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TITLE: 1993-94 REPORTS ON SAND REVEGETATION TRIALS USING NITROGEN-FIXING PLANTS.

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ABSTRACT*

This report documents the achievement of Objective 1 of FRST Contract CO4301 (Programme 93 FRI 08 416 - Revegetation of sand dunes). The report is in five sections.

1. **Assessments of relative plant growth performance after 1½ -2 yr in trials established in 1991-92.** Relative survival rate, vigour, maximum plant height, maximum plant spread and above-ground dry matter production in Spring 1993 were determined for nitrogen(N)-fixing species still present in the six 1991-92 spaced-plant trials located in four North Island sand dune areas. Mortality rates were lower than those observed in the first year after transplanting. Losses were mainly associated with rabbit browsing and burial by drifting sand, but these factors did not account for lower overall productivity noted at the northernmost site (Ninety-mile Beach). Highest values for survival, vigour and productivity over a range of sites were observed in *Acacia sophorae* and *Acacia saligna.* Other species that performed best under specific sets of conditions were *Chamaecytisus palmensis, Lotus pedunculatus, Teline stenopetala, Dorycnium hirsutum, Lotus tenuis and Medicago arborea. Lupinus arboreus* gave the highest values for all variables except vigour in trials where it had been included.

2. **Assessments of relative plant growth performance after 6 months in trials established in 1993.** In Spring 1993, relative survival rate, vigour, maximum plant height, maximum plant spread and above-ground dry matter production were determined for 18 species of N-fixing plants in three trials established in May 1993. Overall survival and growth were best at Santoft Beach, poorest at Ninety-mile Beach and intermediate at Muriwai Beach, where there was evidence of browsing in spite of rabbit-proof fencing. At this early stage in the study *Lotus tenuis* was the best performer overall and *Lespedeza cuneata* was the poorest. Relative ranking is expected to change in response to summer drought conditions.

3. **Assessments of relative plant growth performance in a 6-month-old trial comparing the effects of potting mix and local sand as media for raising seedlings used in spaced-plant trials.** Relative survival rate, vigour, maximum plant height, maximum plant spread and above-ground dry matter production in Spring 1993 were determined for three species raised and planted in either potting mix or local sand, at Ninety-mile Beach. The type of medium did not affect overall survival

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*** Note: This material is unpublished and must not be cited as a literature reference.**

or dry matter production, but greater height and spread were observed in plants raised in potting mix. *Chamaecytisus palmensis* survived better and produced slightly shorter plants in local sand than in potting mix. No effect of medium on the individual species performance of *Acacia sophorae* or *Lotus pedunculatus* could be detected at this stage.

4. **Assessments of relative N-fixing potential of plants in trials established in 1991, 1992 and 1993.** Acetylene reduction assays were carried out on all species in all trials described in Sections 1,2 and 3 of this report. Greatest N-fixing activity was found in *Acacia sophorae* and *Chamaecytisus palmensis* in trials established in 1991. In the 1992 Santoft C trial, highest values were observed in *Hedysarum coronarium.* In Trials FR193/1, /3 and /4, the highest N-fixing potential after 6 months was recorded for *Teline stenopetala* at Ninety-mile Beach, *Lotus corniculatus* at Muriwai Beach and *Hedysarum coronarium* at Santoft Beach. The effect on N-fixation potential of the medium used to raise the plants was not consistent among the three species tested. For *Acacia sophorae* and *Lotus pedunculatus*, N-fixation rate was higher in plants raised in potting mix than in those raised in sand. *Chamaecytisus palmensis* showed a higher N-fixation rate in plants raised in sand.

5. **Progress made in reviewing the weed potential of species used in the spaced-plant trials.** A literature search for information on the potential for undesirable dissemination of the 18 species used in the above trials is almost complete. A summary review for each species, including any information on known control methods, is being prepared.

1993-94 REPORTS ON SAND REVEGETATION TRIALS USING NITROGEN-FIXING SPECIES

NZ FRI Project Record No. 4104

CONTENTS

BACKGROUND

The NZFRI Sand Dune Revegetation research programme encompasses work which is funded from two sources. Research in sand dune forests is supported by a consortium of sand forest owners, known as the Lupin Disease Research Group. Work on the open dunes is seen as public good research, and is funded by the Foundation for Research, Science and Technology, until at least the end of 1996.

Work on the open dunes is divided into two main projects. One of these is concerned with the restoration of native vegetation and an assessment of the extent to which indigenous plants will assist in dune stabilisation. The other project is concerned with finding a replacement for yellow tree lupin (*Lupinus arboreus*) as a component of the artificial vegetation succession which, since the turn of the century, has proved to be effective in stabilising sand dunes. The onset of lupin blight has necessitated a search for alternative nitrogen (N)-fixing species. Biological N-fixation is considered to be cheaper and more efficient than fertiliser application as a means of raising the N content of the sand dune ecosystem to the point where an effective vegetation cover can be sustained.

Under Objective 1 of the FRST-funded Sand Dune Revegetation Programme, NZFRI was contracted to perform the following tasks:

Investigate the potential of up to 20 N-fixing plant species as alternatives to yellow tree lupin in the artificial vegetation succession used to prevent coastal sand dune erosion.

* Assess, in November 1993, the performance of surviving species planted in six screening trials in 1991/92.

* Assess, in November 1993, the performance of 20 species planted in three standardised screening trials in Autumn 1993.

* Assess, in November 1993, the relative performance of plants in a 1993 trial designed to compare the effects of local sand and potting mix used to raise the seedlings.

* Begin to investigate the weed potential of each species used in the above trials.

* Consult land managers and identify the most effective methods of publicising interim and final recommendations of the research programme.

Prepare two 6-monthly progress reports for the NZ Forest Research Institute CEO.

This Project Record completes the 1993-94 work by providing reports on :

1. Assessments of relative plant growth performance after 1½ -2 yr in trials established in 1991-92.

2. Assessments of relative plant growth performance after 6 months in trials established in 1993.

3. Assessments of relative plant growth performance in a 6-month-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 N-fixing potential of plants in trials established in 1991, 1992 and 1993.

5. Progress made in reviewing the weed potential of species used in the spaced-plant trials.

Progress with consultation of land managers to determine effective means of publicising research results has already been reported (Gadgil. Douglas, Skinner, Sandberg and Lowe, 1994).

1. ASSESSMENTS OF RELATIVE PLANT GROWTH PERFORMANCE AFTER 1½ -2 YR IN TRIALS ESTABLISHED IN 1991-92.

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(c/o NZ FOREST RESEARCH INSTITUTE)

AND

GRANT DOUGLAS

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INTRODUCTION

Details of the establishment and first-year performance of plants in the three FR 165 series trials (Ninety-mile Beach, Kawhia and Harakeke) and in three trials designated A, B and C at Santoft Beach, have been documented by Gadgil and Sandberg (1992a; 1992b), Lowe (1992) and Gadgil, Douglas, Sandberg and Lowe (1993). Tables 1-1 and 1-2 summarise details of location, site characteristics and layout of the six trials. Assessments made in November/December 1993, after 2 years' field growth, indicated maximum survival rates of 51% at Kawhia (*Acacia saligna*); 42% at Harakeke (*Chamaecytisus palmensis*) and 18% at Ninety-mile Beach (*Acacia sophorae*). In the Santoft Beach C trial, which was established 6 months later than the other 5 trials, several species showed survival rates between 70 and 80% (Gadgil *et al* 1994). This report presents the results of plant measurements made in all six trials in November/December 1993.

METHODS

Starting with the most northerly trial and working south, measurements were made between late October and early December 1993. The vigour of plants in each experimental plot was scored on a scale of 1 (weak) to 5 (robust), and the height and maximum spread of each surviving plant was recorded. Where individual plants could not be distinguished, estimates of the percentage of the plot covered, mean height (from 10 random measurements) and maximum height were made. One plant per plot with height and spread nearest to the plot mean, or, in the case of low survival rate, the species mean, was destructively sampled and the mean oven-dry weight of tops/plant/plot (or tops/plant/species) was determined. Where cover estimates had been made,all material was sampled within a vertical projection of a square centred on the original planting position, with side length equal to that of the original distance between plants.

Overall performance was so poor in the unfenced A and B trials at Santoft that statistical analysis of the measurement data was impossible. For all other trial sites, values for mean height and mean maximum spread were subjected to analysis of variance, and species characteristics were compared using the Least Significant Difference test. Dry weight data were not analysed statistically because they had been collected by different methods.

