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This contract report by Environmental Restoration Ltd (ERL) is prepared for the Dune Restoration Trust of New Zealand as part of a collaborative project with the Ohiwa Beach Coast Care group, Whakatohea Trust, Environment Bay of Plenty and Opotiki District Council.

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Restoring our coastal environments using native plants

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ABSTRACT

An indigenous species coastal planting trial was established at Ohiwa Spit, eastern Bay of Plenty in mid-2005 by the the Ohiwa Beach Coast Care group, Whakatohea Trust, Environment Bay of Plenty and Opotiki District Council. The aim of the trial was to evaluate the performance of a range of local indigenous ground cover and shrub species planted within three demarcated zones on a relatively stable backdune site and to compare the relative performance of seedlings raised in Tinus rootrainers with those raised in PB planter bags.

Three years after planting there were significant differences in plant performance between front, mid and back zones. While overall survival was high, growth was poor for most species especially on the exposed front and mid zones compared to the more sheltered back zone that comprised a cover of vegetation dominated by exotic species. There were few differences in survival and growth for most species 3-years after planting between seedlings raised in root trainers and PB2 planter bags.

Degree of exposure is considered to be a major factor in limiting performance of planted indigenous species; most plants on the open sites had lost height and plant spread probably due to severe exposure to onshore winds and salt spray. While increased shelter in the landward backzone contributed to improved growth and plant vigour, competition from exotic vegetation had resulted in higher early mortality for some species.

Care is required in selecting the appropriate zone for the planting of coastal backdune species and to avoid planting a wide range of indigenous species too far seaward in exposed zones. It is recommended that existing vegetation cover on backdunes should be used wherever possible to provide shelter for assisting in establishment of indigenous shrub species. Ground cover plant species are more likely to succeed on open dune sites rather than taller shrub species. The trial indicates that a small selection of hardy indigenous coastal shrub species can be successfully established within the shelter of existing back dune vegetation.

KEYWORDS: sand dunes, backdunes, indigenous, coastal, Coast Care, planting, nursery-raised seedlings, rootrainers, containers.

INTRODUCTION

An indigenous species coastal plant trial was established in mid-2005 by the Ohiwa Beach Coast Care group, the Whakatohea Trust, Coast Care BOP, Opotiki District Council (ODC) and Ensis (formerly Forest Research Institute). The trial was located at Ohiwa Spit, eastern Bay of Plenty with the aim of evaluating the performance of a selection of mainly local woody indigenous species planted on a relatively stable backdune site. A further objective was to compare for each species the relative performance of seedlings raised in two types of containers in the nursery – rootrainers and planter bags.

The Dunes Restoration Trust of New Zealand (formerly the Coastal Dune Vegetation Network) has indicated that research on the revegetation of the often highly modified backdunes using indigenous species is a key priority. There are few regions in New Zealand where backdunes have not been substantially modified by human disturbance where indigenous vegetation cover is either non-existent or severely degraded (e.g., Partridge 1992; Johnson 1992). Considerable challenges exist in restoration of an effective cover of indigenous vegetation on semi-stabilised backdunes. Sites are invariably exposed and subject to desiccation and salt-laden on-shore wind, there is little organic matter in the substrate, exotic weeds and animal pests are usually abundant, and human disturbance often continues unabated in high use areas. In addition, there is often a lack of seed sources of appropriate indigenous species to assist natural regeneration.

Planting is likely to be one of the main options for re-establishing indigenous vegetation on backdune sites in many regions, especially where there is a desire by local communities and agencies for ecological improvement of their dunes, and where there are sufficient resources and knowledge to undertake the task of revegetation. Unlike foredunes where only a relatively small number of mainly sand binding or sand trapping species occur, backdunes are a complex of plant communities and site conditions where a greater diversity of indigenous species occur - from ground cover to high forest.

This trial evaluated 12 indigenous ground cover, shrub and small tree species on backdunes that were known to occur locally on or in the vicinity of backdunes (Jenks, undated). Plants were tested on a range of sites to evaluate performance in relation to proximity to the sea. Moving inland, planting sites have increasing shelter from predominantly exotic woody species and there is likely to be greater organic matter content in the soil on more landward areas compared to the seaward zone.

There are a wider range of techniques for raising indigenous seedlings in nurseries, especially choice of container type. Smaller containers are likely to produce smaller plants at lower cost compared to larger container options. Different species are likely to perform better when large seedlings are used compared to smaller ones. The trial therefore compared relative performance of seedlings raised in two commonly used container types - rootrainers (Tinus) and planter bags (PB2).

The trial was monitored over a 3-year period and the results are presented in this report to add to existing guidelines on general principles for restoration of degraded backdune areas, using assemblages of local indigenous plant species.

PREVIOUS WORK

There are numerous guidelines for the planting of indigenous species for a wide range of reasons and covering many different sites including relatively sheltered inland sites and exposed upland

forest sites (eg., Evans 1983; Pollock 1986; Beveridge *et al.* 1985, 1987; Bergin and Gea 2007). Over the last decade or more there have been a number of trials, management-scale planting programmes, and publications on restoration of our coastal sand dunes. Efforts were initially focussed on evaluating our indigenous sand binders for stabilising degraded dunes and providing viable options for restoration of dunes (e.g. Environment Waikato 2001; Jenks and O'Neil 2004; Bergin and Herbert 1998; Bergin 1999). Attention then turned to restoration of backdune areas with major backdune species trials established in Whitianga on the Coromandel Peninsula, Awhitu Peninsula west of Auckland, and on several sites along the Christchurch dunes (Bergin *et al*. 1995a; 1995b).

The backdune trials at Whitianga established on a dune nourishment area south of Taputaputea Stream (near the centre of Buffalo Beach) involved comparing 26 different coastal tree, shrub and ground cover species testing a range of establishment treatments including proximity of planting to the sea (degree of exposure to onshore winds), application of fertiliser at planting, use of mulches, and benefit of artificial shelter using wind cloth fences (Bergin *et al*. 1995a). A list of hardy species that performed well included pohuehue (*Muehlenbeckia complexa*), karo (*Pittosporum crassifolium*), tauhinu (*Ozothamnus leptophylla*), taupata (*Coprosma repens*), akeake (*Dodonea viscosa*), ngaio (*Myoporum laetum*), harakeke (*Phormium tenax*) and pohutukawa (*Metrosideros excelsa*). Coastal five-finger or houpara (*Pseudopanax lessonii*) also established well but an increase in rabbit numbers within 12 months of planting killed many of the seedlings. The nursery-raised seedlings used in these trials were grown in containers, mostly polythene planter bags (PB2) or similar sized RX 90 pots.

