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NZ FOREST RESEARCH INSTITUTE LTD **PROJECT RECORD NO.:** 5285

DIVISION: FOREST TECHNOLOGY

RESOURCE CENTRE: SOILS AND SITE PRODUCTIVITY

CODE: 95 / 96 (Financial Year) | 120 (Resource Centre No.) | 1331 (Project) | (Sub-project) | 08 (FRST Output) | 416 (Prog.)

WORK PLAN NO.: 2216; 2461 **EXPERIMENT NO.:** FR 165; FR 193; FR 253

TITLE: 1995-96 REPORTS ON SAND REVEGETATION TRIALS USING NITROGEN-FIXING SPECIES.

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KEYWORDS: SAND REVEGETATION; CONSERVATION; NITROGEN FIXATION, SURVIVAL; LEGUMES; SEED.

ABSTRACT*

Progress made during the third year in the achievement of Objective 1 of the three-year FRST Contract 4301 (Programme 93FRI08416 - Revegetation of Sand Dunes) is described under seven headings :

1. Observations on relative plant growth performance after 3½ - 4 years in spaced-plant trials established at Ninety-mile Beach, Kawhia, Harakeke and Santoft Beach in 1991-92.

Rabbit damage undoubtedly contributed to the total failure, within 4 years, of planted species in the unfenced Santoft A trial and to very poor survival rates in the unfenced Santoft B trial. In other trials, early protection by fences resulted in better overall development, particularly of woody shrubs, which appear to have an advantage in the sand dune environment. After 3½ - 4 years, *Acacia saligna, A. sophorae* and *Chamaecytisus palmensis* were, in fact considered to be too aggressive to act as replacements for lupin at some sites, and have been removed from the trials. They may have value in the emergency stabilisation of sand drifts but only if their rate of spread can be strictly controlled.

Of the remaining species tested in these trials, *Teline stenopetala, Lathyrus latifolius* and *Lotus pedunculatus* showed the greatest potential for replacing lupin due to their relatively high degree of persistence and ground-covering ability at more than one location. Seedling establishment was rare at Ninety-mile Beach, Kawhia and Harakeke, but at Santoft *Dorycnium hirsutum, D. pentaphyllum, Hedysarum coronarium, Lathyrus latifolius* and *Medicago arborea* showed potential for population maintenance through sexual reproduction. They could be considered as additional possible replacements for lupin at this location.

2. Assessments of relative plant growth performance after 2½ yr in spaced-plant trials established in 1993.

Of 20 species/accessions compared at three locations (Ninety-mile Beach, Muriwai Beach and Santoft Beach), *Acacia sophorae, Dorycnium hirsutum, D. rectum, Lathyrus latifolius* and *Lotus pedunculatus* showed the best overall potential for survival. All can be considered as candidates for lupin replacement, although *A.sophorae* can only be recommended for emergency sand drift treatment where follow-up control can be ensured.

Dry matter productivity was greatest in the woody shrubs, to the extent that *Acacia saligna, A. sophorae* and *Chamaecytisus palmensis* are perceived as a threat to surrounding land management and have been removed from the trials. *Teline stenopetala* is regarded as the least aggressive of the shrub species that were successful at all three locations. Productivity of *Dorycnium hirsutum* was high at Santoft.

New plants of *Lotus tenuis* had established from seed at all locations; *Teline stenopetala* seedlings were found at Ninety-mile Beach and Muriwai Beach only, and *Dorycnium pentaphyllum, D. hirsutum, Hedysarum coronarium, Lotus corniculatus* and *Medicago arborea* seedlings only at Santoft. *Lotus tenuis* at all locations and *D. hirsutum* at Santoft seemed to have the best potential for population maintenance through sexual reproduction, and are unlikely to pose a threat as weeds.

Shelter afforded by marram grass and by developing legume plants was identified as an important factor determining legume survival and growth on the open dunes. Seedling establishment after 2 years' growth of planted individuals is not necessarily an indication that plant introduction to dune sites by oversowing will be successful.

3. Assessments of relative plant growth performance in a 2½ yr-old trial comparing the effects of potting mix and local sand as media for raising seedlings used in spaced-plant trials.

Plants of three species which had been raised and planted out with either local sand or potting compost as the rooting medium were compared on the basis of survival, vigour, height, spread, and above-ground dry matter production on the open dunes. After 2½ years' growth of *Acacia sophorae, Chamaecytisus palmensis,* and *Lotus pedunculatus* at Ninety-mile Beach, no significant differences could be attributed to the nature of the original rooting medium.

4. Assessments of relative nitrogen-fixing potential of plants in trials established in 1993.

After 2½ years, species in the FR 193 trial series showing the greatest nitrogenase activity (estimated over a 30 min period in root material sampled from a fixed volume of soil) were :

FR 193/1, Ninety-mile Beach	*Lathyrus latifolius, Acacia sophorae, Lotus pedunculatus.*
FR 193/3, Muriwai Beach	*Hedysarum coronarium, Acacia saligna, A. sophorae.*
FR 193/4, Santoft Beach	*Lathyrus latifolius, Acacia sophorae, A. saligna/Teline stenopetala.*

In the FR 193/2 trial at Ninety-mile Beach, nitrogenase activity was greater in the *Acacia sophorae* and *Lotus pedunculatus* plants that had been raised in potting compost than in those that had been raised in local sand. Low plant survival rates precluded root sampling of *Chamaecytisus palmensis.*

5. Assessments of seedling establishment in the 1995 oversowing trials.

Very low seedling establishment rates were recorded during the first year after broadcast sowing of eight selected legume species in one-year-old marram grass growing on sand dunes at Kawhia and at Santoft Beach. The highest rates, all noted at Santoft, were 9% for *Acacia sophorae*, 6% for *Astragalus cicer* and 4% for *Teline stenopetala.* Numbers of seedlings of the only two species (*Dorycnium hirsutum* and *Lotus pedunculatus*) found at Kawhia represented less than 1% of viable seeds sown. No seedlings of *Acacia saligna* were found at either site.

Poor seedling establishment rates may have been related to damage caused by insects, snails or birds, or to unfavourable conditions for plant growth at the sand surface (temperature fluctuations, drought or wind). Seed was found outside the sown plots and measurements suggest that wind-related problems are greater at the Kawhia site than at Santoft.

6. Establishment of the 1996 oversowing trials.

Poor seedling establishment in the 1995 oversowing trials at Kawhia and Santoft has necessitated the investigation of the effects of different sowing methods. Two further trials were laid out in June 1996. At Kawhia and at Santoft seed of three legume species was sown in single-species plots where it was either left on the sand surface (broadcast); partly buried (broadcast, raked into the sand surface which was then rolled); or completely buried (sown in covered drills).

Lupinus arboreus was used as a benchmark species and establishment rates will be compared with those of *Lathyrus latifolius* and *Lotus pedunculatus* during 1996-97. Attempts have been made to reduce the snail populations at both experimental sites.

7. Technology transfer.

During 1995-96, current research results from the Sand Dune Revegetation Programme were publicised in a television interview for "Agritech 2000"; through the distribution of progress reports, and by contact with District and Regional Council staff. The need for a Sand Dune Information Network encompassing all levels of interest has been discussed. Feasibility planning for such a network is in progress.

CONTENTS

BACKGROUND

A major objective in the Sand Dune Revegetation Programme funded by the Foundation for Research, Science and Technology is the determination of the relative potential of 26 selected nitrogen-fixing plant species for replacing yellow tree lupin in the artificial vegetation succession used to prevent coastal sand erosion. Seven spaced-plant screening trials were established in 1991-92 to examine groups of these species under a range of conditions and sites. In 1993 a more comprehensive spaced-plant trial series was established to examine the relative performance of 20 species/accessions under standardised experimental conditions at three locations. Two oversowing trials, using species selected from the spaced-plant trials, were established in June 1995. Details of annual trial assessments, up to June 1995, have been documented by Gadgil and Sandberg (1992a; 1992b); Lowe (1992); Gadgil, Douglas, Sandberg and Lowe (1993), Gadgil, Douglas, Skinner, Sandberg and Lowe (1994), Gadgil, Douglas, Knowles, Lowe, and Sandberg (1994), and Gadgil, Douglas, Lowe, Beeser, Foote, Graham, and Oliver (1995).

During the funding year from July 1995 to June 1996, the Forest Research Institute was contracted to FRST (with AgResearch Grasslands as sub-contractor) to perform the following tasks under Objective 1 of the Sand Dune Revegetation Programme :

Determine the relative potential of 26 nitrogen-fixing plant species for replacing yellow tree lupin in the artificial vegetation succession used to prevent coastal sand dune erosion, by

* **observing, between October and December 1995, the relative growth of surviving species planted in six screening trials in 1991/92;**

* **assessing, between October and December 1995, the relative growth and N-fixation rate of surviving species planted in three standardised screening trials in Autumn 1993;**

* **assessing, between October and December 1995, the relative growth and N-fixation rate of plants in a 1993 trial designed to compare the effects of local sand and potting mix used to raise the seedlings;**

* **assessing, between October and December 1995, seedling establishment rate in two single-species direct-seeding trials sown in Autumn 1995;**

* **establishing either mixed-species direct-seeding trials or (depending on establishment results from the 1995 trials) single-species trials with modified sowing methods.**

Prepare two six-monthly progress reports on results of the above studies for the NZ FRI CEO. These will provide the basis of a refereed manuscript for a scientific journal which will be published in 1996/97.

A progress report documenting field work and trial maintenance carried out between October and the end of December 1995 (Gadgil, Douglas and Ede, 1996) was submitted to the CEO of the NZ Forest Research Institute in January 1996.

This Project Record completes the 1995-96 work by providing detailed reports on :

1. Observations on relative plant growth performance after 3½-4 years in spaced-plant trials established at Ninety-mile Beach, Kawhia, Harakeke and Santoft Beach in 1991-92.

2. Assessments of relative plant growth performance after 2½ years in spaced-plant trials established in 1993.

3. Assessments of relative plant growth performance in a 2½ year-old trial comparing the effects of potting mix and local sand as media for raising seedlings used in spaced-plant trials.

4. Assessments of relative nitrogen-fixing potential of plants in trials established in 1993.

5. Assessments of seedling establishment in the 1995 oversowing trials.

6. Establishment of the 1996 oversowing trials.

7. Technology transfer.

Tables B-1 and B-2 provide details of the location, establishment methods and species used in trials established 1991 - 1995.

1. OBSERVATIONS ON RELATIVE PLANT GROWTH PERFORMANCE AFTER 3½ - 4 YEARS IN SPACED-PLANT TRIALS ESTABLISHED AT NINETY-MILE BEACH, KAWHIA, HARAKEKE AND SANTOFT BEACH IN 1991-92.

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By 1995 the six trials established in 1991and 1992 had been measured and sampled four times at annual intervals. Characteristics of each species and relative growth performance in one or more of the four locations had been documented over this period (Gadgil *et al,* 1995b). It was acknowledged that further intensive measurements and biomass sampling were likely to yield spurious results due to reduction in plant numbers and the increasing influence of edge-effects. It was still possible to gain valuable information about persistence, reproductive ability, and potential aggressiveness, and a system of measurements was devised to assess surviving species on the basis of these characteristic.

METHODS

In November 1995, all plots containing one or more surviving plants were identified at each trial site. The following observations were made in each plot of the FR 165 trials:

(a) Original plants

(i) Percentage of plot covered (to nearest 25%)
(ii) Maximum length of extension outside plot boundary (cm)
(iii) Plant vigour, scored on a scale of 1-5 :
  1 = barely alive
  2 = weak
  3 = growth acceptable but not vigorous
  4 = vigorous with evidence of minor disease or damage
  5 = robust - no disease or damage apparent.
(iv) Presence of flowers or flower buds
(v) Presence of seed pods

(b) Seedlings

(i) Number observed inside plot boundary (to nearest 50)
(ii) Number observed outside plot boundary (to nearest 50)
(iii) Maximum distance outside plot boundary (cm)
(iv) Vigour, scored as in (a) (iii) above

In the Santoft C trial, where the original experimental unit was a row of 10 plants, assessments were carried out in a different way. Here mean values were obtained for plant survival, height, spread, and root collar diameter (where appropriate). Plant vigour and seedling development within one metre of each row were assessed by the above scoring method.

RESULTS

By November 1995 all of the planted species had disappeared from the Santoft A trial and all except one from the Santoft B trial. One plant of *Dorycnium hirsutum* was present in two of the three replicated plots in Trial B. In one plot *D. hirsutum* had a vigour score of 4, height 75 cm, and spread 130 cm, while in the other, vigour was scored 3, and the plant was 82 cm high and 35 cm wide. Both plants were flowering.

For the remaining four trials, values for each plot assessment are shown in Tables 1-1 (Trial FR 165/1, Ninety-mile Beach), 1-2 (Trial FR 165/2, Kawhia), 1-3 (Trial FR 165/3, Harakeke) and 1-4 (Santoft C Trial).

Trial FR 165/1 - Ninety-mile Beach

All species which had survived to November 1994 were still present in November 1995.

Acacia sophorae was the only species that formed more than 75% cover in all plots. Plants were vigorous, with regrowth outpacing any dieback. Plants extended 125 - 520 cm beyond the plot boundaries. The flowering period was over, but no seed pods were observed. No seedlings were found.

Acacia saligna had survived in three of the four plots. Cover estimates did not exceed 25% and plants in one plot had spread to 20 cm beyond the boundary. Plant vigour was poor, due to frequent dieback and leaf necrosis. No flowers, seedpods or seedlings were observed.