RESULTS

Table 1-3 shows that in the three FR 165 trials, more species received vigour ratings of 4-5 at Harakeke (total 6) than at Kawhia (3) or Ninety-mile Beach (2). Mean height and spread of most species tended to increase with latitude although this trend was not tested statistically. Above-ground dry matter production, or herbage mass, reflected vigour within species and it was clear that productivity was greater at the two more southerly sites. Species with the best combination of survival, vigour and productivity were *Acacia sophorae, Chamaecytisus palmensis* and *Acacia saligna* at Ninety-mile Beach, *Acacia sophorae, Acacia saligna* and *Lotus pedunculatus* at Kawhia; *Teline stenopetala, Chamaecytisus palmensis* and *Acacia sophorae* at Harakeke, *Lupinus arboreus* at Santoft Site A (Table 1-4); *Lupinus arboreus, Dorycnium hirsutum* and *Chamaecytisus palmensis* at Santoft Site B (Table 1-5). Among the younger Santoft Site C plants, *Medicago arborea, Acacia sophorae* and *Lotus tenuis* showed the best survival/vigour/productivity combination (Table 1-6). Part of the Santoft C trial was buried by drifting sand, a factor that would have increased variability both within and between the species affected.

Several species were flowering and seed pods had formed in *Chamaecytisus palmensis* (Kawhia; Harakeke), *Teline stenopetala* (Kawhia; Harakeke), *Sutherlandia frutescens* (Harakeke), *Hedysarum coronarium* (Santoft C) and *Medicago arborea* (Santoft C). One seedling of *Sutherlandia frutescens* was found at Harakeke and several of *Dorycnium hirsutum, Lotus corniculatus* and *Lotus tenuis* at Santoft Site C.

DISCUSSION

Because the 1991-92 trials were diverse in terms of layout. fencing, seedling treatment before trans-planting, and species used, care must be taken in making comparisons between trials. Comparisons with data from a previous assessment (Gadgil *et al*, 1993) suggested that in all trials the mortality rate was lower in the second year after transplanting than during the first year. Species which were represented at the Spring 1992 assessment but disappeared during the following year were *Lotus corniculatus* at Ninety-mile Beach, *Sutherlandia frutescens* at Kawhia and *Vicia sepium* at the Santoft B site. Losses greater than 5% during this 12 month period were recorded for *Teline stenopetala* (9%) and *Trifolium ambiguum* (7%) at Ninety-mile Beach; *Lotus corniculatus* (13%) and *Trifolium ambiguum* (17%) at Kawhia; *Sutherlandia frutescens* (18%) at Harakeke; *Chamaecytisus palmensis* (41%), *Lathyrus latifolius* (8%), *Lotus tenuis* (40%) and *Lupinus arboreus* (6%) at Santoft Site A; *Acacia saligna* (7%), *Hedysarum coronarium* (13%), *Hippophae rhamnoides* (7%) and *Lotus corniculatus* (20%) at Santoft Site C.

Low productivity in the unfenced Santoft A and B trials was at least partly due to browsing by rabbits. This observation is consistent with the relatively high survival rates noted after 1½ years for several species in the fenced Santoft C trial (*Acacia saligna, Acacia sophorae, Casuarina glauca, Medicago arborea)* that were not inundated with sand. In the fenced trial at Ninety-mile Beach, productivity was low in comparison with that of the other two trials in the FR 165 series. This could not have been due to browsing. Meteorological and other site data shown in Table 1-1 do not suggest any particular factor that might have been involved but higher soil moisture deficits and higher evapotranspiration losses at the warmer site could have been responsible.

The 1991-92 trials have revealed a range of growth performance from N-fixing species planted out on the open dunes. Ground cover of over 60% can be achieved within two years by plants spaced at 50 x 50 cm even when the survival rate is only 40% (*Acacia sophorae* at Kawhia). The relatively high dry matter production rates and reproductive potential observed for *Acacia saligna*, *Acacia sophorae*, *Chamaecytisus palmensis* and *Teline stenopetala* may prove to be too great for some sand dune situations, since they are likely to be associated with the suppression of other species. It is, however possible that such species will provide the only practical means of rapidly achieving an effective vegetation cover in areas where sand drift is an economic or physical threat to neighbouring areas.

The relative growth performance of *Lupinus arboreus* in Santoft trials A and B was greater than might have been expected from Williams' (1993) account of the disease caused by *Colletotrichum gloeosporioides*. Although at both sites the plants were only moderately vigorous, showing signs of both lupin blight and defoliation, the survival rate was superior to or less variable than that of all other species at Site A. At Site B none of the planted species, including *Lupinus arboreus,* showed consistent survival rates. Plant height, spread and above-ground dry matter production were all greater for lupin than for those of other species selected for screening under the same conditions.

ACKNOWLEDGMENTS

We would like to thank Mark Kimberley for performing the statistical analyses, also Alison Lowe, Steve Pearce and Lex Foote who assisted with field work.

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2. ASSESSMENTS OF RELATIVE PLANT GROWTH PERFORMANCE AFTER 6 MONTHS IN TRIALS ESTABLISHED IN 1993.

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INTRODUCTION

Details of the location, establishment and layout of the 1993 spaced-plant trials have been described by Gadgil, Douglas, Sandberg and Lowe (1993). The aim of the FR 193 trial series was the comparison of the performance of 18 nitrogen-fixing species (one represented by three different accessions) when planted out at three different sand dune sites: Ninety-mile Beach (Trial FR 193/1); Muriwai Beach (Trial FR 193/3); and Santoft Beach (Trial FR 193/4). Because care had been taken to standardise seedling preparation, planting techniques and plot layout, between-site differences in species performance were expected to be related mainly to differences in local climate and sand type.

Each of the three trials consisted of six randomised complete blocks of single-species plots. Plants were allocated to blocks on the basis of relative size at time of transplanting so that Block 1 contained the smallest, and Block 6 the largest plants of each species. Overall distribution of plant sizes was similar at each site. Each individual plot was a row of up to 15 plants at 30cm spacing.

This report documents the results of the first assessment of plant growth carried out in the Spring of 1993, 6 months after transplanting. Survival data have already been presented by Gadgil, Douglas, Skinner, Sandberg and Lowe (1994).

METHODS

Starting at Ninety-mile Beach and working southwards, measurements were made in each trial between late October and early December 1993 on dates that were staggered to allow a six month interval from the date of transplanting. Plant vigour on a scale of 1 (= weak) to 5 (= robust) was assessed in each plot. The maximum height and maximum spread (diameter measured at right angles to the planting line) of each plant were recorded and the plant with height and spread closest to the plot mean was harvested. Where only one plant had survived in a plot there was no harvest. Tops of the selected plants were severed at ground level, and their oven-dry weights were determined.

Data for mean height, spread and top dry weight per plot were subjected to analysis of variance after logarithmic transformation. Mean values were compared using the Least Significant Difference Test.

RESULTS

Survival data from an earlier progress report (Gadgil *et al.* 1994) are re-presented in the current format. All values shown in Tables 2-1 to 2-5 are real (i.e. untransformed) means. Letters used to indicate statistically significant differences have been allocated according to tests carried out on transformed data and this has led to some apparent anomalies in cases where variablity was high.

The effects of site, species, and site/species interaction on the four variables tested (mean survival, mean height, mean spread and mean herbage mass) were all highly significant (p = > 0.001). Considerable between-plot variability was observed at all sites, but a mean survival rate of 50% or more was recorded for many species (Table 2-1). Total establishment failure occurred only for two species (*Lespedeza cuneata* and *Sutherlandia frutescens*) and then only at one site (Ninety-mile Beach).

Table 2-1 shows that overall survival and growth were always best at Santoft Beach and poorest at Ninety-mile Beach. Species which did not conform to this pattern were *Dorycnium rectum*, *Lotus pedunculatus*, *Lotus tenuis* and *Medicago arborea*, which survived equally well at all sites (but tended to produce bigger plants at Santoft); *Lespedeza cuneata*, which had not grown well at any site, and *Teline stenopetala* which survived best at Muriwai Beach but grew best at Santoft.

Overall survival and species characteristics in Table 2-2 indicate the relatively poor performance of *Lespedeza cuneata*; high survival rates of *Lotus tenuis*, *Lotus pedunculatus* and *Medicago arborea*; and superior dry matter production by *Lotus tenuis*.