There has been excellent growth of several hardy indigenous coastal woody species planted amongst marram grass on a severely eroding dune in trials at Awhitu Peninsula. Best performing species included pohutukawa, tauhinu, akeake, harakeke, karo and ngaio (Bergin *et al*. 1998).

Results for the backdune trials to date indicated that application of slow release NPK fertilisers improved initial growth as did provision of shelter particularly for plants immediately landward of the exposed foredunes. Application of mulches in the form of bark or woody material did not reduce the need for regular early weed control or improve performance of planted seedlings.

Most woody indigenous plants raised in nurseries for revegetation are grown in containers such as polythene planter bags PB2 or PB3 or similar size containers (Bergin and Gea 2007). Smaller containers such as rootrainers are an attractive option as they take less space and potting material in the nursery, are lighter to transport, and can be more easily distributed around the planting site. However, anecdotal evidence suggests that there may be more difficulties achieving reasonable survival and growth rates where seedlings raised in smaller containers are planted, particularly on difficult sites.

OBJECTIVES

The objectives of this trial were:

- To quantify early survival and growth of 12 selected local indigenous coastal trees and shrub species planted on a backdune site typical of the Bay of Plenty coast.
- To compare planting performance of seedlings raised in PB2 polythene planter bags and Tinus rootrainers (RTT).
- To compare early growth performance of seedlings planted within and without cover of low existing vegetation in several zones that are at different distances from the sea.

- To provide coastal managing agencies and local Coast Care groups with recommendations for large-scale backdune revegetation programmes using nursery-raised indigenous species.

METHOD

Establishment

The trial was planted in July 2005 by the Whakatohea Trust, the Ohiwa Beach Coast Care Group and staff from Coast Care BOP, Opotiki District Council and Ensis.

Species

The 12 species planted in the trial were:

Coprosma acerosa	tarakupenga, sand coprosma
Coprosma repens	taupata
Cordyline australis	ti kouka, cabbage tree
Cortaderia fulvida	toetoe
Dodonea viscosa	akeake
Hebe stricta	koromiko
Muehlenbechia complexa	pohuehue
Myoporum laetum	ngaio
Ozothamnus leptophylla	tauhinu, cottonwood
Phormium tenax	harakeke, flax
Pittosporum crassifolium	karo
Pseudopanax lessonii	houpara; coastal five finger

One hundred of each species were grown in Tinus rootrainers and 100 raised in PB2 polythene bags in similar conditions at the Whakatane-based National Coastal Revegetation Centre, Naturally Native New Zealand Plants Ltd. Plants were one-year-old and all raised from seed collected locally in the Bay of Plenty.

Trial area

The trial was located on a semi-stable backdune site on the seaward side of the Ohiwa Spit, which is the eastern spit of the Ohiwa Harbour. In a brief survey of the beach, Partridge (1992) described the Ohiwa Harbour Spit as a single wide dune ridge with sand sedge (*Carex pumila*) growing at the base of the dunes, with spinifex (*Spinifex sericeus*), rare pingao (*Desmoschoenus spiralis*) and occasional sea rocket (*Cakile maritima*) on the front face. The back dune was described as poorly defined and dominated by tree lupin (*Lupinus arboreus*), sea couch (*Elymus pycnanthus*) and occasional pampas (*Cortaderia splendens*) and ngaio.

In a detailed survey of the Ohiwa Harbour vegetation, Beadel (1993) notes that the margins of the Ohiwa Spit comprise a spinifex sandfield where spinifex dominates the foredunes with the occasional adventives catsear (*Hypocharis radicata*) and fleabane (*Conyza* spp.) and the local sand convolvulus (*Calystegia soldanella*). While Beadel found only two clumps of pingao in surveys in the late 1980s and early 1990s, considerable planting by the local Coast Care group over recent years has seen a significant increase in this species along the foredunes seaward of the backdune planting trial. Landward zones at Ohiwa comprised adventives including sea couch, pampas, lupin, gorse (*Ulex europaeus*) and blackberry (*Rubus fruticosus* agg.), along with pohuehue and spinifex (Beadel 1993). Other species seaward of the backdune trial which appear to have been planted in recent years include *Carex testacea* and wiwi or knobby clubrush (*Isolepis nodosa*), both of which appear to be growing well despite rabbit browsing.

The area selected for the trial was approximately 100 m from the high water mark at the transition from open spinifex dunes to an increasing cover of mainly adventive species more landward. The area was divided into three planting zones based on the proximity to the sea and the degree of shelter provided by existing cover. Zones ran parallel to the coast and each was approximately 10-12 m wide with the front zone approximately 75 m from the toe of the front dune. The zones were:

1. Front zone – located landward of the active spinifex-dominated foredune. This exposed front zone was lightly vegetated with mostly spinifex and very scattered low growing adventives such as catsear and fleabane.
2. Mid zone – site located landward of the front zone comprising a low dune crest with a cover of spinifex and increasing density of herbaceous adventives inland with occasional scattered small groups of, mostly dead, low tree lupin.
3. Back zone – most landward zone comprising a plant cover dominated by adventive herbaceous species, exotic grasses and woody cover up to 1 m high including tree lupin, occasional pampas, a dense patch of ice plant (*Carpobrotus edulis*) and many garden escapes. Patches of bracken (*Pteridium esculentum*) dominate parts with scattered ngaio and harakeke.

Trial design and treatments

The trial consisted of 3 replicates in each of the three zones. Each replicate contained 12-paired plots of 10 plants each - one paired plot contains seedlings raised in Tinus rootrainers (RTT), the other raised in PB2 planter bags. The trial design therefore comprised:

3 sites x 3 replicates x 2 stock types x 10 plants = 180 plants/species (90 RTT & 90 PB2s)

With 12 species, a total of 2160 seedlings were planted in the trial.

While it is likely that some species will not perform as well in the more exposed seaward zones compared to the more landward sites, this has not been quantified previously. All species were therefore tested throughout the trial area to quantify their relative performance to more accurately determine optimum site requirements.

Three-metre diameter circular planting plots were established with a plant spacing of approximately 1 m within plots and a minimum of 2 m between plot boundaries. A 30 cm wooden peg with plot number was located centrally within each plot as identification. Flexible placement of circular plots allowed for a natural planting pattern and also ensured unsuitable microsites were avoided.

All plants were fertilised as per standard practice used by the BOP Coast Care programme with 30 g of controlled-release Hi-N Agroblen (full plastic film canister) incorporated into the planting pit as each seedling was planted. Seedlings were planted with the root collar at least 5 cm below ground level.

After planting, there was no weed control undertaken. Rabbit control was undertaken immediately before planting by Environment Bay of Plenty in consultation with the local community using a standard Pindone poisoning operation.

