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SUBSURFACE SOWING OF YELLOW LUPIN (*LUPINUS ARBOREUS*) FOR ECONOMICAL AND RAPID SAND DUNE STABILIZATION AT WOODHILL FOREST

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increased to 85% by this means, at a cost of only $0.036/kg, but the use of unscarified seed is preferred because germination is then spread over a period of 6 to 8 weeks. In unseasonable dry spells plants just germinating may die, and this long period allows some of the crop, at least, to survive The second area of risk is from insects. Widespread defoliation may be caused at various stages of growth. A weevil, *Cecyopa modesta*, feeds on emerging cotyledons, while caterpillars of the kowhai moth, *Mecyna maorialis*, and of *Heliothis amigera*, may completely defoliate and kill adult plants. The third element of risk, rabbits, can eliminate or weaken seedlings and smaller plants by constant browsing. However, these risks apply equally whatever the method of sowing and are only important where lupin is used without marram grass.

ACKNOWLEDGEMENTS

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(3) Ridge tops and upper slopes. High-density planting of marram grass and subsurface sowing lupin seed by hand.

(4) More exposed sand flats and westerly-facing hollows, where sand movement is too great for lupin stabilization alone. Machine planting of marram grass at 1.2 m square spacing, followed by machine drilling of lupin seed.

It is expected that these methods will result in a 50% cut in the use of marram grass for stabilization at Woodhill.

A comparison of manual and machine sowing costs at South Head, Woodhill Forest, is given in Table 2.

TABLE 2: COSTS OF SUBSURFACE SOWING BY HAND AND BY DRILL

	Subsurface Manual Sowing	*Subsurface Drill Sowing*
Area — ha	81	132
Seed sown — kg	450.4	381.9
Kilograms of seed sown/ha	5.6	2.9
Labour — productive man-hours	600	77
Man-hours/ha sown	7.41	0.59
Kilograms seed sown per man-hour	0.8	5.0
Costs — $/ha		
Labour	7.41	0.59
Lupin seed	4.68	2.42
Tractor hire	—	2.30
Totals	$12.09	$5.31

DISCUSSION

The development of the subsurface lupin seed sowing technique at Woodhill Forest has resulted in considerable cost saving. In all cases this method results in more effective germination and tends to reduce the time between initial stabilization and tree planting by one or more years — in itself a cost saving. In less exposed areas the need to use marram grass as well is obviated. While in more exposed situations both marram grass and lupin are required for effective stabilization, subsurface sowing of lupin results in a more uniform cover being obtained more rapidly than by previous methods. The importance of the improved results, in relation to the following tree crops, is two-fold. First, the shortened stabilization period reduces the time taken to obtain revenue from the tree crop and, secondly, the uniform stabilization obtained means that tree planting may be undertaken in an orderly manner; there is no need to avoid partially stabilized areas and little likelihood of tree failure resulting from partial stabilization within the planting area.

However, sowing lupin seed on its own involves some risk. Viability of seed may be poor. Although potential germination is normally 45 to 50%, it is not uncommonly less than 20%. Recent seed scarification trials show that germination can be

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SYNOPSIS

Subsurface sowing of yellow lupin (Lupinus arboreus) *seed has proved a successful and economical means of rapid sand dune stabilization at Woodhill Forest, North Auckland. On easterly faces, less exposed flats and hollows, and unstabilized patches of bare sand, after subsurface sowing the growth of yellow lupin alone leads to rapid stabilization. In the most exposed situations, planting of marram grass* (Ammophila arenaria), *in addition to sowing lupin, is advocated. Present methods of subsurface sowing of lupin seed, and the trials leading up to the development of these, are considered.*

INTRODUCTION

Coastal sands, of Quaternary age, cover extensive areas of land on the west coast of the North Island of New Zealand, and are commonly present as a coastal strip that varies from 2 to 16 km in width, extending from one side of the Island to the other in the Ninety Mile Beach district (Kear, 1964). Cockayne (1911) speaks of some 10 000 ha of sand in the South Island and 117 000 ha in the North, of which some 74 000 are in the Auckland Province. Moore (1963), in her publication on coastal plants, states that four out of every 1 000 ha in the country are sand, giving a total of 106 000 ha for the two main islands. Whilst these deposits may include the most extensive of New Zealand's iron ore resources and provide sand for the building industry, they also represent a threat to farm land wherever dunes are actively advancing inland. Many areas are geologically too young to have developed an adequate soil cover and are therefore of little use to the farmer. From a forestry point of view, the sand areas represent a challenge as places to grow trees with a view to arresting the invasion of agricultural land and for obtaining a productive tree crop.