Comparative data for species at the individual trial sites (Tables 2-3, 2-4 and 2-5) show the effects of dieback and defoliation in many species at Ninety-mile Beach, and of heavy browsing at Muriwai Beach. *Lotus pedunculatus*, *Lotus tenuis* and *Medicago arborea* survived best at Ninety-mile Beach and Muriwai Beach and at both sites *Lotus tenuis* produced the greatest amount of dry matter. At Santoft Beach several species showed survival rates equivalent to those of *Lotus tenuis*, *Lotus pedunculatus* and *Medicago arborea*, which again were the highest for the site. Here the greatest dry matter production was recorded for *Lotus tenuis, Lotus pedunculatus, Lotus corniculatus* and *Lespedeza cuneata.*

DISCUSSION

Relative growth performance over this 6-month period reflected the response of the different species to conditions on the open dunes during the winter months. Exposure to strong winds and salt spray would probably have been the main inhibitory influence during this period: sand moisture conditions were likely to have been at the most favourable levels during the cooler part of the year.

Browsing damage observed in the Muriwai Beach trial was unexpected. Large numbers of droppings provided evidence that rabbits or hares were responsible. There was no sign of damage to the fence or of burrowing and it must be concluded either that rabbits were trapped inside the fenced area (none were seen during planting or measurement sessions) or that hares were not excluded by the 50 cm high chicken wire. The inadequacy of the fencing introduced an additional variable at the Muriwai Beach site and results for all browsed species must be treated with caution when making comparisons with other sites or with data for unpalatable species in this trial.

There is no doubt that important site differences existed between the three areas chosen for the trials and that these tended to affect most of the test species in the same way. Results from this trial series support observations made in the older FR 165 trials which suggest a general trend of improved growth performance as latitude increases (see Section 1 of this report). This trend is more likely to be associated with climate differences than with sand type, but the main influence has not yet been identified. Summer drought may be involved but is clearly not the only factor, since the effects were apparent immediately after the winter establishment period.

Differential species responses to local conditions were superimposed on the overall "north-south"trend. *Lespedeza cuneata* was among the poorest performers at all sites. It should be noted that seedlings of this species were very relatively small when transplanted (Gadgil *et al*, 1993). The high performance ranking of *Lotus tenuis* at all sites was probably related to its prostrate growth habit. It will be interesting to see whether this species retains its ranking after exposure to summer drought and high temperatures. Some changes in relative species performance can be expected at the next assessment (due in Spring 1994) and it is probably not appropriate to place too much emphasis on differences observed at this early stage.

ACKNOWLEDGMENTS

We are most grateful to Mark Kimberley for performing the statistical analyses and to Steve Pearce, Alison Lowe and Lex Foote for assistance in the field.

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3. ASSESSMENTS OF RELATIVE PLANT PERFORMANCE IN A 6-MONTH-OLD TRIAL COMPARING THE EFFECTS OF POTTING MIX AND LOCAL SAND AS MEDIA FOR RAISING SEEDLINGS USED IN SPACED-PLANT TRIALS

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INTRODUCTION

In May 1993 a trial was established in the unused part of an area at Ninety-Mile Beach, that was fenced against rabbits for Trial FR165/01. The object of the trial was to compare the effects of local sand and of potting compost on the long-term growth and N-fixing performance of three species (a herb, a shrub and a tree) selected from species which survived and grew for at least one year in the 1991-92 trials, FR165/1,2,3.

Details of the site and layout of this trial (FR 193/02)have been recorded (Gadgil, Douglas, Sandberg and Lowe,1993)

METHODS

In November 1993 maximum height and spread of all plants in each block were recorded. Plant vigour was assessed in each plot.

Two representative plants of each species per treatment were destructively sampled to determine above-ground dry matter production (oven-dry weight of tops/plant) and nitrogenase activity.

Data for survival, mean height, mean spread and dry weight were subjected to analysis of variance. Comparisons between species and treatment were made using the Least Significant Difference Test.

RESULTS

Survival of *Acacia sophorae* and *Lotus pedunculatus* plants was superior to that of *Chamaecytisus palmensis* plants (Table 3-1). *Chamaecytisus palmensis* raised in local sand had a better survival rate (41%) than in potting compost(18%).

Overall height and spread of plants were greater in potting compost than in sand. There were no significant differences in weight between species or growth medium. This was probably due to the small number of samples taken for destructive sampling.

Acacia plants raised in local sand showed less dieback and leaf scorch than those raised in potting compost. There was much dieback in *Chamaecytisus palmensis* . Many *Lotus* plants appeared to have died off at the centre.

Table 3-2 shows that only *Acacia* plants raised in sand had an overall growth and weight increase of tops since planting, while lotus in sand decreased in growth and weight of tops.

A further assessment in spring 1994 will be carried out.

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4. ASSESSMENTS OF RELATIVE N-FIXING POTENTIAL OF PLANTS IN TRIALSESTABLISHED IN 1991, 1992 AND 1993

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INTRODUCTION

Measurement of relative nitrogenase activity was the method selected for providing estimates of the N-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 N_2-fixing species to supply N in the sand-dune revegetation trials funded by FRST in the 1993/94 financial year. The trials are described in sections 1, 2 and 3 of this report . Selected species were incubated in the field and the rate of ethylene production from acetylene has been reported as an estimate of the relative N-fixing potential.

METHODS

Acetylene (C_2H_2) production

Acetylene for the incubations 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 samples of each species from the trials described in previous sections in this report were assessed for their relative N-fixing potential. After the top was severed for biomass determination, the root system was removed using a metal corer (108mm diameter x 85mm deep). The corer was placed over the centre of the root system to incorporate the majority of the root system of the harvested plant. This was then lifted and most of the sand separated from the root system by passing it through a 2mm soil sieve. The acacia species at Kawhia (FR 165/02) were very large, therefore a larger square metal sampler (0.5m x 0.5m square x 85mm deep) was used and included the majority of the root system. Depending on the size of the root system, it was placed in either a 550ml or 1000ml Agee jar with a seal top. 50 ml of air was removed from the jar and 50 ml of acetylene was added, via a syringe, through a rubber bung in the lid of the jar. If a 1000ml jar was used then 100ml of air was removed and 100ml of acetylene added. The syringe was pumped 3 times to ensure thorough mixing of the acetylene. This gave a concentration of 9.1% acetylene in the 550ml jar and 9.6% acetylene in the 1040ml jar. Blank gas samples (the prepared acetylene mixed with air in a jar as described but without a root system) 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. The jar was then placed in the shade to approximate existing soil temperature conditions. After approximately 30 minutes the gas in the jar was mixed by pumping with the sample syringe and a gas sample was collected. The gas samples remained in the syringes with the needle tips inserted into rubber and were transported back to the laboratory for ethylene analysis. The time the gas sample was taken was recorded to determine and correct for the incubation period.

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 ^oC
Column	Glass, 5' x ¼" I.D., Poropak N (50-100 mesh)
Carrier gas	N_2
Oven temperature	95 ^oC
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. 1000ppm ethylene was used to determine the slope of the curve, R, where R = peak area / ethylene concentration. 1000ppm was injected periodically throughout sample analysis as a system check. Where duplicate samples were taken ethylene peak ares were averaged. The background level (peak area) of ethylene in the acetylene used, 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 / plant / 30 minutes.

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

s	=	mean sample peak area
b	=	mean blank peak area
R	=	slope of calibration curve (1000ppm peak area/1000)
inc	=	incubation time (minutes)
vol. cf	=	46.43 (conversion of ppm to nmol in large agee jar)*
		24.55 (conversion of ppm to nmol in small agee jar)*

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

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

RESULTS AND DISCUSSION

Results for the amount of ethylene produced per sample over a 30 minute incubation for each of the trial sites are presented in Tables 4-1 to 4-10. Results are variable due to variability in the size and degree of nodulation between plant replicates.

The surviving species with the highest rates of ethylene production in the trials established in 1991 were *Acacia sophorae* at both Ninety-mile Beach and Kawhia, *Chamaecytisus palmensis* at Harakeke and both trials in Santoft Forest. *Hedysarum coronarium* had the highest rate of ethylene production in the trial established in Santoft in 1992. The surviving species with the highest rates of ethylene production in the trials established in 1993 were *Teline stenopetala* at Ninety-mile beach, *Lotus corniculatus* at Woodhill, and *Hedysarum coronarium* at Santoft Forest.

Results presented in Table 4-5 from the trial established at Ninety-mile beach in 1993 show that both *Acacia sophorae* and *Lotus pedunculatus* were fixing more nitrogen after being raised in potting mix compared to sand. *Chamaecytisus palmensis* is fixing slightly more nitrogen after being raised in sand.

Table 4-11 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.

REFERENCES

Hardy, R.W.F. and Knight E. JR. (1967) ATP-dependent reduction of azide and HCN by N_2-fixing enzymes of *Azotobacter vinelandii* and *Clostridium pasteurianum. Biochim. Biophys. Acta 139,* 69-90.

