

Open-Ground

and Container-Raised Indigenous Plants Comparison

Sustainable Farming Fund project 06-041 titled:
Omaha Pilot Open-Ground Indigenous Plant Nursery

PROGRESS REPORT

July 2008

David Bergin¹ and Cimino Cole²

¹Scion—a Crown research institute

²Open-Ground Indigenous Plants

PO Box 115 Warkworth 0941 manager@mahurangi.org.nz
+64 27 462 4872 +64 9 422 0872

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INDIGENOUS



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ABSTRACT

Significant areas of riparian margins and steep hill country in our largely pastoral landscapes require retirement and establishment in indigenous vegetation that will improve environmental outcomes, particularly for our waterways. Most revegetation programmes involve the planting of indigenous seedlings raised in nurseries. While techniques for large-scale open-ground production of indigenous trees and shrubs were developed in the 1960s, currently, virtually all indigenous plants are raised in containers and can cost \$3–5 or more each.

The reason indigenous species are predominantly container-raised has not been specifically studied but likely reflects the relatively small orders handled by a nascent indigenous plant nursery industry, coinciding with the then new polythene planter bag methods being adopted by retail nurseries.

Container-grown plants provide a much longer shelf life between uplift from a nursery and establishment than do open-ground plants, which are bare-rooted and subject to desiccation. This flexibility, however, is often at the cost of quality because container-housed plants frequently exhibit root circling and can become root-bound, which can potentially compromise short-term growth long-term plant stability.

Open-ground production would potentially result in cheaper seedlings, particularly for large-

scale, well-planned revegetation programmes on a catchment scale. This project aims to compare practicality and economics of three nursery-raising methods for large-scale production of indigenous species for revegetation programmes—PB3 planter bag containers, Hillsons Roottrainers and bare-root transplants from open-ground beds. Six indigenous shrub hardwood and monocot species commonly used in revegetation programmes were compared for each of the three nursery raising treatments.

Within 10 months of sowing, seedlings of most species evaluated have grown to a planting height of at least 50cm high whether raised in containers or as open ground plants. However, the plant crowns and root collar diameter of PB3 container-raised seedlings and open-ground stock have significantly larger plant canopy cover and root collar diameter compared to seedlings raised in Hillsons Roottrainers. These differences are largely related to the growing space available in the nursery beds where seedlings raised in open beds or PB3 containers are spaced at 15–20cm between seedlings compared to the confined growing space of less than 5cm for root trainers.

Over 10 000 seedlings will be planted in trials on several site in the Mahurangi catchment, north Auckland, to compare survival and growth between the three nursery raising treatments for the six indigenous revegetation species.



Mahurangi Catchment: A rolling hill country productive landscape dominated by pasture typical of many where property holders and managing agencies are keen to revegetate riparian and erosion-prone areas with indigenous trees and shrubs.

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INTRODUCTION

Planting of indigenous trees and shrubs is underway throughout New Zealand to fulfil a wide range of objectives including enhancement of indigenous plant and animal biodiversity for conservation, establishment of indigenous cover on erosion-prone sites, and improvement of water quality by careful revegetation of riparian areas. Most of this work is undertaken by local community groups and councils in our highly productive landscapes often dominated by pastoral, horticultural or exotic forestry land uses. There is increasing concern at the need for large-scale restoration of indigenous vegetation cover in these landscapes that will improve environmental outcomes and enhance sustainable land management practices.

The Mahurangi catchment, which is the first natural harbour north of Auckland in the Hauraki Gulf, is a typical example of a productive landscape dominated by pastoral farming and horticulture, and under intense development pressures with subdivisions and an increasing population (Locker 2001). Forest clearance for farming over the last 150 years and intensive development has contributed, and still is, to elevated levels of sediment accumulation in the Mahurangi estuary and a range of other environmental factors including with loss of water quality and consequent loss of once productive kaimoana—e.g. cockle populations studied are no longer breeding (Cummings et al. 2003).

Concern with sedimentation led to the Ōmaha Pilot Open-Ground Indigenous Plant Nursery project, a joint Friends of the Mahurangi Incorporated and Rodney District Council initiative. The primary object was to investigate cost-effective methods for large-scale revegetation of critical areas of the catchment contributing to sedimentation, largely the restoration of riparian areas and erosion-prone steep land with indigenous vegetation.

One of the most significant impediments to large-scale revegetation by planting with indigenous species is the cost of seedlings (Tane's Tree Trust 2001). The project, constituted as Open-Ground Indigenous Plants Incorporated, was successful in a Sustainable Farming Fund application for partial funding with other collaborators to undertake and investigation of methods for raising indigenous plants for revegetation programmes. This builds on earlier work in this area by the Forest Research Institute and the New Zealand Forest Service.

This report covers the first two years of progress made with this three-year project.

Better than anticipated progress has been realised towards project's goal of kick-starting the transfer of the open-ground methods used to raise exotic forestry species, to the production of indigenous species:

- in larger quantities
 - at lower prices, and
 - with more reliable root systems
- to greatly enhance sustainable land use options.

The project has a growing base of parties who share the need to establish indigenous plants more economically, including Auckland Regional Council, Federated Farmers Rodney, Ngati Manuhiri, Ōmaha Sandcliffs Coast Care, Rodney District Council and Tane's Tree Trust.

BACKGROUND

Large-scale revegetation

Significant areas of riparian margins and steep hill country in our largely pastoral landscapes require retirement and establishment in indigenous vegetation to improve environmental outcomes, particularly for our waterways. It will also provide sustainable management opportunities for planted indigenous forest that integrate into, and enhance, current agricultural land uses (e.g. Parliamentary Commissioner for the Environment 2002).

Areas prioritised for revegetation are significant and require a major increase in commitment and the implementation of more cost-effective measures of establishing indigenous vegetation. If just 1% of New Zealand's 13.5 million hectares of pasture was to be converted, some 630million plants would be required at 1.5 x 1.5 m spacing (approximate planting density of 4500 stems per hectare) and allowing for 5% for replacements within the first year for early losses.

Clearly, large-scale methods for revegetation with indigenous species that are both practical and cost-effective are required. This project seeks to investigate whether indigenous seedlings raised in open-ground beds as bare-root transplants can be used in large-scale revegetation programmes, and to compare the performance and economics of planting open-ground stock with the standard industry practice of using seedlings raised in containers.

Nursery raising plants

While there are a range of options for re-establishing indigenous vegetation cover such as encouraging natural regeneration or direct seeding, these are not practical or proven as



Seedlings for the project were raised using standard nursery techniques for indigenous tree and shrub species at the Taupō Native Plant Nursery. Seedlings raised in PB3 containers and root trainers were raised in relatively sheltered conditions including for a time under light shade cloth.

PHOTOGRAPHER JONATHAN BARRAN

effective on most sites, particularly for large-scale revegetation programmes. Most revegetation programmes will therefore involve the planting of seedlings raised in nurseries (Bergin and Gea 2007).