Chamaecytisus palmensis was present in only two of the original four plots. Although no more than 25% of each was covered, plants extended 50 - 60 cm beyond the boundaries. Plants showed evidence of considerable dieback and were no more than moderately vigorous although flowers and seedpods were present in one plot. No seedlings were observed.

Lotus pedunculatus continued to survive in two of the four plots originally planted, but covered only 25% of the plot area. Growth was vigorous but not robust. No flowers, seedpods or seedlings were observed.

Teline stenopetala survived in only one plot. Here plants were vigorous but did not cover more than 25% and did not extend beyond the plot boundary. Flowers were observed, but no seedpods or seedlings.

Trial FR 165/2 - Kawhia

Two species that had been present in November 1994 were not found in November 1995. These were *Chamaecytisus palmensis* and *Trifolium ambiguum*. One seedling of *Lotus corniculatus*, a species thought to have died out during 1993-94, was located.

Acacia saligna covered more than 75% of the area of all four plots and branches extended 100 - 170 cm beyond the plot boundaries. Most plants were vigorous; flowering was observed in all plots and seedpods in one plot. No seedlings were found.

Acacia sophorae was present in all four plots and covered more than 75% in each. Plants were very vigorous and had grown 180 - 710 cm beyond plot boundaries. Seedpods were observed in three of the four plots. One vigorous seedling was found in Plot 30 during the formal assessment in November. Two seedlings noted during an informal visit in June were not relocated.

Lotus pedunculatus had survived in all four plots but cover was usually less than 25% and never greater than 50%. Plants extended up to 130 cm beyond the plot boundary, but growth was not vigorous.

Flowering was observed in three plots and seedpods were forming in plants growing in plot 40. No seedlings were present.

Lathyrus latifolius had persisted in only one plot where it covered no more than 25% of the available area and was not growing outside the plot boundary. Growth was vigorous. Flowers, but no seedpods were observed. No seedlings were found.

Trial FR 165/3 - Harakeke

Sutherlandia frutescens was the only species present in November 1994 that did not survive to November 1995.

Acacia saligna was present in all three plots planted but cover never exceeded 25%. Although plants extended up to 60 cm from the plot boundaries, growth was only moderately vigorous. Flowers were observed in one plot, but no seedpods or seedlings were found.

Acacia sophorae plants were only present in two out of three plots planted and cover did not exceed 25% although shoots extended up to 70 cm beyond plot boundaries. Growth was moderately vigorous and seedpods were seen in one plot. No seedlings were found.

Chamaecytisus palmensis covered more than 50% of all plots in which it had been planted. Branches extended 230 - 295 cm beyond the plot boundaries and growth was usually vigorous. Seedpods were seen in all plots but no seedlings were found.

Lathyrus latifolius had survived in two out of three plots planted. Cover was less than 50% in one of these where plant growth was acceptable but not vigorous. In the other plot more than 75% of the area was covered and plants, which were flowering, extended 100 cm beyond the boundary. No seedpods or seedlings were observed.

Lotus pedunculatus covered a maximum of 25% in all three plots, and extended 60 - 110 cm beyond the boundary of two of them. Plants were vigorous to robust, and were in flower, but no seedpods had formed. No seedlings were seen.

Teline stenopetala was present in only two of the three plots planted, but in each of these more than 75% cover was noted with branches reaching 140 - 250 cm outside the boundaries. Plants were vigorous to robust, and flowers and seedpods were observed in both plots. No seedlings were seen.

Trifolium ambiguum had survived in all three plots but again plant cover was never greater than 25%. In one plot plants had extended 25 cm beyond the boundary. Most plants were vigorous. No flowers, seedpods or seedlings were observed.

Santoft C Trial

Species varied considerably in survival (Table 1-4), ranging from zero for *Hippophae rhamnoides* to 81% for *Medicago arborea*. Six species had more than 50% survival, namely *Acacia saligna* (69%), *Acacia sophorae* (59%), *Astragalus cicer* (59%), *Casuarina glauca* (69%), *Lathyrus latifolius* (59%), and *Medicago arborea* (81%).

Vigorous growth was shown by eight species, as indicated by a vigour score of four. The three accessions of *Chamaecytisus palmensis* had consistently low vigour (scores 1-2), and were typified by all plants having partial to complete leaf loss. Parts of plants above the height of the marram tussocks were frequently dead, but lower plant parts were often alive.

The tallest species was *Acacia saligna* (126 cm), and with the exception of *Acacia sophorae* (114 cm) and *Chamaecytisus palmensis* (PMC 3552)(111 cm), all other species were less than 90 cm tall. The maximum spreads of *Acacia sophorae* and *Dorycnium rectum* were at least 40-60 cm greater than the other species, and they were over ten-fold more than species such as *Astragalus cicer* and *Lotus corniculatus*. Root collar diameters ranged from 12 to 41 cm, but this three-fold difference was not significant (P>0.05).

Seedlings occurred in plots of *Dorycnium hirsutum*, *Dorycnium pentaphyllum*, and *Medicago arborea*, and in some plots of *Hedysarum coronarium* and *Lathyrus latifolius*. These five species were also the only ones to produce flower buds/flowers. *Medicago arborea* was unique in also producing pods.

DISCUSSION

The absence of survivors in the Santoft A trial and the reduction of numbers to two plants of *Dorycnium hirsutum* in the Santoft B trial indicates the harshness of the sand dune conditions for plant growth. Some of the species planted in all three of the older trials at Santoft (*Astragalus cicer, Chamaecytisus palmensis, Dorycnium hirsutum, Lathyrus latifolius* and *Lotus tenuis*) were clearly performing better in the C trial. This suggests that either exclusion of rabbits or the later planting season (autumn rather than spring), or both, were responsible. The A and B trial sites were more sheltered from prevailing winds than the C site. Rabbit damage has been observed in the unfenced trials and is likely to be a major factor determining plant persistence on sand dunes. In this regard *D. hirsutum* appears to have a very slight advantage over the other species planted.

Of the nine species common to all of the FR 165 trial series, only three persisted into the fifth year at all three sites. These were *Acacia saligna, A. sophorae* and *Lotus pedunculatus*. More site-specific species were *Chamaecytisus palmensis* and *Teline stenopetala* (Ninety-mile Beach and Harakeke only); *Lathyrus latifolius* (Kawhia and Harakeke only), and *Trifolium ambiguum* (Harakeke only). After 3½ years, and under different establishment conditions (Table B-1) 16 of the original 19 species had survived at Santoft. If persistence were the only criterion of acceptable performance, any of these species could be recommended as replacements for *Lupinus arboreus* at the appropriate sites.

An important additional criterion for acceptable performance is the rate of spread by vegetative and sexual propagation. The ideal replacement for lupin would maintain an even cover with frequent to abundant distribution in the sand dune plant community, without suppressing all other plants. It would not spread aggressively or pose a threat to productivity on sites adjacent to open sand dunes. Direct comparisons with lupin distribution prior to 1985 are difficult to make. Sprent and Silvester (1973) reported 100% lupin cover on an open dune site sown with *Lupinus arboreus* almost two years previously, but noted that marram grass was present below the lupin canopy. Carter (1974) recorded lupin cover of 45-47% in the same stand one year later.

Cover estimates could not be made in the Santoft C trial where individual plots were rows of plants. In the FR 165 trial series the original plant spacing was 50 x 50 cm at Ninety-mile Beach and Kawhia, and 30 x 30 cm at Harakeke. After four years and a certain amount of destructive sampling, legume ground cover of 50% might be considered to indicate a reasonable compromise between an effective presence and unacceptable aggressiveness. The rate of vegetative spread of *Acacia sophorae* at Ninety-mile Beach, *A saligna* and *A. sophorae* at Kawhia, and *Chamaecytisus palmensis* and *Teline stenopetala* at Harakeke may be too great for these species to be regarded as candidates for use in sand stabilisation. They might be appropriate for use in crisis situations, providing that careful control measures could be adopted as part of the management strategy.

Very few of the other species that had persisted for 4 years covered 50% of the experimental plots. *Lotus pedunculatus* at Kawhia and *Lathyrus latifolius* at Harakeke gave 50% cover in some, but not all of the plots. These species are probably the most promising candidates for lupin replacement out of the nine species screened at all sites in the FR 165 trial series. With the exception of one seedling, the two species planted at Ninety-mile Beach and Kawhia only (*Lotus corniculatus* and *Lupinus nootkatensis*) did not persist into the fifth year.

At Ninety-mile Beach no species other than *Acacia sophorae* had produced more than 25% cover. Even this low degree of representation was not consistent across replicated plots. Poor plant growth undoubtedly reflected the relative harshness of this site.

Results suggest that among nitrogen-fixing species, woody shrubs may have an advantage over herbaceous plants in the open sand dune environment. The absence of seedlings in the FR 165 trial series (two only observed throughout the three trial sites) was surprising after 4 years' growth where flowering and seedpod formation were known to occur. Although it must be concluded that either the production of viable seed, or seedling establishment, or both, were inhibited in the sand dune environment, it must also be acknowledged that before the onset of lupin blight, *Lupinus arboreus* was a prolific producer of seed and that populations were maintained only by sexual reproduction. In this respect none of the species tested in the FR 165 trial series can be regarded as a satisfactory alternative to *Lupinus arboreus*. At Santoft Beach five species (*Dorycnium hirsutum, D. pentaphyllum, Hedysarum coronarium, Lathyrus latifolius* and *Medicago arborea*) appear to have been able to re-establish from seed and could be considered for use at this site if dissemination remains within reasonable bounds.

During the early part of 1996, managers of forest land adjacent to two of the trials (Ninety-mile Beach and Kawhia) sought permission for removal of potentially-aggressive species (*Acacia saligna* and *A. sophorae*) from the experimental areas. In the interests of responsible trial management, this permission was granted.

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2. ASSESSMENTS OF RELATIVE PLANT GROWTH PERFORMANCE AFTER 2½ YEARS IN SPACED-PLANT TRIALS ESTABLISHED IN 1993.

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INTRODUCTION

In the FR 193 trial series, 20 species/accessions of nitrogen-fixing plants are being compared in a standardised experimental layout at three widely-separated sites. Seedlings for Trials FR 193/1 (Ninety-mile Beach), 193/3 (Muriwai Beach) and 193/4 (Santoft Beach) were raised and planted out in potting compost in May 1993. Each trial was fenced to exclude rodents and grazing stock. Individual plots were rows of 15 plants at 30 cm spacing. Details of the trial layout and results of assessments in 1993 and 1994 have been documented by Gadgil *et al* (1993, 1994, 1995).

This report presents results from assessments of plant growth carried out in 1995 when the plants had been in the field for 2.5 years.

METHODS

Starting with the most northerly trial and working south, measurements were made between late October and early December 1995. Plant vigour, scored on a scale of 1 (poor) to 5 (robust), was recorded for each plot. Maximum height and maximum spread of all surviving plants were measured. Where vegetative growth precluded the identification of individuals, maximum height and spread for the appropriate segment of the row was recorded. It was found necessary to redefine "survival rate" as "occupancy rate", a variable which measured both survival and plant spread into previously-harvested or unoccupied row segments. Stem diameter of woody species was measured at ground level. Seedling numbers within one metre of the original plant positions were recorded by allocation of the following scores : 0 = nil; 1 = <50 per plot; 2 = >50 per plot.

One individual (or the row segment originally allocated to an individual plant) in each plot was selected at random for destructive harvesting to determine above-ground dry matter production. Two sampling boundary lines were marked at right angles to the planting row, each 15 cm from the original position of the plant to be sampled. All material within a vertical projection of these lines was taken, regardless of plant spread. Destructive harvesting was not undertaken in plots with less than two plants. Harvested material was dried to constant weight at 70°C in forced draught ovens.

Data for occupancy rate, plant vigour, height, maximum spread, and above-ground dry weight were subjected to analysis of variance. In order to achieve homogeneous variance and closer-to-normal error distribution, a square root transformation was used for height and spread data and a natural logarithmic transformation for dry weight values. Comparisons between means were made using the Least Significant

Difference (LSD) test. Where transformations had been used the LSD test was performed on transformed data means.

RESULTS

Survival (occupancy) of most species was best at Muriwai Beach and poorest at Ninety-mile Beach (Tables 2-1, 2-2, and 2-3). During 1995 *Astragalus cicer* and *Teline stenopetala* failed at Ninety-mile Beach. Of the 13 species/accessions remaining at this site, only *Acacia sophorae* and *Dorycnium hirsutum* achieved a mean occupancy value exceeding 50%. One species failure was observed at each of the other two sites (*Sutherlandia frutescens* at Muriwai Beach and *Lupinus nootkatensis* at Santoft). Of 18 species/accessions still represented, 14 at Muriwai and 14 at Santoft (not the same species in each case) had mean occupancy rates of 50% or more. *Dorycnium hirsutum* and *Acacia sophorae* were the only species which occupied, on average, more than half of the 15 row segments/plot at all three sites. Overall occupancy rates (all sites) were highest for *Acacia sophorae, Dorycnium hirsutum, D. rectum, Lathyrus latifolius,* and *Lotus pedunculatus* (Table 2-4).

Plant vigour was variable, with the highest number of species scoring 4 or 5 recorded at Muriwai. *Dorycnium hirsutum* was the only species with a mean score of 4 or 5 at all sites.

