periodic replacement and/or upgrading of the hard structure, rather than remove an old and valuable tree. The tree has its value, which must be recognised, and appropriate priorities for interaction established.

Most tree species possess tap roots, if at all, only as a juvenile phenomenon that perhaps persists for the first eight to fifteen years of life (Moore, 1990). Given that tree roots generally are spreading and shallow, often no more than 0.5 metres deep, it is both easier and more cost-effective to tunnel and bore under mature trees than it is to trench near or around them.

Pruning strategies for tree canopies have been considerably improved, but little has been done to specify management of tree root growth. Accordingly watering, aeration, compaction, and nutrient regimes should be specified and, if root development is restricted through such practices, the effective life span of the tree may be curtailed for safety reasons. Certainly the canopy cannot be allowed to develop out of proportion to the root system that supports it.

Pruning and Transplanting: Issues of Managment

Pruning specifications must include reference to collars, the branch bark ridge, and the regenerative capacity of the species involved (Moore, 1991b). Knowledge of canopy manipulation has improved considerably, and these changes must be accommodated in specifications. It is possible that chemical pruning and root manipulation that affect canopy development will become common practices in future, and such rapid changes emphasise the need for constantly updating the training and specifications provided to those working with trees.

As environmental awareness has increased amongst the public, so there has been a temptation for managers of open space to consider transplanting substantial trees as part of site redevelopment or landscape works. Such an approach is usually made to promote more rapid development of the site, and to appease those opposed to the works on an environmental basis. Accordingly, these transplantings are often the result of political decisions rather than sound management practice, and the record of success is poor.

Successful transplanting of mature trees has occurred for many centuries. The practice is not only possible, but when done properly is highly successful. In developing specifications to deal with transplanting, it is essential that the elements of a successful operation be recognised. The first element is proper planning and specimen preparation, which often requires a year to eighteen months of work before lifting.

A mature tree with an appropriate rootball can weigh many tonnes. Indeed, many of the formulas for calculating mature tree weight substantially undervalue the all-up weight, which can be up to twice the calculated figure. Recent transplantings of a palm and an elm involved weights of 26 tonnes and 34 tonnes respectively. It was essential that a proper appreciation of total plant weight was arrived at when organising trucks, cranes, and the necessary transport permits. The technology for successful transplanting is available, however.

Finally, any mature specimen that is transplanted requires special post-transplant management. This might include regulated irrigation, appropriate supplementary fertilising, use of root promoting hormones, and even some formative pruning of the canopy if necessary. However, the canopy should not be pruned without first considering the physiological implications.

The simple rule of 'prune off as much of the canopy as you have disturbed of the root system' is simplistic; both water balance and carbon balance need to be considered before pruning established canopies. If water is readily available, then the canopy should be left intact. This will provide the photosynthate needed to repair root damage and for resumption of growth, because the carbon balance is the key to success. If water is limiting, or there are seasonal considerations, the water balance may be of greater significance, especially for trees with poor stomatal control. In such a situation appropriate pruning, or the use of a suitable anti-transpirant, may enhance the survival prospects of a transplanted tree.

Trees and Disasters: Managing the Backlash

Recent fires in New South Wales and Queensland, and the prospect of a major drought with its associated bushfire risks in southern Australia, are reminders of the importance of understanding the relationship of vegetation, climate, and fire. Fire is a natural part of eucalypt forest ecology, and is inevitable in such communities. Frequently, people are allured by the natural beauty of these communities to build their homes in regions that are fire-prone.

Although it is tempting to change the environment rather than the buildings, it is essential that the created landscapes be designed and engineered to cope with fire. Management techniques such as control burning or complete clearing may be understandable, but there is no point in destroying the very attributes of native plant communities that make them attractive places to live in. Instead of 'blaming' the forests for the fires and the damage they inflict, hard structures must be designed to withstand fire.

