Choice of Nursery Method - container or open-ground

Although large numbers of natives have been raised in containers, plants produced open-ground – forestry nursery style – are increasingly being chosen.

INTRODUCTION

Establishment of native forest species is normally performed by planting nursery-raised plants grown from seed, although cuttings and wildings are used for some species (Davis et al. 2009). The method of choice for raising native plants has been the use of containers, first introduced into the horticultural industry, including planter bags, impervious pots, peat pots, and root trainers.

The alternative method for raising nursery stock is in open-ground beds where plants are raised in the open and leave the nursery bare-rooted. This is the method used for more than 100 years for the economical production of radiata pine (*Pinus radiata*) seedlings and to a lesser extent other tree species in the plantation forest industry (MacLaren 1993).

While the vast majority of native trees and shrubs has been raised in containers over the last few decades, the use of open-ground beds for raising natives is not new. Kauri was raised in open ground beds from at least the early 1950s in New Zealand Forest Service nurseries (e.g. Reed 1953; Morrison 1955). Research and operational programmes for raising a wide range of native tree and shrub species open-ground were underway at the Forest Research Institute nursery from the late 1950s (van Dorsser 2010).

The role of nurseries in producing cost-effective and well-conditioned planting stock is critical to native tree establishment in New Zealand. In this article we explore the merits of these two plant production systems based on early work as well as recent fieldwork initiated by Mahurangi Action. This work has been supported by the Ministry for Primary Industries' Sustainable Farming Fund, Tane's Tree Trust, Scion, Future Forests Research, Auckland Council, Bay of Plenty Regional Council, Waikato Regional Council and the Taupo Native Plant Nursery.

CONTAINER VS. OPEN-GROUND NURSERY STOCK

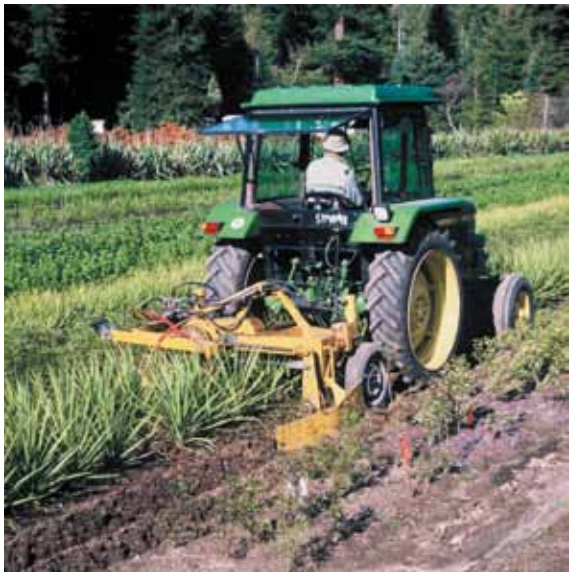
Both CG (container-grown) and OG (open-ground) methods for nursery production of natives, when well executed, can produce the robust, well rooted planting stock that is critical to the success of a planting programme.

Container-grown methods allow wide flexibility in planting programmes as stock can be held in the nursery and in the field until planting conditions are favourable. While CG plants may allow greater flexibility for the nursery, these plants are prone to root circling and root binding and subsequent poor establishment if root distortions are not remedied prior to planting. A further disadvantage of CG is the large weight of potting mix to be carried to, and on the planting site.

The open-ground method, used almost exclusively in the exotic forest industry, was, until recently, rarely used for native species, despite effective techniques having been developed for them (Forest Research Institute 1980; van Dorsser 2010). The open-ground method is well suited to large production volumes at low cost but, because the plants must be 'lifted' from their open-ground beds to order and planted within the following few days, much tighter project management is required than for container-raised plants.

Capital start-up costs for large-scale OG production requiring specialised tractor-drawn machinery for conditioning plants is prohibitive for small operations. Good quality flat land with free-draining soil is also required (Smith 2010).

The two major advantages of OG plants, as seen in many trials with exotic species, are firstly the much-reduced cost of production and secondly the production of a conditioned plant with a compact, fibrous root system, ready to form new roots after planting.



'Open-ground' or 'bare-root'

'Open-ground' and 'bare-root' are often used interchangeably to refer to plants raised by open-ground methods. Here, to avoid the impression that the terms refer to different methods, 'open-ground' is used throughout, while 'bare-root' refers to the state of the plants raised in open-ground beds when they are lifted from the bed, packed, transported and replanted.