Plant assessments

Within a month of planting, height and plant cover (length x breadth) were measured and plant vigour assessed for a one-third sample across all treatments within the trial to provide a baseline on which to determine growth rate. The major parameters measured were:

- survival

- plant height
- plant cover – length and breadth of the live crown of each plant
- subjective assessment of plant vigour and health as one of five categories:
    1 - poor - few or no leaves, just alive
    2 - unthrifty - loss of leaves, poor foliage colour and plant vigour
    3 - average - moderate health and vigour
    4 - good - minor browsing or leaf discolouration, otherwise good growth
    5 - excellent - healthy plant with good foliage colour and growth
- comments - any addition information on plant condition (eg., browsing)

The subjective assessment of plant vigour and health was based on a comparison of seedling condition within each species, not between species. All seedlings were identified and measured separately. Plant cover for each plant was calculated as the square root of length x breadth.

After planting, the site was inspected regularly by the Ohiwa Beach Coast Care group and at approximately three monthly intervals for the first year by Environment BOP Coast Care and Ensis staff to record any factors affecting plant performance such as browsing by rabbits or hares, disturbance by beach users, and competing weed growth.

An assessment of survival was undertaken 5 months and 18 months after planting. A full survival and plant growth assessment using the parameters listed above was carried out 3 years after planting.

RESULTS

Nursery-raised seedlings

Seedlings raised in the PB2 planter bags were generally larger that their equivalents raised in Tinus root trainers at time of planting (Table 1). In particular, the hardwood species karo, houpara, tauhinu, ngaio and koromiko as well as the monocot ti kouka and groundcover tarakupenga raised in PB2 containers were higher and had greater plant spread than those raised in root trainers. For example, both tauhinu and ngaio raised in PB2 bags were up to 20 cm taller on average and almost 20 cm^2 greater in plant cover than their equivalents raised in root trainers.

Of the other species, most were similar in size between stock types at time of planting. The exceptions included root trainer-grown harakeke and akeake which were taller and root trainer pohuehue which was greater in plant spread compared with their PB2 counterparts. Root systems within each container type adequately bound the potting mix and there appeared to be no significant root distortion.

Early performance

Five months after planting, most species had between 80-100% survival with higher mortality of root trainer stock compared with PB stock. Most early mortality occurred in the back zone with up to 30% of pohuehue, toetoe, ti kouka, houpara and tauhinu either dead or lost within dense weed growth. Over half of the tarakupenga plants raised in root trainers had died within 5 months of planting, particularly on the front and back zones.

By 18 months, most toetoe had died in all planting zones, up to 80% of tauhinu had died in the mid and back zones, and 50% of pohuehue in the back zone. Tarakupenga survival decreased to less than 20% except for PB stock on the front and mid zones where 60% had survived.

Table 1: Mean plant height, spread and vigour for the 12 indigenous species at planting, Ohiwa Spit backdune trial.

Species	Stock type	Plant height (cm)	Plant spread (cm^2)	Plant vigour (1-5)*
Pittosporum crassifolium (karo)	Root trainer	33.3	16.7	5
	PB2	46.5	27.2	5
Muehlenbeckia complexa (pohuehue)	Root trainer	15.5	30.2	5
	PB2	17.4	26.6	5
Pseudopanax lessonii (houpara)	Root trainer	26.4	21.6	5
	PB2	34.5	26.3	5
Phormium tenax (harakeke)	Root trainer	57	52.6	5
	PB2	53.1	42.9	5
Dodonaea viscosa (akeake)	Root trainer	46.7	19.7	5
	PB2	41.2	21.2	5
Ozothamnus leptophylla (tauhinu)	Root trainer	34.1	15.2	5
	PB2	58.2	27.4	5
Myoporum laetum (ngaio)	Root trainer	41.3	22.1	5
	PB2	64.7	41.6	5
Cordyline australis (ti kouka)	Root trainer	45.2	41.6	5
	PB2	53.1	63	5
Hebe stricta (koromiko)	Root trainer	37.4	25.4	5
	PB2	45.2	32.1	5
Coprosma repens (taupata)	Root trainer	29.6	15.6	5
	PB2	29	33.1	5
Cortaderia fulvida (toetoe)	Root trainer	71.1	51.3	5
	PB2	69.8	85.7	5
Coprosma acerosa (tarakupenga)	Root trainer	13.7	17	5
	PB2	22.3	35	5

* Plant vigour score: 1=poor, 3=average, 5=excellent

Overall performance

Mean survival and growth for the 12 indigenous shrubs and ground cover species that had been planted for three years in the Ohiwa Spit trial are summarised in Table 2. Two species, akeake and harakeke, exceeded 90% survival, and three other species, ngaio, ti kouka and karo, exceeded 80% survival three years after planting. A further four species, pohuehue, koromiko, taupata and houpara, had survivals within 50-70%. Only 40% of tarakupenga survived and less than 20% of tauhinu survived after 3 years. As virtually all toetoe had died by the earlier assessment 18 months after planting, this species was not included in further analysis of plant growth or vigour.

Species with high survival generally had the better growth rates. Akeake, harakeke, ngaio, and karo had the greatest increments in both height and plant spread over the three years since planting and average-to-good scores for mean plant vigour (Table 2). Of the two groundcovers, pohuehue had the third highest plant spread and average plant vigour compared to the relative poor performance of tarakupenga.

Table 2: Average survival and growth of indigenous shrubs and groundcover three years after planting in the Ohiwa Spit backdune trial, Eastern Bay of Plenty.

Species		Mean survival (%)	Mean height (cm)	Mean annual height increment (cm)	Mean plant spread (cm^2)	Mean annual spread increment (cm^2)	Mean plant vigour (1-5)*
Coprosma acerosa (tarakupenga)		39.6	18.8	2.8	26.8	3.5	2.2
Coprosma repens (taupata)		60.6	28.7	-3.0	16.5	-6.8	2.0
Cordyline australis (ti kouka)		85.6	53.5	2.1	47.6	-6.8	2.5
Cortaderia fulvida (toetoe)		0.6	70.0	7.2	50.2	-21.7	2.0
Dodonaea viscosa (akeake)		94.8	81.5	37.5	44.5	25.0	2.8
Hebe stricta (koromiko)		62.8	53.6	10.1	41.2	12.8	2.4
Muehlenbeckia complexa (pohuehue)		70.2	25.7	9.4	46.7	19.1	2.9
Myoporum laetum (ngaio)		87.2	65.0	11.2	48.9	16.8	2.4
Ozothamnus leptophylla (tauhinu)		17.8	49.2	3.7	41.3	21.1	3.0
Phormium tenax (harakeke)		94.4	74.7	20.1	50.6	5.6	3.1
Pittosporum crassifolium (karo)		80.6	70.0	29.1	34.1	12.7	3.4
Pseudopanax lessonii (houpara)		53.7	37.3	4.3	25.5	1.4	3.0
Stock type	Rootrainers	50.0	51.7	13.2	35.0	8.8	2.7
	PB2 bags	64.7	53.2	11.5	42.8	9.2	2.7
Planting zone	Front	74.0	32.1	-6.4	28.6	-0.9	1.6
	Mid	66.0	49.2	10.2	36.7	8.1	2.6
	Back	46.9	82.0	38.8	54.5	22.7	4.3