Most of the commonly planted indigenous tree and shrub species used in revegetation programmes can be raised in a variety of containers or as bare-root transplants in open-ground beds (Bergin and Gea 2007). The cost of nursery-raised seedlings of indigenous species is a major impediment to large-scale revegetation programmes. Furthermore, those contemplating large-scale planting of indigenous species are confronted with considerable variation in the size and type of containers, as well as the size and quality of seedlings available.

Virtually all indigenous plants are raised in containers to allow sufficient flexibility in providing a large variety of plant sizes and species on demand. The most commonly used nursery stock types used in large-scale planting programmes are those raised in polythene planter bags (PB $\frac{3}{4}$, PB2, PB3), a wide variety of hard plastic containers of various sizes (e.g. RX90), and root-trainers (either Hillsons or larger Tinus).



A sample of seedlings for all six species raised in root trainer, in PB3 containers or equivalent size pots, and as bare-root transplants in open beds were assessed for growth and vigour nine months after sowing. This included plant height, plant crown cover and root collar diameter. Visiting forestry student from Vanuatu, Tare Kaere assisted in seedling measurements. PHOTOGRAPHER MICHAEL BERGIN

Cost of revegetation programmes

Seedling cost usually varies according to the size and type of container and size of seedlings at planting. Even for relatively large-scale revegetation programmes, this can range from less than \$2 for small plants in small containers such as root-trainers and \$3–5 or more each for plants raised in larger containers such as polythene planter bags. Lack of sufficient lead-in times results in ad hoc supply and demand for indigenous plant nurseries and inevitably lack of long-term ordering results in speculation and higher seedling costs.

Revegetation planting at wide spacing requires weed control for many years, which is often not carried out—resulting, in many instances, in total failure (e.g. Pardy et al. 1992; Beveridge and Bergin 1999). While dense planting of indigenous plants gives canopy cover within two years, the cost of using standard lines of container-grown stock at high planting densities (up to 10000 plants per hectare) can be in excess of \$40000 per ha (Bergin and Gea 2007).

Techniques have been developed by Jaap van Dorsser at Forestry Research Institute from the 1960s through to the early 1980s for large-scale low-cost production of bare-rooted indigenous plants for virtually all indigenous tree and shrub species used in revegetation programmes (e.g. Forest Research Institute 1980, 1988). These have been based on the bare-root techniques developed for a wide range of exotic conifer and hardwood species that are used by dozens of nurseries throughout the country. This involves large-scale highly mechanised production systems where plants are produced in 90cm-wide nursery beds prepared by tractor. Lined-out plants are mechanically root pruned and wrenched using reciprocal undercutters to stimulate the development of a compact ball of dense fine roots so that they can be easily lifted and transported to the planting site. An important component is the inspection and trimming of root systems as plants are lifted, and the rejection of plants with poorly developed fibrous or distorted roots. All the major tree and shrub species planted in indigenous revegetation programmes can be raised open-ground and readily conditioned using these mechanised nursery techniques to stimulate dense fibrous root systems ideal for transplanting to the establishment site.

Despite these early developments, very few nurseries have adopted open-ground techniques for the large-scale production of indigenous species, largely because of the piecemeal approach and lack of planning of indigenous revegetation programmes. Hence nurseries are forced to grow small numbers of a range of species speculating that some orders will eventuate. Despite the estimate that at least 10 million indigenous plants are being propagated throughout New Zealand annually (Bergin and Gea 2005), virtually all nurseries raise even the major indigenous revegetation species in containers that are easier to handle in small numbers and plants can be carried over from

one year to the next more easily by potting on (although there is increasing evidence of plant quality deterioration). There are a range of sizes and types of containers from root trainers, polythene planter bags to plastic pots in which there is often conjecture as to the best option to use regarding container size and type for the different species and planting sites. Further confusing the situation is the large variation in plant quality and size, and differences in cost. In addition to the need for maintaining good planting practice, there are continuing concerns that stock quality including root systems of container-grown plants are adequately developed and are not distorted or root bound (e.g. Davis and Meurk 2001; Bergin and Gea 2005). Only a handful of nurseries (such as Appletons Nursery in Nelson, and Ngongotahā Nursery, Rotorua) produce, small quantities of a limited range of, indigenous species as part of their open-ground mostly exotic tree nursery (e.g. Appletons 2006). Taupō Native Plant Nursery uses open-ground techniques but only with a very small proportion of its production.

The cost of establishing indigenous vegetation is therefore economically prohibitive when compared with radiata pine or eucalypts.

In contrast to indigenous species, many exotic tree species are raised using open-ground techniques to produce stock for less than \$1 each. While techniques have been developed over 30 years for raising many of the indigenous tree and shrub species as bare-root seedlings (e.g., Forest Research Institute 1980), revegetation programmes using indigenous species are invariably fragmented and poorly planned. Open-grown seedlings must be raised on a large scale due to the mechanical nature of production. Methods for lifting, storage and planting of indigenous species are based on those used for exotic species such as radiata pine but relative tolerances of a range of indigenous species to various handling and storage procedures have not been well documented.

Root distortion

A significant concern with stock raised in containers is the condition of the root systems. Root system distortion and quality of quantity of feeding roots are largely ignored where container-grown stock is used in revegetation programmes (Bergin and Gea 2007).

Unless root systems of container stock are removed from containers and most of the potting medium removed, it is difficult to assess root system condition. There is evidence of failure of planted trees and shrubs within two decades due to toppling or premature death by root strangulation as a direct result of root malformation where plants have been raised in containers using poor nursery raising techniques (van Dorsser, pers. comm.).

Most problems occur when seedlings at early stages of growth are improperly transplanted from seedbeds to containers to leave severely distorted roots.

Root distortion will remain with the plant after planting unless seedlings are inspected before planting and remedial action is taken. In most cases distorted roots can be planted after the problem is alleviated by root pruning but this is time consuming and not ideal as roots can be heavily disturbed. Seedlings with severe root distortion should be discarded.

In contrast to container grown stock, root systems of seedlings raised in open beds can easily be inspected when lifted and most soil is removed, as per standard practice. Open-ground stock tends to have less root distortions, as roots are not impeded by containers. However, care is still required at all early stages of transplanting for all nursery raising methods including open-ground stock. Growing-on lines of seedlings are often raised in cells or small containers before transplanting to open-ground beds, and it is at these stages that roots can become distorted if good transplanting practice has not been followed at any stage or where roots in the small plug have become root-bound where transplanting had been delayed.

For substantial revegetation involving the planting of a range of long-lived indigenous trees, it is imperative to employ high quality stock with viable root systems that will contribute to long-term forest stability.



Root Circling: Roots spiralling around for the potted seedlings was evident in all PB3 and plastic pot stock. This sample is exhibiting more than the average across the trial. PHOTOGRAPHER: JONATHAN BARRAN

Open-ground project

In addition to the national need, there are powerful local drivers for a project to compare the practicality and cost of raising and planting open-grown indigenous revegetation species in erosion prone catchments such as the Mahurangi, north of Auckland. These include the extensive need and enthusiasm for:

- indigenous revegetation within the Mahurangi Harbour catchment to address an elevated sediment accumulation rate, e.g. cockle populations studied are no longer breeding: (Cummings et. al. 2003)
- dune stabilisation along Rodney District's considerable (twin) coastlines that, in common with much of our coastline, is becoming highly developed and often severely degraded (Dahm et. al. 2005).

