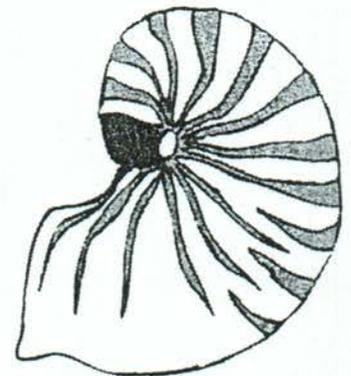


Revegetation of Sand Dunes using Spinifex (*Spinifex sericeus*) in New Zealand



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ABSTRACT:

Techniques for revegetation of degraded foredunes in New Zealand using spinifex have been investigated in research trials and through observations of management-based practices. Emphasis has focussed on the planting of nursery-raised seedlings and enhancing established stands of spinifex with fertiliser. The aim is to develop practical techniques that are of use to coastal managers and community-based interest groups such as Beach Care and Coast Care.

Transplanting of cuttings and direct seeding of spinifex have been investigated at two beaches using successful techniques developed in Australia where spinifex is also a native species. In contrast to management-scale restoration of dunes in New South Wales, there was poor survival of cuttings and poor germination and growth from direct seeding of spinifex in the New Zealand based trials.

Nursery-raised seedlings of spinifex can be successfully planted on foredunes. Planting trials have been established at two North Island and two South Island sites. Growth is significantly boosted by the addition of a slow-release NPK fertiliser at planting especially on the less exposed beaches of the eastern North Island. However, there are difficulties in raising large numbers of spinifex seedlings at reasonable cost because there is relatively high mortality during most stages of nursery handling.

Fertiliser trials on existing spinifex stands indicate that, as in Australia, they respond vigorously to applications of high-nitrogen fertiliser with no increase in exotic weed species on fertilised foredunes.

Ongoing research priorities for spinifex include identifying techniques of seed sowing that optimise seedling production at a commercial scale; evaluating performance of seedlings planted on exposed sand dune sites; determining factors affecting seed production with the aim of increasing the proportion of sound seed in seed heads; and determining the optimum fertiliser regimes for enhancing existing dune vegetation.

INTRODUCTION

Sand dunes along most parts of the coast of New Zealand have been highly modified since the time of earliest human settlement. Degradation of the vegetation cover was initially attributed to widescale grazing and fire (Cockayne 1911) and more recently to residential and industrial development, recreational activities, spread of weeds, localised sand mining, and browsing and trampling by introduced animals (Courtney 1984). Inventories of the vegetation of sand dune systems of the North Island (Partridge 1992) and of the South Island and Stewart Island (Johnson 1992) document some of the continuing widescale degradation of native vegetation communities on foredunes.

In recent years, there have been programmes on some beaches to restore natural sand dune communities on the sand dunes to meet a range of objectives including cultural, aesthetic and recreational values as well as conservation and biodiversity considerations. In addition, the Resource Management Act (1991) places an obligation on land managers to protect and preserve the natural character of the coastal environment, including areas of significant native vegetation, and to recognise traditional, cultural and historical values, particularly those of Maori.

Forest Research, a crown-owned research organisation, has been investigating methods of propagation and management-scale establishment of native sand binding species on foredunes. A feature of the sand dune research programme has been the high level of collaboration with local community-based Beach Care and Coast Care groups which have proved effective in the design and implementation of dune management programmes (Dahm 1994). The aim of the research programme is to establish trials and monitoring programmes which will result in practical methods for successful rehabilitation and management of dunes and to interact with managing agencies and local communities over management issues (Bergin *et al.* 1997).