Hardy, R.W.F., Burns, R.C. and Holsten R.D. (1973) Applications of the acetylene-ethylene assay for measurement of nitrogen fixation. *Soil Biol. Biochem. Vol.* 5, 47-81.

5. PROGRESS MADE IN REVIEWING THE WEED POTENTIAL OF SPECIES USED IN THE SPACED-PLANT TRIALS

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The literature relevant to factors affecting the weedy potential of 18 species being trialled as substitutes for lupin in sand dune reclamation has largely been searched and some progress has been made in preparing a review. The species being investigated are *Acacia saligna* (syn. *A. cyanophylla*), *Acacia sophorae* (syn. *A. longifolia* var. *sophorae*), *Astragalus cicer*, *Chamaecytisus palmensis*, *Dorycnium hirsutum*, *D. pentaphyllum*, *D. rectum*, *Hedysarum coronarium*, *Lathyrus latifolius*, *Lespedeza cuneata*, *Lotus corniculatus*, *L. pedunculatus*, *L. tenuis*, *Lupinus nootkatensis*, *Medicago arborea*, *Sutherlandia frutescens*, *Teline stenopetala* and *Trifolium ambiguum*.

In the investigation particular attention has been given to characteristics of significance to weedy potential including reproduction and dissemination characteristics, rate of spread, special nuisance factors and known facts on control. A brief preliminary summary of the relevant factors found to date for each species has been prepared and can be made available if required. Very little information has been found on four of the species, *Dorycnium rectum*, *Lupinus nootkatensis*, *Teline stenopetala* and *Sutherlandia frutescens*.

There is a particularly significant amount of information from South Africa pertaining to the weedy potential of the two species of *Acacia*, *A. saligna* and *A. sophorae*. These species were introduced to South Africa for sand dune stabilisation over 100 years ago (*A. sophorae* as *A. longifolia* var. *sophorae*). They have since spread from the sand dunes invading and transforming natural habitats and landscapes and ousting natural vegetation. The extent of the impact of these and another *Acacia* species introduced for the same purpose, *A. cyclops*, has been such that the present policy is to stabilise areas only when absolutely necessary and then using indigenous species. The Directorate of Forestry in South Africa has been actively involved in removing these species from areas of natural vegetation and older stabilisation sites along the coast.

In New Zealand, although *A. longifolia* var. *longifolia* is known as a weed in Northland, no reports have so far been found of problems with *A. longifolia* var. *sophorae* which was planted extensively on the open dunes at Santoft Beach, on the coast near Bulls, more than 30 years ago (Whitehead 1964).

REFERENCE

Whitehead, P.S. 1964: Sand dune reclamation in New Zealand. New Zealand Journal of Forestry 9: 146-53.

TABLE 1-1 - Location of sand dune revegetation trials

Location	Region	Approximate coordinates	Annual rainfall[1] (mm)	Mean rainfall Sept-Feb (incl.) 1976-1986[1] (mm)	Sand pH	Mean air temperature (°C)[1]	
						January	July
Ninety-mile Beach	Northland	173°08'E 34°59'S	1187	586	6.2 - 7.3	19.6	12.4
Muriwai Beach	Auckland	174°20'E 36°41'S	1328	545	5.0 - 6.0	18.4	10.4
Kawhia	Waikato	174°42'E 37°22'S	1418	554	7.1	18.5	10.9
Harakeke	Wanganui	175°05'E 40°02'S	906	417	6.7	17.8	8.7
Santoft Beach	Manawatu	175°11'E 40°09'S	874	455	8.1	17.1	8.0

[1] Long-term average from nearest meteorological station.

TABLE 1-2 - Points of similarity and contrast between 1991-92 spaced-plant trials

	TRIAL					
	FR 165/1 Ninety-mile Beach	**FR 165/2 Kawhia**	**FR 165/3 Harakeke**	**Santoft A**	**Santoft B**	**Santoft C**
Established Spring 1991	+	+	+	+	+	-
Established Autumn 1992	-	-	-	-	-	+
Rabbits excluded	+	+	+	-	-	+
Seedlings raised in potting compost	-	-	-	+	+	+
Seedlings raised in local sand	+	+	+	-	-	-
Plant number per plot	36	36	20	8	8	10
Number of replicates	4	4	3	3	3	4
Species						
Acacia saligna H. Wendl.[1]	+	+	+	-	-	+
Acacia sophorae (Labill.) C. Martius[11]	+	+	+	-	-	+
Astragalus cicer L.[1]	-	-	-	+	+	+
Casuarina glauca Sieb.[1]	-	-	-	-	-	+
Chamaecytisus palmensis (Christ) Bisby et K. Nicholls[1]	+	+	+	+	+	+ (3 accessions)
Dorycnium hirsutum (L.) Ser.[1]	-	-	-	+	+	+
Dorycnium pentaphyllum Scop.[1]	-	-	-	-	-	+
Dorycnium rectum (L.) Ser.[1]	-	-	-	-	-	+
Hedysarum coronarium L.[1]	-	-	-	+	+	+
Hippophae rhamnoides L.	-	-	-	-	-	+
Lathyrus japonicus Willd.	+	+	+	+	+	+
Lathyrus latifolius L.[1]	-	-	-	+	+	-
Lathyrus tuberosus L.	-	-	-	+	+	-
Lespedeza cuneata G. Don[1]						
Lotus corniculatus L.[1]	+	+	-	-	-	+
Lotus pedunculatus Cav.[1]	+	+	+	-	-	-
Lotus tenuis Waldst. & Kit.ex Willd.[1]	-	-	-	+	+	+
Lupinus arboreus Sims	-	-	-	+	+	-
Lupinus nootkatensis Donn[1]	+	+	+	-	-	-
Medicago arborea L.[1]	-	-	-	-	-	+
Robinia pseudoacacia L.	-	-	-	-	-	+
Sutherlandia frutescens R.Br.[1]	+	+	+	-	-	+
Teline stenopetala Webb et Berth.[1]	+	+	+	-	-	-
Trifolium ambiguum Bieb.[1]	+	+	+	-	-	-
Vicia gigantea Hook.	-	-	-	-	-	+
Vicia sepium L.	-	-	-	+	+	-

[1] Chosen for May 1993 planting at three sites

TABLE 1-3 - Results of the November/December 1993 assessment (2 years after transplanting) in Trials FR165/01, FR165/02 and FR165/03

	Overall Survival (%)	Vigour (1 = weak, 5 = robust)	Mean plant height (cm)	Mean plant spread (cm)	Mean D.Wt. tops/survivor/ species (kg/ha)	Mean D.Wt. tops/no. planted/ species (kg/ha)	Cover (%)	Mean Height (cm)	Maximum Height (cm)	Notes
<u>FR 165/01 - Ninety Mile Beach</u>										
Acacia saligna	11a*	2	34a	50ab	1008	111				Leaf scorch, new growth,dieback
Acacia sophorae	18a	4	40a	79a	2806	505				Much new growth
Chamaecytisus palmensis	8a	3	51a	70ab	1476	118				Dieback
Lathyrus latifolius	-	-	-	-	-	-				
Lespedeza cuneata	-	-	-	-	-	-				
Lotus corniculatus	-	-	-	-	-	-				
Lotus pedunculatus	8a	4	13b	47a	125	10				Yellowing, dieback
Lupinus nootkatensis	-	-	-	-	-	-				
Sutherlandia frutescens	-	-	-	-	-	-				
Teline stenopetala	9a	3	33a	37b	160	14				Flowering, dieback
Trifolium ambiguum	2a	1	2b	3c	1	<1				
<u>FR 165/02 - Kawhia</u>										
Acacia saligna	51a	4	113a	91a	27273	13334				Scorch,dieback,new growth
Acacia sophorae	40a	5	ND	ND	26695	22100	63a	85a	145a	Growing out of plot
Chamaecytisus palmensis	2b	2	61a	73a	891	20				Browsed,seeding,resprouting,few leaves
Lathyrus latifolius	1b	3	10b	102a	ND	ND				Browsed,dead at centre,growing at edges
Lespedeza cuneata	-	-	-	-	-	-				
Lotus corniculatus	3b	2	7b	6b	6	<1				Very yellow, thin
Lotus pedunculatus	ND	4	ND	ND	3656	1005	28a	25b	43b	Flowering,buds,dieback,resprouting,wilting
Lupinus nootkatensis	-	-	-	-	-	-				
Sutherlandia frutescens	-	-	-	-	-	-				
Teline stenopetala	1b	ND	110a	97a	ND	ND				Flowering,seeding,sprouting at top,rabbits?
Trifolium ambiguum	10b	2	4b	6b	3	<1				Browsed, scorched, reddish
<u>FR165/03 - Harakeke</u>										
Acacia saligna	21a	3	51bc	41c	503	92				Leaf scorch, dieback, suppressed by lupin
Acacia sophorae	13a	4	81abc	67bc	11780	1374				Good plants, not very big
Chamaecytisus palmensis	42a	4	171a	161a	34744	15156				Growing out of plot,many seedpods,dieback
Lathyrus latifolius	7a	5	80bc	205a	1600	107				Growing out of plot, flowering, some necrosis
Lespedeza cuneata	ND	5	ND	ND	3900	261	7a	50a	77a	Flowering, growing out of plot
Lupinus nootkatensis	-	-	-	-	-	-				
Sutherlandia frutescens	28a	3	57c	81b	3632	1090				Flowering, seedpods, some dieback and defoliation,suppressed by lupin, 1 seedling
Teline stenopetala	30a	4	123ab	121ab	53484	13371				Flowering, seedpods, no seedlings, rabbits?
Trifolium ambiguum	ND	5	ND	ND	16	<1	45a	12a	33a	Diffuse, spreading, large leaves under cover