Plant height and maximum spread were often greater at Muriwai and Santoft than at Ninety-mile Beach although *Acacia sophorae* and *Chamaecytisus palmensis* 3820 had both achieved most lateral growth at Ninety-mile Beach (4.7 and 2.2 m respectively). *Dorycnium rectum, Hedysarum coronarium, Lotus corniculatus* and *Medicago arborea* also showed greater lateral growth at this site than at Santoft. Tallest species were *Chamaecytisus palmensis* 3211/3218 and 3573, and *Teline stenopetala* (average over all sites 1.0 - 1.25m). An overall mean maximum spread exceeding 1.5 m was achieved by *Acacia sophorae, Chamaecytisus palmensis* 3211/3218, and *Teline stenopetala.*

Root collar diameters were difficult to measure as some plants had multiple stems. The data show that stems of the shrub species were quite robust, a diameter of 25 - 30 mm at ground level (averaged over all sites) being achieved by *Acacia saligna, Chamaecytisus palmensis* (all accessions), and *Teline stenopetala.*

Above-ground dry weight values were highly variable but indicated that the most productive species were *Acacia sophorae* at Ninety-mile Beach; *Chamaecytisus palmensis* 3211/3218 and 3820, and *Teline stenopetala* at Muriwai and *Acacia saligna, A. sophorae, Chamaecytisus palmensis* 3211/3218 and 3573, *Dorycnium hirsutum* and *Teline stenopetala* at Santoft. Species with the greatest productivity at all sites were *Acacia saligna, A. sophorae, Chamaecytisus palmensis* (all three accessions), and *Teline stenopetala.*

Occasional seedlings of five species were observed at Ninety-mile Beach. At Muriwai only two of these species (*Lotus tenuis* and *Teline stenopetala*) had produced seedlings, but more than 50/plot were recorded for *L. tenuis*. At Santoft six species had produced seedlings. Here counts of up to 50/plot were noted for *D. pentaphyllum, Hedysarum coronarium, Lotus corniculatus* and *Medicago arborea* and more than 50/plot for *Dorycnium hirsutum* and *L. tenuis*.

Leaf necrosis and shoot dieback were common at all sites. Localised chlorosis was also fairly common. Red/yellow discoloration of leaves was noted in some species at Muriwai. Severe leaf loss occurring at Santoft was not recorded at the other two sites.

DISCUSSION

The tendency noted for overall survival and plant growth to be poorest at Ninety-mile Beach and best at Santoft in 1994 (Gadgil *et al*, 1995) was not maintained during the subsequent year. In November 1995 mean values for nearly all measured variables were highest at Muriwai Beach. Trial sites at Ninety-mile Beach and Santoft are both very exposed, while that at Muriwai is sheltered on the seaward side by a large dune. Marram grass development is greater at Muriwai than at Ninety-mile Beach and intermediate at Santoft. Shelter provided by marram tussocks is undoubtedly important for the development of associated plants. Frequent dieback and leaf necrosis were often confined to plant parts which had grown above the surrounding marram grass. This was particularly noticeable at Ninety-mile Beach where the ratio of plant spread to plant height was much greater (5.0) than at Muriwai (1.7) or Santoft (1.7). The causes of chlorosis are not so clear, but some species (e.g. *Medicago arborea*) appeared to be affected more than others. Many plants showed evidence of vigorous regrowth in addition to dieback, necrosis and chlorosis, and showed a net growth gain in spite of these symptoms.

The 1995 results confirm that, of the 20 species and accessions tested, *Lespedeza cuneata, Lupinus nootkatensis, Sutherlandia frutescens and Trifolium ambiguum* were least tolerant of conditions on the open sand dunes. The five species with highest overall occupancy rates (*Acacia sophorae, Dorycnium rectum, D. hirsutum, Lathyrus latifolius* and *Lotus pedunculatus*) can be considered to have the most general potential for replacing *Lupinus arboreus*. Growth of *A. sophorae* may be too aggressive for use in artificial stabilisation programmes (Knowles, 1995) unless the need for a rapid coloniser is extreme and provision can be made for effective control measures where necessary.

Before the late 1980s, *Lupinus arboreus* populations in the sand dune environment were self-sustaining. Longevity of individual lupin plants was thought to be about 5 years (Sandberg, 1987) and continuous development of new plants from seed played an important role in maintenance of lupin cover. It is not yet known whether *Dorycnium rectum, D. hirsutum, Lathyrus latifolius* or *Lotus pedunculatus* will be capable of similar long-term persistence. Older trials indicate that individual plants of *Lathyrus latifolius* and *Lotus pedunculatus* can survive for at least 4 years, and those of *Dorycnium rectum* and *D. hirsutum* for at least 3½ years in the sand dune environment (Section 1 of this report). It remains to be seen whether any of these species can maintain indefinite co-dominance with marram grass through individual plant longevity and/or the production of new individuals from seed. The results described here suggest that this may be possible in the case of *Dorycnium rectum, D. hirsutum,* and several other species (*Lotus corniculatus, L. tenuis* and *Medicago arborea*) at Santoft. At Ninety-mile Beach there were no signs of vigorous seedling development. *Lotus tenuis* and *Teline stenopetala* were the only species at Muriwai Beach that showed potential for regeneration from seed. There is no particular known concern about the weed potential of any of these species (Knowles, 1995).

Criteria determining potential for replacement of *Lupinus arboreus* may vary with location. On harsher sites where conditions are inimical to seedling establishment, individual plant persistence and a capacity for vigorous, prostrate growth may be the most essential characteristics. These would satisfy the requirement for maintenance of plant cover. If the need for revegetation is sufficiently urgent, planting rather than introduction by seed might be an attractive option at these sites. Where conditions are not so extreme, a less vigorous and more upright growth habit, complemented by plant replacement through seedling development, might be more appropriate. In such situations the original introduction of N-fixing plants by oversowing may be possible.

Conditions during 1994-95 for seedling establishment in the FR 193 trial series were quite different from those which can be expected in a one-year-old marram grass stand. Additional shelter from the planted species and from older marram tussocks, as well as benefits associated with litterfall, would have enhanced the environment for germination and early seedling growth. It must also be remembered that rabbits and grazing animals were excluded from the FR 193 trials. Development of seedlings recorded here is therefore only an indication of potential and has little to do with expectations for the development of legume stands through introduction of seed, rather than young plants.

POSTSCRIPT

At the request of managers of adjoining land, species considered to have weed potential were removed from the FR 193 trials in December 1995. These removals and a list of species remaining for assessment in 1996 have been documented by Gadgil, Douglas and Ede (1996).

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3. ASSESSMENTS OF RELATIVE PLANT GROWTH PERFORMANCE IN A 2½ YR-OLD TRIAL COMPARING THE EFFECTS OF POTTING MIX AND LOCAL SAND AS MEDIA FOR RAISING SEEDLINGS USED IN SPACED-PLANT TRIALS.

Ruth Gadgil, Helena Beeser, Alison Lowe and Fiona Ede

NZ Forest Research Institute

INTRODUCTION

The decision to use potting mix for raising and planting-out seedlings in the 1993 spaced-plant trials (FR 193 series) was made on the assumption that this would give plants the best possible preparation for acclimatisation to the sand dune environment. Not only would the seedlings be more vigorous, but their roots would be protected from less favourable physical and chemical conditions in the sand during early field growth.

In order to test this assumption, an additional trial (FR 193/2) was set up at Ninety-mile Beach as part of the 1993 trial series. Details of the site and layout were described by Gadgil *et al* (1993). After six months' field growth, greater overall mean height and maximum spread were observed where potting compost had been used, but there was no effect on survival or on above-ground dry matter production (Gadgil *et al*, 1994). When the three species were considered individually at this stage, no effect of rooting medium could be detected in the performance of *Acacia sophorae* or *Lotus pedunculatus*. *Chamaecytisus palmensis* survived better and produced slightly shorter plants when grown in local sand.

After the first summer season in the field, the November 1994 assessment indicated that early growth advantages had not been maintained (Gadgil *et al.*, 1995). Of all the measured variables, only height growth of *Chamaecytisus palmensis* was greater in plants raised in potting compost.

Results of the final assessments in this trial (November 1995) are reported here.

METHODS

Maximum height and spread of all plants were recorded, and plant vigour was scored on a scale of 1 (poor) to 5 (robust). In each row (plot), either one plant or its 30 cm row segment was selected at random for destructive harvesting. The oven-dry weight of above-ground material was determined. In order to achieve homogeneous variance and closer-to-normal error distribution, a square root transformation was used for height and spread data and a natural logarithmic transformation for dry weight values before analysis of variance was performed on all data. Comparisons between means were made using the Least Significant Difference test. Where transformations had been used the LSD test was performed on transformed data means.

RESULTS

Very few plants of *Chamaecytisus palmensis* had survived to November 1995. Table 3-1 shows that no significant difference between plants raised in potting compost and those raised in sand could be demonstrated in terms of survival, vigour, plant height, maximum spread, or above-ground dry matter production.

DISCUSSION

The 1995 results confirm that differences observed in 1993 were ephemeral. No lasting advantage in terms of plant growth characteristics appears to have been conferred on plants raised in potting compost rather than in the local sand at Ninety-mile Beach.

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4. ASSESSMENTS OF RELATIVE NITROGEN-FIXING POTENTIAL OF PLANTS IN TRIALS ESTABLISHED IN 1993.

ALISON LOWE and GRAEME OLIVER

Forest Research Institute.

INTRODUCTION

Measurement of relative nitrogenase activity was used to estimate the nitrogen (N_2)-fixing potential of the replacement species for *Lupinus arboreus*. The relative nitrogenase (acetylene-reducing) activity was measured over a 30-minute incubation period in the spring. The method is based on the assay proposed by Hardy and Knight (1967). Details of the N_2ase-catalyzed reduction of acetylene to ethylene ($C_2H_2 \rightarrow C_2H_4$) are found in Hardy *et al.*, (1973). The amount of ethylene produced from the reduction of acetylene ($C_2H_2 \rightarrow C_2H_4$) is proportional to the rate of N_2ase activity. Theoretically it is possible to calculate absolute rates of N_2-fixation by using a conversion ratio of C_2H_4 to N_2 of 3:1. In practice however, rates have been recorded from 1.5:1 up to 25:1 in anaerobic soil (Hardy *et al.* 1973). Also, as variations in activity may occur diurnally, from day to day, or seasonally, it is inaccurate to extrapolate the levels of nitrogenase activity found in the short-term incubation to quantify overall activity. The objective of this study was to evaluate the relative ability of the leguminous species in the trials described in Sections 2 and 3 of this report to fix nitrogen. In this section the rate of ethylene production from acetylene during the incubation of a sample of the root system has been reported as an estimate of the relative N_2-fixing potential.

METHODS

Acetylene (C_2H_2) production

Acetylene for the assays was prepared on the day of use, in the field. Water was added to commercial calcium carbide, and the acetylene gas produced was collected in an inflatable beach ball. The reaction also forms small amounts of PH_3, CH_4, and C_2H_4. Samples of the gas were analysed to determine the background level of C_2H_4 in the acetylene.

Field sampling and incubations

Where sufficient plants were still alive, two plants of each species from each trial were randomly selected, one per row from Blocks 5 and 6, to determine the relative nitrogenase activity. If there were not 2 live plants in either of the 2 chosen blocks a plant was selected from the next closest block. After the top of the sample plant was severed for biomass determination, a sample of the fibrous root system immediately below the soil surface was carefully removed using a metal corer (108 mm diameter x 85 mm deep). Half of each root system sample was placed in a 1040 ml Agee jar with a seal top. 100 ml of air was removed and 100 ml of acetylene added to the jar by syringe. The syringe tip was placed in the jar and pumped 3 times to ensure thorough mixing of the acetylene. This gave a concentration of 9.6% acetylene in the 1040 ml jar. Blank gas samples (no root systems) were prepared to correct for the background concentration of ethylene. Slight variation in the concentration of acetylene during the incubation is inconsequential as it is the excess of reductant present during the incubation that is important. The time was recorded at the point of acetylene addition, and the jar was then placed in the shade. After approximately 30 minutes the gas in the jar was sample syringe. Two gas samples of at least 4 ml each were collected and time recorded to determine and correct for the incubation period. The reduction of acetylene to ethylene is linear over time. The tip of the needle of each gas sample was inserted into rubber immediately after collection to prevent gas loss, and syringes were transported to the laboratory for ethylene analysis.

Laboratory

The following gas chromatography system was used for the analysis of ethylene:

Detector type	H_2 FID. H_2 10 lb, air 8 lb. Temperature 150 °C
Column	Glass, 5' x ¼" I.D., Poropak N (50-100 mesh)
Carrier gas	N_2
Oven temperature	95 °C
Retention times	C_2H_4 2.2 min, C_2H_2 3.2 min
Injection loop	1 ml

Calculations

Linearity of the gas chromatography system was checked by a calibration curve of injections of known concentrations of ethylene. 1000 ppm ethylene was used to determine the slope of the curve, R, where R = peak area / ethylene concentration. 1000 ppm was injected periodically throughout sample analysis as a system check. Where duplicate samples were taken ethylene peak areas were averaged. The background level (peak area) of ethylene in the acetylene used (the mean of the blank samples), was subtracted from the sample peak area. This was then divided by R, adjusted for incubation time, adjusted for incubation volume, and ethylene production expressed as nmol C_2H_4 / core / 30 minutes.

Ethylene production (nmol) per core per 30min incubation = ((s-b)/R) * (30/t) * (vol. cf) where:

s	=	mean sample peak area
b	=	mean blank peak area
R	=	slope of calibration curve (1000ppm peak area/1000)
t	=	incubation time (minutes)
vol. cf	=	39.7 (conversion of ppm to nmol in large agee jar with a half-core sample)*
		17.9 (conversion of ppm to nmol in small agee jar with a half-core sample)*

* See Appendix 1 for conversion of ppm to nmol.