Manuka, toetoe and koromiko raised in open-ground beds, Taupo Native Plant Nursery

CONTAINER STYLES AND SIZES

Lightweight containers filled with moist, nutrient-rich potting mix provide an ideal rooting environment for developing plants. Choice of container will depend on species grown and the age and size of plants required. Most container-raised native shrubs and trees are produced in containers of three broad types:

- **Planter bags** made of flexible black polythene, usually PB¾, PB2 or PB3 where number corresponds to capacity of the bag, measured in pints—a PB3, 3 pints, or 1.7 litres. Bag diameter ranges from about 10 to 15 cm, height about 14 cm. Cost of seedlings varies from $2 to $5 per seedling, depending on the size of bag and volume of order.
- **Semi-rigid pots** are increasingly being used, particularly by nurseries using mechanisation. Because the pots are tapered, they are readily removed from the root ball, increasing their recycling potential. Sizes are in litres. Cost of plants raised in semi-rigid pots is similar to the equivalent planter bags.
- **Root trainers** are commonly available in two sizes:
  - *Tinus root trainers* come in 20 cm high "books," each having four cavities 5.1 x 3.8 cm in size. The hinged books open for easy removal of seedlings and 12 fit into a wire cage that holds them upright and elevated so that any roots that protrude below the container are "air pruned". The compact form of the cage makes root trainer plants cheaper to transport and easier to manhandle on the planting site than trays of planter bags or pots. However the plants are much smaller, reflecting the limited space available to each individual. Cost per seedling ranges from $1-2.
  - *Hillson root trainers* are 12.7 cm high, each book having four cavities 3.8 x 3.8 cm. Hillson root trainers have less than half the volume of the Tinus version, and only 9.4% of the volume of a PB3.

There are a wide range of other containers used for natives including peat pots of different sizes and moulded cavity trays featuring a range of sizes and number of cavities. These are sometimes used in mechanised production systems. However the vast majority of natives are raised in planter bags, semi-rigid pots and root trainers.

Plants raised for nine months in open-ground nursery beds (left); 1.2 -litre semi-rigid pots (centre); and in Hillson-sized root trainers (right).

Container-raised plants are often transferred from seed trays to small propagation cells before potting-on to final containers.

OPEN-GROUND METHOD

The production of bare-rooted plants

The philosophy and practice of open-ground techniques is to produce plants that are physiologically conditioned to allow them to be transported and planted in a bare-root state.

Techniques for the OG production of many native trees and shrubs were developed by the Forest Research Institute in the 1950s and 1960s, and used for forest rehabilitation by the New Zealand Forest Service (Forest Research Institute1980; Bergin and Gea 2007). For large-scale afforestation the costs of production are significantly less than for CG plants (van Dorsser 2010).

Typically seed is germinated indoors in seed trays, similar to the prevailing practice in container nurseries. Once sufficiently developed and hardened off, the seedlings are transplanted into open-ground beds with the plants spaced at 15 x 15 cm, or wider when plant-growth habit demands. The technique provides root volume at least twice that of containers set out at the same spacing.

Plant conditioning

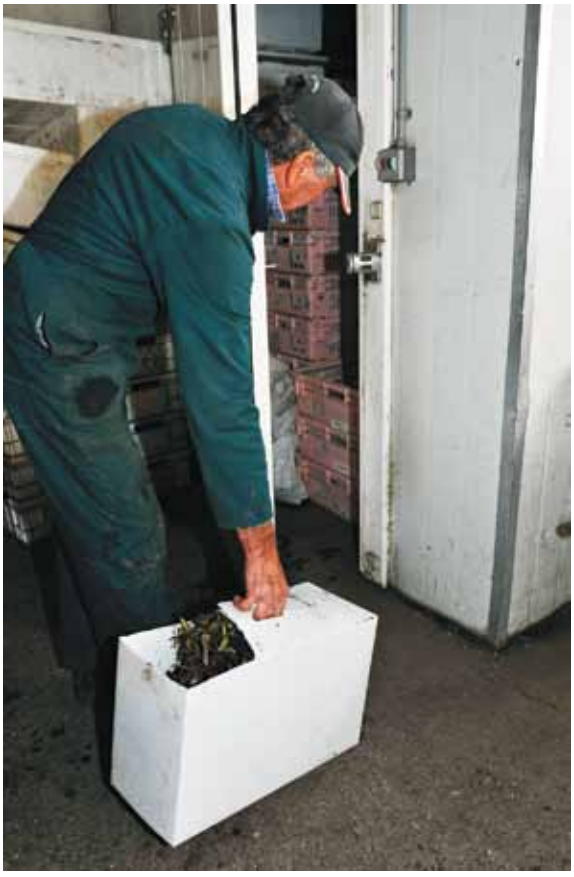
To produce conditioned well-rooted plants, they are provided with adequate individual space to develop robust tops and to respond to mechanical treatments aimed at developing compact fibrous root systems.