Natural vegetation has a remarkable capacity for regeneration after fire, and it is possible that excessive zeal in cleaning up, clearing, and felling damaged trees after a fire actually creates more problems than it solves (Moore, 1995). For some species, such as most conifers and other thin-barked trees, the fire is lethal, but for others damage is relatively minor.

The risk of fire is becoming a substantial concern, not only in remnant vegetation sites in urban areas, but also in sites that have been revegetated. Many urban areas which previously had few trees or other plants are now sufficiently densely vegetated to carry a significant fire. This situation is of concern not only to planning authorities and emergency services, but also to householders, many of whom have had no experience in coping with the risks of fire near their homes.

Other natural events can also cause disasters, especially in urban areas. There are risks from flooding and drought, and even excessive insect browsing can cause major damage to plant communities, and especially to old and already stressed trees. These problems are particularly common in remnant stands of vegetation, which are often dominated by trees. Accordingly, in managing trees in urban sites, their capacity to either tolerate or resist such stresses must be appreciated.

Conclusion

The importance of trees in the urban landscape must not be underestimated, and far too often tree selection has been based upon simplistic and superficial criteria. A more subtle and ecologically based set of selection criteria is therefore advocated (Moore, 1991a, 1993, 1994). Furthermore, successful establishment of plantings requires detailed specifications to be provided for site preparation, planting, irrigation, pest and weed control, and post-planting maintenance over an extended period.

Soft options and 'economic' compromises will not resolve the issues that arise when trees and other vegetation interact with hard surfaces and structures. In any community that places a substantial value upon its trees, as the population becomes more conscious of the environment so the need for proper plant selection and breeding and for appropriate design and engineering specifications will become more important. Such interest is not just another social fad, but rather reflects an innate need to have plants – and trees in particular – where people work and live.

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The Conservation Status of Temperate Trees

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We hear a great deal these days about the destruction of tropical rain forests. But what about the forests and woodlands of the temperate zone, the source of the hardy trees and shrubs of gardens and arboreta in higher latitudes?

Since 1983 the Conservation Committee of the International Dendrology Society (IDS) and the World Conservation Monitoring Centre have been working together to produce a list of temperate trees threatened with extinction in the wild. Its purpose is three-fold:

- to publicise the plight of trees;
- to solicit help from IDS members in those countries where the trees grow and/or where influence is held to press for the conservation of those species in situ;
- to help prioritise which species should be grown ex situ as part of an integrated conservation strategy.

The 'Threatened Temperate Tree List' compiled by Michael Lear was published in the 1990 IDS Yearbook. It lists nearly 800 threatened species, including 250 species of *Acacia* and *Eucalytpus*. The list includes many choice and well known species as well as others that are rare in cultivation or not yet introduced. Some examples:

Abies pinsapo – Spain, Morocco – vulnerable;
Araucaria heterophylla – Norfolk I. – vulnerable;
Dracaena draco – Canary Is, Madeira – vulnerable;
Eucryphia glutinosa – Chile – rare;
Howea forsteriana – Lord Howe I. – rare;
Magnolia wilsonii – Sichuan, Yunnan – vulnerable.

There are some interesting features in the report, especially the number of threatened species in the S.W. Pacific:

Norfolk Island	13 species
Lord Howe Island	19 species
New Caledonia	61 species
New Zealand	14 species

Norfolk Island, Lord Howe Island, and New Caledonia have been identified by IUCN (the International Union for the Conservation of Nature) as Centres of Plant Diversity, of which there are several hundred worldwide. These centres of plant diversity must have one or both of the following characteristics:

- the area is species rich, even if the number of species is not accurately known;
- the area is known to contain a large number of endemics.

Four Centres of Plant Diversity have been identified in New Zealand: Campbell Island, the Chatham Islands, North Auckland, and Northwest Nelson.

The Threatened Temperate Tree List is not definitive, and its publication in 1990 was a good chance for people and organisations to comment on it and suggest changes. Data was available from the following countries.