Research has concentrated, initially at least, on developing practical techniques for establishing two major native sand binding species, spinifex (*Spinifex sericeus*) and pingao (*Desmoschoenus spiralis*). These species were identified early this century as the major sand binding species in the native flora that were widespread (Cockayne 1911). Spinifex occurs on sand dunes throughout the North Island and the northernmost part of the South Island. In most areas spinifex is the dominant sand-binding species on the foredune, sometimes forming continuous colonies for long stretches of sandy coastline. Spinifex is also native to Australia where it is a major component along coasts in the eastern states as well as in South Australia and Tasmania. It has been used for many years as one of the major species in large-scale sand dune rehabilitation programmes in NSW and Queensland (eg. Beach Protection Authority of Queensland 1981; Barr *et al.* 1983; Soil Conservation Service of NSW 1990). Techniques widely used in Australia for establishing spinifex are now being evaluated in trials in New Zealand.

SEED COLLECTION AND SEEDLING PROPAGATION

Plant description

Spinifex is a stout perennial grass with runners or stolons up to 20 m long (Craig 1984). Each node produces upright, silvery green leaves up to 38 cm long that are hairy on both sides (McDonald 1983). Spinifex is dioecious, i.e., male and female inflorescences (or flowers) are borne on separate plants. Male and female plants form colonies of equal size (Conner 1984; Maze & Whalley 1990). The male plant produces pale brown, branched but compact inflorescences about 5 cm long on short branches (Harty & MacDonald 1972). The female plant produces large, softly-spiny, spherical inflorescences about 20-30 cm in diameter. This seedhead consists of many spine-like branches 10-15 cm long. Each spine has a single spikelet just above its base, which contains the seed, although not all spikelets will have sound seed. The head becomes detached from the plant and the spines enable wind dispersal along the shoreline. Both male and female inflorescences can become infected by a floral smut, *Ustilago spinificis*. High infection rates have been found in spinifex populations in Australia and New Zealand (Kirby 1988). The diseased female inflorescence is strikingly different from normal with a swelling occurring just above the base of each spine. Kirby found that almost all the infected inflorescences were destroyed by the smut and estimates that in infected populations, the reproductive cost of the smut is nearly 20%. As seed of infected inflorescences is not likely to be viable, these inflorescences should be avoided for revegetation purposes.

On sand dunes, spinifex is an effective sand-binding plant that is dominant on the seaward face of foredunes (eg., Esler 1970). It is deep-rooting, thrives in raw sand, and is tolerant of salt spray, drought, extreme temperatures, and strong wind (van Kraayenoord 1986). The upright shoots reduce surface wind velocity, resulting in sand deposition with frequent burial of the leaves and stems (Beach Protection Authority of Queensland 1981). On the foredune it has a competitive advantage over introduced marram grass (*Ammophila arenaria*) which tends to colonise sand areas inland from the seaward face of the foredune (Esler 1974).

Seed collection and nursery practice

Spinifex seed is best collected in mid to late summer when seed heads are beginning to detach from the parent plants. Over a period of three years, seedheads sampled from a range of North Island beaches had a low proportion of sound seed (less than 17%). Seed sown in early winter took up to 3 months to germinate whereas seed sown in spring took 1-2 months. Extracted sound seed sown individually in vertical positions germinated in about half the time needed for broadcast seed or whole seedheads.

Raising large numbers of spinifex seedlings in the nursery has proved difficult. Large losses occur at most stages of nursery handling. Methods tested at the *Forest Research Nursery* have included:

- Standard nursery practice of sowing into trays and pricking-out into containers.
- Direct sowing of sorted sound seed individually or in pairs into final-size containers designed to reduce handling.
- Broadcast sowing of broken-up seedheads on to trays and transplanting seedlings into containers.
- Burying of whole spikes and transplanting resultant seedlings to containers.
- Propagation stolon sections using misting and bottom heat facilities.

The most promising method is direct sowing of sorted sound seed into final planting containers with up to 80% of containers having at least one live seedling after 6 months. This avoids the relatively large losses when seedlings are transplanted in the nursery. Large-scale nursery trials are currently underway evaluating commercial production including costs of raising seedlings.

