RESEARCH IN SOUTHERN QUEENSLAND INTO THE MANAGEMENT OF COASTAL SAND DUNES

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1. INTRODUCTION

Queensland's Beach Protection Act (1968-1974) resulted, inter alia in the formation of the Beach Protection Authority, which is responsible for investigating coastal erosion, planning remedial works, recording and evaluating results of investigations, and various other functions.

Control of windblown sand and retention of vegetated and naturally stable coastal sand dunes are valuable means of decreasing coastal erosion and because of this the Authority implements a broad research program into the management of coastal dunes in Queensland. Field trials are carried out at the Authority's Dune Management Research Station on South Stradbroke Island to determine methods of repairing, stabilizing and managing coastal dunes.

The research program conducted so far consists of fifteen separate field trials within four general areas of investigation:-

(a) Dune Forming Fences

Two trials were installed in blown-out sections of the frontal dune to compare different types of semi-permeable fences (eg. wooden slats) and brush matting (a surface mulch of tree branches) on the basis of their ability to accumulate windblown sand and initiate dune formation.

(b) Dune Stabilization Techniques

Three trials were installed on bare dunal areas to evaluate methods of temporary sand surface stabilization (organic mulches and spray-on materials) as an aid in establishing dune vegetation.

(c) Dune Vegetation

Two trials were conducted to produce and compile information on the performance of important or potentially useful dune plants.

(d) Plant Nutrition

Eight trials using different combinations and rates of fertilizer were used to study methods of improvement of establishment and early growth of dune stabilizing plants, particularly sand spinifex grass (*Spinifex hirsutus*). Good establishment and rapid early growth is required in order to accelerate, improve, and decrease the costs of, the stabilization process.

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The trials carried out in each area of investigation are described below.

2. DUNE FORMING FENCES

Where there is a significant width of sand of suitable median grain size between high water mark and the seaward toe of the dune strong on-shore winds will transport large quantities of sand landwards.

In the absence of dune vegetation which traps and holds windblown sand, semi-permeable dune forming fences can be used for the same purpose. The fences function by lowering wind velocities adjacent to the fence below the critical threshold velocity required to keep sand moving. This results in sand accumulating on both sides of the fence, eventually burying it, and an artificial sand dune is formed.

Semi-permeable dune forming fences can be used to repair dune "blow-outs" or to initiate rebuilding of a new dune line. The most satisfactory types of dune forming fence in use are those constructed of spaced timber slats, brush material and moulded plastic or nylon materials.

(a) Trial 1

In 1971, a trial was installed in blown-out sections of frontal dune to measure and compare the rate of accumulation of windblown sand against three types of semi-permeable material attached to wooden post and wire fences. The semi-permeable materials used were spaced hardwood timber slats, 'Trical' (moulded polyethylene mesh) and 'Raschel' (woven polyethylene netting). Each fence material had a solid to space ratio of about 1:1. The fences were erected across each of three dune "blow-outs" and placed above, and parallel to high water mark. The fence treatments were replicated to enable statistical analysis.

Cross sections at each fence were surveyed to calculate volumes of accumulated sand. The cross section lines extended 6 m on both the seaward and landward side of the fence. Each fence was about 1 m high.

The volume of sand accumulated by each type of fence treatment, and the results of statistical analysis are presented in Table 1.

The slat fence initially accumulated windblown sand at a faster rate than the 'Trical' or 'Raschel' fence. During the 6 week period following installation the sand surface beneath the 'Raschel' fence suffered wind erosion (indicated by the negative value in Table 1). However, after 23 weeks the 'Raschel' fence was effectively trapping windblown sand. At 66 weeks after trial installation all fence treatments had completely filled with windblown sand.

(b) Trial 2

Another trial was installed in 1972 across a large blown-out section of frontal dune to compare the sand trapping ability of 6 types of semi-permeable material when attached to two parallel fences 6 m apart. The treatments used were: brush fence (pieces of brush attached to the fence wires), brush matting (successive layers of brush placed on the sand

TABLE 1: VOLUME OF SAND ACCUMULATED BY FENCE TREATMENTS

6 weeks after installation	Tr.	Slats	Trical	Raschel
	C.V	1 089	146	-1 077
	Sig.			
		L.S.D. = 1271 (P = 0.95)		
23 weeks after installation	Tr.	Slats	Trical	Raschel
	C.V	2 423	1 357	193
	Sig.			
		L.S.D. = 1067 (P = 0.95)		
38 weeks after installation	Tr.	Slats	Trical	Raschel
	C.V	6 059	4 511	3 765
	Sig.			
		L.S.D. = 756 (P = 0.95)		
66 weeks after installation	Tr.	Trical	Raschel	Slats
	C.V	12 179	12 009	11 839
	Sig.			
		L.S.D. = 5676 (P = 0.95)		

Notes: Tr. = fence treatment
C.V = cumulative volume of sand (m^3 km^{-1})
Sig. = lines join treatment means not significantly different
L.S.D. = least difference necessary for significance.

surface), wooden slats, 'Trical', 'Easy Fencing' (plastic impregnated netting) and 'Sarlon' (loose woven polypropylene ribbon fabric). The parallel fences were placed above and parallel to high water mark. The experimental design used was that for a Randomised Complete Block:- 6 fence treatments randomly allocated within each of 3 replicates.