* Plant vigour score: 1=poor, 3=average, 5=excellent

While there was slightly higher overall survival for stock raised in PB2 planter bags, there was no consistent difference in growth or plant vigour between the two stock types (Table 2). However, there were significant differences in survival and growth performance of plants located on the three planting zones – front, mid and back. While survival increases from the back to the front zone, plant growth was significantly higher for plants in the back zone for both height increment (39 cm) and plant spread (23 cm^2) compared to the more exposed mid and front zones. There was in fact a reduction in crown cover for plants established on the front zone with 6 cm and 1 cm^2 mean decrease in height increment and plant spread increment respectively. Similarly, plant vigour was assessed as near excellent for back zone plantings but only unthrifty-to-poor for front zone plants.

Species performance and zonation
Survival of species planted within each of the planting zones (front, mid, back), are given in Figure 1. Survival for most species is similar on the front and mid zones but decreases significantly for those planted in the back zone. Akeake and harakeke maintained over 90% survival in all three zones. Ngaio, ti kouka, pohuehue, taupata, houpara and tarakupenga were all significantly lower in survival in the back zone compared to the seaward zones.

While six species (akeake, harakeke, ngaio, ti kouka, karo, pohuehue) had over 80% survival in the front zone, only pohuehue, karo and akeake recorded some growth, and mostly in plant spread rather than height (Fig. 2 & 3). Growth however did improve for these species in the mid zone where additional shelter was afforded by increasing vegetation cover and distance from the sea. All other species within this zone decreased in at least one of the growth parameters measured. Growth in the more sheltered back zone was greatest for the akeake, ngaio, koromiko, and to a lesser extent, harakeke and tauhinu, although the latter had poor survival. Poor performers in terms of growth across all zones included ti kouka, houpara, tarakupenga and taupata.

Plant vigour was consistently better for all species planted in the back zone except tarakupenga which had a below average plant vigour across all three planting zones (Fig. 4). Vigour scores for ngaio and taupata in particular, show that these species appear to be struggling on the exposed mid and front zones compared to other species planted.

Photographs with captions are appended showing the three demarcated zones (front, mid, back) on the backdune along with a selection of planted indigenous species within each zone.

Performance of stock types
There was no significant difference in survival three years after planting between plants that had been raised in Tinus root trainers or PB2 planter bags for virtually all indigenous species evaluated in this trial (Fig. 5). The only two exceptions were houpara and tarakupenga where survival was significantly higher for seedlings raised in PB2 containers compared with root trainers. However, these two species were amongst the poorest overall performers in the trial.

Of the growth parameters assessed, plant spread was the only one to show significant difference in plant performance between stock types for a minority of the species (Fig. 6). However, while akeake and harakeke had significant increases in plant spread for PB2 stock compared to their equivalents raised in root trainers, root trainer tauhinu performed significantly better than those raised in PB containers.

There were no significant differences in plant height or vigour between seedlings raised in PB2 containers and Tinus root trainers across all species three years after planting.

Weed growth
There is a considerable observed increase in weed cover from the front zone to the back zone of the planting trial area. The transition to the back zone to a cover dominted by a mixture of lupin, bracken, scattered pampas and indigenous shrubs is relatively rapid. One area within the backdune is smothered in ice plant and expanded in size during the course of the trial. Most indigenous seedlings planted within or adjacent to the ice plant colony had died.

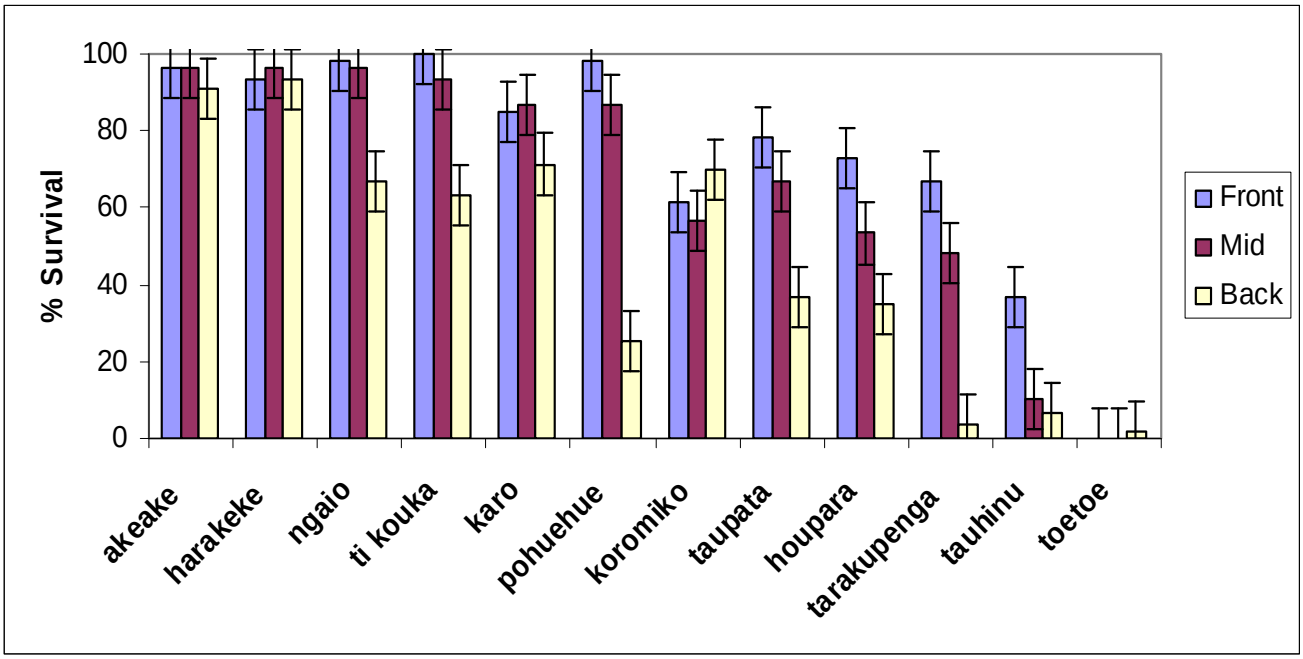

Figure 1: Survival for indigenous species three years after planting on the three zones, Ohiwa Spit backdune trial.