Stage 1 – nursery raising options

Stage 1 of this project has focused on evaluating nursery-raising methods of selected indigenous species commonly raised in large quantities for revegetation programmes. The project involves quantifying and comparing plant development, root system quality and cost of production for seedlings raised in two different types of containers and seedlings raised in open beds as bare-root transplants. A further work plan will be required for Stage 2 comparing performance after planting.

An initial small-scale trial was established in the first months of the project, at Ōmaha, where it was originally planned to conduct the entire three-year trial.

The Rodney District location arose from the need for large-scale retirement of steep erodible land in the Mahurangi catchment, and the availability of a suitable council-owned site with the added dimension of treated wastewater for irrigation.

However, with the considerable distance from any nursery operation employing large-scale open-ground methods, it was decided that a larger, more robust trial was possible by it being moved to a production nursery, Taupō Native Plant Nursery in the volcanic plateau, which has facilities for raising indigenous species and is keen to collaborate in comparing various propagation methods.

OBJECTIVES

The aims for the nursery raising project at the Taupō Native Plant Nursery are:

- To compare three nursery-raising methods for large scale production of indigenous species for revegetation programmes
- To demonstrate the relative performance of these nursery-raising methods on six selected indigenous shrub species commonly used in revegetation programmes and one indigenous tree species
- To compare plant performance, including root system development and distortion, for each nursery-raising method and species tested
- To determine appropriate storage treatments

for bare-root transplants during transplanting from nursery to planting site

- To determine efficacy and costs for each nursery-raising method and species.



Independent strategy: Philip Smith, manager of the Taupō Native Plant Nursery, at the time of the project was already embarking on a long-term plan to step up open-ground production, at a new location in the Auckland region.

PHOTOGRAPHER MICHAEL BERGIN

NURSERY TRIAL SITE

The trial is located at the Taupō Native Plant Nursery. This nursery already produces harakeke open-ground and has in previous years produced a limited range of other indigenous species in open beds.

The nursery, located in the central North Island immediately north of the Taupō township, is at an elevation of just under 400 metres. Taupō has warm summers and cold winters with severe frosts during winter and occasional late spring frosts.

Most species at the nursery are currently produced in either PB3s or in Hillsons Rootainers.

Rapidly increasing demand for indigenous plants, particularly from the Auckland region, determined a decision to establish a nursery closer to that market, and a 40-hectare property was secured in Kumeu. Stepping up open-ground production was part of that plan.

The nursery was therefore keen to collaborate in trials to quantify and compare the performance and economics of raising indigenous tree and shrub species in the two major container types and as open-ground transplants.

METHODS

Nursery-raising treatments

The three nursery raising methods compared are:

- Large containers – PB3 polythene planter bags,
- Small containers – Hillsons Roottrainers,
- Bare-root transplants from open-ground beds prepared by tractor.

The selection of PB3 bags and Hillsons Roottrainers are representative of the major container types used for large-scale raising of indigenous species. Most indigenous revegetation species are raised in PB3 polythene planter bags or containers of similar size and represent the larger container part of the market used for large-scale planting programmes.

For those preferring smaller containers and seedlings, the Hillsons Roottrainers are often used. These tend also to be considerably cheaper than seedlings raised in larger containers as root trainers take less potting medium and less space in the nursery.

Bare-root transplants will use techniques that have been developed for some decades for raising of indigenous trees and shrubs (Forestry Research Institute 1980). Open-ground raising of seedlings is the standard practice for raising millions of radiata pine (*Pinus radiata*) seedlings for the exotic forestry industry for decades.

Species treatment

Six indigenous shrub hardwood and monocot species were compared for each of the three nursery raising treatments. The three shrub hardwoods evaluated were:

- karamū—*Coprosma robusta*
- mānuka—*Leptospermum scoparium*
- koromiko—*Hebe stricta*

The three monocot species evaluated were:

- tī kōuka—cabbage tree, *Cordyline australis*
- toetoe—*Cortaderia fulvida*
- harakeke—flax, *Phormium tenax*

These species were all raised within 12 months of sowing, as is standard nursery practice for most indigenous shrub hardwood and monocot species.

All species were raised from seed collected in the Mahurangi catchment as seedlings will be established in planting trials to be located on retired farmland in that area.

Raising of seedlings

For planting one-year-old seedlings in the field, sufficient seedlings are required for several selected treatment combinations of different species, sites and planting methods. Additional seedlings are also required for assessing and photographing root development and distortion during the course of the nursery trial, and to allow for any early mortality. An estimate of 1000 plants for each species was therefore raised for each nursery treatment.

For each species this will be:

- 1000 seedlings raised in PB3 planter bags (or similar container size)
- 1000 seedlings raised in Hillsons Roottrainers



Three of the six species raised in containers or open-ground—toetoe (above), mānuka (mid) and karamū (below). The three nursery stock treatments are PB3 containers, or equivalent rigid pot (left), bare-root transplants raised in open-ground beds (centre), and Hillsons Roottrainers (right). Note the large crown development for the open-ground plants in particular, compared to the root trainer seedlings—elongated and single-stemmed.

PHOTOGRAPHER JONATHAN BARRAN

- 1000 seedlings raised as bare-root transplants.

For the six species, up to 18000 plants were raised.

As per standard practice at the Taupō nursery, seed was sown in seed trays, pricked into plugs and then transplanted into one of the three nursery-raising treatments – PB3 planter bag or equivalents, root trainers, and open-ground. In practice, additional seed was sown to allow for non-germination and early mortality for each species, to ensure sufficient seedlings were raised for each species.

Due to late planning, seed was sown in seed trays in October, several weeks later than is normally carried out at the Taupō Nursery. Seedlings germinated in the heated propagation house and were transplanted within two months into one of the three nursery raising treatments. Wherever practical, consistent sowing, transplanting, and other nursery practices were carried out as per standard operations used at the Taupō nursery for raising the bulk of indigenous trees and shrubs.



Root trainers require less potting stock and occupy considerably less nursery area—booklets of four seedlings are stacked into crates—than larger container stock, contributing significantly to lower cost per plant.

PHOTOGRAPHER JONATHAN BARRAN

Container-grown seedlings were placed in shade houses for the first few months after pricking into final containers and then moved to open conditions within three months. Container seedlings were regularly watered throughout the season as part of normal practice. Open-ground seedlings were not covered with shade cloth and were only irrigated over a month during the height of a significant mid-summer drought.

Maintenance and monitoring

Once seedlings were pricked into containers and open beds, standard practices of maintenance and monitoring were followed. The only species requiring special attention is koromiko where a mildew fungus attack leaves, which if severe, will depress growth. Standard nursery practices involving several sprays with fungicide were followed in controlling mildew on koromiko which was only prevalent on seedlings raised in containers.

In May, 9 months after seed was sown, and when seedlings had virtually stopped height growth due to cooler temperatures, a representative sample of 50-100 seedlings were randomly sampled from all treatments and assessed for growth and plant vigour. Measurements included plant height, canopy cover development and plant vigour, as well as recording any other factors such as incidence of insect or fungal attack.