RESULTS AND DISCUSSION

Results for the amount of ethylene produced per core of root sampled over a 30 minute incubation for each of the trial sites are presented in Tables 4-1 to 4-4. Results are variable due to variability in the size and degree of nodulation between plant replicates. Results represent the relative nitrogenase activity for the specific volume of root sampled during a 30 minute incubation period. Note that the total volume of nodulated root system for individual plants was generally more extensive than this.

The three species with the highest rates of nitrogenase activity were:

Ninety-mile Beach	*Lathyrus latifolius, Acacia sophorae, Lotus pedunculatus*
Muriwai Beach	*Hedysarum coronarium, Acacia saligna, Acacia sophorae*
Santoft Beach	*Lathyrus latifolius, Acacia sophorae, Acacia saligna/Teline stenopetala*

The results from trial site FR 193/02 (Ninety-mile Beach), indicate that nitrogenase activity was higher in the surviving *Acacia sophorae* and *Lotus pedunculatus* plants that were raised in potting mix than in those raised in sand.

Table 4-5 presents a summary of the relative acetylene reduction rates. For each site the rate of ethylene produced is expressed as a percentage of the highest value recorded for a species at that site.

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5. ASSESSMENTS OF SEEDLING ESTABLISHMENT IN THE 1995 OVERSOWI

Ruth Gadgil[1], Helena Beeser,[1] Fiona Ede[1], Alison Lowe[1], Grant Douglas[2] and Le

[1] Forest Research Institute

[2] AgResearch Grasslands.

INTRODUCTION

The first oversowing trials in the Sand Dune Revegetation Programme were established at Ka 253/1) and at Santoft Beach (FR 253/2) in June 1995. Details of the location and methods us trials were recorded by Gadgil *et al* (1995a).

Both trials were laid out in 1-year-old planted marram grass stands and were fenced to excluc Single-species plots (1 x 1 m) were broadcast-sown with legume seed. The 8 species under c been selected after consideration of the 1993-94 results from the oldest spaced-plant trials.

Assessments of seedling establishment were made in December 1995 and in April 1996, six a respectively after sowing.

METHODS

In December 1995 the number of seedlings found inside and outside each plot was recorded a incidence of necrosis or discoloration was noted. For seedlings found outside the plot, maxim from the plot boundary was measured. Where possible the height and spread of 10 seedlings/ at random, was recorded. The influence of marram grass and of other species ("weeds") was estimating the percentage cover in each plot. In the case of marram, overhanging tillers were the assessment.

In April 1996 a full assessment, similar to that made in November 1995, was made at Santof the assessment was confined to a seedling count.

RESULTS

No seedlings of *Acacia saligna* or *Teline stenopetala* were found at either site in December 1 5-1, 5-2, 5-3). At this assessment *Acacia sophorae, Astragalus cicer, Chamaecytisus palm* *Lathyrus latifolius* were observed at Santoft but not at Kawhia. Species represented at both *Dorycnium hirsutum* (similar numbers of seedlings in each case), and *Lotus pedunculatus* (3 seedlings at Santoft as at Kawhia).

In April 1996 *Acacia saligna* was the only species not found at either site. At Kawhia no ad were present. Here the total number of *Dorycnium hirsutum* seedlings had decreased from 7 *Lotus pedunculatus* increased from 4 to 7. At Santoft, *Teline stenopetala* was now represen numbers of *Acacia sophorae* and *Astragalus cicer* had increased. Net mortality since Decen recorded for *Chamaecytisus palmensis, Dorycnium hirsutum, Lathyrus latifolius* and *Lotus* (Table 5-3).

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The few seedlings observed at Kawhia appeared to be healthy, but many of those at Santoft had abnormalities which included reddening, necrosis and chlorosis. Considerable amounts of ungerminated seed were found inside and outside the plots at both sites. At Kawhia, in December, seed was identified up to 5 m (usually in a north-easterly direction) from the boundaries of the plots in which it was sown. The maximum distance of seed from plot boundaries at Santoft was 0.8 m. Many live snails were seen in the trial area at Kawhia. Insect damage to seedlings was observed at Santoft.

The second assessment at Santoft (Table 5-4) showed that seedling height and spread had not increased greatly over the past 4 months. *Lotus pedunculatus* was the only exception and seedlings now had a mean spread of 11.3 cm.

Marram grass cover in the experimental plots averaged 20% at Kawhia, but did not exceed 6% at Santoft. Most of the above-ground marram influence in the plots was from overhanging tillers. "Weed" development was slightly greater at Kawhia (6% cover) than at Santoft (4%).

DISCUSSION

Although conditions for plant growth in recently-planted marram grass stands on open dunes are known to be harsh, the very low seedling establishment rate of all species in these trials was unexpected. Germination/establishment rates for broadcast-sown *Lupinus arboreus* under similar conditions were normally 45 - 50% (Berg and Smithies, 1973; Gadgil *et al,* 1981). In the FR 253 trials, the sowing rate for all species was 200 viable seeds/m^2. The highest germination/establishment rates in April 1996, all observed at Santoft, were 9% for *Acacia sophorae,* 6% for *Astragalus cicer* and 4% for *Teline stenopetala.* The highest rate observed at Kawhia was less than 1% (*Lotus pedunculatus*).

It had been expected that germination/establishment rates would be higher during spring/early summer than in the mid-summer/autumn period. This was not the case at Santoft where 88 - 100% of seedlings of the most successful species developed between December 1995 and April 1996. Over the same period net losses were recorded for *Chamaecytisus palmensis*, *Dorycnium hirsutum*, *Lathyrus latifolius* and *Lotus pedunculatus*, even though these species were known to have been relatively successful as spaced plants in a similar environment.

Poor seedling establishment is unlikely to have been associated with nutritional problems. Urea and superphosphate were broadcast over the plots at time of sowing, and all seed was coated with the appropriate strain of *Rhizobium* as well as with lime, sulphur and sodium molybdate. Chlorosis and reddening of seedlings at Santoft could have been related to the high sand pH at that site.

Insect damage was observed at Santoft and it is more than likely that snails were responsible for some seedling losses at Kawhia. Birds may have eaten some of the seed. Exposure to wind and to conditions of high temperature and drought at the sand surface are additional likely causes of failure. The fact that seed was often found at distances up to 5 m from the experimental plots at Kawhia, but only up to 0.8 m at Santoft, is evidence of the greater influence of wind at Kawhia. This was probably associated with sand movement (sand blasting) and sweeping action of marram leaves, which have a hard outer surface. In this respect the greater marram grass cover at Kawhia may have had an abrasive, rather than a protective effect unless developing seedlings were close to the base of a tussock. Wind-related problems are likely to have accounted in part for the poor seedling performance at Kawhia. At both sites unidentifed "weed" seedlings were sparse and poorly-developed, indicating the difficult growing conditions for all plants except those (like marram grass) which are well-adapted to the sand dune environment.

It will be interesting to see whether the seedlings of *Acacia sophorae*, *Astragalus cicer*, *Lathyrus latifolius* and *Lotus pedunculatus* that were observed in April will overwinter successfully at Santoft. Continued germination from hard seed is possible at both sites, but further seedling development is unlikely at Kawhia.

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6. ESTABLISHMENT OF THE 1996 OVERSOWING TRIALS.

Ruth Gadgil[1], Helena Beeser,[1] Fiona Ede[1], Grant Douglas[2] and Lex Foote[2]

[1] **Forest Research Institute**

[2] **AgResearch Grasslands.**

INTRODUCTION

Results of 1995-96 assessments in the FR 253 trials (Section 5 of this report) were disappointing. After 5 months, very few seedlings of any of the 8 species sown could be found. In a second assessment, 10 months after sowing, a total of 8 seedlings was found in the Kawhia trial and 173 seedlings in the Santoft trial. These numbers represented 0.1 and 2.7% respectively of the 6400 viable seeds sown at each site.

Reasons for establishment failure could be :

(i) Removal of seeds by birds.
(ii) Removal of seeds beyond trial boundaries by wind.
(iii) Unfavourable conditions for germination and/or seedling establishment at the sand surface.
(iv) Destruction of seedlings by snails.

Rabbit damage can be ruled out since all plots were protected with chicken wire buried to a depth of 0.2 m.

Proper comparisons between species at the seedling establishment stage cannot be carried out until it is known whether conditions in the sand dune environment (planted marram stands) are inimical to the germination and development of species other than lupin.

In 1996 it was decided that the effects of three different sowing methods on the establishment of three legume species (including *Lupinus arboreus*) should be compared at Kawhia and at Santoft, under conditions where rabbit damage is precluded and the possibility of snail damage is reduced. Two of the sowing methods were designed to improve the microenvironment for seed germination and seedling establishment through partial or complete burial of the seed. Burial was also likely to reduce seed removal by birds or by wind. Broadcast sowing was included for comparison.

METHODS

Figs 6-1 to 6-4 show the layout and location of the trials established in 1996.

Sites

In order to reduce costs, the stock-proofed and rabbit-proofed FR 253/1 trial area at Kawhia was used again, and the new trial was given the number FR 253/3. A new rabbit-proofed site, recently planted with marram grass, was used at Santoft Beach for Trial FR 253/4. Both trials were established in June 1996.

Experimental layout

A randomised complete block design incorporating three species and three sowing methods was used at both sites. Single-species plots were each sown using one of the methods. Each combination of species and sowing method was replicated 4 times (3 species x 3 sowing methods x 4 replicates = 36 plots/trial).

Plot size and location

Plots of 1 x 1 m were laid out between rows of marram grass. Each plot was positioned so that one side lay against a marram grass tussock with diameter greater than 10 cm.

Species

The three species selected for comparison were *Lupinus arboreus*, *Lotus pedunculatus* and *Lathyrus latifolius*. Lupin was included because lupin blight (*Colletotrichum gloeosporioides)* is not likely to affect germination and very early growth of *Lupinus arboreus* grown from seed collected in the late 1980's (Dick, 1994). Lupin seed collected in 1988 (current viability 79%) was therefore selected for these trials. It seems reasonable to expect from Dick's work on open dunes that fewer than 25% of lupin seedlings would be affected by the disease during spring (i.e. before December). Providing that an assessment of establishment performance is carried out before December 1996, it should be possible to use lupin as a benchmark for comparisons.

In spite of their low establishment rate, *Lotus pedunculatus* and *Lathyrus latifolius* were the best-performing species in the Santoft oversowing trial (FR 253/2) in November 1995, and were chosen on this basis.

Sowing methods

The three methods used for sowing were :

1. **Broadcast.** Seed scattered evenly over the sand surface; no further treatment.
2. **Rake-and-roll (partial burial).** Seed scattered evenly over the sand surface. Seed raked in lightly and then sand rolled with a light garden roller.
3. **Drill (total burial).** Seed sown in furrows approximately 2 cm deep and parallel to the marram rows. Three furrows/plot, each 100 cm long and 30 cm from the next one, with the centre furrow on the 50 cm line. One third of the total seed allocated to the plot scattered evenly along each furrow and covered with sand which was then tamped flat.

Seed was sown at a rate of 200 viable seeds/m^2.

General treatment of experimental areas

Slug bait pellets (Mesurol - a.i. methiocarb, 20 g/kg) were scattered in marram tussocks and around the experimental plots at time of seed sowing. Experimental areas were treated with urea (25 kg/ha) and superphosphate (250 kg/ha) broadcast at time of sowing.

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7. TECHNOLOGY TRANSFER.

Ruth Gadgil[1], Grant Douglas[2], Fiona Ede[1] and Helena Beeser[1].

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During 1995-96, all the photographs and slides taken since the Sand Dune Revegetation Programme commenced were sorted and catalogued. Copies are available through the Forest Research Institute Photolibrary.

The 1994-95 reports on sand revegetation trials using nitrogen-fixing species were distributed to 15 interested individuals, groups and organisations. These included Regional Councils, the Awhitu Peninsula Land Group, private landowners, and the Department of Conservation.

Television exposure for the Sand Dune Revegetation Programme was achieved on 10 September 1995 when Grant Douglas was interviewed in the programme "Agritech 2000", and demonstrated spaced-plant trials with nitrogen-fixing plants at Santoft Beach.

On 12 October 1995 Grant Douglas, Ruth Gadgil and Fiona Ede visited Himatangi Beach at the request of Colin Giles of the Manawatu District Council. The urgent need for readily-accessible current information on sand stabilisation techniques was expressed. Researchers offered advice on the stabilisation of drifting sand which was inundating residential properties.

Contact has been made with the Local Government Association who have identified erosion of coastal dunelands as an issue common to most regional councils. The need for a review of methods and plants used to stabilise coastal dunes, and for reports on methodology and plant material for coastal dune stabilisation was stated in a document produced in June 1995 (Local Government Association, 1995). Our response to this formally-stated need produced interest and support for 1996-98 PGSF funding of research in the Sand Dune Revegetation Programme.

In May 1996 the idea of a nationwide self-funding Sand Dune Information Network was floated. Personnel and expertise for the coordination of such a network are available at the Forest Research Institute. The prospect of information-sharing at all levels of interest and on all topics relating to sand dune stabilisation is an exciting one which should lead to soundly-based action in the protection of coastal resources.

ACKNOWLEDGMENTS

We are most grateful to Nick Franich, and to Paul and Cheryl Doyle who assisted with assessments, processing of field samples and with data preparation.

Mark Kimberley performed the statistical analysis of the data, and we would like to thank him for his help.

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TABLE B-1 - Points of similarity and contrast between the ten trials established 1991 - 1995.