(1) Almost complete data – Australia, Europe, Lord Howe Island, New Zealand, Norfolk Island, U.S.A.
(2) Substantial data – Central America, China, India, Israel, Japan, Mexico.
(3) Some data – Canary Islands, Egypt, Jordan, Madeira, New Caledonia, North Africa, South Africa, South America, South Korea, Taiwan, U.S.S.R.
(4) Virtually no data – Afghanistan, Arabian peninsula, Bhutan, Canada, Iran, Iraq, Lebanon, Mongolia, Nepal, Pakistan, Syria, Turkey.

Later this year, IDS in association with IUCN is organising a conference in Bonn, Germany, to give further publicity to threatened trees and to promote concerted action. Speakers will assess the current status of temperate woody vegetation in various regions, and of selected groups of interest such as conifers, magnolias, and oaks, and identify particular threats to the survival of individual species. The conference will then develop strategies for effective conservation action, what the priorities are, and how IDS can collaborate with agencies like IUCN and BGCI (Botanic Gardens Conservation International).

I have been invited to attend and report on the current situation in New Zealand. My paper will be jointly written with Peter De Lange, Threatened Plants Botanist with the Department of Conservation. It will identify the changes that have occurred to New Zealand's woody vegetation since humans arrived over 1000 years ago, and the current threats. It will detail the species currently under threat and look at case studies in the genus *Metrosideros*, including *M. excelsa, M. bartlettii*, and *M. robusta*.

The Status of New Zealand's Woody Vegetation: a Summary

New Zealand provides a unique example of the devastating changes that can occur to the ecology of a country when humans arrive. Until little more than 1000 years ago, New Zealand had a forest cover of 85% and a unique flora and fauna that had developed in isolation since New Zealand split from Gondwanaland 85 million years ago.

The arrival of the Maori and the introduction of kiore and kuri (Polynesian rat and dog) had a devastating effect on the bird population. By the time of European settlement 35 species of land bird had become extinct and only 53% of the land area was covered in forest. Some types of forest such as inland conifer-broadleaf were almost eliminated.

Destruction and modification of forests continued with the arrival of Europeans. Large area of forest were felled for timber, and subsequently converted to pasture, exotic forestry, or urban development. A good example is the decline of the kauri forest. There was 1.2 million hectares of kauri forest at the time of European settlement. This was reduced to 200 000 hectares in 1900, and only 5000 hectares today.

Exotic plants were imported for economic and ornamental purposes. Today 2000 of these have naturalised. Animals were introduced as game (deer, chamois) and for economic reasons (possum). As animals became pests, others were introduced to control them – for instance stoats against rabbits and rodents.

Today only 23% of New Zealand is covered in native forest, and much of that is montane forest.

Not only has the area of woody vegetation reduced dramatically, but the forest ecosystems left, even if protected, are under pressure for the following reasons.

Ecosystem fragmentation

Formerly continuous areas of forest have been reduced to fragments. This causes pressure from exotic weed invasion, especially if the canopy is broken, a decline in reproductive success, and lack of landscape and niche diversity for some species to survive.

Structural damage

Plants are eaten by predators such as possums, causing long-term changes to forest composition. This affects animals that depend on the plants for food and shelter. A reduction in native animals will also affect the ability of many trees to disperse their seed. About 75% of

Table 1. Conservation status (by IUCN category) of plant species in New Zealand.

Critical	*Pittosporum dallii*
Pennantia baylisiana	*Pittosporum turneri*
Endangered	**Rare**
Chordospartium muritai	*Brachyglottis arborescens*
Clianthus puniceus	*Brachyglottis huntii*
Coprosma 'violacea'	*Coprosma obconica* subsp. *obconica*
Metrosideros bartletti	*Corokia macrocarpa*
Olearia hectorii	*Olearia chathamica*
Olearia polita	*Olearia fragrantissima*
Pittosporum patulum	*Olearia traversii*
Vulnerable	*Olearia 'Pomahaka'*
Boehmeria australis var. *dealbata*	*Pittosporum obcordatum*
Chordospartium stevensonii	*Plagianthus regius* var. *chatamicus*
Coprosma wallii	**Insufficiently known**
Hebe barkerii	*Olearia angulata*

native trees and shrubs have fleshy fruits and are dispersed by birds.