These treatments are carried out during late summer and autumn, and comprise the following:

- Undercutting – cutting of tap roots at a pre-determined depth;
- Wrenching – a loosening operation to encourage fibrous root development;
- Lateral Pruning – cutting lateral root growth between adjacent rows;
- Box Pruning – cutting lateral root growth between trees in the row; and
- Topping – when necessary to contain excessive height growth.

Resultant, well-developed plants have dense, fibrous root systems close to the tap root. Plants are lifted from the beds by hand with the aim of preserving the fibrous root mass; excess soil is gently shaken off, and straggly roots trimmed.

Trimming of straggly roots systems of bare-root seedling at lifting.



Cool moist storage is essential between lifting and planting for bare-rooted plants. Where possible, placing seedlings in a cool store provides ideal short term storage.

Handling after lifting

Once lifted, OG plants, essentially free of soil, are light to transport and should be kept cool and moist prior to planting within a few days (ideally within 3 days of lifting). In contrast to CG plants that can be reserved for use over an extended period, OG plants have a relatively short 'shelf-life' between removal from the open-ground beds and planting.

While many species respond well to conditioning, once bare-rooted they can be intensely sensitive to drying out and need special attention to avoid transplantation shock and transport desiccation. Care in keeping root systems wet and cool after lifting, and during storage and transport is critical. Stored plants should be watered every day until planted.

Open-ground aptitude

Differing physiology means that some species are particularly well suited to the open-ground method. Species such as totara *(Podocarpus totara)*, kahikatea *(Dacrycarpus dacrydioides)*, many of the *Coprosma* species, manuka *(Leptospermum scoparium)* and kanuka (*Kunzea ericoides)*, readily develop dense fibrous root systems in response to root conditioning during the process of open-ground production. Harakeke responds particularly well by virtue of its rhizomatous root system, and is relatively immune to desiccation during the transplanting and planting stages.

In contrast, some native species such as kauri *(Agathis australis)* (Bergin and Steward 2004), tawa *(Beilschmiedia tawa)*, rewarewa *(Knightia excelsa)*, and some *Pittosporum* species can be reluctant at forming fine feeding roots. Kauri, and to a lesser degree rewarewa, often have one or more woody vertical taproots and a feeble network of fibrous roots irrespective of whether raised in containers or in open-ground beds. Further research aimed at increasing fibrous root development of these species is required.

EVALUATION OF PLANTING STOCK

Plant size

Size of nursery-raised plants can be measured in terms of plant height, canopy cover and root collar diameter. All of these parameters are influenced by the time taken to raise plants in the nursery as well as the method of raising and lateral space allowed for each plant during the nursery phase.

CG plants are normally grown close together to conserve valuable greenhouse or shadehouse space. Although smaller individual containers could be spaced out in the nursery to allow room for more foliage, and a more squat form to develop, in practice they are grown container-to-container both to conserve standout space and to limit capsize. Root-trainer plants are, by design, confined by 'books' tightly packed into wire frames with very limited growing space.

NURSERY TRIALS

In an evaluation of OG and CG nursery stock of six native species commonly used in revegetation programmes, canopy spread of most species of OG plants, nine months after seed sowing, was greater than that of CG plants (PB3 bags), which in turn was greater than that of plants in small containers (Hillson root trainers) (Bergin and Cole 2010; Smith 2010). Root collar diameter of OG plants was on average twice that of CG plants and three times that of plants in Hillson root trainers.

OG plants had better-developed shoot growth than plants grown in containers probably related to the available soil volume (including nutrient source) and space for canopy expansion. Nursery area allocated to each plant in this trial was:

- 20 x 20 cm in open-ground beds (equivalent to 25 plants per m^2);
- 15 x 15 cm in PB3 containers or equivalent (44 plants per m^2);
- 5 x 5 cm in Hillson-sized root trainers (400 plants per m^2).