ESTABLISHMENT OF SPINIFEX ON DUNES

Four dune trials using spinifex have been established in New Zealand over the past 5 years: two trials located at Whiritoa Beach (pilot and main trials), Coromandel Peninsula, North Island, and two at Christchurch, South Island (South Brighton and Taylors Mistake beaches). All trials were established on bare sand on the seaward face of the foredune in groups of 10-20 plants. Trials were fully replicated randomised complete block designs with establishment treatments assigned to individual groups.

Whiritoa Beach pilot trial

Treatments

This pilot trial comprised plots comparing establishment of spinifex from seed, vegetative material and seedlings. Treatments tested included:

- sowing of 2-3 seedheads into 15 cm deep holes similar to the New South Wales method of direct seeding (NSW Public Works Department and Soil Conservation Service 1987).
- burial of vegetative material including:
 - * end sections of stolons up to 1.2 m long placed in 10-15 cm deep trenches with 7.5 cm of the tip left exposed, and
 - * divisions (leafy shoots with roots attached) taken from established spinifex plants.
- planting of 18-month-old high nursery raised seedlings which were 30-40 cm tall at time of planting.

Nursery-raised seedlings were planted with and without the application of a slow release NPK Magamp (magnesium ammonium phosphate) fertiliser at the rate of 30 g per plant.

Results and Discussion

The most effective establishment method was planting of nursery-raised seedlings (Table 1). High survival was maintained with or without application of Magamp for the first five months after planting. Although no measurements were made of plant growth, fertilised seedlings appeared larger with greater bulk and greener foliage compared with unfertilised plants.

Of the buried vegetative material treatments, stolons (40% survival) fared better than divisions (31%) five months after transplanting (Table 1). However, surviving stolons were not vigorous at any stage after planting. In dune restoration projects in Queensland use of vegetative material is usually successful (Beach Protection Authority of Queensland 1981). The low survival of stolons in this trial was possibly related to the difficulty of finding suitable transplant material in early spring. At this time stolons were often partially covered in sand and were generally inflexible and brittle with no new growth. There is greater scope for collecting suitable vegetative material in autumn where stolons are young, green and actively growing. Autumn transplanting of cuttings is also preferred in Queensland.

Table 1: *Survival of spinifex vegetative material and nursery-raised seedlings (with and without fertiliser) in a pilot trial, Whiritoa Beach, Coromandel Peninsula.*

Plant material	Number of plants	Survival 6 weeks after establishment (%)	Survival 5 months after establishment (%)
Stolons	20	70	40
Divisions	80	36	31
Seedlings without fertiliser	80	94	85
Seedlings with fertiliser	80	94	90

Six weeks after sowing, there was no germination of spinifex seed. Seedlings were first observed almost 4 months after sowing with a limited number of seedlings ranging in height from 3-20 cm. The poor viability of seed used in the trial probably contributed to the poor germination rate.

Whiritoa Beach main trial

Treatments

A second trial comparing performance of seedlings, direct seeding and burial of stolons was established on a larger scale one year later testing autumn and spring establishment. Treatments included:

- Planting - 200 nursery-raised spinifex plants.
- Seeding - up to 3 seedheads placed into 10-15 cm deep spade holes.
- Stolons - stolon sections 60 cm long cut from nearby colonies buried into 10 cm deep channels with 5-10 cm of the tip left exposed.

Magamp fertiliser was applied at planting to the seedling treatment only and involved incorporating 30 g of fertiliser into the planting hole for each seedling.

Results and Discussion

Planted nursery-raised seedlings had at least 80% survival up to 2 years after planting (Table 2). There were no differences in seedling survival and height growth between autumn and spring plantings nor with the application of Magamp fertiliser at planting. The application of Magamp fertiliser at planting did have a significant effect on other aspects of plant growth with increases in plant spread, vigour, root collar diameter and average length of runners (Table 2). Fertilised spinifex seedlings were noticeably greener and also showed a greater accumulation of sand than unfertilised seedlings.