The Public Works Department started large-scale reclamation at Woodhill in 1932, the scheme continuing until 1939 under the title of Woodhill-Helensville Sand Reclamation Scheme. The objectives were: first, to give relief for unemployment; secondly, to fix the sands and prevent further

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encroachment on to adjacent farm land; and, thirdly, to plant productive forests. In 1951, sand stabilization on this and other projects became the responsibility of the Forest Service. An annual stabilization programme of 800 to 1 000 ha at Woodhill, and similar or greater areas at Ninety Mile Beach, have been regularly achieved.

STABILIZATION OF SAND

Before tree planting is possible, stabilization of the bare (and often rapidly changing) sand surface is required. Provision of cover protects the tree seedlings from sand movement and lessens fluctuations in moisture content below the surface. The principles of sand reclamation have not changed significantly since 1932, but the methods have (Whitehead, 1964; Restall, 1964). Initially, marram grass is planted on the bare sand drifts to slow sand movement and to form a more amenable environment for secondary species such as yellow lupin. The deposits are deficient in nutrients, and promotion of vigorous growth of marram grass after planting is best achieved by topdressing with a nitrogenous fertilizer. At present calcium ammonium nitrate, containing 23% N, is applied in two dressings of 125 kg/ha in spring and autumn.

Yellow lupin has proved the most successful secondary species; a legume, it provides further nitrogen necessary to promote marram grass growth and, later, tree growth (Gadgil, 1971). Past practice has been to sow the lupid seed with a spinning disc fertilizer applicator, often in conjunction with the second (autumn) topdressing of fertilizer. Generally a lapse of one year is required before marram grass is adequate to nurse the young lupin seedlings. After the initial marram planting, an average of 4 or 5 years is required before tree planting can begin, although this varies with the degree of exposure.

For several years the establishment of fully stocked stands of young trees at Woodhill has been complicated by patches of incompletely stabilized sand, caused by a failure to follow up one or more of the stabilization processes. Surface-sown lupin seed has in some instances failed to strike after two, or occasionally three, attempts and during this period of 2 or 3 years the marram grass becomes unhealthy and is again over-

TABLE 1: AVERAGE COST FOR SAND DUNE STABILIZATION (1972)

Operation	*Cost per hectare ($)*		*Percent of Total Cost*	
	Machine Planting	*Hand Planting*	*Machine Planting*	*Hand Planting*
Dig and transport marram grass	13.84	13.84	19.8	11.7
Plant marram grass	25.95	74.13	37.1	62.8
Topdress marram grass	20.01	20.01	28.6	16.9
Surface-sow lupin seed	10.13	10.13	14.5	8.6
Totals	69.93	118.11	100.0	100.0

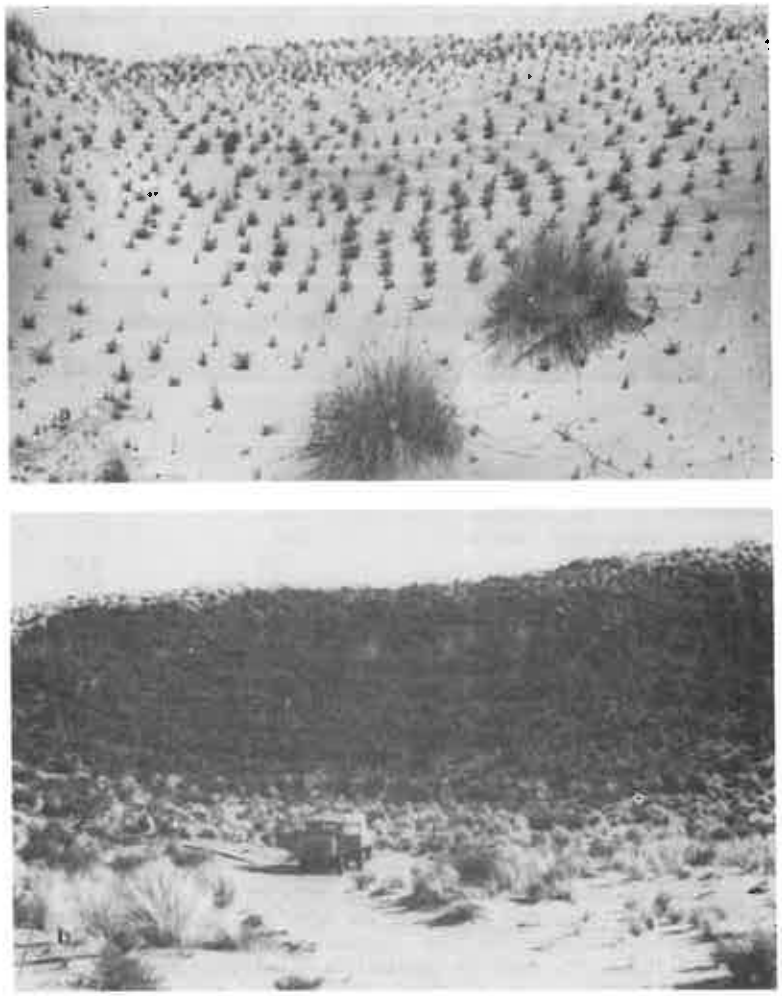

FIG. 3: (a) *Steep east-facing slip face sown with lupin seed at 60 cm × 60 cm spacing, 8 weeks after sowing.* (b) *The same slope after 6 months, showing complete lupin cover.*

The following sand stabilization methods, related to sites, have now been adopted for Woodhill, Mangawhai and Pouto Forests:

(1) Bare sand patches, less exposed flats, and poorly stabilized sand dunes. Subsurface drilling of yellow lupin seed.