Plant height was measured to the natural highest live point for the three shrub hardwood species, koromiko, mānuka and karamū, usually identified as the highest green foliage. Height for the monocots toetoe, tī kōuka and harakeke, was measured by pulling up the leaves vertically.

Plant canopy cover, a measure of length by breadth of maximum spread of live (green) crown to nearest cm, was assessed as follows:

- widest point of crown measured, second measurement taken at right angles
- for analysis, plant spread was calculated as square root of length x breadth.

Plant vigour was based on the following subjective score visual criteria, within each species, into one of five categories:

- 1 poor – few or no leaves, just alive
- 2 unthrifty – loss of leaves, severe frosting damage or browsing, poor foliage colour
- 3 average – moderate health and vigour
- 4 good – minor browsing, frosting damage, etc., otherwise good growth
- 5 excellent - healthy plant with good foliage colour and growth.

Any additional information on plant condition was recorded such as:

- Br** – browsing by animals (possum, rabbits, etc.)
- In** – insect attack
- Fr** – frosting damage
- Br** – breakage of stems or branches

Root development and any root distortion or disease was assessed from a minimum sample of 5 seedlings from each nursery treatment and for each species immediately before planting. Root systems, top growth and root collar diameter were studio photographed for all treatments. Nursery beds were also photographed.



Plants raised in root trainers are elongated and spindly due to the confined growing space of less than 5cm between plants. Root systems for all species for the nine-month old seedlings are adequately filling the cavity. Vertical ribs are designed to direct roots downwards to a small opening at the base where they are air-pruned, or more accurately, air-arrested.

PHOTOGRAPHER JONATHAN BARRAN

RESULTS TO DATE

Relative growth of each species raised in root

trainers, PB3 or similar containers and as open-grown seedlings are presented in Table 1, below.

Nursery Stock Treatment	Species	Sample Size	Height (cm)	Canopy Length (cm)	Canopy Width (cm)	Plant Spread (cm ²)	Root Diameter (mm)	Plant Vigour (1-5)*
Root Trainer	Harakeke	50	80.2	42.1	22.4	30.7	6.3	4.6
	Toetoe	50	115.5	60.9	34.4	45.8	9.3	4.3
	Tī kōuka	50	44.4	28.5	13.9	19.9	5.9	4.9
	Koromiko	50	42.1	14.4	14.1	14.3	4.1	3.2
	Mānuka	50	43.1	13.3	11.8	12.5	3.1	3.9
	Karamū	50	35.5	13.3	10.1	11.5	3.7	3.7
PB or Pot	Harakeke	50	51.6	44.2	19.4	29.3	8.9	4.3
	Toetoe	50	84.5	71.9	47.7	58.5	13.6	4.8
	Tī kōuka	50	59.0	42.2	33.9	37.8	17.5	4.7
	Koromiko	50	44.3	21.4	20.2	20.8	5.6	4.6
	Mānuka	50	61.9	24.5	23.0	23.8	4.3	5.0
	Karamū	50	55.0	20.8	21.4	21.1	6.4	4.2
Open-Ground	Harakeke	62	52.1	41.4	21.1	29.5	15.8	3.9
	Toetoe	50	73.9	84.6	76.7	80.5	35.6	4.6
	Tī kōuka	50	54.7	51.9	44.2	47.9	22.8	4.8
	Koromiko	100	47.5	31.0	29.4	30.2	11.1	3.8
	Mānuka	50	58.4	43.4	32.5	37.6	7.0	5.0
	Karamū	50	50.1	34.7	29.9	32.2	11.3	4.6

*Plant vigour scores: 1=Poor, 2=Unthrifty, 3=Average, 4=Good, 5=Excellent

Table 1: Average plant growth data and plant vigour scores for a sample of seedlings within each nursery treatment for the six indigenous revegetation species raised at the Taupō Native Plant Nursery.

Height growth

Within 10 months of seed sowing, seedlings of most species and nursery raising methods had on average grown to a height of 40–60cm (Fig.1, below). The main exception was toetoe, which like the other monocots harakeke and tī kōuka was measured as pulled up height. Root trainer harakeke and toetoe seedlings had

grown significantly higher than their respective counterparts raised in PB3 containers and as open-ground stock. In contrast, root trainer seedlings of tī kōuka, mānuka and karamū were significantly shorter than those grown in larger containers or open-ground. With the exception of koromiko, all species raised in containers and as open-ground exceeded a planting height of 50cm.

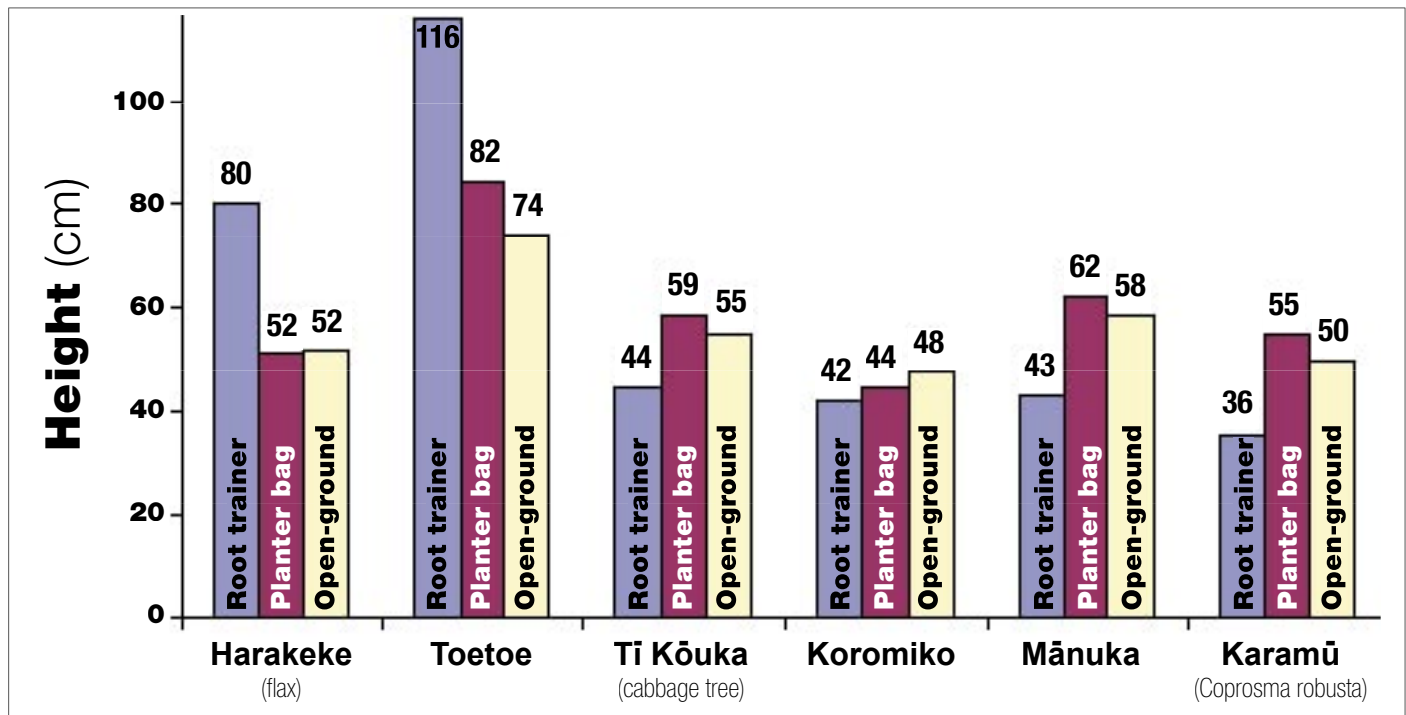


Figure 1: Comparison of average height growth for the six indigenous shrub hardwood and monocot species in nursery, nine months after sowing.