Table 2: *Performance of spinifex seedlings planted in autumn and spring at the main trial site, Whiritoa Beach, Coromandel Peninsula. Spinifex were assessed 18 months after planting for spring planted seedlings and 2 years after planting for autumn planted seedlings. Treatments with the same letter are not significantly different ($p=0.05$).*

	Survival %	Height (cm)	Plant spread (length x breadth) (cm ²)	Seedling vigour* (1-5)	Root collar diameter (cm)	Average length of runners (cm)	Sand accumulation (cm)
Autumn	83 a	40.8 a	1979 a	4.1 a	13.8 a	167 a	24 a
Spring	84 a	41.8 a	1763 a	4.0 a	11.5 a	74 a	27 a
Fertiliser	80 a	42.1 a	2903 a	4.7 a	20.2 a	257 a	32 a
No fertiliser	87 a	40.6 a	1028 b	3.5 b	6.6 b	14 b	15 b

* Seedling vigour score assessed as 1 - poor, 2 - unthrifty, 3 - average, 4 - good, 5 - excellent.

Despite use of local Whiritoa seed collections with 14-25% sound seed, less than 10% of the spots where 2-3 seedheads had been sown had germinated seedlings. Nearly all spots where seedlings had germinated had only one seedling and growth was limited. Germination began within 2 months of planting for the spring sown seed in contrast to autumn sown seed which did not germinate for several months until early spring. Although numbers of germinated seedlings are too low to allow statistical testing of performance, spinifex germinated from spring sowing tended to be larger and have greater survival than seedlings from autumn sown seed.

Although stolons were established in both autumn and spring using methods successfully used in Queensland, overall survival from a total of 100 transplanted stolons was less than 5% in the 18 months to 2 years after the trials were established. Attempts at establishment of spinifex using stolons was time consuming in both the collection of runners and setting them into holes or trenches. Although much of the work was easily carried out by volunteers in locally based Beach Care groups, the very poor survival clearly demonstrates that this method is unrewarding at this site.

South Brighton

A trial incorporating only the direct seeding treatment as at the Whiritoa main trial site was established in autumn 1995. Where seedheads were sown directly into spots, less than 5% of the spots had one or more germinated seedling in October 1995 and within 2 months all seedlings had disappeared. Excessive sand movement on the relatively steep site and strong easterly winds in late spring were the probable cause of seedling demise.

The Christchurch City Council Coast Care Unit also established 100 18-month old spinifex seedlings nearby with 30 g of Magamp applied to all seedlings. Inspection of planted seedlings 2 months after planting indicated very high survival and strong growth of most seedlings. Some seedlings were inundated by sand accumulation near wind break fences on the seaward edge of the foredune. However, there was poor survival 12 months after planting due to excessive sand accumulation.

Taylor's Mistake

The Christchurch City Council Coast Care Unit are planting spinifex to re-introduce the species back to the Christchurch beaches. Historical records indicate that spinifex did occur this far south (McCombs 1992) but there are no existing populations.

Treatments

Two hundred seedlings planted in groups tested application of Magamp at planting within and outside rabbit-proof enclosures. Seedlings were planted in autumn and assessed for a range of parameters one year later. Seed was sourced from the nearest natural spinifex population north of Kaikoura.

Results and Discussion

Initial inspection of the planting site three months after planting indicated high survival of with no browsing of plants outside enclosures despite evidence of rabbits in the vicinity of the trial. The 25-35 cm high seedlings were vigorous with late spring growth evident. There was no difference in performance of fertilised and non-fertilised seedlings at this early stage.

Spinifex in trial plots 12 months after planting averaged over 90% survival with a significant boost in height growth, plant spread and mean runner length for fertilised seedlings compared to unfertilised controls (Table 3). There was less response to fertiliser than in the North Island trials and this may be related to the greater additions of fresh sand to planted plots on the more exposed South Island sites.