	TRIAL LOCATION											
	Ninety-mile Beach			Muriwai Beach	Kawhia		Harakeke	Santoft Beach				
	FR 165/1	FR 193/1	FR 193/2	FR 193/3	FR 165/2	FR 253/1	FR 165/3	A	B	C	FR 193/4	FR 253/2
Spaced-plant trial	+	+	+	+	+	-	+	+	+	+	+	-
Oversowing trial	-	-	-	-	-	+	-	-	-	-	-	+
Established Spring 1991	+	-	-	-	+	-	+	+	+	-	-	-
Established Autumn 1992	-	-	-	-	-	-	-	-	-	+	-	-
Established May 1993	-	+	+	+	-	-	-	-	-	-	+	-
Established June 1995	-	-	-	-	-	+	-	-	-	-	-	+
Rabbits excluded	+	+	+	+	+	+	+	-	-	+	+	+
Seedlings raised in potting mix	-	+	+	+	-	-	-	+	+	+	+	-
Seedlings raised in local sand	+	-	+	-	+	-	+	-	-	-	-	-
Single-species plots of 36 plants	+	-	-	-	+	-	-	-	-	-	-	-
Single-species plots of 20 plants	-	-	-	-	-	-	+	-	-	-	-	-
Single-species plots of 8 plants	-	-	-	-	-	-	-	+	+	-	-	-
Single-species rows of 10 plants	-	-	-	-	-	-	-	-	-	+	-	-
Single-species rows of 15 plants	-	+	+	+	-	-	-	-	-	-	+	-
Replicates 3	-	-	-	-	-	-	+	+	+	-	-	-
Replicates 4	+	-	-	-	+	+	-	-	-	+	-	+
Replicates 6	-	+	+	+	-	-	-	-	-	-	+	-

TABLE B-2 - Species planted or sown in the ten trials established 1991 - 1995.

	TRIAL LOCATION											
	Ninety-mile Beach			Muriwai Beach	Kawhia		Harakeke	Santoft Beach				
	FR 165/1	FR 193/1	FR 193/2	FR 193/3	FR 165/2	FR 253/1	FR 165/3	A	B	C	FR 193/4	FR 253/2
Acacia saligna	+	+	-	+	+	+	+	-	-	+	+	+
Acacia sophorae	+	+	+	+	+	+	+	-	-	+	+	+
Astragalus cicer	-	+	-	+	-	+	-	+	+	+	+	+
Casuarina glauca	-	-	-	-	-	-	-	-	-	+	-	-
Chamaecytisus palmensis	+	3 accessions	+	3 accessions	+	+	+	+	+	3 accessions	3 accessions	+
Dorycnium hirsutum	-	+	-	+	-	+	-	+	+	+	+	+
Dorycnium pentaphyllum	-	+	-	+	-	-	-	-	-	+	+	-
Dorycnium rectum	-	+	-	+	-	-	-	-	-	+	+	-
Hedysarum coronarium	-	+	-	+	-	-	-	+	+	+	+	-
Hippophae rhamnoides	-	-	-	-	-	-	-	-	-	+	-	-
Lathyrus japonicus	-	-	-	-	-	-	-	-	-	+	-	-
Lathyrus latifolius	+	+	-	+	+	+	+	+	+	+	+	+
Lathyrus tuberosus	-	-	-	-	-	-	-	+	+	-	-	-
Lespedeza cuneata	+	+	-	+	+	-	-	+	+	-	+	-
Lotus corniculatus	+	+	-	+	+	-	-	-	-	+	+	-
Lotus pedunculatus	+	+	+	+	+	+	+	-	-	-	+	+
Lotus tenuis	-	+	-	+	-	-	-	+	+	+	+	-
Lupinus arboreus	-	-	-	-	-	-	-	+	+	-	-	-
Lupinus nootkatensis	+	-	-	-	+	-	+	-	-	-	-	-
Medicago arborea	-	+	-	+	-	-	-	-	-	+	+	-
Robinia pseudoacacia	-	-	-	-	-	-	-	-	-	+	-	-
Sutherlandia frutescens	+	+	-	+	+	-	+	-	-	+	+	-
Telins stenopetala	+	+	-	+	+	+	+	-	-	-	+	+
Trifolium ambiguum	+	+	-	+	+	-	+	-	-	-	+	-
Vicia gigantea	-	-	-	-	-	-	-	-	-	+	-	-
Vicia sepium	-	-	-	-	-	-	-	+	+	-	-	-

TABLE 1-1 : RESULTS OF THE NOVEMBER 1995 ASSESSMENT IN TRIAL FR 165/1

NINETY-MILE BEACH

		Original plants					Seedlings			
Species	**Plot No.**	**Cover (%)**	**Maximum distance outside plot (cm)**	**Vigour (1-5)**	**Flowers or buds present**	**Seedpods present**	**Number inside plot**	**Number outside plot**	**Maximum distance outside plot (cm)**	**Vigour (1-5)**
Acacia saligna	21	0 - 25	-	2	No	No	0	0	-	-
	17	0	-	-	-	-	0	0	-	-
	23	0 - 25	20	2	No	No	0	0	-	-
	42	0 - 25	-	2	No	No	0	0	-	-
Acacia sophorae	13	50 - 75	160	4	No	No	0	0	-	-
	19	75 - 100	520	3	No	No	0	0	-	-
	37	50 - 75	125	3	No	No	0	0	-	-
	43	75 - 100	340	4	No	No	0	0	-	-
Chamaecytisus palmensis AL 3570	14	0 - 25	50	3	Yes	Yes	0	0	-	-
	6	0 - 25	60	3	No	No	0	0	-	-
	24	0	-	-	-	-	0	0	-	-
	32	0	-	-	-	-	0	0	-	-
Lotus pedunculatus	3	0 - 25	-	4	No	No	0	0	-	-
	5	0 - 25	-	4	No	No	0	0	-	-
	39	0	-	-	-	-	0	0	-	-
	41	0	-	-	-	-	0	0	-	-
Teline stenopetala	10	0 - 25	-	4	Yes	No	0	0	-	-
	18	0	-	-	-	-	0	0	-	-
	40	0	-	-	-	-	0	0	-	-
	31	0	-	-	-	-	0	0	-	-

TABLE 1-2 : RESULTS OF THE NOVEMBER 1995 ASSESSMENT IN TRIAL FR 165/2

KAWHIA

Species	Plot No.	Original plants					Seedlings			
		Cover (%)	Maximum distance outside plot (cm)	Vigour (1-5)	Flowers or buds present	Seedpods present	Number inside plot	Number outside plot	Maximum distance outside plot (cm)	Vigour (1-5)
Acacia saligna	8	75 - 100	100	3	Yes	No	0	0	-	-
	20	75 - 100	150	4	Yes	Yes	0	0	-	-
	27	75 - 100	100	4	Yes	No	0	0	-	-
	36	75 - 100	170	4	Yes	No	0	0	-	-
Acacia sophorae	4	50 - 75	180	4	No	No	0	0	-	-
	16	75 - 100	520	5	No	Yes	0	0	-	-
	30	75 - 100	470	5	No	Yes	1	0	-	4
	44	75 - 100	710	5	No	Yes	0	0	-	-
Lathyrus latifolius	3	0 - 25	-	4	Yes	No	0	0	-	-
	15	0	-	-	-	-	0	0	-	-
	23	0	-	-	-	-	0	0	-	-
	34	0	-	-	-	-	0	0	-	-
Lotus corniculatus	10	0	-	-	-	-	0	1	200	5
	12	0	-	-	-	-	0	0	-	-
	25	0	-	-	-	-	0	0	-	-
	38	0	-	-	-	-	0	0	-	-
Lotus pedunculatus	11	0 - 25	-	2	Yes	No	0	0	-	-
	14	0 - 25	40	3	Yes	No	0	0	-	-
	31	0 - 25	-	1	No	No	0	0	-	-
	40	25 - 50	130	3	Yes	Yes	0	0	-	-

TABLE 1-3 : RESULTS OF THE NOVEMBER 1995 ASSESSMENT IN TRIAL FR 165/3

HARAKEKE

Species	Plot No.	Original plants					Seedlings			
		Cover (%)	Maximum distance outside plot (cm)	Vigour (1-5)	Flowers or buds present	Seedpods present	Number inside plot	Number outside plot	Maximum distance outside plot (cm)	Vigour (1-5)
Acacia saligna	9	0 - 25	60	4	Yes	No	0	0	-	-
	17	0 - 25	0	3	No	No	0	0	-	-
	19	0 - 25	20	3	No	No	0	0	-	-
Acacia sophorae	4	0	-	-	-	-	0	0	-	-
	15	0 - 25	30	3	No	No	0	0	-	-
	27	0 - 25	70	4	No	Yes	0	0	-	-
Chamaecytisus palmensis AL 3570	7	75 - 100	230	4	No	Yes	0	0	-	-
	14	75 - 100	240	4	No	Yes	0	0	-	-
	26	50 - 75	295	3	No	Yes	0	0	-	-
Lathyrus latifolius	8	50 - 75	100	4	Yes	No	0	0	-	-
	11	0	-	-	-	-	0	0	-	-
	21	25 - 50	-	3	-	-	0	0	-	-
Lotus pedunculatus	3	0 - 25	0	4	Yes	No	0	0	-	-
	16	0 - 25	60	4	Yes	No	0	0	-	-
	23	0 - 25	110	5	Yes	No	0	0	-	-
Teline stenopetala	1	0	-	-	-	-	0	0	-	-
	13	75 - 100	140	4	Yes	Yes	0	0	-	-
	20	75 - 100	250	5	Yes	Yes	0	0	-	-
Trifolium ambiguum	2	0 - 25	-	4	No	No	0	0	-	-
	12	0 - 25	25	4	No	No	0	0	-	-
	22	0 - 25	-	3	No	No	0	0	-	-

TABLE 1-4 - RESULTS OF THE NOVEMBER 1995 ASSESSMENT IN TRIAL C

SANTOFT BEACH

Species	Survival (%)	Vigour (1=weak, 5=robust)	Plant height (cm)	Plant spread (cm)	Root collar diameter (mm)	Seedling score†	Reproductive development#	Notes
Acacia saligna	69 a‡	4	126 a	116 bc	41 a	0	0	Dieback above marram; vigorous new growth from near ground level
Acacia sophorae	59 ab	3	114 a	177 a	34 a	0	0	Considerable leaf loss at top of plants; suckering profusely.
Astragalus cicer	59 ab	4	11 g	11 e		0	0	Healthy light green foliage; rhizomatous spread.
Casuarina glauca	69 a	4	31 fg	13 e		0	0	Occasional plant has patchy red foliage.
Chamaecytisus palmensis (AL 3573)	9 cd	1	83 bcde	97 cd	30 a	0	0	Often almost complete leaf loss.
Chamaecytisus palmensis (AL 3820)	16 cd	2	47 ef	90 cd	27 a	0	0	Often almost complete leaf loss; shoots on one plant.
Chamaecytisus palmensis (PMC 3552)	6 cd	1	111 ab	99 cd	12 a	0	0	Complete leaf loss.
Dorycnium hirsutum	47 abc	4	56 cdef	117 bc		1	1	Healthy, dense foliage. Most plants with flower buds/flowers.
Dorycnium pentaphyllum	3 d	4	63 bcdef	99 cd		1	1	Flower buds. Slight leaf tip necrosis
Dorycnium rectum	25 bcd	3	85 bcd	158 ab		0, 1	1	Flower buds. Necrotic leaves near top of plants. Slight leaf chewing.
Hedysarum coronarium	3 d	3	8 g	12 e		0	0	Most plants probably aged less than 1 year.
Hippophae rhamnoides	0	-	-	-		0	-	-
Lathyrus latifolius	59 ab	3	56 cdef	75 cd		0, 1	1	Few flower buds. Scrambling growth habit.
Lotus corniculatus	38 abcd	4	27 fg	14 e		0	0	-
Lotus tenuis	47 abc	4	32 fg	48 de		0	0	Vigorous growth, particularly from plant centres.
Medicago arborea	81 a	4	86 bc	102 c	25 a	1	1	Flowers/pods. Dense, uniform growth.
Robinia pseudoacacia	16 cd	3	47 ef	48 de		0	0	New shoots, mainly from near ground level.
Sutherlandia frutescens	0	-	-	-		0	-	-
Vicia gigantea	0	-	-	-		0	-	-

* Backtransformed means.
† Seedling count score : 0 = Nil; 1 = < 50/plot.
# 0 = absent; 1 = development in at least one replicate plot.
‡ For each column, values followed by the same letter do not differ at the 5% significance level (LSD test).

TABLE 2-1 - Mean values for 1995 assessments in Trial FR 193/1, Ninety-mile Beach.