* For each site, values within a column followed by the same letter do not differ at the 5% significance level

ND = Not Determined

- = No survivors

TABLE 1-4 - Results of the November/December 1993 assessment (2 years after transplanting) in the unfenced Santoft A trial

Species	Survival (%)		Vigour (1 = weak, 5 = robust)	Height (cm)	Spread (cm)	Dry weight tops/survivor (g)	Comments
Astragalus cicer	33	(58)*	5	8.0	9.4	0.6	
Chamaecytisus palmensis	21	(19)	2	32.4	3.4	3.7	Browsed
Dorycnium hirsutum	8	(14)	4	8.5	17.0	2.5	Heavily browsed. Flowering.
Hedysarum coronarium	4	(8)	2	4.0	9.0	ND	
Lathyrus japonicus	0		-	-	-	-	
Lathyrus latifolius	25	(43)	2	5.3	11.0	1.7	Heavily browsed.
Lathyrus tuberosus	4	(8)	4	9.0	2.0	N.D.	
Lotus tenuis	8	(14)	4	2.5	6.0	2.3	
Lupinus arboreus	21	(7)	3	83.8	99.2	254.0	Some defoliation.
Vicia sepium	0		-	-	-	-	

( )* = standard error
ND = Not determined

TABLE 1-5 - Results of the November/December 1993 assessment (2 years after transplanting) in the unfenced Santoft B trial

Species	Survival (%)		Vigour (1 = weak, 5 = robust)	Height (cm)	Spread (cm)	Dry weight tops/survivor (g)	Comments
Astragalus cicer	17	(19)*	5	15.4	17.9	2.1	Chewed
Chamaecytisus palmensis	13	(13)	4	47.8	36.3	19.5	Browsed
Dorycnium hirsutum	25	(33)	5	32.3	45.0	38.1	Flowering
Hedysarum coronarium	0		-	-	-	-	
Lathyrus japonicus	0		-	-	-	-	
Lathyrus latifolius	13	(22)	5	73.3	65.0	13.0	Flower buds
Lathyrus tuberosus	33	(57)	4	8.3	21.9	0.6	Chewed
Lotus tenuis	4	(8)	3	18.0	35.0	N.D.	
Lupinus arboreus	13	(13)	3	101.3	235.0	2670.0	Flowering
Vicia sepium	0		-	-	-	-	

( )* = standard error
ND = Not determined

TABLE 1-6 - Results of the November 1993 assessment in Trial C at Santoft Beach

	Survival (%)	Vigour (1 = weak, 5 = robust)	Mean Height (cm)	Mean Spread (cm)	Mean Dry Weight tops/survivor/plot (g)	Comments
Acacia saligna	73abc*	4	58.0cde	61.5cdef	123 bcde	
Acacia sophorae	73abc	4	55.1cdef	99.4abc	141abc	
Astragalus cicer	70abcd	5	25.6g	53.1 def	45e	One plot buried.
Casuarina glauca	95a	3	27.5g	16.5g	7 f	
Chamaecytisus palmensis (3735)	10c	4	95.0a	92.5 bcd	195abc	One plot buried.
Chamaecytisus palmensis (3820)	20c	5	44.1 def	78.6 bcd	153abc	
Chamaecytisus palmensis (3552)	18c	5	63.0 bcd	47.6ef	70cde	One plot buried.
Dorycnium hirsutum	38 bcde	5	55.5cdef	66.4cde	306ab	2 plots buried. Flowers. Seedlings.
Dorycnium pentaphyllum	0	-	-	-	-	All plots buried
Dorycnium rectum	28 cde	4	86.0ab	121.0ab	142abc	One plot buried. Flower buds.
Hedysarum coronarium	35 bcde	4	67.7abc	152.5a	421a	2 plots buried. Flowers. Seed pods.
Hippophae rhamnoides	3 c	4	7.0 h	3.0 h	N.D.	One plot buried.
Lathyrus latifolius	50abcde	4	63.4 bcd	80.0 bcde	131 bcd	2 plots buried. Flowers.
Lotus corniculatus	28 cde	4	35.6efg	65.7cde	121 bcd	One plot buried. Seedlings.
Lotus tenuis	70abcd	4	38.8efg	114.2ab	260abc	1 plot buried. Flowers. Seedlings.
Medicago arborea	78ab	4	50.2cdef	56.0 def	184abc	Flowering. Seed pods.
Robinia pseudocacia	23 de	3	43.2 fg	40.2 f	41 de	Three plots buried.
Sutherlandia frutescens	0	-	-	-	-	All plots buried.
Vicia gigantea	0	-	-	-	-	All plots buried.

* For each species, values within columns followed by the same letter do not differ at the 5% significance level
 - = no surviving plants
N.D. = Not Determined

TABLE 2-1 - Species characteristics recorded in the November/December 1993 assessments of Trials 193/1,3,4*
(Values presented are actual means; statistical tests were performed on logarithmically-transformed data)

Species	Survival (%)			Vigour (1=robust, 5=robust)			Mean plant height (cm)			Mean plant spread (cm)			Mean D.Wt top/survivors (g)		
Site	1	3	4	1	3	4	1	3	4	1	3	4	1	3	4
Acacia saligna	38b**	56ab	74a	3	2	3	14.1a	10.6a	14.9a	17.5a	13.6a	20.5a	3.47a	0.50b	7.40a
Acacia sophorae	69b	60b	96a	4	2	4	17.5a	8.7b	17.1a	23.0a	5.7b	17.8a	4.52a	0.17b	4.75a
Astragalus cicer	10b	72a	66a	2	3	5	2.3b	4.3a	3.5ab	5.0b	8.4a	7.0ab	0.08a	0.33a	0.75a
Chamaecytisus palmensis (3211/3218)	13b	91a	92a	2	2	3	23.8c	32.7b	57.7a	29.4a	9.9b	31.0a	6.73ab	4.41b	15.28a
Chamaecytisus palmensis (3573)	8b	85a	90a	2	2	3	20.0c	35.4b	61.2a	31.7b	9.9c	41.5a	6.64b	4.42b	23.38a
Chamaecytisus palmensis (3820)	34b	45b	68a	2	2	4	13.8b	31.4a	36.7a	24.9b	11.9c	53.9a	5.60b	3.96b	21.10a
Dorycnium hirsutum	72b	89ab	99a	3	4	4	6.4c	14.3b	20.1a	26.8b	26.2b	43.8a	2.51b	2.62b	18.72a
Dorycnium pentaphyllum	8b	81a	89a	2	3	4	3.3c	6.9b	13.3a	14.1b	12.7b	26.8a	0.46b	0.31b	3.37a
Dorycnium rectum	67a	81a	84a	3	3	4	17.1b	13.8b	38.0a	25.9a	14.3b	27.5a	4.03b	1.35c	11.32a
Hedysarum coronarium	64b	47b	92a	3	3	2	10.6b	11.0b	22.0a	36.0b	15.5c	60.6a	8.90b	0.53c	35.97a
Lathyrus latifolius	66b	99a	93a	3	3	3	6.9b	14.2a	18.9a	15.9b	25.2a	35.0a	1.50b	1.51b	7.58a
Lespedeza cuneata	0b	27a	8ab	-	1	4	-	9.1a	5.3b	-	1.8a	1.7a	-	0.05b	0.18a
Lotus corniculatus	61b	100a	100a	3	4	4	6.6c	12.0b	18.2a	20.6b	26.1b	44.2a	3.86b	2.29b	27.67a
Lotus pedunculatus	80a	99a	100a	2	4	4	5.8b	23.3a	18.8a	27.3b	43.6a	46.2a	4.40b	6.46b	26.90a
Lotus tenuis	99a	100a	100a	4	4	3	11.6b	26.1a	14.8b	58.3a	67.8a	78.8a	17.42b	12.38b	47.08a
Lupinus nootkatensis	6b	73a	72a	1	2	3	2.2b	3.8a	3.2a	2.8a	6.4a	5.8a	-	0.17b	0.48a
Medicago arborea	96a	84a	100a	2	1	3	14.4b	14.0b	24.7a	14.0a	7.9a	15.8a	2.14b	1.68b	3.62a
Sutherlandia frutescens	0c	85a	47b	-	3	3	-	38.6a	32.5a	-	27.9a	16.6a	-	10.50a	2.78a
Teline stenopetala	25c	88a	57b	2	2	3	22.3b	27.9b	46.6a	23.5b	8.3c	38.0a	7.47b	2.41b	27.85a
Trifolium ambiguum	20b	100a	81a	2	3	4	2.3a	4.2a	2.7a	5.8b	9.9a	6.8b	0.03c	0.18b	0.62a
All species	41b	78a	80a	2	(2-3)	(3-4)	10.1c	17.1b	23.5a	22.4b	17.7b	31.0a	4.43b	2.81b	14.34a