Canopy spread

With the exception of harakeke, there were significant differences in crown spread between the three nursery raising methods for all species (Fig. 2, below).

Canopy cover of open-ground plants is up to third larger than those raised in PB3 containers, and in turn PB3 containers have a crown size up to half as large as that of seedlings raised as root trainers.

Toetoe is significantly larger than any other species in corresponding nursery stock treatments with open-ground canopy cover (average 81cm²) nearly twice that of the next largest species, tī kōuka (48cm²).

The shrub hardwood species (koromiko, mānuka, karamū) had significantly smaller

canopy spread across all nursery treatments compared to the monocots (harakeke, toetoe, tī kōuka). Koromiko, mānuka and karamū raised in root trainers had the smallest crowns of only 12–14 cm² compared to seedlings raised in larger containers or as open-ground seedlings.

Open-ground plants were spaced at up to 20cm apart in open beds, PB3 containers are spaced at approximately 15cm apart, and Hillsons Roottrainers are growing at a comparatively confined spacing of only 5cm between plants. Consequently, plant spread across all species for open-ground seedlings ranging from 30–80cm² are significantly larger than those raised in PB3 containers with a range of 20–58cm², which in turn are significantly larger than root trainers with a crown spread range of only 11–45cm² (Table 1).

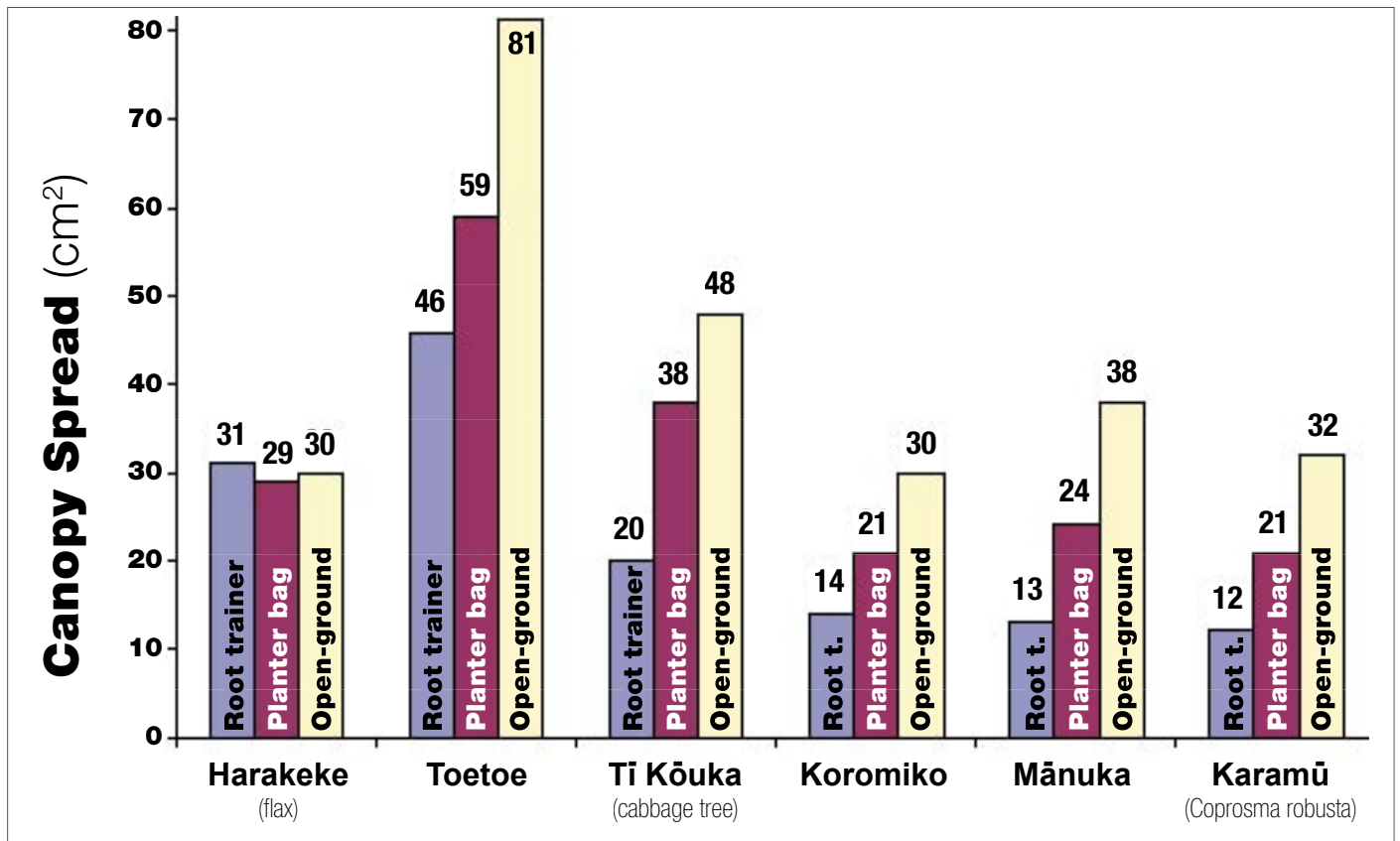


Figure 2: Comparison of average canopy spread growth for the six indigenous shrub hardwood and monocot species in nursery, nine months after sowing.

Root collar diameter

Open ground stock had significantly larger root collar diameters for 9-month-old plants compared with those raised in containers for all six species (Fig. 3). In contrast, root trainer stock had the smallest root collar diameter, again for all species.

Root collar diameter for the monocots (harakeke, toetoe, tī kōuka) are as expected larger than the shrub hardwood stems (koromiko, mānuka, karamū). Across the monocots, root collars averaged 7 mm, 13.7 mm and 25 mm for root-trainer, PB3 container and open-ground seedlings respectively. For the shrub hardwoods average root collar was 3.3 mm, 5.1 mm and 9.8 mm for root-trainer, PB3 container and open-ground seedlings respectively. In both plant groups, open-ground stock had root collars twice the size of seedling raised in the larger containers.



Cheap But Flimsy: Root trainer-raised mānuka exhibiting spindly stems to the degree that plants are falling over when this booklet of four seedlings is removed from the mutual support provided by compact growing environment.