Species	Occupancy of original planting positions (%)	Vigour (1=weak, 5=robust)	Plant height* (cm)	Plant spread* (cm)	Root collar diameter (mm)	Above-ground D. Wt.* (g / 0.3m of row)	Seedling score†	Notes
Acacia saligna	37 bcde‡	2.8 c	26 bc	56 cd	17	188 b	0	Seedpods. Extreme dieback, leaf necrosis; healthy new growth.
Acacia sophorae	74 a	4.0 a	46 a	472 a		818 a	0	Some leaf necrosis; some dieback; much regrowth.
Astragalus cicer	0	-	-	-		-	0	-
Chamaecytisus palmensis (3211/ 3218)	17 de	3.0 bc	27 bc	188 b	32	-	1	Flowers; seedpods. Some dieback; new shoots.
Chamaecytisus palmensis (3573)	0	-	-	-		-	0	-
Chamaecytisus palmensis (3820)	42 bcd	3.5 abc	26 bc	221 b	ND	-	0	Flowering, seedpods. Some shoot tip scorch, dieback. New growth.
Dorycnium hirsutum	53 ab	4.0 a	30 b	77 cd		78 bc	0	Flowering profusely. Some dieback; small amount of chlorosis.
Dorycnium pentaphyllum	13 e	3.5 abc	14 de	52 cd		35 bc	0	Flower buds. Some dieback; some chlorosis.
Dorycnium rectum	46 bc	3.4 abc	32 ab	67 cd		40 bcd	0	Flower buds. Some chlorosis; some dieback.
Hedysarum coronarium	21 cde	3.5 abc	16 cd	61 cd		15 cde	0	Flowering. Some dieback, some chlorosis.
Lathyrus latifolius	37 bcde	2.8 c	18 cd	63 cd		3 e	0	Flowering. Some leaf necrosis; some dieback. New growth.
Lespedeza cuneata	0	-	-	-		-	0	-
Lotus corniculatus	22 cde	4.0 a	13 de	34 d		6 cde	1	A little dieback. A very little chlorosis.
Lotus pedunculatus	41 bcd	3.8 ab	8 e	53 d		11 de	0	Some chlorosis. Some dieback.
Lotus tenuis	25 cde	4.0 a	15 de	33 d		4 e	1	Some leaf necrosis.
Lupinus nootkatensis	0	-	-	-		-	0	-
Medicago arborea	23 cde	4.0 a	30 b	124 bc		-	1	Flowering, profuse seedpods; some dieback.
Sutherlandia frutescens	0	-	-	-		-	0	-
Teline stenopetala	0	-	-	-		-	1	Some necrosis; some chlorosis.
Trifolium ambiguum	0	-	-	-		-	0	-
All species	23	2.3	15	75	25	60	0 - 1	

* Backtransformed means

† Seedling count score in one or more plots: 0 = Nil; 1 = < 50/plot; 2 = >50/plot.

‡ For each column, values followed by the same letter do not differ at the 5% significance level (LSD test).

ND Not determined.

TABLE 2-2 - Mean values for 1995 assessments in Trial FR 193/3, Muriwai Beach.

Species	Occupancy of original planting positions (%)	Vigour (1=weak, 5=robust)	Plant height* (cm)	Plant spread* (cm)	Root collar diameter (mm)	Above-ground D. Wt.* (g / 0.3m of row)	Seedling score†	Notes
Acacia saligna	73 bcde‡	3.7 cd	118 a	113 cd	29 a	376 bcd	0	Leaf necrosis; some dieback. New growth.
Acacia sophorae	79 abcd	4.0 bc	71 b	140 bc	20 b	570 bcd	0	Seedpods. Some leaf necrosis.
Astragalus cicer	9 f	2.5 ef	6 fg	25 ef		-	0	Suckering.
Chamaecytisus palmensis (3211/ 3218)	95 ab	3.8 cd	139 a	213 ab	33 a	1384 ab	0	Flowering, many seedpods. Leaf necrosis. Much dieback and much regrowth. Some discoloration and chlorosis.
Chamaecytisus palmensis (3573)	62 de	3.5 cd	135 a	176 abc	34 a	701 bc	0	Flowers, seedpods. Leaf necrosis. Dieback and regrowth.
Chamaecytisus palmensis (3820)	65 cde	3.0 de	77 b	133 bc	35 a	2061 a	0	Seedpods. Dieback. Regrowth.
Dorycnium hirsutum	100 a	5.0 a	65 b	104 cd		116 cde	0	Flowers, seedpods forming.
Dorycnium pentaphyllum	85 abc	4.7 ab	41 de	87 d		165 de	0	Flowering. Localised necrosis. Some chewing.
Dorycnium rectum	92 ab	4.3 abc	127 a	205 ab		544 bcd	0	Flowering. Leaf necrosis; some dieback; some chlorosis.
Hedysarum coronarium	56 e	3.7 cd	59 bc	110 cd		61 de	0	Flowers, seedpods. Some discoloration. Some chewing.
Lathyrus latifolius	100 a	3.7 cd	69 b	170 abc		65 de	0	Flowering, seedpods. Some leaf necrosis, dieback, chlorosis; chewing.
Lespedeza cuneata	3 f	2.5 ef	12 f	6 fg		-	0	Chlorotic.
Lotus corniculatus	100 a	4.2 abc	34 de	65 de		43 e	0	Some localised discoloration and dieback.
Lotus pedunculatus	99 a	4.3 abc	45 cd	133 bc		21 e	0	Flowering. Some localised necrosis, discoloration, chlorosis, chewing.
Lotus tenuis	80 abcd	3.7 cd	35 de	58 de		66 de	1 - 2	Flowering. Localised chlorosis.
Lupinus nootkatensis	0	-	-	-		-	0	-
Medicago arborea	2 f	1.0 g	27 e	10 fg		-	0	-
Sutherlandia frutescens	0	-	-	-		-	0	-
Teline stenopetala	100 a	4.0 bc	130 a	235 a	31 a	1130 ab	1	Flowers, profuse seedpods. Dieback and new growth.
Trifolium ambiguum	5 f	2.0 f	2 g	3 g		-		-
All species	60	3.2	60	99	30	401	1 - 2	

* Backtransformed means
† Seedling count score in any one plot : 0 = Nil; 1 = < 50/plot; 2 = >50/plot.
‡ For each column, values followed by the same letter do not differ at the 5% significance level (LSD test)

TABLE 2-3 - Mean values for 1995 assessments in Trial FR 193/4, Santoft Beach.

Species	Occupancy of original planting positions (%)	Vigour (1=weak, 5=robust)	Plant height* (cm)	Plant spread* (cm)	Root collar diameter (mm)	Above-ground D. Wt.* (g / 0.3m of row)	Seedling score†	Notes
Acacia saligna	58 bcde‡	3.0 cde	94 ab	86 cd	29 a	444 ab	0	Dieback and regrowth.
Acacia sophorae	97 a	3.5 bc	69 bc	155 a	18 cd	677 a	0	Suckering. Defoliation at top of plants.
Astragalus cicer	51 de	4.2 a	10 g	24 e		5 h	0	Slight rhizome spread.
Chamaecytisus palmensis (3211/ 3218)	57 cde	1.7 fg	94 ab	99 c	27 ab	409 ab	0	Dieback and defoliation. Some vigorous new growth.
Chamaecytisus palmensis (3573)	59 bcde	2.0 fg	110 a	95 c	24 abc	252 abc	0	Defoliation and dieback. Regrowth below marram height. Borer?.
Chamaecytisus palmensis (3820)	59 bcde	2.0 fg	53 cde	89 c	25 abc	180 bcd	0	Prostrate growth. Dieback. Insect damage.
Dorycnium hirsutum	99 a	4.5 a	56 cd	110 b		274 abc	2	Flowering.
Dorycnium pentaphyllum	85 a	4.2 a	38 def	83 cd		134 cde	1	Flowering. Some plants with up to 50% dead stems.
Dorycnium rectum	83 ab	3.0 cde	41 def	58 d		78 def	0	Severe leaf loss. Dieback. Some regrowth from base.
Hedysarum coronarium	5 f	2.3 efg	20 g	34 e		-	1	Many dead plant remains. Some regrowth.
Lathyrus latifolius	91 a	3.3 bcd	41 def	75 cd		56 efg	0	Flowers. Slight leaf tip necrosis. Some localised chlorosis. Snails.
Lespedeza cuneata	0	-	-	-		-	0	-
Lotus corniculatus	73 abcd	3.7 ab	15 g	26 e		14 h	1	Slight chewing. Dead plant remains. Regrowth from plant centres.
Lotus pedunculatus	95 a	3.2 bcd	33 f	69 cd		27 g	0	Flowering. Slight chlorosis. Rhizome spread. Dieback.
Lotus tenuis	82 abc	4.0 ab	35 ef	57 d		47 fg	1 - 2	Vigorous growth. Dead plant parts.
Lupinus nootkatensis	0	-	-	-		-	0	
Medicago arborea	33 e	4.0 ab	56 cd	86 cd	20 bcd	240 bc	1	Flowers, seedpods. Slight leaf chlorosis.
Sutherlandia frutescens	1 f	4.0 ab	45 def	82 cd	12 d	-	0	Flowers, seedpods.
Teline stenopetala	50 de	1.6 g	82 b	83 cd	23 abc	428 ab	0	Severe leaf loss and dieback. Some regrowth at base of plants.
Trifolium ambiguum	5 f	2.5 def	14 g	21 e		-	0	
All species	54	2.8	45	67	22	163	1 - 2	

* Backtransformed data

† Seedling count score in any one plot : 0 = Nil; 1 = < 50/plot; 2 = >50/plot.

‡ For each column, values followed by the same letter do not differ at the 5% significance level (LSD test).

TABLE 2-4 - Performance of individual species at three sites in the FR 193 trial series, November 1995.

Species	Occupancy of original planting positions (%)	Vigour (1=weak, 5=robust)	Plant height* (cm)	Plant spread* (cm)	Root collar diameter (mm)	Above-ground D. Wt.* (g / 0.3m of row)	Seedling score†	Notes
Acacia saligna	56 cd	3.2 cde	86 b	89 cdef	26 ab	360 ab	0	
Acacia sophorae	84 a	3.8 abc	62 cd	256 a	18 cd	688 a	0	Suckering.
Astragalus cicer	20 fg	3.8 abc	9 j	24 gh		4 g	0	Rhizomes. Failed at Ninety-mile Beach in 1995.
Chamaecytisus palmensis (3211/ 3218)	56 cd	2.8def	103 ab	160 abc	30 a	896 a	0	
Chamaecytisus palmensis (3573)	40 de	2.7 ef	121 a	131 bcd	28 a	420 ab	1 (one site)	Failed at Ninety-mile in Beach 1994.
Chamaecytisus palmensis (3820)	55 cd	2.8 def	55 de	138 bcd	28 a	651 ab		
Dorycnium hirsutum	85 a	4.5 a	52 de	99 bcde		169 bc	2 (one site)	
Dorycnium pentaphyllum	61 bc	4.3 ab	36 efgh	80 def		139 cd	1 (one site)	
Dorycnium rectum	74 ab	3.6 bcd	69 cd	112 bcde		243 bc		
Hedysarum coronarium	27 ef	3.3 cde	41 efg	80 def		38 def	1 (one site)	
Lathyrus latifolius	76 ab	3.3 cde	43 efg	103 bcde		49 de		Rhizomes.
Lespedeza cuneata	1 h	2.5 ef	12 ij	6 h		-		Failed at Ninety-mile Beach in 1993 and at Santoft in 1994.
Lotus corniculatus	65 bc	3.9 abc	22 hi	43 fg		24 ef	1 (two sites)	
Lotus pedunculatus	78 ab	3.8 abc	29 gh	85 def		20 ef		Rhizomes.
Lotus tenuis	62 bc	3.9 abc	29 fgh	51 efg		49 de	1-2(all 3 sites)	
Lupinus nootkatensis	-	-	-	-		-		Failed at Ninety-mile and Muriwai Beach in 1994; Santoft in 1995.
Medicago arborea	19 fg	3.6 bcd	45 def	86 def	20 bc	240 bc	1 (two sites)	
Sutherlandia frutescens	1 h	4.0 abc	45 de	82 cdef	12 d	-		Failed at Ninety-mile Beach in 1993; Muriwai Beach in 1995.
Teline stenopetala	50 cd	2.9 def	108 ab	166 ab	27 a	849 a	1 (two sites)	Failed at Ninety-mile Beach in 1995.
Trifolium ambiguum	4 gh	2.2 f	7 j	10 h		-		Failed at Ninety-mile Beach in 1994.

* Backtransformed data.
† Seedling count score in any one plot : 0 = Nil; 1 = < 50/plot; 2 = >50/plot.
‡ For each column, values followed by the same letter do not differ at the 5% significance level (LSD test).

TABLE 3-1 - Mean values for 1995 assessments in Trial FR 193/2 (Effects of different rooting media).

Treatment		Survival (%)	Vigour (1=weak, 5=robust)	Plant height* (cm)	Plant spread* (cm)	Above-ground productivity* (g / 30 cm of row)
Sand		41 a†	3.8 a	41 a	64 a	185.3 a
Potting mix		48 a	3.7 a	39 a	62a	170.8 a
Species	**Rooting medium**					
Acacia sophorae	Sand	100 a	3.8 a	64 a	99 a	277.4 a
	Potting mix	100 a	3 5 a	59 a	96 a	255 7 a
Chamaecytisus palmensis 3570	Sand	1 d	3.0 a	36 ab	61 b	ND
	Potting mix	7 dc	3.5 a	46 b	52 b	ND
Lotus pedunculatus	Sand	22 bc	3.8 a	14 c	23 c	1.3 b
	Potting mix	37 b	4.0 a	13 c	25 c	0.9 b

* Backtransformed means.

† For each table column, values followed by the same letter do not differ at the 5% significance level (LSD test)

ND = Not determined (poor survival)

TABLE 4-1. Ethylene production of N-fixing species in the trial planted 1993, Ninety-mile Beach (FR193/01). November 1995 measurement.