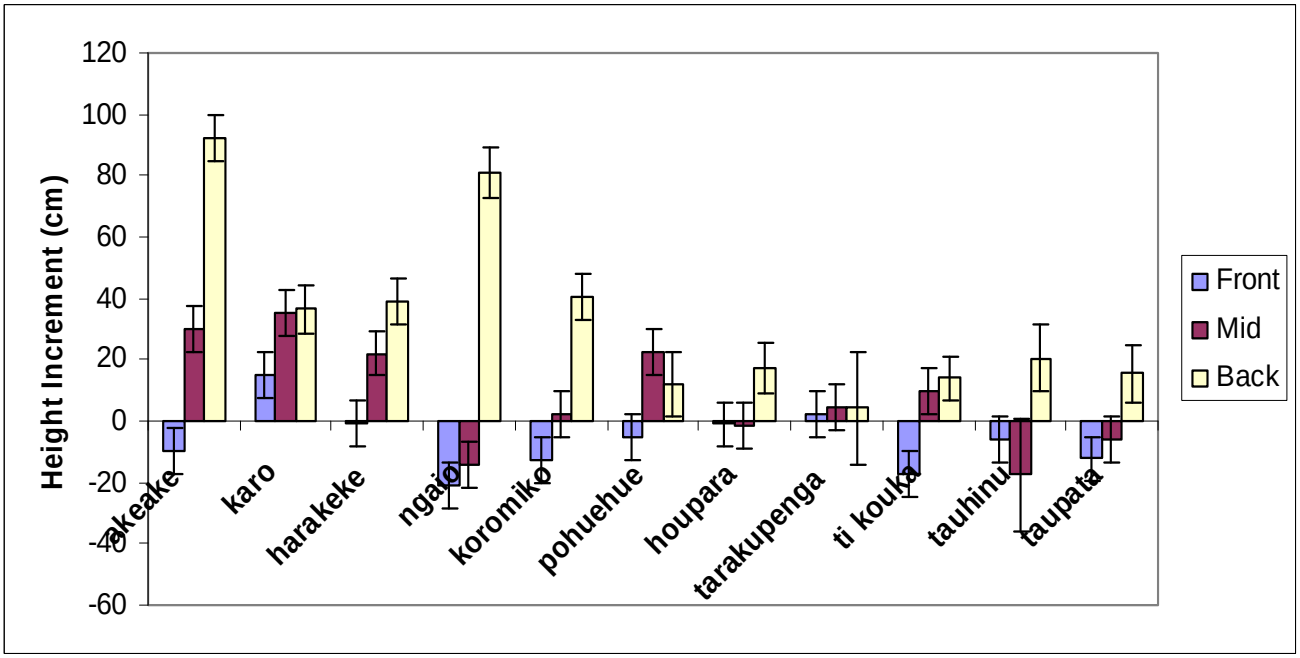

Figure 2: Annual height increment for indigenous species three years after planting on the three zones, Ohiwa Spit backdune trial.

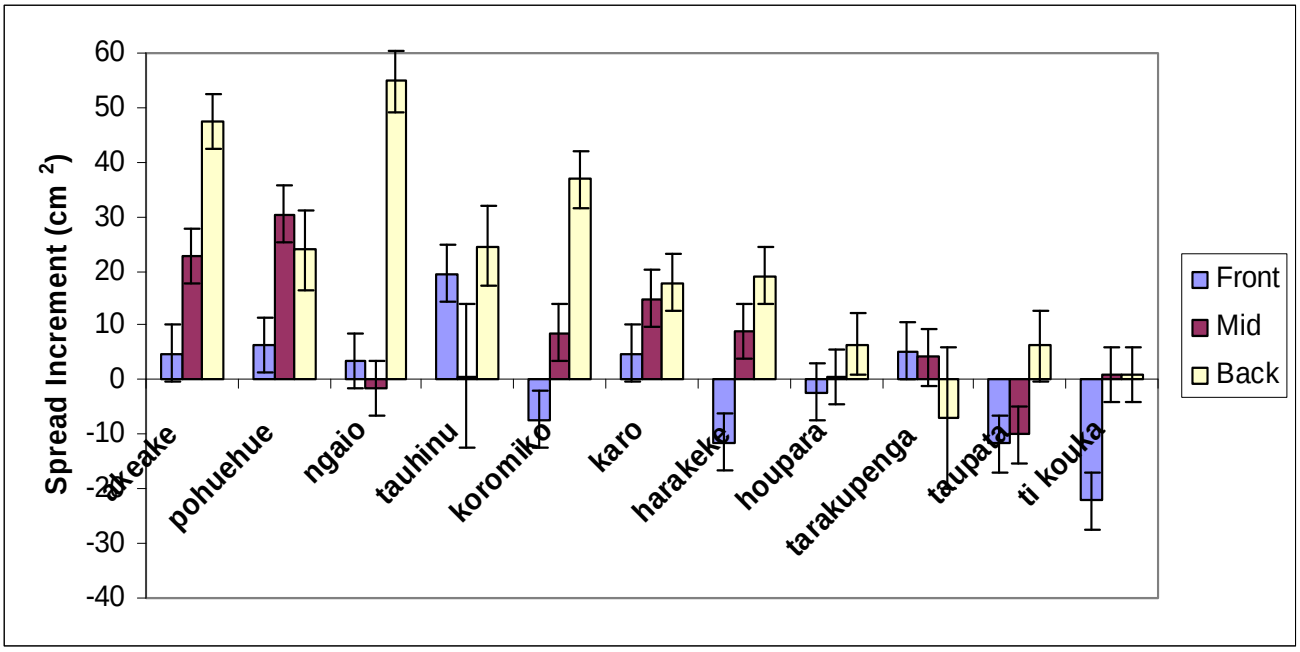

Figure 3: Annual increment for plant spread for indigenous species three years after planting on the three zones, Ohiwa Spit backdune trial.