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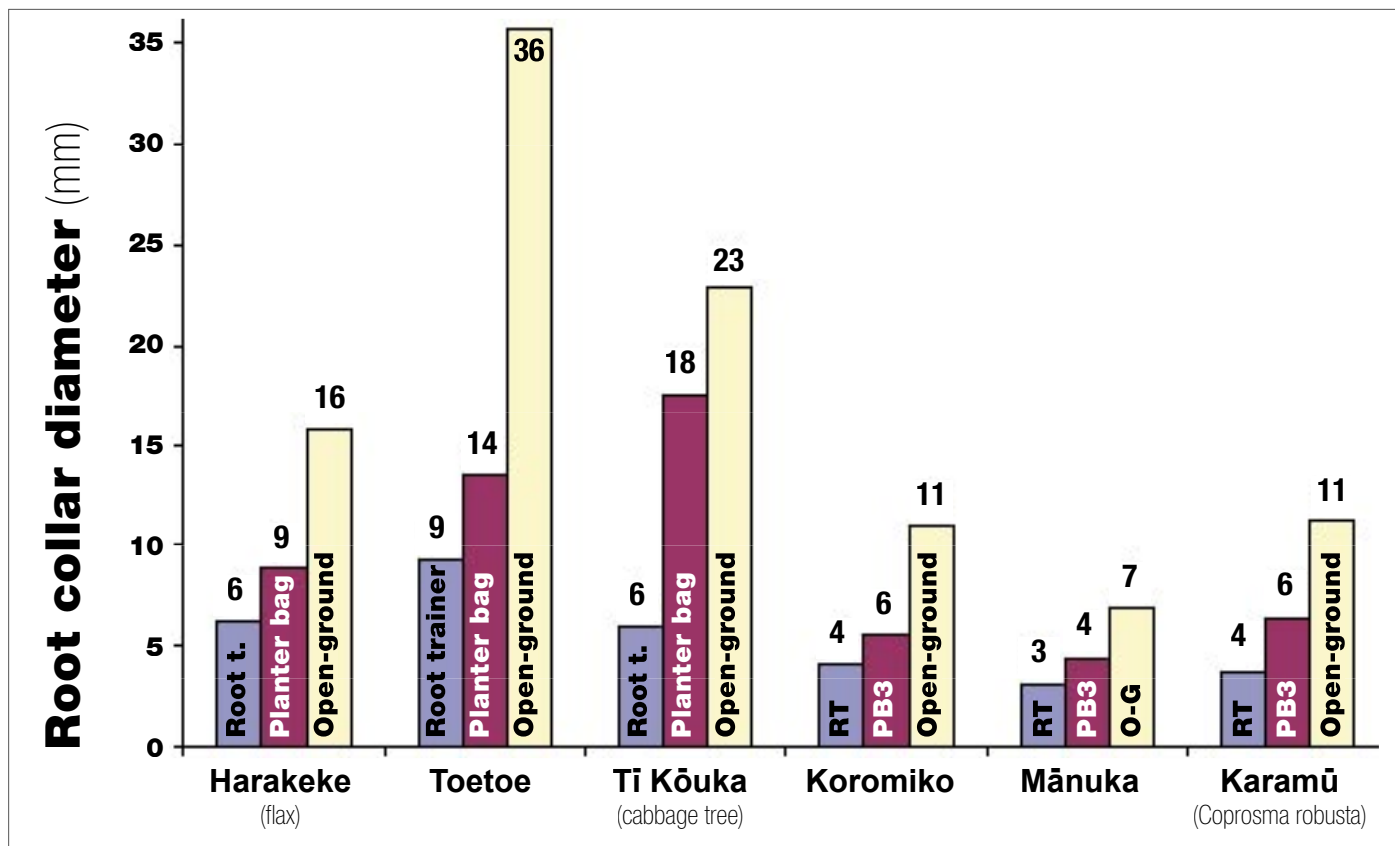


Figure 3: Comparison of average root collar diameter growth for the six indigenous shrub hardwood and monocot species in nursery, nine months after sowing.

Plant vigour

Plant health scores indicate all seedlings raised in containers or open-ground are above average in health and vigour as assessed using the subject score of 1–poor vigour to 5–excellent vigour (Table 1). However, the root trainer shrub hardwoods have lower plant vigour scores (3.2–3.9) than the monocot species (4.3–4.9).

DISCUSSION

Nursery trial

Within 10 months of sowing, seedlings of most species evaluated have grown to a planting height of at least 50cm high whether raised in containers or as open ground plants. Large well-conditioned plants at least 50cm tall are likely to give the best results in large-scale planting programmes using indigenous species (Bergin and Gea 2007). With the exception of koromiko, all species raised as in PB3 containers and as open-ground plants exceeded a planting height of at least 50cm. Smaller plants will require more intensive weed control and site maintenance.

Canopy cover and root collar diameter, however, are likely to be a more robust measure of plant size and vigour than plant height alone. The results indicate root collar growth is directly correlated with crown size. Plant cover and root collar of open-ground and PB3 container stock were up to twice the size of the average plant cover root collar of root trainer stock. The elongated spindly stems of particularly the shrub hardwoods raised as root trainers were very flimsy when separated into individual plants.

Plant spread and root collar diameter are correlated to the amount of growing space available for development. Open-ground plants

at 20cm spacing in beds (approximately 25 plants per m²) had more space to develop larger crowns compared to PB3 containers spaced at 15cm apart (approximately 44 plants per m²). The crowns of PB3 container-raised seedlings and open-ground stock were very robust often with multiple leaders.

Growing space for plants in Hillsons Roottrainers is particularly confined, at only 4–5cm between stems (estimated to be at least 200 plants per m²) so tops tend to grow spindly and tall, and often only as single stems compared to seedlings of the same species raised in larger containers or as open-grown plants. Root trainers are most suited to growing small seedlings (Bergin and Gea 2007).

The shrub hardwood species (koromiko, mānuka, karamū) had relatively small crown spread compared to the monocots (harakeke, toetoe, tī kōuka) reflecting the different physiognomic forms of the plant groups, monocotyledons and dicotyledons. It is likely that monocotyledonous plants are more suited to propagating in the confined conditions of root trainers than shrub hardwood species.

Of the six species raised for this project, fungal infection appears with only koromiko and is particularly prevalent for this species where seedlings have been raised from seed collected from northern part of the North Island (Philip Smith, Taupō Native Plant Nursery, pers. comm.). However fungicidal spraying to control leaf infection was only required for container-grown seedlings. Infection of open-grown seedlings only occurred toward the end of autumn to a minor extent and may be reflecting the slightly lower plant vigour scores for open-ground koromiko compared the containerised stock.

Size matters

With the strong focus here on the measurements of the plants, the impression will tend to be given that the size of plants is the paramount consideration.

Size at the nursery, however, does not necessarily equate to size after establishment.

First the plant must survive planting, or in the case of open-ground, transplanting. Only at the end of successive growth seasons can the size of the established plant be considered significant.

Even then, there are additional, important requirements for successful establishment:

- Contribution to the successional process—of the species in the given conditions and stage, and
- Contribution to provision of habitat.