Species	Ethylene production (nmol/core/30min)								
	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Mean 1995	Mean 1994	Mean 1993
Acacia saligna				9		17	13	394	2,349
Acacia sophorae					2058	435	1,246	3,183	4,250
Astragalus cicer									0
Chamaecytisus palmensis (3211/3218)									743
Chamaecytisus palmensis (3573)									5,818
Chamaecytisus palmensis (3820)								78	149
Dorycnium hirsutum				87		76	82	308	507
Dorycnium pentaphyllum					396		396	96	0
Dorycnium rectum					105	99	102	1,584	842
Hedysarum coronarium					10	199	104	1,201	985
Lathyrus latifolius					2098	1255	1,676	729	1,952
Lespedeza cuneata									
Lotus corniculatus					41	137	89	857	970
Lotus pedunculatus					784	1470	1,127	797	574
Lotus tenuis				54	462		258	1,318	2,070
Lupinus nootkatensis									
Medicago arborea									0
Sutherlandia frutescens									
Teline stenopetala								319	10,801
Trifolium ambiguum									8

TABLE 4-2. Ethylene production of N-fixing species in the trial planted 1993, Ninety-mile Beach (FR193/02). November 1995 measurement.

Species	Ethylene production (nmol/core/30min)								
	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Mean 1995	Mean 1994	Mean 1993
Acacia sophorae (p)			379	132			256	1093	8,070
Acacia sophorae (s)			133	153			143	1509	2,018
Chamaecytisus palmensis (3570) *(p)*									1,990
Chamaecytisus palmensis (3570) *(s)*									2,684
Lotus pedunculatus (p)			460	870			665	378	2,938
Lotus pedunculatus (s)			341	75			416	921	1,292

(p) = seedlings raised in potting mix
(s) = seedlings raised in sand

TABLE 4-3. Ethylene production of N-fixing species in the trial planted 1993, Muriwai Beach (FR193/03). November 1995 measurement.

Species	Ethylene production (nmol/core/30min)								
	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Mean 1995	Mean 1994	Mean 1993
Acacia saligna					3,873	4,854	4,364	2,064	1,026
Acacia sophorae					1,010	5,507	3,258	7,776	261
Astragalus cicer						9	9	62	145
Chamaecytisus palmensis (3211/3218)					187	700	444	506	1,460
Chamaecytisus palmensis (3573)					442	18	230	402	9
Chamaecytisus palmensis (3820)						772	772	954	231
Dorycnium hirsutum					19	8	14	0	654
Dorycnium pentaphyllum					35	112	74	697	1,936
Dorycnium rectum					36	211	124	2,889	1,780
Hedysarum coronarium	37,006				962		18,984	2,990	256
Lathyrus latifolius					1,796	12	904	196	2,511
Lespedeza cuneata								0	0
Lotus corniculatus					96	2,050	1,073	9,581	3,362
Lotus pedunculatus					416	502	459	195	2,306
Lotus tenuis					43	21	32	1,157	3,315
Lupinus nootkatensis									406
Medicago arborea								38	0
Sutherlandia frutescens								208	1,030
Teline stenopetala					32	53	42	250	52
Trifolium ambiguum								0	0

TABLE 4-4. Ethylene production of N-fixing species in the foredune trial planted 1993, Santoft Beach (FR193/04). November 1995 measurement.

Species	Ethylene production (nmol/core/30min)								
	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Mean 1995	Mean 1994	Mean 1993
Acacia saligna				869		3,469	2,154	13,209	4,973
Acacia sophorae (3066)					2,477		2,477	20,860	10,247
Acacia sophorae (3066(2))				12,224			12,224	12,436	5,562
Astragalus cicer					32	171	102	146	3,794
Chamaecytisus palmensis (3211/3218)				17	35		26	2,428	7,491
Chamaecytisus palmensis (3573)				998		108	553	3,879	8,643
Chamaecytisus palmensis (3820)				180		61	120	4,272	7,490
Dorycnium hirsutum				128	92		110	862	1,856
Dorycnium pentaphyllum				1,615	89		852	891	1,793
Dorycnium rectum				679	208		444	1,562	11,056
Hedysarum coronarium								892	24,152
Lathyrus latifolius				47,634	3,420		25,527	21,065	2,028
Lespedeza cuneata									3,697
Lotus corniculatus				874	404		639	892	7,440
Lotus pedunculatus				456	695		576	199	6,264
Lotus tenuis				234	93		164	1,592	10,203
Lupinus nootkatensis (4242)									11,026
Medicago arborea (1069)					543	703	623	184	
Sutherlandia frutescens (4072)								0	3,149
Sutherlandia frutescens (3755)								0	6,559
Teline stenopetala			1,191	3,119			2,155	3,532	10,550
Trifolium ambiguum								0	30

TABLE 4-5. Relative acetylene reduction rates. For each site ethylene production is expressed as a percentage of the highest value recorded.

Species	Ninety-mile beach FR 193/01	Ninety-mile beach FR 193/02	Muruwai beach FR 193/03	Santoft FR 193/04
Acacia saligna	<1		23	8
Acacia sophorae (raised in sand)	74	22	17	
Acacia sophorae (raised in potting mix)		38		
Acacia sophorae (3066)				10
Acacia sophorae (3066(2))				48
Astragalus cicer			<1	<1
Chamaecytisus palmensis (3211/3218)			2	<1
Chamaecytisus palmensis (3573)			1	2
Chamaecytisus palmensis (3820)			4	<1
Dorycnium hirsutum	5		<1	<1
Dorycnium pentaphyllum	24		<1	3
Dorycnium rectum	6		<1	2
Hedysarum coronarium	6		100	
Lathyrus latifolius	100		5	100
Lotus corniculatus	5		6	3
Lotus pedunculatus (raised in sand)	67	63	2	2
Lotus pedunculatus (raised in potting mix)		100		
Lotus tenuis	15		<1	<1
Medicago arborea				2
Teline stenopetala			<1	8
Trifolium ambiguum				

TABLE 5-1 - RESULTS OF THE DECEMBER 1995 ASSESSMENTS IN THE OVERSOWING TRIAL AT KAWHIA (FR 253/1).

Species	Mean no. of seedlings inside plots	Mean no. of seedlings outside plots	Maximum distance of seedlings from plot boundary (cm)	Mean seedling height (cm)	Mean seedling spread (cm)	Mean marram cover inside plots (%)	Mean "weed" cover inside plots (%)	Comments
Acacia saligna	0	0	-	-	-	20	5	Ungerminated seed found in plots. Seed found up to 240 cm outside plot.
Acacia sophorae	0	0	-	-	-	20	5	Ungerminated seed found in plots. Seed found up to 290 cm outside plot in a NE direction.
Astragalus cicer	0	0	-	-	-	20	8	Ungerminated seed found in plots. Seed found up to 100 cm outside plot. Snails frequent.
Chamaecytisus palmensis	0	0	-	-	-	19	5	Ungerminated seed found up to 150 cm outside plot.
Dorycnium hirsutum	0	1.8	5	7.0	1.0	19	9	Ungerminated seed found up to 150 cm outside plot. ?*Lathyrus* seeds found in plot.
Lathyrus latifolius	0	0	-	-	-	18	8	Ungerminated seed found up to 320 cm outside plot. *Acacia* seeds found in plot.
Lotus pedunculatus	1	0	-	6.0	3.0	20	5	Seedlings protected by marram.
Teline stenopetala	0	0	-	-	-	21	6	Ungerminated seed found up to 500 cm outside plot.

TABLE 5-2 - RESULTS OF THE DECEMBER 1995 ASSESSMENTS IN THE OVERSOWING TRIAL AT SANTOFT (FR 253/2).

Species	Mean no. of seedlings inside plots	Mean no. of seedlings outside plots	Maximum distance of seedlings from plot boundary (cm)	Mean seedling height (cm)	Mean seedling spread (cm)	Mean marram cover inside plots (%)	Mean "weed" cover inside plots (%)	Comments
Acacia saligna	0	0	-	-	-	4	4	Ungerminated seed found in plots.
Acacia sophorae	2.3	0	-	1.7	2.1	2	6	Ungerminated seed found in plots. Seedlings under marram. Some leaf tip reddening. Some chlorosis.
Astragalus cicer	1	0	-	1.2	1.2	4	2	Seedling chlorotic. *Teline* seed found in plot.
Chamaecytisus palmensis	0	0.3	ND	2.0	1.0	6	6	Ungerminated seed found in plots. Some leaflets chewed. *Lathyrus* seedlings and seed found in plot.
Dorycnium hirsutum	1.3	0	-	1.2	0.8	2	2	Reddish/yellow leaflets. *Teline* seed found in plot.
Lathyrus latifolius	3.8	+	ND	5.0	2.5	2	5	Ungerminated seed and many seed shells found in plots. Seedlings protected by marram. Some necrosis and chlorosis. *Acacia* seeds found in plots.
Lotus pedunculatus	2.8	0.3	20	2.5	2.0	4	5	Seedlings protected by marram. Some reddening and chlorosis.
Teline stenopetala	0	0	-	-	-	1	3	Ungerminated seed found in plots.

TABLE 5-3 - SEEDLING COUNTS IN THE FR 253 OVERSOWING TRIALS.

Species	Total number of seedlings found			
	Kawhia Trial		Santoft Trial	
	December 1995	April 1996	December 1995	April 1996
Acacia saligna	0	0	0	0
Acacia sophorae	0	0	9	73
Astragalus cicer	0	0	4	49
Chamaecytisus palmensis	0	0	1	0
Dorycnium hirsutum	7	1	5	1
Lathyrus latifolius	0	0	15	8
Lotus pedunculatus	4	7	12	10
Teline stenopetala	0	0	0	32

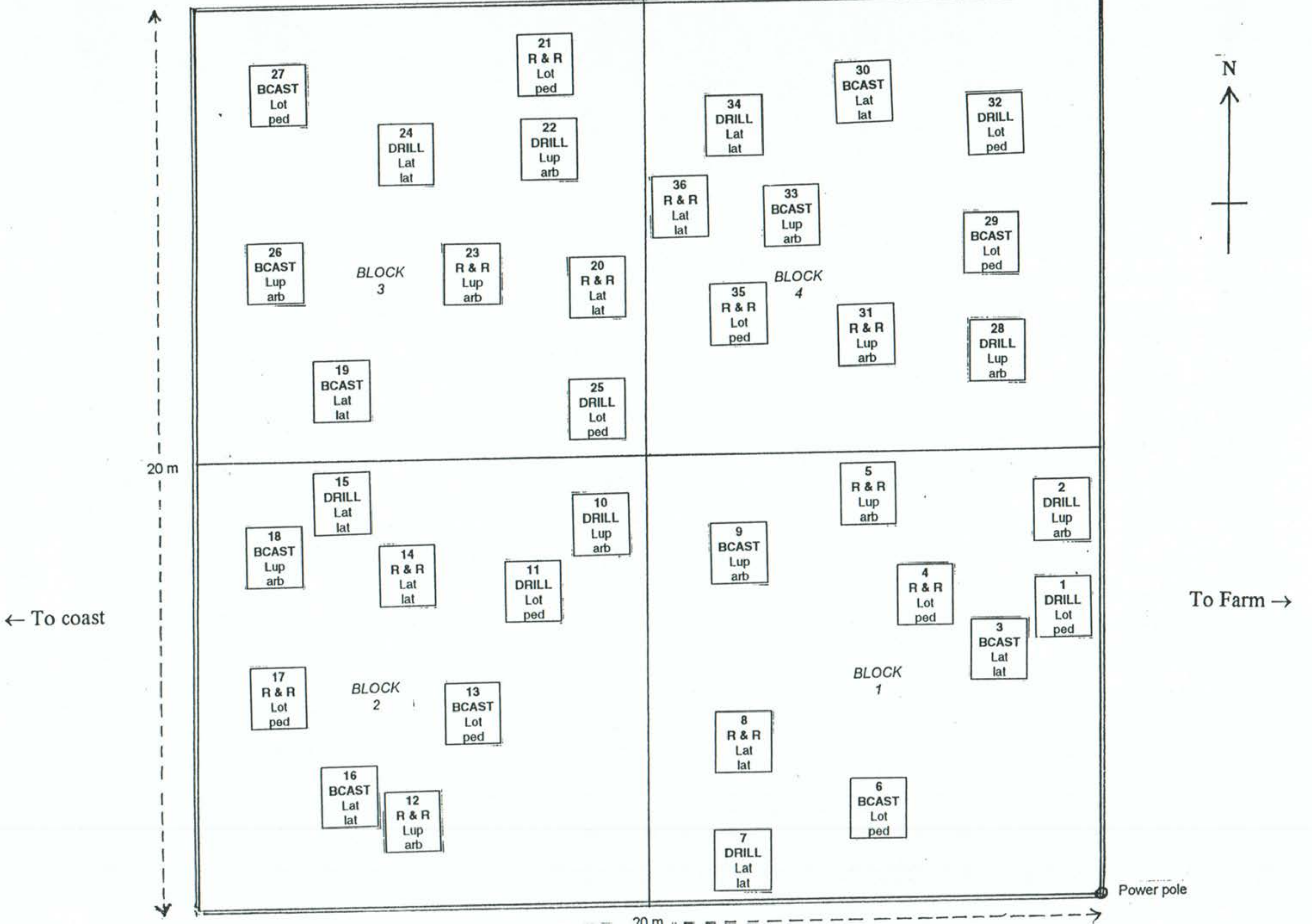
TABLE 5-4 - RESULTS OF THE APRIL 1996 ASSESSMENT IN THE OVERSOWING TRIAL AT

SANTOFT (FR 253/2).