High volume open-ground production will result in plant spacing in open-ground beds reduced from the 20 cm plant spacing used in the trials to 15 cm between plants, similar to PB3 containers at 44 plants per m^2 and therefore with similar space for shoot development. This plant spacing has been standard practice for native plants used at the Forest Research Nursery (now Scion) over the last three decades.

Plants raised in root trainers were particularly spindly in the trial reflecting a growing space of only 25 cm^2 whereas seedlings raised in larger containers such as PB3 planter bags have up to nine times the area (225 cm^2) available for crown development .

Stem diameters (at root collar) of 9-month-old open-ground plants (left) were on average twice those in pots (centre) and three times those in root trainers (right) - koromiko pictured.

Root growth

While plant tops are easily checked for vigour, size and presence of fungus and insect damage, the development and health of root systems is not routinely assessed for CG stock, while OG plants are readily inspected when lifting and culling takes place.

Root distortion can occur at the base of the stem when seedlings are transferred from the seed tray to the propagation cells. This can be difficult to identify later and can lead to root strangulation and tree toppling.

With CG stock, ideally plants will have been transferred to a larger bag or potted on as soon as the roots have bound the available potting mix in the first container. Any root distortion found during repotting must be rectified at the time to avoid later root strangulation and toppling.

Before planting, a random selection of plants, both OG and CG, should be carefully inspected. Root systems of OG plants should be inspected at lifting and those with distorted or poorly developed roots should be rejected if defects cannot be rectified. Roots of lifted OG plants should be trimmed to a compact root system.

For CG stock a sample should be removed from containers to check root development and quality. Where root systems are rootbound, have distorted taproots, or have poorly developed fibrous feeding roots, then whole batch should be rejected if the defects cannot be rectified. If the root systems have not had sufficient time to develop after potting-on into larger containers, the potting mix will fall away and root exposure may increase transplanting stress .

Check that container-grown plants are not rootbound; reject seedlings with grossly distorted root systems.

Rootbound plants should ideally be rejected. If they have to be used, the root mass should be loosened and any fibrous roots teased out or cut to encourage growth into the surrounding soil after planting. Seedlings with grossly distorted or underdeveloped root systems should be discarded.

Nursery-raised seedlings have been planted out on several sites in the upper half of the North Island to compare performance of seedlings raised as open-ground plants, in large containers or in root trainers. There has been wide interest in field-based workshops including these trials in the Taupo catchment with Tane's Tree Trust and NZ Farm Forestry Association members, and with regional council Land Management Officers.

COMPARING COSTS

A comparison of plant characteristics, operations at planting time and estimated nursery costs is provided for the more commonly planted native shrub hardwood species used in revegetation programmes in Table 1. OG stock is potentially half the cost of the commonly produced larger CG options. However, estimated 'shelf life' after lifting OG stock is very limited compared to container options (e.g. Smith 2010).

A significant cost for large container stock is the space that it takes up during storage and transport compared to OG and the small root trainer stock. Plants raised in PB3 planter bags require at least four times the space for storage and transport compared to OG stock. Similar numbers of OG stock can be transported to the site and carried around the planting site as the root trainer stock (Table 1).