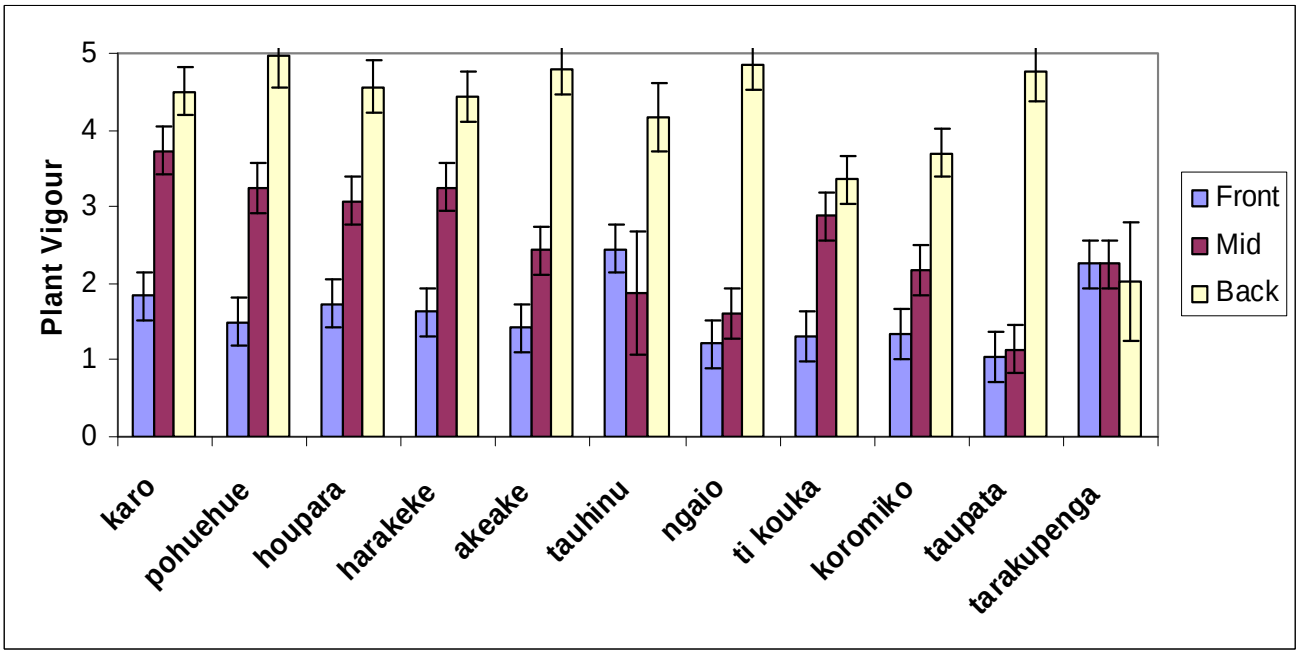

Figure 4: Plant vigour score for indigenous species three years after planting on the three zones, Ohiwa Spit backdune trial.

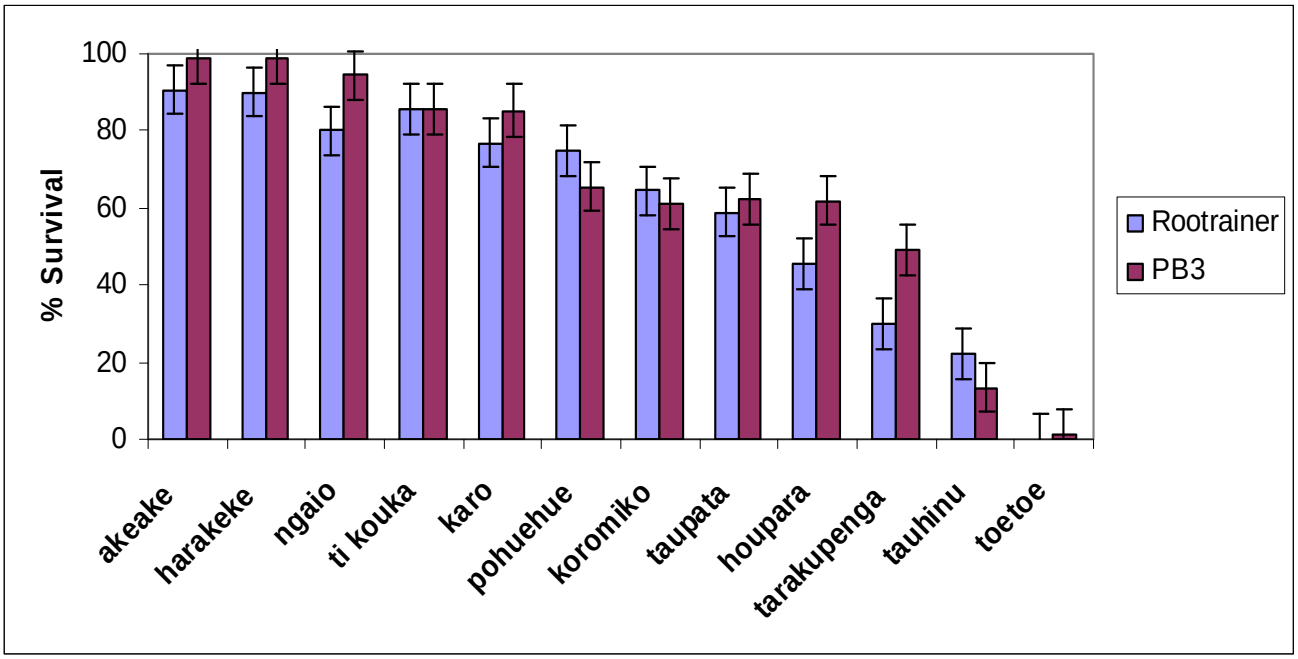

Figure 5: Survival for indigenous species three years after planting between Tinus root trainers and PB2 planter bags, Ohiwa Spit backdune trial.