Species	Mean no. of seedlings inside plots	Mean no. of seedlings outside plots	Maximum distance of seedlings from plot boundary (cm)	Mean seedling height (cm)	Mean seedling spread (cm)	Mean marram cover inside plots (%)	Mean "weed" cover inside plots (%)	Comments
Acacia saligna	0	0	-	-	-			
Acacia sophorae	16.5	1.8	52	1.5	2.0	1	5	Some chlorotic seedlings.
Astragalus cicer	10.0	2.3	85	1.3	1.6	3	2	Many seedlings chlorotic.
Chamaecytisus palmensis	0	0	-	-	-			
Dorycnium hirsutum	0.3	0	-	2.0	1.0	1	1	
Lathyrus latifolius	1.8	0.3	18	3.4	2.8	2	4	Ungerminated seed found in plots. Slight chlorosis. Slight insect damage.
Lotus pedunculatus	1.5	1.0	20	2.7	11.3	4	4	Some chlorosis.
Teline stenopetala	0.8	7.3	30	1.0	1.0	1	2	

Fig 6-1 - 1996 OVERSOWING TRIAL - FR 253/3, KAWHIA.

Trial layout (not to scale)



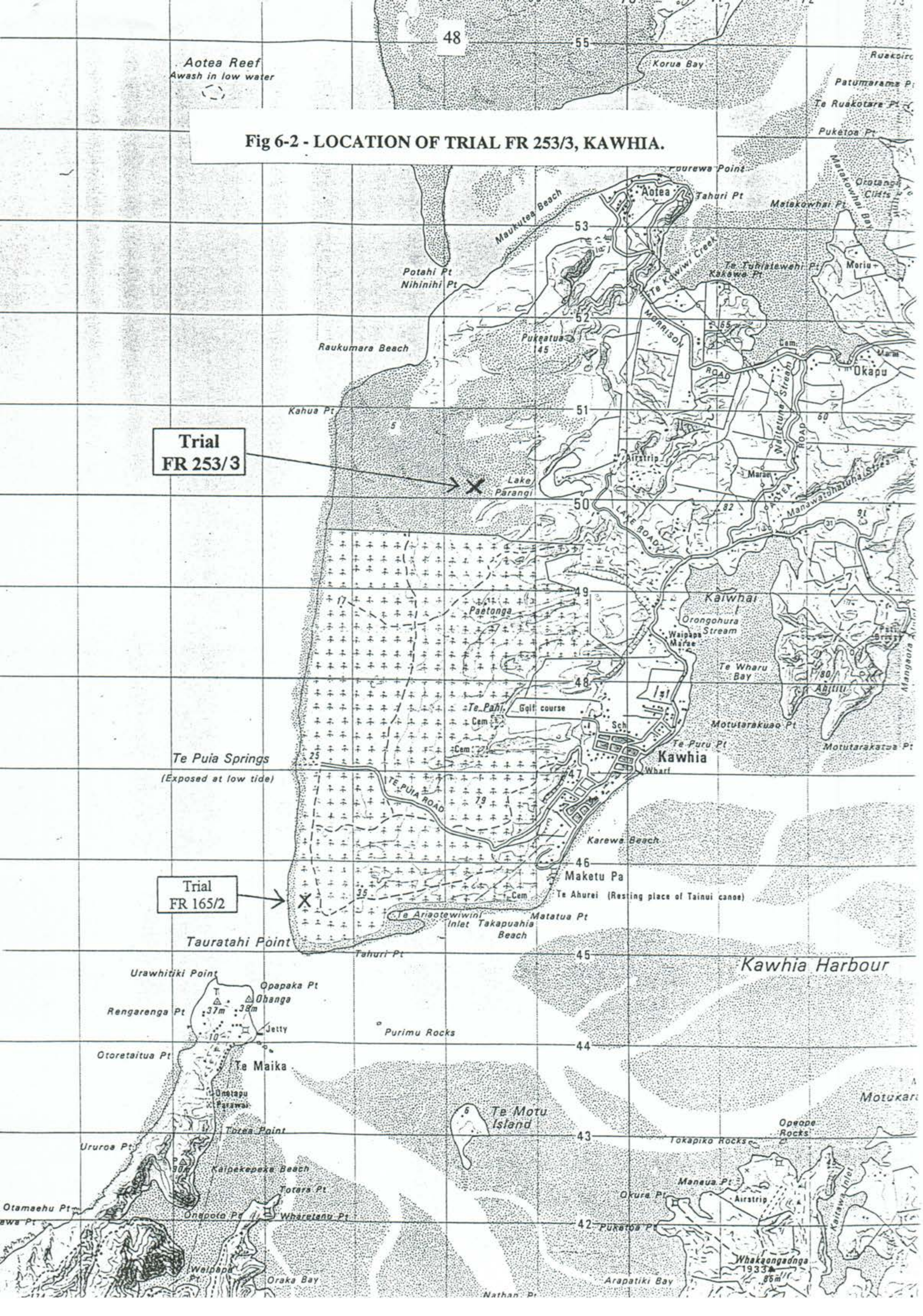
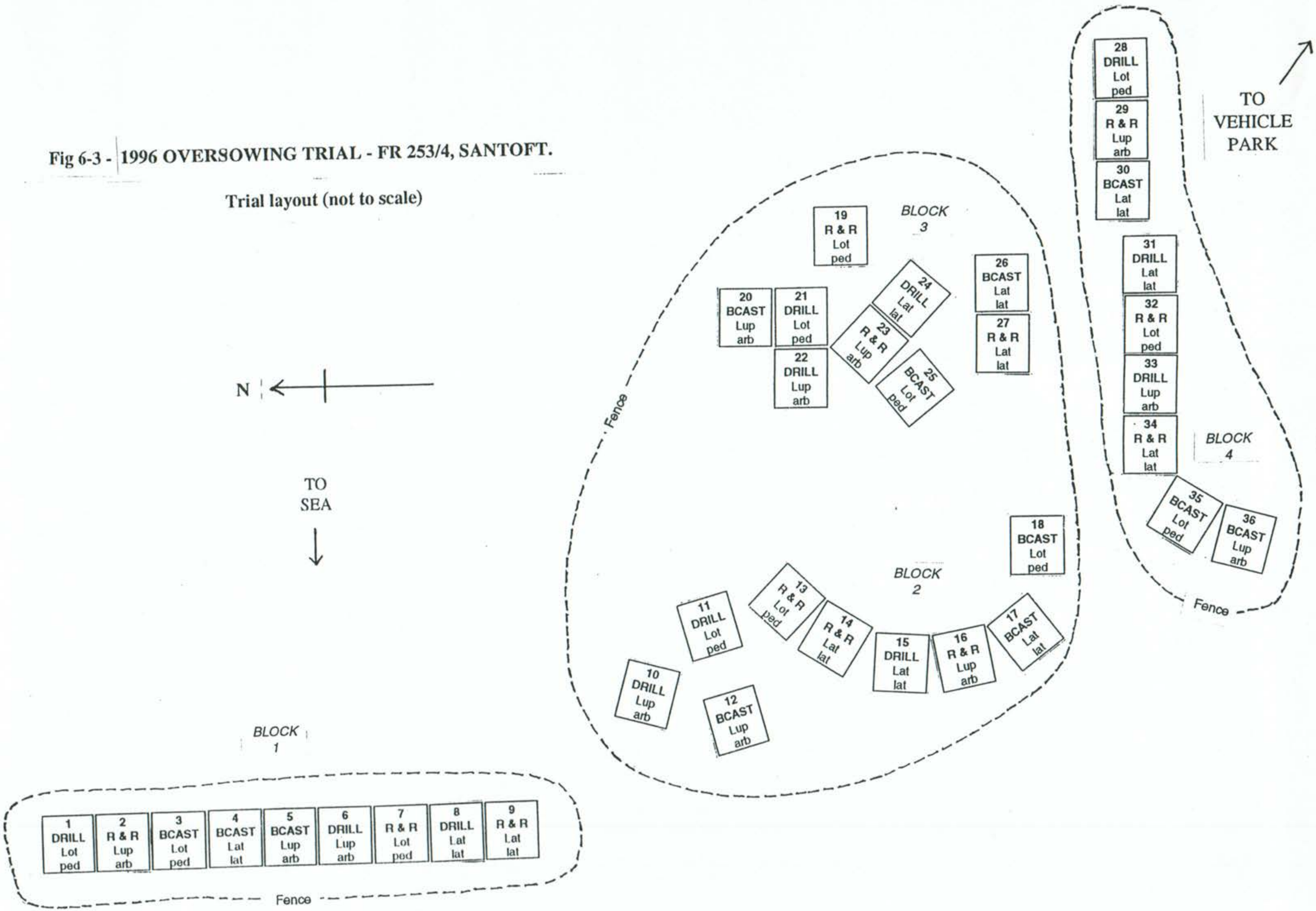


Fig 6-2 - LOCATION OF TRIAL FR 253/3, KAWHIA.

Fig 6-3 - 1996 OVERSOWING TRIAL - FR 253/4, SANTOFT.

Trial layout (not to scale)



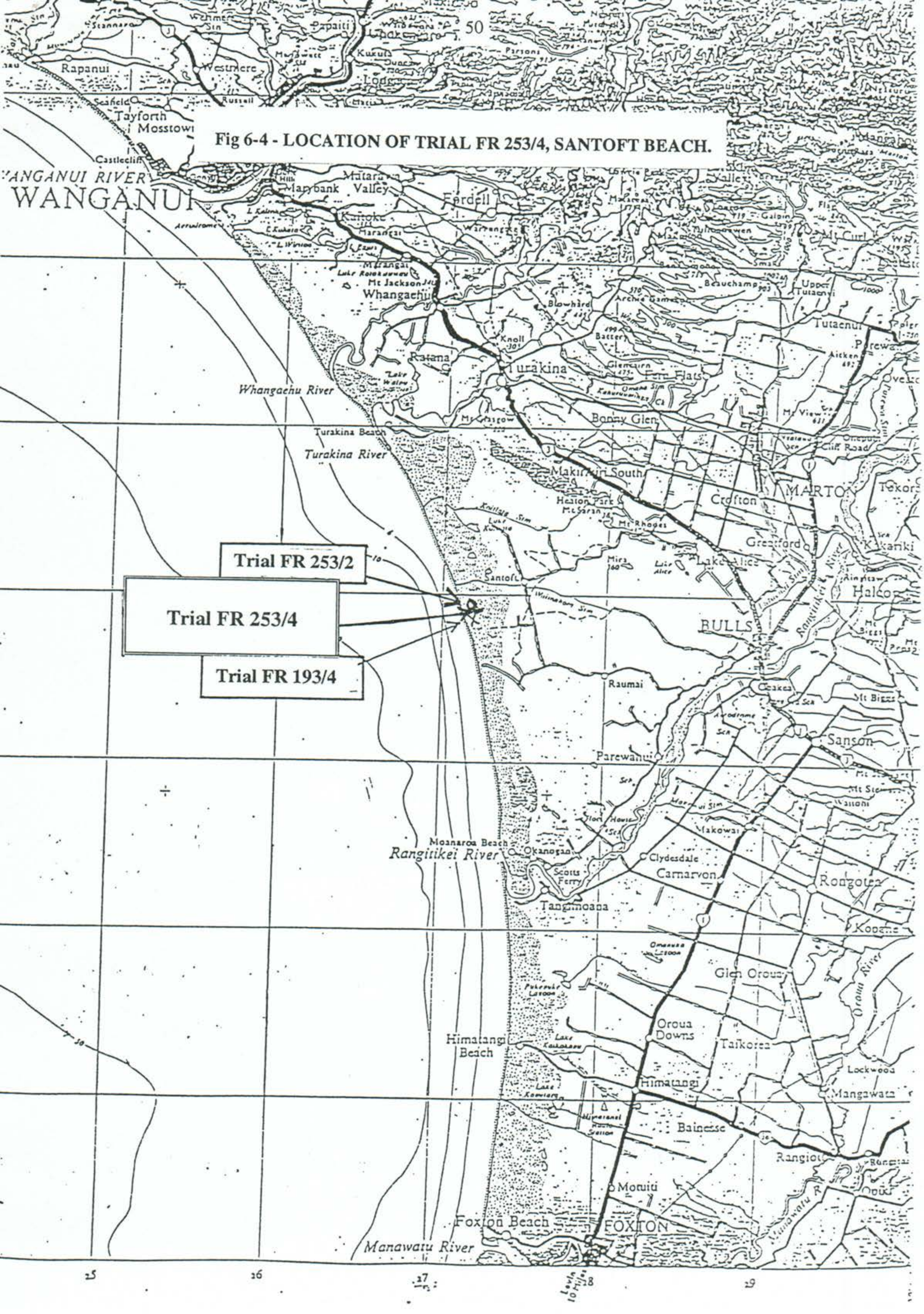


Fig 6-4 - LOCATION OF TRIAL FR 253/4, SANTOFT BEACH.

APPENDIX 1

Conversion of ppm ethylene to nmol ethylene for small and large agee jar volumes

Given:
Gas volume in a large agee jar = 1040 ml

Gas volume in a small agee jar = 550 ml

Gas volume in a large agee jar with half a core of sand + root sample
= jar volume - sample volume
= 1040 - (volume of core * 0.5 / particle density of sand)
= 1040 - (778.7 * 0.5 / 2.6)
= 1040 - 150
= 890 ml

Gas volume in a small agee jar with half a core of sand + root sample
= 550 - 150
= 400 ml

Conversion of ppm ethylene to nmol ethylene:

	1 mol C_2H_4	=	28g C_2H_4 (at STP)
		=	22.4 L
⇒	1 μL	=	44.64 nmol C_2H_4
∴	1 ppm	=	44.64 nmol C_2H_4 / L
∴	1 ppm	=	24.55 nmol C_2H_4 / 550ml
∴	1 ppm	=	46.43 nmol C_2H_4 / 1040ml
∴	1 ppm	=	17.9 nmol C_2H_4 / 400ml
∴	1 ppm	=	39.7 nmol C_2H_4 / 890ml