*FR193/1 = Ninety-Mile Beach Dune Site
FR193/3 = Muriwai Beach Dune Site
FR193/4 = Santoft Beach Dune Site
** For each species, values within a row followed by the same letter do not differ at the 5% significance level
- = No surviving plants

TABLE 2-2 - Overall species performance in Trials 193/1,3 and 4*, November/December 1993
(Values presented are actual means; statistical tests were performed on logarithmically-transformed data)

All Sites Species	Overall Survival (%)	Mean plant height (cm)	Mean plant spread (cm)	Mean D.Wt tops/survivors/plot (g)
Acacia saligna	56efg***	13.2f	17.2gh	3.79fg
Acacia sophorae	75cd	14.4ef	15.5h	3.15h
Astragalus cicer	49fgh	3.4h	6.8j	0.39i
Chamaecytisus palmensis (3211/3218)	66de	38.1a	23.4efg	8.81bc
Chamaecytisus palmensis (3573)	61ef	38.9a	27.7defg	11.48b
Chamaecytisus palmensis (3820)	49gh	27.3cd	30.2def	10.22bcd
Dorycnium hirsutum	85bc	13.6f	32.3bc	7.95cdef
Dorycnium pentaphyllum	59ef	7.8g	17.9gh	1.38fg
Dorycnium rectum	77cd	23.0d	22.6efg	5.57def
Hedysarum coronarium	68de	14.5ef	37.4cd	15.13ef
Lathyrus latifolius	86bc	13.3f	25.4cde	3.53fg
*Lespedeza cuneata***	12i	7.2g	1.81	0.12j
Lotus corniculatus	87bc	12.3f	30.3cd	11.27bcde
Lotus pedunculatus	93ab	16.0ef	39.0b	12.59b
Lotus tenuis	100a	17.5e	68.3a	25.63a
Lupinus nootkatensis	50fgh	3.1h	5.0k	0.33i
Medicago arborea	93ab	17.7e	12.6i	2.48fg
*Sutherlandia frutescens***	42h	35.6bc	22.3g	6.64fg
Teline stenopetala	56efg	32.3ab	23.3fg	12.58b
Trifolium ambiguum	67de	3.1h	7.5j	0.28i

*FR193/1 = Ninety-Mile Beach Dune Site
FR193/3 = Muriwai Beach Dune Site
FR193/4 = Santoft Beach Dune Site
**No surviving plants in Trial FR/193/1
***For each species, values within columns followed by the same letter do not differ at the 5% significance level.

TABLE 2-3 - Results of the November/December 1993 assessments in Trial FR193/1 at Ninety Mile Beach
(Values presented are actual means; statistical tests were performed on logarithmically-transformed data)

Species	Survival (%)	Vigour (1 = weak, 5 = robust)	Mean Plant Height (cm)	Mean Plant Spread (cm)	Mean D. Wt tops/survivors/plot (g)	Comments
Ninety-Mile Beach Dune Site						
Acacia saligna	38c*	3	14.1bcde	17.5de	3.47bcdef	Leaf scorch, new growth
Acacia sophorae	69b	4	17.5ab	23.0bcd	4.52bc	Leaf scorch, new growth
Astragalus cicer	10de	2	2.3i	5.0f	0.08ik	Green small, chewed
Chamaecytisus palmensis (3211/3218)	13de	2	23.8a	29.4b	6.73b	Prostrate, dieback
Chamaecytisus palmensis (3573)	8de	2	20.0abc	31.7bc	6.64bcd	Some plants prostrate, dieback
Chamaecytisus palmensis (3820)	34c	2	13.8cde	24.9bcd	5.60bcde	Very prostrate, dieback
Dorycnium hirsutum	72b	3	6.4g	26.8bc	2.51efg	Buds, flowers
Dorycnium pentaphyllum	8de	2	3.3h	14.1e	0.46h	
Dorycnium rectum	67b	3	17.1ab	25.9bc	4.03bcde	Defoliation, dieback, yellow leaf margins
Hedysarum coronarium	64b	3	10.6ef	36.0bc	8.90bc	Flowers dieback, yellowish/reddish
Lathyrus latifolius	66b	3	6.9fg	15.9de	1.50g	Leaf scorch, necrosis, green in shelter
Lespedeza cuneata	0e	-	-	-	-	
Lotus corniculatus	61c	3	6.6g	20.6cde	3.86fg	Green, chewed, poor in bare sand
Lotus pedunculatus	80ab	2	5.8g	27.3b	4.40bcdef	Dead centres, desiccated
Lotus tenuis	99a	4	11.6de	58.3a	17.42a	Dark green, vigorous
Lupinus nootkatensis	6de	1	2.2i	2.8g	-	Not harvested, too few plants
Medicago arborea	96a	2	14.4bcd	14.0e	2.14cdef	Defoliated, dieback, yellow
Sutherlandia frutescens	0e	-	-	-	-	
Teline stenopetala	25cd	2	22.3a	23.5bcd	7.47b	Leaf scorch, dieback, defoliation
Trifolium ambiguum	20cd	2	2.3i	5.8f	0.03k	Some green plants

* For each species, values within a column followed by the same letter do not differ at the 5% significance level

Table 2-4 - Results of the November/December 1993 assessment in Trial FR193/3 at Muriwai Beach
(Values presented are actual means; statistical tests were performed on logarithmically-transformed data)

Species	Survival (%)	Vigour (1 = weak, 5 = robust)	Mean Plant Height (cm)	Mean Plant Spread (cm)	Mean D. Wt tops/survivors/plot (g)	Comments
Muriwai Beach Dune Site						
Acacia saligna	56de*	2	10.6cde	13.6def	0.50fg	Browsed, dieback
Acacia sophorae	60cde	2	8.7ef	5.7i	0.17hi	Severely browsed
Astragalus cicer	72bc	3	4.3g	8.4ghi	0.33ik	Yellow, chewed
Chamaecytisus palmensis (3211/3218)	91ab	2	32.7a	9.9fg	4.41bc	Browsed, sprouyting at base
Chamaecytisus palmensis (3573)	85ab	2	35.4a	9.9fg	4.42bc	Heavily browsed
Chamaecytisus palmensis (3820)	45ef	2	31.4ab	11.fg	3.96bcd	Heavily browsed
Dorycnium hirsutum	89ab	4	14.3c	26.2c	2.62cde	Browsed, in bud
Dorycnium pentaphyllum	81abc	3	6.9f	12.7ef	0.31ghi	Browsed
Dorycnium rectum	81abc	3	13.8c	14.3ef	1.35ef	Browsed, resprouting
Hedysarum coronarium	47ef	3	11.0cd	15.5de	0.53gh	Buds, flowers, browsed
Lathyrus latifolius	99a	3	14.2c	25.2c	1.51de	Browsed
Lespedeza cuneata	27f	1	9.1def	1.8k	0.05k	Yellow
Lotus corniculatus	100a	4	12.0cd	26.1c	2.29cd	Browsed, wilted, flowers
Lotus pedunculatus	99a	4	23.3b	43.6b	6.46ab	Browsed,wilted, buds
Lotus tenuis	100a	4	26.1ab	67.8a	12.38a	Buds, flowers, some yellowing
Lupinus nootkatensis	73bcd	2	3.8g	6.4hi	0.17hi	Browsed, wilting upwards
Medicago arborea	84ab	1	14.0c	7.9gh	1.68de	Very yellow, browsed
Sutherlandia frutescens	85ab	3	38.6a	27.9cd	10.50bc	Some plants with "feathery" habit, flowers, pods, seeds
Teline stenopetala	88ab	2	27.9ab	8.3gh	2.41cd	Heavily browsed, resprouting
Trifolium ambiguum	100a	3	4.2g	9.9fg	0.18hi	Browsed, some yellow, wilting upwards

* For each species, values within a column followed by the same letter do not differ at the 5% significance level.