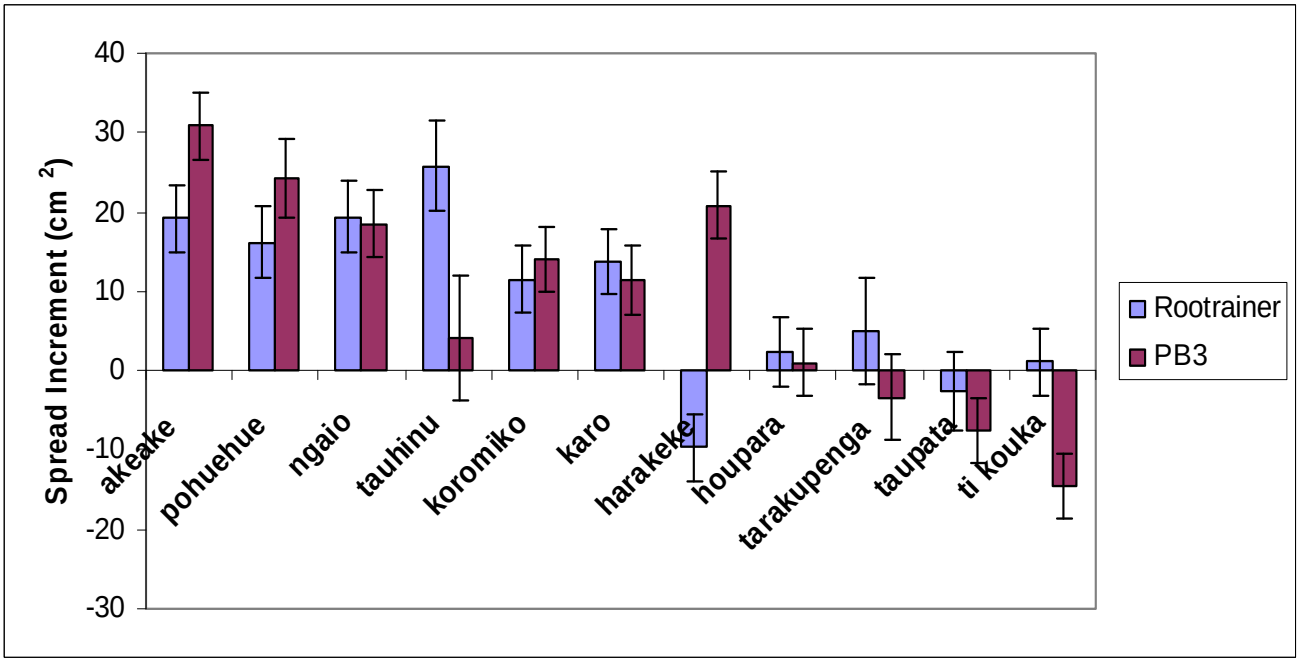

Figure 6: Annual increment for plant spread for indigenous species three years after planting between Tinus root trainers and PB2 planter bags, Ohiwa Spit backdune trial.

While overall survival within the back zone is less than seaward zones, six species (akeake, harakeke, ngaio, koromiko, ti kouka, karo) have 60-90% survival after three years, despite no weed control (Fig. 1). Shelter within the back zone has clearly had a positive effect on plant growth (Fig. 2 & 3) and plant vigour (Fig. 4).

The trial area is immediately seaward of a small carpark where there is considerable evidence of dumping of garden waste. The backdune area had many garden escapes from a long history of this practice.

Rabbits

While the trial area had been controlled for rabbits immediately before planting, three years later rabbit numbers appeared to have increased with a detrimental effect on planted seedlings. Foredunes along the beach immediately landward of the planting trial had severe browsing of pingao. Rabbit browsing, scratching sign and droppings were common throughout the open sites in both the front and mid zones of the planting trial area.

Taupata and ti kouka were severely browsed by rabbits with many plants largely defoliated. This is likely to have been a major contributing cause to the poor performance of these species in open sites.

The dense cover of vegetation throughout most of the back zone where planted groups had been established had kept rabbit damage to a minimum with in this zone.

A rabbit control operation recently underway was evident during assessment of the trial three years after planting. Signs indicated Pindone had been recently laid and one dead rabbit was found in the trial area.

DISCUSSION

Site preferences

The performance of the 12 plants established in this trial clearly indicates there are major differences in site characteristics between the front, mid and back zones as demarcated for the purposes of this trial. Overall performance indicates that while survival is good, virtually all species are struggling to grow on the front and mid zones comprising semi-stabilised sand with a covering of spinifex and scattered exotic herbaceous weeds. Within the back zone, survival is less compared to the open zones, but there is significant growth of most shrub species planted amongst an existing cover of taller vegetation dominated by bracken, tree lupin and scattered indigenous shrubs.

The poor growth performance of most species in the open zones suggests that the selected species tested in the trial are being planted too far seaward. Virtually all species on the front zone had reduced in size since planting three years earlier. Best performance only occurred where some degree of shelter was provided usually by scattered exotic woody weeds such as tree lupin. Growth and plant vigour improved even in the shelter of dead standing lupin scattered within the mid zone.

A useful indicator of suitable sites for planting backdune species is the degree of existing vegetation cover. Increasing density and height of plant cover landward appears to significantly ameliorate the site and improve performance of inter-planted indigenous species. However, the increased vegetation cover is also in competition with planted indigenous shrubs and this was reflected in the poor survival in the back zone for half of the species planted in the trial

compared to the exposed seaward zones. While not measured in the Ohiwa Spit trial, other factors are also likely to be influencing the better performance of planted indigenous species on the sheltered back zone including the increasing organic matter that is building up in the soil from the increasing density and diversity of exotic and indigenous cover.

Species choice
Despite the lack of post-plant weed control, five species (akeake, ngaio, karo, harakeke, koromiko) achieved high survival and reasonable growth rate when planted within the sheltered sites amongst existing mostly exotic vegetation on the back zone. Four of these species (akeake, ngaio, karo, harakeke) were also identified in other back dune trials in the Coromandel and Awhitu peninsulas to the north as hardy species suitable for widescale planting in backdune restoration programmes (Bergin et al. 1995a; Bergin et al. 1998).

Tauhinu was the only species of the 12 species tested in the trial to show some growth on the most exposed front zone. The two ground covers, pohuehue and tarakupenga, have better survival on the exposed sites and growth of pohuehue in particular is promising. As listed by Jenks (undated), there are likely to be a range of other species not tested in this trial that would be suitable for planting on these exposed sites landward of the active sand binding foredune zone including *Carex testacea* and wiwi. However, further trials are required to determine relative performance of these species and others on exposed semi-stable backdune sites.

Planting stock
Early survival assessments indicated that root trainer plants were more vulnerable to mortality. However, three years after planting, overall performance indicates that there is no significant difference in plant survival or growth between the two stock types.

Tinus and the considerably smaller Hillsons root trainers are commonly used for raising indigenous plants for revegetation programmes throughout the country. Care is therefore required in extrapolating the results from this trial to Hillsons root trainers.

The significant dieback of crowns across all species in the front zone suggests that tall plants should not be planted on exposed sites. Similar results have been found with planting a range of species over several years on a backdune site at Titahi Bay, Wellington where tall nursery-raised plants consistently suffered severe dieback of plant tops (Robyn Smith, Greater Wellington Regional Council, pers. comm.). A first year assessment of 12 local coastal species planted on an exposed stable backdune at another Wellington site, Petone, found that all shrub species lost up to 30% of their height within 12 months of planting due to severe exposure (Bergin and Bergin 2008). Recent planting at Titahi Bay using small nursery-raised seedlings has resulted in greater success where plants have tended to spread laterally as tops became wind shorn (Robyn Smith, pers. comm.).

Large crowned nursery-raised seedlings of coastal shrub hardwood species are not suitable for planting on exposed dune sites. Further trials are required to compare different sizes of nursery-raised seedlings including the option of reducing the height of seedlings by topping immediately before planting.