These, combined with plant size and vigour, provide increased strength of ecosystem function, and therefore improved services including filtering of stormwater runoff, water quality, nitrate retention and reduced sediment generation.

While there may appear to be a straightforward trade-off between size and cost of plants, very small plants have been found to be vulnerable to desiccation and to pests.

This trial seeks to compare open-ground with container raising methods. Other trials will be needed to determine the economics of various establishment regimes:

- Fewer, larger plants
- More, smaller plants
- Combinations of species—particularly filler species.

The proponents of filler species believe there is the potential to improve establishment and restoration outcomes considerably (see page 15). In tandem with low cost, high quality open-ground plants it could prove pivotal to the economics of indigenous forestry.

Sharing outputs

The target audience for the Open-Ground and Container-Raised Indigenous Plants Comparison project is the national community of interest in establishing indigenous vegetation including:

- Farmers retiring riparian margins, steep hill country or other at-risk land
- Farmers enhancing properties with amenity planting or in connection with the creation of bush lots
- Farmers/nurserymen establishing indigenous species for sale
- Farm-foresters and foresters establishing indigenous trees for sustainable timber production
- Local, regional and central government agencies, particularly those with amenity and/or restoration obligations as part of the local land use policies and the Resource Management Act, and
- Citizens who share the widely held, and often passionate, view that Aotearoa has a long-overdue obligation to begin to plan and plant indigenous timber species to provide future generations the option of sustainable production.

Project outputs

Online *Mahurangi Magazine*

In June 2007, Friends of the Mahurangi commenced building its website and shortly afterwards made the strategic decision to cease producing print editions of its *Mahurangi Magazine* and instead publish the magazine online. A magazine metaphor has been employed by the website with view to creating as broad community of interest as possible. A major driver for taking the *Mahurangi Magazine* online was the need to promote the goals of the open-ground indigenous plant project.

Mahurangi Magazine

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- Built Environment
- Democracy
- Editorial, Letters
- Low-Impact Design
- Open-Ground Project
- Mahurangi West Hall
- Regatta
- Reviews
- Riverside Dinner
- Supporters
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A Mahurangi Initiative: Agencies, business and the community* working together for the Mahurangi Harbour, Mahurangi River and Mahurangi catchment.
*Including friends of the Mahurangi from further afield.
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Open-ground indigenous plant trials Another string

Cimino Cole 9 July 2008

Dr David Bergin is well underway laying out the second and third open-ground trial sites, at Silverdale, using another mile of string and three of his adult and late teens children.

The site beside Sandspit Road is textbook—imminently accessible and sufficiently large to accommodate eight replications of the randomised trial layout.

The Silverdale site is far from accessible but, being part of a large indigenous restoration project, has ample space for two blocks the size of that at Sandspit Road.

With the core trial sites decided, there is now an opportunity to establish a quite different trial—another string to the trial's bow. This second trial will seek to compare open-ground plants with container-raised plants, in a toetoe filler trial.

Background to toetoe as a filler species

One of the strands that intertwined to form the open-ground project was the notion that harakeke might be used as a

Sustainable Farming Fund
www.maf.govt.nz/sff
The open-ground indigenous plant trial is a Sustainable Farming Fund project.

Online: While the magazine is primarily focussed on the Mahurangi Harbour and catchment, the immediate driver for publishing the *Mahurangi Magazine* online was the need to reach the widest possible audience for the indigenous open-ground project.

Open-ground open day

A field day titled Taupō Open-Ground Open Day on 7 June attracted about 40 participants. The event was co-hosted by Open-Ground Indigenous Plants, Scion, Tāne's Tree Trust and Taupō Native Plant Nursery.

In addition to speakers from those organisations, Jaap van Dorsser described open-ground methods and experience applying those to indigenous species and a Ministry of Agriculture and Forestry representative spoke on carbon credits and other support offered to foresters.



Saving the Best for Last: The 'open-ground open day' tour of the Taupō Native Plant Nursery culminated at the beds containing the 6000 plants being raised open-ground for the trial.

PHOTOGRAPHER MICHAEL BERGIN

Lake Taupō Protection Trust chief executive Graeme Fleming explained the trust's work encouraging and assisting land use change to reduce the nitrogen impact the lake. Helen Percy, the project's Sustainable Farming Fund advisor, was introduced, as was Kim Morresey, the Auckland Regional Council's Mahurangi Action Plan project leader.

Nursery manager Philip Smith conducted a tour of the nursery culminating in the open-ground beds. Open-ground plants were compared with seedlings in pots and root trainers.

Open-ground indigenous handbook

At the culmination of the project, it is envisaged that a handbook on open-ground nursery and establishment practice will be published as part of the collaborative series now co-ordinated by Tāne's Tree Trust. This could be particularly cost-effective if much of the pre-press production was performed in-house by Friends of the Mahurangi, as its contribution.

Meantime, the *Mahurangi Magazine* could proceed to publish the manual online in instalments—a process useful in itself for developing and refining the content.

General outputs

Other outputs in addition to the above include articles in the local and national press. Progress with the project was also reported to the Indigenous Forestry Group of the NZ Farm Forestry Association at their 2008 national conference in Christchurch.



Forestry-Strength Plants: Project nursery advisor, Jaap van Dorsser, demonstrating the pros and cons of open-ground—or *bare-root*—transplants vs container-grown plants. Jaap managed the Forest Research Institute nursery in Rotorua and was instrumental in developing techniques for raising indigenous trees and shrubs as open-ground plants.

PHOTOGRAPHER MICHAEL BERGIN

Open-ground plants demonstration

The original goal of this project was to establish a pilot nursery on land currently part of the local community wastewater irrigation area at Ōmaha, north of Auckland. However, that stage has effectively been leap-frogged by the collaboration with Taupō Native Plant Nursery. This nursery is one of the largest producers of indigenous plants and is highly respected by agencies involved with large-scale restoration such as Transit New Zealand and territorial local authorities. Additionally, it has recently established a nursery in the Auckland region partly with a view to significant open-ground production. Clearly, production by an established nursery will be a more authoritative demonstration than could be by a pilot nursery, no matter how well the plants performed.



Undeterred by the Rain: Discussion continued at the open-ground beds comparing the root systems and plant vigour of plants raised in containers with those freshly lifted from the open-ground beds.

PHOTOGRAPHER MICHAEL BERGIN

ONGOING WORK

Storage treatments

Because open-ground plants require careful storage between lifting and planting, a pilot trial was established using two of the shrub hardwood species (mānuka, karamū) to evaluate a selection of different storage times and methods.

Storage treatments included:

- storage intervals from lifting to planting
 - 12 days
 - 2 days (period taken for delivery of seedlings)
- for the 12 day storage
 - cool storage at less than 4° C
 - cool shady site at central North Island night and day temperatures varying from 1–12° C.

Sufficient seedlings were lifted for the storage treatments to allow planting on one site to compare seedling growth in a fully replicated randomised block planting trial. This was established on a typical riparian area near Warkworth, within the Mahurangi catchment (Sandspit Road trial site).