Threatened woody species

The 1994 Botanical Society Threatened Species List contains 84 trees and shrubs listed as nationally threatened. This represents 4% of the total vascular flora. From this information we have updated Lear's list (Table 1).

Strategies for Future Action

Temperate forests are under threat worldwide. Action is needed now to prevent further losses. It is simplistic to look at species in isolation. Often the loss of a species is related to the loss or degradation of a particular ecosystem. Only by fully understanding the whole system can we hope to put in place strategies that will have long-term benefits.

Conservation work needs to be carried out on several fronts:

- Preventing the further fragmentation of our forest continuum, and where possible restoring and then linking forest areas to provide the range of habitats required by some species.
- Managing forests to control exotic species, prevent overuse, etc.
- Implementing recovery programmes for specific plant species, for instance *Muehlenbeckia astonii* and *Clianthus puniceus.*
- Make better use of ex situ conservation as a means of holding and bulking up plant numbers for reintroduction to the wild. Many of us have a role to play here, especially those who have responsibility for tree collections.

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The Forest Research Institute Experimental Nursery: a Brief History

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The Research Nursery as such started in 1947 with about 1 acre of land in a very secluded setting. The actual land and buildings had been in existence long before that because the glasshouse was on the books as R4, while the Conservator's residence, R1, complete with tennis pavilion, was the first building to be constructed in the Rotorua Conservancy. Both are still there today.

FRI nursery records date back to 1949, and it is interesting to note that, although the nursery was still primarily used to raise material for amenity purposes in the Rotorua Conservancy, a range of eucalypts, indigenous species, and pines were being grown. This was in contrast to the adjacent Whakarewarewa nursery, which grew mainly radiata pine, Corsican pine, and Douglas fir for general planting.

I arrived on the scene in 1953, and spent six months on National Forest Survey and several months selecting superior radiata pines in Kaingaroa Forest. Scions from these were grafted onto seedling rootstocks in clay pots in the glasshouse. These grafts were used to establish the first seed orchards, in which much incompatibility has been found.

From 1952 to 1957 seeds of many tree species thought to have promise for New Zealand conditions were imported for provenance and species trials. Only two species of the first batch, from Japan, survived the sea voyage.

Later arrivals from many parts of the world were successful, and at one stage we had 70 species and 230 seedlots in the nursery. All these were started off under scrim-covered frames and lined out in single rows one foot apart so that they could be wrenched by spade. Lifting was quite a job. All seedlings were bundled and puddled – no poly bags or cartons in those days.

From 1954 to 1956 we expanded into two of the horse paddocks. The then Officer in Charge had a beautiful white horse which grazed the paddock nearest the FRI village, until 1957, when part of the latter also became FRI nursery.

Those paddocks had not seen much fertiliser over the years, and large quantities of manure from a Ngongotaha piggery were brought in. With that acquisition we were able to branch out into trials with other species, such as eucalypts and natives. Formal weedkiller trials were started then.

'Mossing' was a technique we used for difficult-to-handle species. This involved wrapping the roots of seedlings in sphagnum moss and rolling the moss sausage in a very thin, self-clinging plastic sheet.

Everything was very labour intensive, but in 1959 we started wrenching lined-out trees (now in beds) by tractor-drawn blade, a fairly hair-raising practice, and it prompted us to design the arrowhead undercutter. We had at least some show of cutting roots without too much drag.

In 1957, when indigenous forest research had started, we added a small sheltered block to the nursery for the specific purpose of researching bare root nursery practice for indigenous species.

About 1962 the Institute's trial work was put on a much more formal footing – no longer was it play-way research. Every trial was subject to a workplan, and so began formal nursery research, aimed at improving practices in forest nurseries New Zealand-wide.

Initially, bare root eucalypt practice received attention, followed of course by radiata pine and other species of importance to forestry at the time.