TABLE 2-5 - Results of the November/December 1993 assessments in Trial 193/4 at Santoft Beach
(Values presented are actual means; statistical tests were performed on logarithmically-transformed data).

Species	Survival (%)	Vigour (1 = weak, 5 = robust)	Mean Plant Height (cm)	Mean Plant Spread (cm)	Mean D. Wt tops/survivors/plot (g)	Comments
Santoft Beach Dune Site						
Acacia saligna	74 bcdef*	3	14.9gh	20.5 fg	7.40 fghi	
Acacia sophorae	96ab	4	17.1 fgh	17.8 fg	4.75ghi	
Astragalus cicer	66 efg	5	3.5k	7.0 h	0.75 k	
Chamaecytisus palmensis (3211/3218)	92abc	3	57.7a	31.0e	15.28cdef	Defoliated,sprouting at base
Chamaecytisus palmensis (3573)	90abcd	3	61.2a	41.5 bcd	23.38abcd	Defoliated, sprouting at base
Chamaecytisus palmensis (3820)	68defg	4	36.7c	53.9ab	21.10 bcd	
Dorycnium hirsutum	99a	4	20.1ef	43.8 bcd	18.72 bcde	Buds, flowers
Dorycnium pentaphyllum	89abcd	4	13.3 h	26.8ef	3.37 hi	Buds, some flowers
Dorycnium rectum	84abcde	4	38.0 bc	27.5ef	11.32 defg	
Hedysarum coronarium	92abc	2	22.0ef	60.6ab	35.97 bcd	Buds, flowers
Lathyrus latifolius	93abc	3	18.9 fgh	35.0cde	7.58efgh	
Lespedeza cuneata	8h	4	5.3 i	1.7i	0.18l	
Lotus corniculatus	100a	4	18.2efg	44.2 bcd	27.67abc	
Lotus pedunculatus	100a	4	18.8efg	46.2 bc	26.90ab	Buds, flowers
Lotus tenuis	100a	3	14.8gh	78.8a	47.08a	Buds, flowers
Lupinus nootkatensis	72cdef	3	3.2 k	5.8 h	0.48k	Some very small shoots
Medicago arborea	100a	3	24.7 de	15.8g	3.62 hi	Some dead leaves
Sutherlandia frutescens	47g	3	32.5cd	16.6g	2.78i	Seed pods
Teline stenopetala	57 fg	3	46.6ab	38.0cde	26.8 abcd	Flowers, shoot at base
Trifolium ambiguum	81abcde	4	2.7k	6.8 h	0.62k	

* For each species, values within a column followed by the same letter do not differ at the 5% signuficance level

TABLE 3-1 - Trial FR193/02. Comparison of species raised0 in local sand (s) or potting compost (p). Results of the November 1993 assessment.

Species	Medium (s/p)	Survival (%)	Vigour 1 = weak, 5 = robust	Height (cm)	Spread (cm)	Dry weight (g)
Species						
Acacia sophorae		100a	3	18b	18b	3.4a
Chamaecytisus palmensis		29b	2	23a	17b	2.0a
Lotus pedunculatus		93a	3	8c	25a	2.1a
Medium						
Local sand		76a	3	15b	18b	1.6a
Potting compost		72a	3	17a	23a	3.4a
Species*Medium						
Acacia sophorae	s	100a	4	18a	17a	2.1a
Acacia sophorae	p	100a	3	19a	19a	4.6a
Chamaecytisus palmensis	s	41b	2	21b	14a	2.1a
Chamaecytisus palmensis	p	18c	2	26a	20a	2.0a
Lotus pedunculatus	s	88a	2	7a	22a	0.7a
Lotus pedunculatus	p	98a	3	9a	28a	3.5a

TABLE 3-2 - Growth and weight increase of seedlings six months after establishment

	Medium s/p*	Height cm	Spread cm	Dry weight g
Acacia sophorae	p	-1.6	5.8	3.86
Chamaecytisus palmensis	s	-5.3	1.3	1.48
Chamaecytisus palmensis	p	-0.7	13.9	1.33
Lotus pedunculatus	s	-0.8	-0.2	-0.08
Lotus pedunculatus	p	0.6	-14.3	1.81

s = local sand
p = potting compost

TABLE 4-1 - Ethylene production of N-fixing species in the foredune trial planted Spring 1991 Ninety-mile beach (FR165/01). November 1993 measurement

Species	Ethylene production (nmol/plant/30min)					
	Block 1	Block 2	Block 3	Block 4	Mean 1993	Mean 1992
Acacia saligna	3928				3928	411
Acacia sophorae				4365	4365	775
Chamaecytisus palmensis (3570)		1021			1021	53
Lathyrus latifolius					*	*
Lespedeza cuneata					*	*
Lotus corniculatus					*	0
Lotus pedunculatus		168			168	41
Lupinus nootkatensis					*	*
Sutherlandia frutescens					*	*
Teline stenopetala		438			438	72
Trifolium ambiguum		50			50	31

TABLE 4-2 - Ethylene production of N-fixing species in the foredune trial planted Spring 1991 Kawhia (FR165/02). November 1993 measurement

Species	Ethylene production (nmol/plant/30min)					
	Block 1	Block 2	Block 3	Block 4	Mean 1993	Mean 1992
Acacia ssligna		8,515	27,730		18,122	9,835*
Acacia sophorae		326,657	74,060		200,358	10,755*
Chamaecytisus palmensis (3570)		204			204	ND
Lathyrus latifolius					ND	ND
Lespedeza cuneata					ND	ND
Lotus corniculatus			18		18	269
Lotus pedunculatus	1036				1036	355
Lupinus nootkatensis					ND	ND
Sutherlandia frutescens					ND	ND
Teline stenopetala					ND	ND
Trifolium ambiguum	9				3	123

ND not determined
* plant root systems were larger than sample volume

TABLE 4-3 - Ethylene production of N-fixing species in the foredune trial planted Spring 1991 Harakeke (FR165/03). November 1993 measurement

Species	Ethylene production (nmol/plant/30min)					
	Block 1	Block 2	Block 3	Block 4	Mean 1993	Mean 1992
Acacia saligna	879				879	5057
Acacia sophorae			23,532		23,532	1,884
Chamaecytisus palmensis (3570)	17,632	53,591			35,612	1,056
Lathyrus latifolius			2,034		2,034	25,711
Lotus pedunculatus	2,539				2,539	6,936
Lupinus nootkatensis					ND	ND
Sutherlandia frutescens			327		327	282
Teline stenopetala			1,266		1,266	7,627
Trifolium ambiguum	327				327	304

ND not determined

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

Species	Ethylene production (nmol/plant/30min)						
	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Mean 1993
Acacia saligna				2,289	2,409		2,349
Acacia sophorae				4,250	ND		4,250
Astragalus cicer						0	0
Chamaecytisus palmensis (3211/3218)			413			1,073	743
Chamaecytisus palmensis (3573)		8,419		3,217			5,818
Chamaecytisus palmensis (3820)			149	ND			149
Dorycnium hirsutum		67				947	507
Dorycnium pentaphyllum						0	0
Dorycnium rectum			247	1,438			842
Hedysarum coronarium		968		1,002			985
Lathyrus latifolius		577				3,326	1,952
Lespedeza cuneata							ND
Lotus corniculatus			994	947			970
Lotus pedunculatus	102			1,047			574
Lotus tenuis	2,106		2,035				2070
Lupinus nootkatensis							ND
Medicago arborea					0	0	0
Sutherlandia frutescens							ND
Teline stenopetala		2,122			19,480		10,801
Trifolium ambiguum		17			0		8

ND not determined

TABLE 4-5 - Ethylene production of N-fixing species in the foredune trial planted 1993, Ninety-mile beach (FR193/02). November 1993 measurement