(2) The lower two-thirds of easterly-facing slopes and all other less exposed untractorable country. Subsurface sowing of lupin seed by hand.

This machine (see Fig. 2a) has been mounted on a salvaged pair of wheels and axle at relatively low cost. The flow of seed is regulated by a cam-operated trip, the cam releasing the trip twice per wheel revolution. This in turn releases about ten seeds (although the number can be controlled by adjusting the aperture size) which is considered the minimum to ensure at least one seedling per point, allowing for losses from mortality and failure to germinate. Two drills are mounted inboard of each wheel which sow seed in lines about 120 cm apart, two "sets" of seed being deposited with each revolution of the sower wheel; this gives a little over 90 cm between sets. The seed is deposited into a slot in the sand formed by a coulter with a widened cutting edge. Spacing between rows and sets can also be varied by relocating drill positions and altering cam timing. Sowing depth is controlled by the depth of the coulter cut. The sowing pattern is illustrated in Fig. 2b, taken about four weeks after germination.

Sowing Lupin Seed by Hand on Steep Slip Faces

During 1967 and 1968 at Woodhill and Mangawhai Forests, steep east-facing dune slip faces were rapidly stabilized by planting marram grass and sowing lupin seed. This technique is not new as it had been used 30 years ago. In 1969 and 1970, trials were established in which lupin seed was sown in sets of about 60 cm × 60 cm spacing, illustrated in Fig. 3.

Rapid growth of lupin leads to stabilization of all but the upper one-third of the slope, where infrequent but damaging easterly winds cause high mortality amongst emerging seedlings. This upper one-third of the dune slope requires stabilization with marram grass.

LUPIN DRILL SOWING IN CONJUNCTION WITH MARRAM PLANTING BY MACHINE

The failure to follow up marram planting by machine with fertilizer, and the failure of surface-sown lupin seed to germinate and so to complete sand stabilization, led to the widespread deterioration of previously stabilized areas at Woodhill and was responsible for the large annual patching programme at present being undertaken. Following up marram planting with the subsurface lupin seed sower, can be expected to counteract effectively any deterioration of marram grass.

Time of sowing is of considerable importance. At Pouto Forest, subsurface lupin sowing at or immediately after marram planting left only a short period of time for the lupin to become established before being exposed to hot, dry, summer conditions. Better results have been obtained where lupin seed has been sown in the autumn after marram planting, allowing the lupin a full winter in which to develop and form a good cover, and so to slow the process of sand drying out. Such an autumn sowing also obviates the need for the customary second nitrogen fertilizer dressing of marram grass.

taken by raw sand. Such scattered and irregular sand patches form the greater part of the current annual stabilization programme at Woodhill. Table 1 indicates that forest establishment on sand dunes is costly and any failure can markedly influence the economics of the process.

STABILIZATION WITHOUT MARRAM GRASS

At an early stage in the investigation of lupin germination it was considered that placing yellow lupin seed beneath rather

FIG. 1: (a) *Lupin germination 4 to 5 weeks after discing in 5 to 45 kg of seed per hectare in a wind-scoured hollow.* (b) *The same hollow after 5 months.*

than above the surface could offer a more satisfactory means of enabling seedling establishment. Sand movement, and the marked moisture and temperature fluctuations at the surface, are more likely to prevent successful germination than the relatively uniform conditions at a depth of 2 to 5 cm.

Sand Cultivation Trials

Initial cultivation trials were carried out in winter 1966, lupin seed being covered, using a spade, to a depth of 2 to 5 cm. The result was a five-fold increase in germination compared with surface-sown seed. Trials were continued during the following winter at Woodhill and Mangawhai Forests. At Woodhill, cultivation was carried out using a nine-tine rake, while at Mangawhai the imprints of tractor tyres driven over the area gave sufficient disturbance to cover the seed and markedly improve germination. Both these trials involved over 30 kg of lupin seed per hectare.