This work involved trials on seedling spacing, seedling quality, seedling storage and handling, undercutting, and wrenching, all aimed at producing high-quality planting stock.

One lot of summer-sown ($1\frac{1}{2}/0$) FRI radiata pine seedlings was the first to survive in Karioi Forest, after many failed plantings.

The period 1963–83 saw tremendous advances in forest practices in New Zealand. The FRI was to have a new building to replace the Nissen and Quonsett huts and old stables that staff had been operating from. Where better to put it than the area occupied by the nursery?

At that stage, Whakarewarewa Forest Nursery was still operating in some of the same blocks being used in the early 1900s. Rotorua Conservancy graciously moved out, and in winter 1963 we took over the old nursery blocks – more pig manure and Borough compost.

Forestry was in an expansionary phase, and soon the new building proved inadequate; the pressure was on once more to shift. So early in 1965 the logging gangs moved into the Long Mile area opposite the Redwood Grove. The Corsican pine and scattered redwoods were felled – except for four which I felt would set off the planned new nursery building. Who, asked the Conservator of Forests, had the audacity to undermine his authority and put venetian blind bands around these redwoods with the instruction 'DO NOT FELL THIS TREE'? The FRI Director proved to be on my side.

Some of the redwood stumps were so large that we blasted them out of the ground and took them away on transporters. Exciting days, those – much more so than the ensuing five years, with diary entries "picking up sticks," "picking up sticks," etc. etc.

While all this breaking-in work was in progress our usual activities continued, and we were making considerable progress in the development of bare-root nursery techniques for conifers and broadleaved species, including the control of weeds in these.

Most of our trial results were achieved by a combination of manual and crude mechanical production methods, but above all meticulous attention to detail. We became increasingly aware that if our techniques were to be applicable to large production nurseries, effective machinery would have to be introduced.

In March 1966 the first reciprocating undercutter/wrencher arrived from the New Zealand Forest Service Engineering Division for testing. After eight years of modification we ended up with a useful machine. During this period we also developed a front-mounted lateral root pruner. These two machines replaced the back-breaking work of space undercutting and wrenching – and no blisters.

In the meantime trials had shown that, no matter how accurately you undercut seedlings, nor how intensively you wrench them, they do not develop a large root mass unless they have enough individual space. This highlighted the need for precision sowing.

In June 1976, after a very long time coming, a prototype precision sower was tested. This never saw the light of day. However, only four years later the prototype Vacuum Drum Sower, after a development period of a mere 20 months, sowed 20 million pine seeds in its first season. The VDS makes the bed and precision-sows the seed in one operation. It was the invention of the Instrument Technician employed at the FRI at the time.

During 1980–83 a new reciprocating undercutter/wrencher was designed and built – a vast improvement on the 1966 model. A steerable lateral pruner and inter-row fertiliser distributor were also developed. All these machines have seen international application, and are regarded as partand parcel of 'The N.Z. System' of raising bare-root stock.

Although radiata pine of various ages has been propagated sporadically via cuttings ever since 1931, it was not until 1976 that vegetative propagation of juvenile cuttings (those from trees up to five years old) was seen as a way of multiplying seed of improved genetic quality that was in short supply.

After a very short initial trial period (approx. two years), propagation of juvenile cuttings progressed from a few thousand to several hundred thousand, and because of their advantages in the field many nurseries in the North Island now produce large numbers of them. They are set in open beds, and are mechanically conditioned by undercutting, wrenching, and lateral root pruning.

During the last 10–15 years some innovative work has been done on the raising of eucalypt species in containers. The method is based on providing the seedlings with only sufficient nutrients to allow them to grow to a predetermined height, so that they do not 'outgrow' their containers.

On 1 April 1987 the N.Z. Forest Service ceased to exist, and FRI became part of the Ministry of Forestry; it is now a Crown Research Institute. Government funding was no longer assured, and the nursery had to become a self-funding commercial enterprise. Although this meant a change of emphasis from research to production, the philosophy is still one of progress and innovation.

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