Planting trials

Planting trials were established in mid-2008 on three sites in the Mahurangi catchment and Silverdale areas, north Auckland. The sites were representative of riparian and erosion-prone hill country sites where large-scale revegetation using indigenous species is either underway or planned by local landowners and agencies. All sites were in grass that had been either recently mowed or retired from grazing. Planting treatments included:

- trial established on 3 sites –
 - fenced mown grass riparian site, Sandspit Road, Warkworth
 - drought-prone hill country site recently retired from grazing, Silverdale
 - retired sheltered riparian site comprising a series of terraces, Silverdale.
- comparison of the six species—mānuka, toetoe, tī kōuka, harakeke, koromiko, karamū
- comparison of the three nursery stock types—open ground, root trainer, PB3 container.



Surprisingly Shallow: Philip Smith, manager of the Taupō Native Plant Nursery stressing the need for care in preparing root systems of open-grown indigenous plants, indicating where the tuberous tap root of tī kōuka, immediately below the stem, is sensitive to too-shallow undercutting. PHOTOGRAPHER MICHAEL BERGIN

The trial was based on a randomised complete block design. Trial design requirements were:

- a total of 18 treatment combinations (species x nursery stock types)
- a minimum of 8 replicates were established at each site
- each replicate comprised 10 trees per treatment combination (single row with 10 plants/row)
- the three nursery stock treatments per species were planted adjacent to each other but allocation of species to each replicate block and allocation of nursery stock type within each species plot was random.

A plant spacing of 1.4-metre x 1.4-metre (approximately 5000 stems per ha) was used on all sites and is similar to existing revegetation programmes in the region. There was no pre-plant spraying before planting although regular carefully spraying of grass will be carried out over at least the first year after planting.

The planting trials across all sites required 7000 plants including planting of buffer rows. All seedlings will be monitored for growth and survival over the next 2–3 years to determine relative performance between species and the nursery stock types. The local community and landowners will inspect trials regularly to monitor weed growth and identify any other factors that may be affecting plant performance.

FUTURE PROJECTS

The role of open-ground methods

Establishing indigenous species is inherently more complex and demanding than establishing radiata pine, which is a vigorous colonising species. Much of what is known is based on anecdotal information or limited planting trial information.

Issues to consider with further work include:

- Many indigenous species are fragile on germination and are therefore unsuited to be grown from seed in open-ground beds.
- Some indigenous species have proved, in the past, to fail to develop vigorous root systems when grown open-ground.
- Some indigenous species may prove difficult to establish in heavy clay soils.
- Some indigenous species have proven difficult in soils or areas prone to be excessively dry.
- On establishment, many woody indigenous species require shelter and can readily be over-topped by competing weeds.

It is therefore likely that open-ground methods will not be a panacea for indigenous plant establishment, but rather, a part of a comprehensive solution.

Toetoe filler establishment method

The use of low-cost plant species interspersed between the target establishment species may be a further method for reducing the cost of establishment of indigenous revegetation

programmes and in particular reduce the cost of the extended weed control period often required. Chris Ferkins—ecologist and indigenous restoration adviser with Waitakere City Council—describes a restoration technique he has developed whereby in a planting, half the plants are toetoe—not South American pampas—serving as a filler species to achieve canopy closure within nine months.

The toetoe serves only a transitional function, and dies out after being over-topped by the interspersed woody species. Toetoe is used because it is sufficiently fast growing to out-compete weeds, particularly kikuyu. In Auckland and Northland regions, it has the additional attraction of needing to be better represented in terms of biodiversity.

There is an urgent need to establish scientific trials of toetoe as a filler species, and in a number of regions. If toetoe proved to be a species that could be produced open-ground from directly sown seed, it could come close to being a silver bullet in reducing establish costs.

Open-ground from direct seeding

A significant factor in the economy of producing radiata pine seedlings open-ground is that the seed is sown directly onto the beds.

This trial using indigenous species required significantly greater labour input, involving standard container nursery propagation practices then transplanting into the open beds—*lining out*.



Tree Scientist's Dream: The Sandspit Road trial site is accessible, even in gradient and in soil type, and sufficiently broad to accommodate the plots of six species times the three plant-raising methods.

PHOTOGRAPHER MICHAEL BERGIN

While it is unlikely that most indigenous species will be suited to direct sowing into open-ground beds, a limited number of key species could significantly alter establishment economics, whether the goal be restoration or sustainable timber production.

Should it prove practicable to grow some indigenous species from directly sown seed, economies approaching those realised for radiata pine could be possible.

Hybrid open-ground system

The project has given rise to an additional avenue of possible investigation. It is a novel hybrid open-ground system involving a porous container that promotes air-inhibiting—the usual term is the misnomer: air *pruning*—of lateral roots and, by virtue of the base being open, allows vertical roots to grow downward into the open ground on which the container would sit.

Other systems have been developed that employ air pruning, some of which are in use in the United States and Australia. However, containers designed to promote air inhibiting on the underside are expensive and root growth is difficult to prevent there—irrigation has to be finely managed to prevent unwanted root growth.

Rather than attempt to prevent root growth beneath the container, the hybrid concept envisages the pragmatic expedient of slicing beneath the open base with a manual or mechanised 'peel' to stimulate fibrous root growth and, at the same time, moving the plant to increase spacing to promote even bushier foliage development. It is envisaged that the container be biodegradable so that it can be planted with the plant.

The first stage of developing the system would involve establishing a small number of plants in containers fabricated from an interim material in order to determine whether sound root systems can be produced.

The trademark eNZopen™ has been obtained for the concept, with view to protecting the interests of funding providers.

Planting techniques

Building on the the experience of establishing radiata pine in Northland's heavy clay soils, trials are required to determine whether these methods can be employed with some, or all indigenous revegetation species.

In any event the planting techniques for open-ground plants are different from planting container-raised stock—potentially less labour intensive.

Future governance options

Friends of the Mahurangi Incorporated and Rodney District Council spearheaded the establishment of a members-based organisation—Open-Ground Indigenous Plants Incorporated—as the long-term representative of the project's wider community of interest. While the initial focus was on the proposed Ōmaha Pilot Open-Ground Indigenous Plant Nursery, the long-

term goal was to encourage innovation and dissemination of indigenous plant nursery and establishment techniques nationally.

With the unanticipated early realisation of the project's objective of having a commercial nursery offer a range of open-ground indigenous species, consideration is now being given to the best vehicle for advancing and promoting open-ground practices, long-term. One possibility would be for the on-going work to be assumed by Tāne's Tree Trust, an organisation with a national focus to 'see the majority of New Zealand landowners successfully planting and sustainably managing indigenous trees for multiple uses by 2020'. This would allow Open-Ground Indigenous Plants to explore the possibility of refocusing with a view to establishing a not-for-profit open-ground indigenous plant nursery, on the Rodney District Council-owned site at Jones Road, Ōmaha.

COLLABORATORS

This is a continuing collaborative project between Open-Ground Indigenous Plants, Friends of the Mahurangi, local property holders, Rodney District Council, Auckland Regional Council, Taupō Native Plant Nursery, Scrub Consultants, Scrub Growers, nursery consultant Jaap van Dorsser and the Crown research institute, Scion.

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