PERFORMANCE AFTER PLANTING

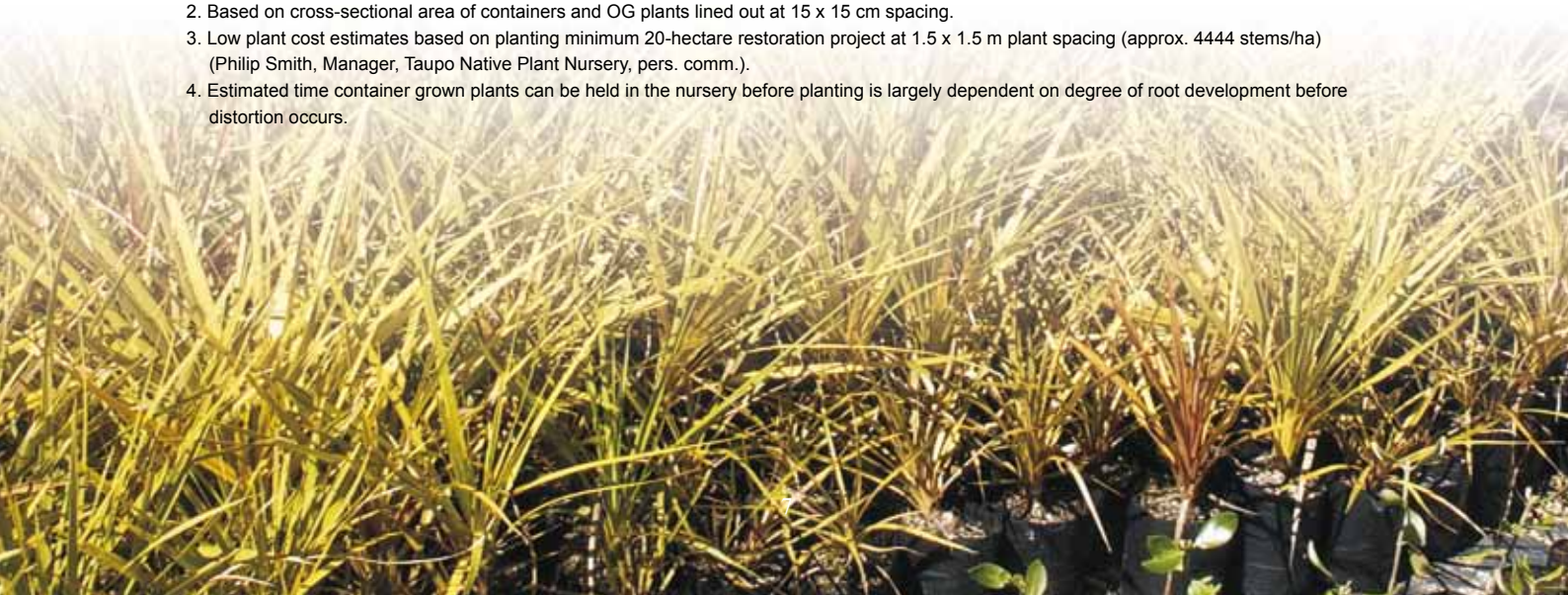
It might be considered that CG plants with intact roots surrounded by potting mix might survive better than OG stock after planting out. However this has not been the case and a number of trials comparing the establishment performance of OG vs. CG plants have been carried out to show there is no significant difference in growth rates or survival.

Results of these trials, of native shrub hardwood species commonly planted in revegetation programmes, measured up to five years after planting are provided in Technical Article No. 5.4 in this Handbook.

Table 1: A comparison of plant size, estimated bulk cost, storage times, transport capacity and times involved at planting for open-ground and container grown plants for native shrub species commonly used in planting programmes.

	Open-Ground	1.2-litre pot or PB3 planter bag	Large root trainer (Tinus)	Small root trainer (Hillsons)
Species available	Most	All	All	All
Mean plant height[1]	50 cm	55 cm	Est. 50 cm	45 cm
Stem collar diameter[1]	8-10 mm	8 mm	Est. 6-7 mm	5 mm
Space available for crown development[2]	15 x 15 cm	15 x 15 cm	5 x 5 cm	4 x 4 cm
Estimated bulk cost[3]	$.50-$1.50	$2.60-$3.35	$1.50	$.90-$1.50
Estimated shelf life before planting[4]	1-3 days after lifting (max. 10 days cool storage)	Several months (max. 6 months)	Several months (est. 3 months)	Several months (est. 2 months)
Transport plants per m^2 of truck deck	480-800	120	500	720
Transport on site – plants carried by one person	20-50 depending on species	8-12	48 (based on 12 books packed into wire cage)	60 (based on 15 books packed into wire cage)

1. Based on average of the shrub hardwoods karamu, koromiko and manuka raised from seed within 12 months of sowing (Bergin and Cole 2010).
2. Based on cross-sectional area of containers and OG plants lined out at 15 x 15 cm spacing.
3. Low plant cost estimates based on planting minimum 20-hectare restoration project at 1.5 x 1.5 m plant spacing (approx. 4444 stems/ha) (Philip Smith, Manager, Taupo Native Plant Nursery, pers. comm.).
4. Estimated time container grown plants can be held in the nursery before planting is largely dependent on degree of root development before distortion occurs.



Planting trial comparing native shrub species raised as open-ground with container-raised plants 5 years after establishment along a riparian zone that forms part of the Mahurangi Farm-Forestry Trail, Auckland region.

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