Rabbits
The return of rabbits after planting has probably significantly affected the survival of several planted indigenous species especially taupata and ti kouka on the open sites. Clearly, a continual rabbit control operation is required where indigenous plants are to be established especially on open dune sites.

RECOMMENDATIONS

Restoration programmes should be aimed at encouraging natural processes wherever possible. This includes encouraging natural regeneration of appropriate local indigenous species to establish on degraded dunes. However, most restoration programmes including coastal sites are so severely degraded that local seed sources of appropriate indigenous species are not necessarily present in sufficient quantities and the sites are often dominated by persistent vigorous exotic species that will not allow establishment of indigenous plants. Control of pest animals, encouraging beach users to use formal accessways and selective removal of pest plants are strategies that should be considered as part of any restoration programme before planting is considered, and action on these aspects may assist with naturally regeneration. However, most restoration programmes on backdunes are likely to comprise a significant component of planting.

Based on the performance of the 12 indigenous species planted in the Ohiwa Spit backdune trial there are several recommendations for future planting programmes on backdunes. These are:

Use of existing shelter:

- Use the degree of existing vegetation cover to guide the placement of indigenous species for planting; if the site is open and sandy without an exotic vegetation cover, it will be too exposed for planting most indigenous shrub species.
- Use a flexible planting pattern to establish small groups of the indigenous species within gaps of existing vegetation cover on backdunes or plant seedlings at landward of any shelter to reduce exposure to on-shore winds.
- Where post-plant weed control is expected to be minimal on exotic-dominated backdune sites, plant predominantly the hardy fast-growing coastal shrub species identified in this trial (ngaio, akeake, karo, harakeke, koromiko) that are more likely to survive and grow;
- Where a wider range of species is desired, timely weed control will be required to reduce competing exotic vegetation overtopping planted indigenous species.
- Avoid planting low growing groundcover species within dense vegetation.

Open sites:

- Restrict planting to low growing ground cover species such as pohuehue and tarakupenga.
- While survival of all species on open sites is high, growth of shrubs will be significantly reduced in response to severe exposure.
- If shrub species are to be planted, tauhinu and karo are key species from those tested in this trial that could be considered for planting on open, exposed backdune sites.
- Avoid planting tall seedlings; use small nursery-raised plants, or top tall plants before planting to less than 30 cm tall;

Choice of planting stock:

- Seedlings raised for one-year in the nursery in either PB2 planter bags or in Tinus root trainers gave similar overall performance in both survival and growth three years after planting.
- Care is required in not extrapolating these results to the smaller commonly used Hillsons root trainers where performance may be significantly different to the two stock types evaluated in this trial.

Site management:

- Continue rabbit control programmes for maintaining both foredune and backdune vegetation; the highly palatable pingao is a good indicator species for determining rabbit presence or absence.
- Continue to minimise damage from beach users by maintaining formal accessways throughout the dune system from roads and carparks to the beach including signage.

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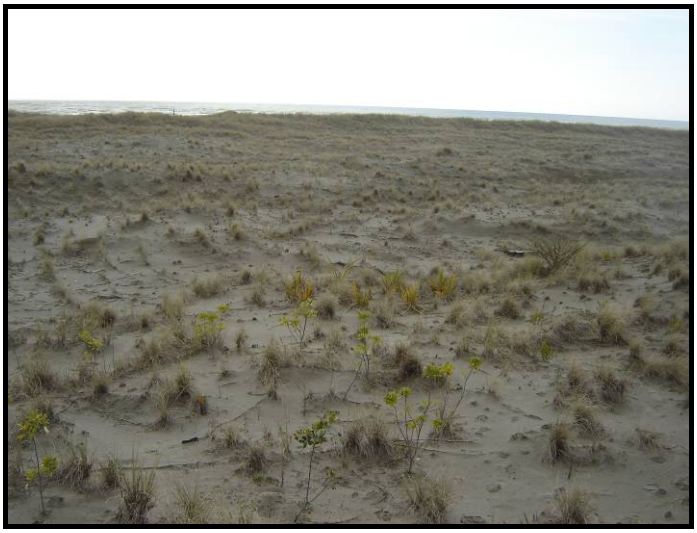

The three planting zones demarcated for the backdune planting trial, Ohiwa Spit, eastern Bay of Plenty, comprised the exposed front zone with scattered spinifex (top), the undulating mid zone with increasing ground cover of exotic herbaceous plants amongst tall spinifex with occasional patches of defoliated low tree lupin (centre), and the most landward back zone dominated by a dense cover of mostly exotic and some indigenous species including tree lupin, bracken, ice plant, pampas and exotic grasses (below).

Karo within the shelter of woody cover on the back zone are thriving where they are not completely swamped by overtopping vegetation. Karo was the only species to increase in both height and plant spread across all planting zones.

Akeake defoliated and wind shorn on the front zone due to onshore winds and salt spray.

Harakeke planted on front zone. Yellow foliage and no growth on this exposed site.

Over 50% survival but no growth for tarakupenga (sand coprosma) planted on the front zone.

Ngaio planted on back zone. Good growth in height and plant spread within the shelter of surrounding vegetation including tree lupin and bracken. Note natural pohuehue scrambling over the planted ngaio.

Houpara on front zone with poor-to unthrifty plant vigour due to exposed conditions.

Tauhinu was the only shrub species planted within the front zone to increase in size (plant spread only). All shrubs except karo planted in this zone suffered considerable crown dieback.

A planted group of 10 ngaio severely defoliated on the front zone.

Taupata planted within mid zone amongst unthrifty spinifex. Rabbit browsing evident and likely to be contributing to the poor performance of this species.

Healthy ti kouka within the shelter of dead and dying tree lupin on the back zone.

Ti kouka planted on mid zone unthrifty due to exposure on this open site and severe rabbit browsing.

Although some toetoe established, most died within 18 months of planting and after three years virtually all had died irrespective of planting zone.

Natural pohuehue dominate parts of the back zone but planted pohuehue were overtopped by vigorous weed growth within 18 months of planting.

A group of harakeke three years after planting on the back zone within a dense cover dominated by tree lupin and bracken. High survival is likely to see most harakeke persist.

Many of the coastal shrub species planted amongst dense vegetation in the back zone have high survival. Where tops have kept above an invading cover (like these akeake), planted shrubs can be expected to continue to grow and eventually dominate the site.

Even the light cover of this dead tree lupin has provided sufficient shelter on this mid zone site to improve growth and vigour of planted karo seedlings.

There was no survival of indigenous shrubs planted within or near a dense colony of introduced ice plant which had expanded considerably during the 3-year course of the trial.

Garden waste dumped along the backdune zone immediately landward of the planting trial at Ohiwa Spit continues to be a major source of garden escapes and form dense vigorous colonies of exotic vegetation.