In 1968 a third trial was established on westerly-facing slopes and in wind-scoured hollows. Seed was sown at rates varying from 5 to 45 kg/ha and cultivated in with tractor-drawn discs. Seed depth varied from 1 to 10 cm, although most was found about 5 cm below the surface. Figure 1 illustrates early and later results from this treatment. A similar trial was carried out at Aupori Forest in 1969, seed being sown into a simulated disc cut 2.5 to 5 cm in depth. As at Woodhill, a marked increase in germination occurred.

It was apparent that the subsurface sowing of as little as 5 to 6 kg/ha of yellow lupin seed into bare sand, even in relatively exposed situations, could lead to rapid sand dune stabilization.

Seed Drilling Trials

In conjunction with the sand cultivation trials, consideration was given to developing a machine capable of sowing yellow lupin seed at a uniform rate over extensive areas — either bare patches or large dunes and hollows where no sand stabilization attempts had yet been made, in total more than 40 000 ha in the Auckland Conservancy alone. In 1966 an agricultural oversower was used to drill the seed into bare sand on a moderately exposed site at South Head, Woodhill Forest. Germination was rapid and by 1968 bushes were 1.2 m tall and all sand was covered. However, the mechanical sowing was slow, irregular and very large quantities of seed were required. Spacing trials, using hand-placed seed in winter 1969, suggested that rapid stabilization could be achieved by sowing lupin seed in rows 90 to 120 cm apart, with spacings of 30 to 60 cm along the rows. A corn planter adapted to sow lupin seed was able to meet this specification, but the cost of this unit was excessive. In winter 1970, Woodhill Forest staff developed a machine which has subsequently sown 1 200 ha of bare sand, partially stabilized patches and dunes previously planted with marram grass, with an average of 3.4 kg of seed per hectare. The most important features of this machine are:

— It can sow seed in a regular fashion over the whole surface to be stabilized.

— It can maintain a low sowing rate (2.2 to 5.0 kg/ha) sufficient to give an effective cover of lupin.

— The machine is robust and can be operated in a wide range of conditions to the limit of tractorable country.

— It can cover large areas of land in a relatively short time.

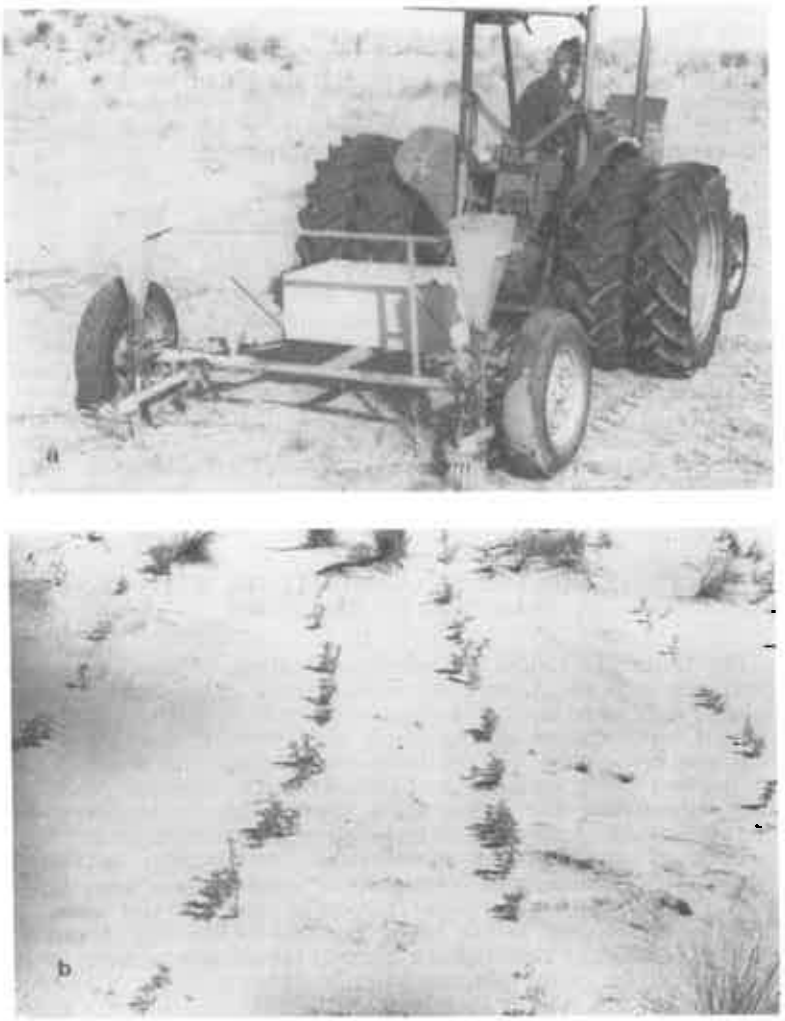

FIG. 2: (a) *Subsurface lupin seed sower developed at Woodhill Forest.* (b) *Germination of seed sets, with lines spaced about 120 cm apart, and 90 cm spacing in the lines.*