Table 3: Performance of spinifex seedlings planted at Taylor's Mistake, Christchurch assessed 12 months after planting. Treatments with the same letter are not significantly different ($p=0.05$).

	Survival (%)	Height (cm)	Spread (cm)	Vigour* (1-5)	Mean runner length (cm)	Mean no. runners/plant
No fertiliser	87.8 a	40.0 a	62.4 a	4.1 a	58.3 a	0.69 a
Fertiliser	94.0 a	43.8 b	72.9 b	4.7 a	78.9 b	1.04 a

* Seedling vigour score assessed as 1 - poor, 2 - unthrifty, 3 - average, 4 - good, 5 - excellent.

TREATMENT OF EXISTING FOREDUNE VEGETATION WITH FERTILISER

Australian experience indicates that application of high-nitrogen fast-release fertilisers to existing spinifex stands is an efficient way of improving their quality and extent (Barr & McDonald 1980; Barr et al. 1983). In New Zealand, fertiliser trials have been established on spinifex-dominated foredunes at Matarangi and Whiritoa Beaches on the Coromandel Peninsula (Bergin & Herbert 1997).

Treatments

The fertiliser types tested were urea, nitram (ammonium nitrate) and DAP (di-ammonium phosphate). Rates of 200 and 400 kg/ha of nitrogen were applied as single or split dressings in the first year of the trial. The trials consisted of 45 30x5 m plots at Matarangi and 20 15x6 m plots at Whiritoa with treatments allocated to each plot in a randomised complete block design. Changes in percentage vegetation cover were monitored using a point sampling frame.

Results and Discussion

Results indicate that, as in Australia, spinifex responds vigorously to applications of high-nitrogen fertiliser. The effects of fertiliser were apparent within one month of application with fertilised plots significantly greener in colour compared to unfertilised plots. Two years after fertiliser application there was a significant increase in spinifex cover from 39% in unfertilised controls to 52% where 200 kgN/ha had been applied, and 61% where 400 kgN/ha had been applied at the Matarangi site. At Whiritoa, fertiliser increased spinifex cover from 21% to 35% for the 200 kgN/ha rate and to 37% for the 400 kgN/ha rate. There were no significant differences between the different types of fertiliser. Exotic herbaceous and other species responded initially to fertiliser application but were eventually out-competed by spinifex. Differences remained apparent for at least three years after fertilising. Results have been used to determine application rates for an operational-scale fertilising programme for Bay of Plenty beaches where monitoring of vegetation response is being undertaken to determine the most cost-effective option.

CONCLUSIONS

Although it has been relatively costly to raise nursery seedlings because of low germination and mortality in the nursery, planting trials clearly indicate that spinifex seedlings can be successfully established on bare foredunes on most sites. Further investigation of the exposed dune systems along the west coast of the North Island and exposed beaches of the east coast of the South Island is required. Trials are planned in which the planting of spinifex and other native sand binders will be carried out in conjunction with establishment of dune trapping fences or planting of temporary exotic sand binders to provide initial shelter while native species are establishing. Trials indicate that spinifex seedlings respond positively to application of the slow-release fertiliser Magamp at the rate of 30g per plant incorporated with the sand at time of planting. Because of the difficulties and cost of raising nursery seedlings, a major research priority is the identification of practical nursery-raising techniques that optimise seedling production at a commercial scale.

Spinifex seed sown directly on dunes or stolons sections buried on dunes have shown low establishment rates at both North Island and South Island sites. On the basis of experimental results to date, and in contrast to Australian experience, direct seeding or transplanting of cuttings for spinifex cannot be recommended for New Zealand conditions at this stage. Direct seeding trials in New Zealand have been hampered by the lack of large quantities of seedheads with a reasonable proportion of sound seed. A further research priority is, therefore, determining factors affecting seed production with the aim of increasing the proportion of sound seed in seed heads so that direct seeding on dunes can be evaluated further as well as providing better quality seed collections for nursery-raising of seedlings.

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