Species	Ethylene production (nmol/plant/30min)						
	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Mean 1993
Acacia sophorae (p)			7,440			8,701	8,070
Acacia sophorae (s)	1,904					2,133	2,018
Chamaecytisus palmensis (3570) (p)			2,491		1,488		1,990
Chamaecytisus palmensis (3570) (s)		3,559	1,808				2,684
Lotus pedunculatus (p)		3,948				1,927	2,938
Lotus pedunculatus (s)					1,425	1,158	1,292

p seedlings raised in potting mix
s seedlings raised in sand

TABLE 4-6 - Ethylene production of N-fixing species in the foredune trial planted 1993, Muriwai Beach (FR193/03). November 1993 measurement

Species	Ethylene production (nmol/plant/30min)						
	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Mean 1993
Acacia saligna			1,026		ND		1,026
Acacia sophorae	261					ND	261
Astragalus cicer		82		208			145
Chamaecytisus palmensis (3211/3218)			950	1,969			1,460
Chamaecytisus palmensis (3573)				0	18		9
Chamaecytisus palmensis (3820)			287	175			231
Dorycnium hirsutum			987	321			654
Dorycnium pentaphyllum				3,325	548		1,936
Dorycnium rectum	1,895		1,665				1,780
Hedysarum coronarium			494			18	256
Lathyrus latifolius			2,405			2,617	2,511
Lespedeza cuneata			0		0		0
Lotus corniculatus					3,533	3,190	3,362
Lotus pedunculatus		2,674		4,612			2,306
Lotus tenuis	4,183				2,447		3,315
Lupinus nootkatensis				371	442		406
Medicago arborea			0			0	0
Sutherlandia frutescens			5	2,055			1,030
Teline stenopetala				88		15	52
Trifolium ambiguum			0	0			0

ND not determined

TABLE 4-7 - Ethylene production of N-fixing species in the foredune trial planted 1993, Santoft (FR193/04). November 1993 measurement

Species	Ethylene production (nmol/plant/30min)						
	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Mean 1993
Acacia saligna				622	513	13,745	4,973
Acacia sophorae (3066)					10,247		10,247
Acacia sophorae (3066(2))				5,562			5,562
Astragalus cicer					3,794		3,794
Chamaecytisus palmensis (3218)							ND
Chamaecytisus palmensis (3573)				14,831	8,053	3,044	8,643
Chamaecytisus palmensis (3820)				7,490			7,490
Chamaecytisus palmensis (3211)			13,183	75	9,215		7,491
Dorycnium hirsutum				3,679	32		1,856
Dorycnium pentaphyllum				3,305	281		1,793
Dorycnium rectum				1,902	20,210		11,056
Hedysarum coronarium				24,152	ND		24,152
Lathyrus latifolius				4,035	22		2,028
Lespedeza cuneata					3,697		3,697
Lotus corniculatus				6,476	8,405		7,440
Lotus pedunculatus				9,335	3,194		6,264
Lotus tenuis				19,450	956		10,203
Lupinus nootkatensis (4242)				3,166	18,886		11,026
Medicago arborea (1069)				ND	ND		ND
Sutherlandia frutescens (4072)				266	6,032		3,149
Sutherlandia frutescens (3755)						6,559	6,559
Teline stenopetala			23,066	10	8,575		10,550
Trifolium ambiguum				29	6	55	30

ND not determined

TABLE 4-8 - Ethylene production of N-fixing species in the foredune trial planted 1991, Santoft (A). November 1993 measurement

Species	Ethylene production (nmol/plant/30min)				
	Block 1	Block 2	Block 3	Mean 1993	Mean 1992
Astragalus cicer		818		818	0
Chamaecytisus palmensis	ND		4,943	4,943	264
Dorycnium hirsutum	56			56	1,320
Hedysarum coronarium				ND	394
Lathyrus latifolius		798		798	2,172
Lathyrus tuberosus				ND	4
Lathyrus japonicus				ND	ND
Lotus tenuis		0		0	1,004
Lupinus arboreus	5,565	251		2908	10,052
Vicia sepium				ND	ND

ND not determined

TABLE 4-9 - Ethylene production of N-fixing species in the foredune trial planted 1991, Santoft (B). November 1993 measurement

Species	Ethylene production (nmol/plant/30min)			
	Block 1	Block 2	Block 3	Mean 1993
Astragalus cicer	1,079	60		570
Chamaecytisus palmensis			10,283	10,283
Dorycnium hirsutum	438			438
Hedysarum coronarium				ND
Lathyrus latifolius	904			304
Lathyrus tuberosus	156			156
Lathyrus japonicus				ND
Lotus tenuis				ND
Lupinus arboreus	7,046			7,046
Vicia sepium				ND

ND not determined

TABLE 4-10 - Ethylene production of N-fixing species in the foredune trial planted 1992, Santoft (C). November 1993 measurement

Species	Ethylene production (nmol/plant/30min)				
	Block 1	Block 2	Block 3	Block 4	Mean 1993
Acacia saligna	18,626	3,418			11,022
Acacia sophorae	15,130	5,451			10,290
Astragalus cicer	17,379		46		8,712
Casuarina glauca	3	19			11
Chamaecytisus palmensis (PMC 3552)	10,156	367			5,262
Chamaecytisus palmensis- 'Waikari' (3820) (c)	16,194			4,165	10,180
Chamaecytisus palmensis- 'Carvossa' (3573) (b)			26,392		26,392
Dorycnium hirsutum	276	244			260
Dorycnium pentaphyllum					ND
Dorycnium rectum	22,768	13,001			11,391
Hedysarum coronarium			47,809	26,000	36,904
Hippophae rhamnoides					ND
Lathyrus latifolius		2,457	1,820		2,138
Lotus corniculatus	16,984	1,472			9,228
Lotus tenuis	393	4,246			2,320
Medicago arborea	13,800	748			7,274
Robinia pseudoacacia			333		333
Sutherlaandia frutescens					ND
Vicia gigantea					ND

ND not determined

TABLE 4-11 - Relative acetylene reduction rates on foredune sites. For each site ethylene production is expressed as a percentage of the highest value recorded

Establihment year	1991	1991	1991	1993	1993	1993	1993	1991	1991	1992
Trial	Ninety-mile beach FR 165/01	Kawhia FR 165/02	Harakeke FR 165/03	Ninety-mile beach FR 193/01	Ninety-mile beach FR 193/02	Muruwai Beach FR 193/03	Santoft FR 193/04	Santoft A	Santoft B	Santoft C
Acacia saligna	90	9	2	22		9	21			30
Acacia sophorae (raised in sand)	100	100	66	39	25	2				
Acacia sophorae (raised in potting mix)					100					28
Acacia sophorae (3066)							42			
Acacia sophorae(3066(2))							23			
Astragalus cicer				0		1	16	16	6	24
Casuarina glauca										<1
Chamaecytisus palmensis (3570)	23	<1	100							
Chamaecytisus palmensis (raised in sand)					33					
Chamaecytisus palmensis (raised in potting mix)					25			100	100	
Chamaecytisus palmensis (3211/3218)				7		12	31			
Chamaecytisus palmensis (3573)				54		<1	36			
Chamaecytisus palmensis (3820)				1		2	31			
Chamaecytisus palmensis PMC 3552										14
Chamaecytisus palmensis 'Waikari' (3820)(c)										28
Chamaecytisus palmensis 'Carvossa' (3573)(b)										72
Dorycnium hirsutum				5		6	8	1	4	<1

TABLE 4-11 continued.

Establihment year	1991	1991	1991	1993	1993	1993	1993	1991	1991	1992
Trial	Ninety-mile beach FR 165/01	Kawhia FR 165/02	Harakeke FR 165/03	Ninety-mile beach FR 193/01	Ninety-mile beach FR 193/02	Muruwai Beach FR 193/03	Santoft FR 193/04	Santoft A	Santoft B	Santoft C
Dorycnium pentaphyllum				0		17	7			
Dorycnium rectum				8		16	46			31
Hedysarum coronarium				9		2	100			100
Hippophae rhamnoides										
Lathyrus latifolius			6	18		22	8	16	3	6
Lathyrus tuberosus									2	
Lespedeza cuneata						0	15			
Lotus corniculatus		<1		9		100	31			25
Lotus pedunculatus (raised in sand)	4	<1	7	5	16					
Lotus pedunculatus (raised in potting mix)					36	20	26			
Lotus tenuis				19		29	42	0		6
Lupinus arboreus								59	68	
Lupinus nootkatensis						4				
Lupinus nootkatensis (1069)							46			
Medicago arborea				0		0				20
Robinia pseudoacacia										<1
Sutherlandia frutescens			<1			9				
Sutherlandia frutescens (4072)							13			
Sutherlandia frutescens (3755)							27			
Teline stenopetala	10		4	100		<1	44			
Trifolium ambiguum	1	<1	<1	<1		0	<1			
Vicia gigantea										