Cross sections at each fence treatment were surveyed to calculate volumes of accumulated sand, and the results are presented in Table 2.

Initial rates of sand accumulation were similar in all treatments but later in the trial brush matting showed a superior ability to accumulate windblown sand. The brush fence and wooden slats were similar in terms of rate and volume of sand accumulation and superior to the plastic materials ('Trical', 'Sarlon', 'Easy Fencing') which were the less effective sand accumulators. All fence treatments had completely filled with windblown sand after 128 days. The parallel fences in this trial accumulated sand more rapidly than the single fences in the first trial.

A wider dune having a more uniform profile of accumulated sand can be formed using two fences parallel to each other. Provided there is a sufficient quantity of sand blown landward from the beach both fences will fill quite rapidly with the seaward fence filling first.

To provide more permanently stability to the re-formed dune it is advisable to apply brush matting to prevent wind erosion and to plant the dune with suitable dune colonising vegetation.

TABLE 2: VOLUME OF SAND ACCUMULATED BY FENCE TREATMENTS

22 days after installation	Tr.	B.F	S	E.F	T	B.M	SA
	C.V	1 534	1 395	1 287	1 154	1 070	5 885
	Sig.						
		L.S.D. = 646 (P = 0.95)					
52 days after installation	Tr.	B.M	E.F	S	B.F	SA	T
	C.V	4 393	3 961	3 952	3 553	3 210	2 976
	Sig.						
		L.S.D. = 837 (P = 0.95)					
91 days after installation	Tr.	B.M	B.F	S	E.F	SA	T
	C.V	8 336	7 236	6 612	5 136	4 629	4 466
	Sig.						
		L.S.D. = 1653 (P = 0.95)					
128 days after installation	Tr.	B.M	B.F	S	E.F	SA	T
	C.V	16 843	11 467	8 470	7 733	6 608	5 885
	Sig.						
		L.S.D. = 3538 (P = 0.95)					

Notes: Tr. = fence treatment
viz. B.F = brush fence; B.M = brush matting; E.F = 'Easy Fencing';
S = timber slats; SA = 'Sarlon'; T = 'Trical'
C.V, Sig., L.S.D. = see notes for Table 1.

3. DUNE STABILIZATION TECHNIQUES

Initial sand surface stabilization using organic mulches and spray-on materials and rapid establishment of vegetation are integral parts of any program designed to stabilize exposed wind eroded coastal dunes. Surface stabilizing agents prevent wind erosion for a sufficient period of time to allow establishment of dune colonising vegetation which stabilizes the sand surface more permanently.

(a) Field Stabilization Trial

In 1971 a bare unstable dune area (4.6 ha) was selected to test the normally recommended method of frontal dune stabilization. Stabilization was to be a step-wise procedure utilizing the growing seasons and growth habits of annual and perennial plant species. The area was planted with sand spinifex grass (*Spinifex hirsutus*), marram grass (*Ammophila arenaria*) and cover crops consisting of cereal rye (*Secale cereale*), sand plain lupin (*Lupinus cosentii*), Zulu sorghum (*Sorghum vulgare*), Tamworth pearl millet (*Pennisetum typhoideum*) and Rhodes grass (*Chloris gayana*). Fertilizer containing nitrogen, phosphorus and potassium was applied at planting and throughout the trial period. The planted area was brush matted (about 10 tonne brush material per hectare) to prevent wind erosion. Tree seedlings of horsetail she-oak (*Casuarina equisetifolia* var. *incana*) and coastal wattle (*Acacia sophorae*) were also planted.

Ground cover estimates were used to assess development of a stabilizing vegetative cover. Brush matting provided initial sand surface stabilization, prevented wind erosion and allowed establishment of vegetation. Ground cover of vegetation averaged 60-65% within 30 months from planting and the trial area was completely stabilized by sand spinifex grass, Rhodes grass and the tree species. The annual plant species (cereal rye, sorghum) were dominant ground cover components early in the trial and were gradually replaced by the perennial species (sand spinifex grass, Rhodes grass) which stabilized the sand surface more permanently. The application of fertilizer (over 1 tonne ha^{-1}) throughout the trial period assisted establishment and growth of vegetation.

(b) Mulch Trial 1

In the winter of 1971 a plot trial was installed on a bare area of wind eroded dune to compare the effectiveness of various surface stabilizing agents in initially stabilizing sand and allowing establishment of vegetation. The trial area (0.4 ha) was planted with sand spinifex grass (28 kg ha^{-1}), marram grass (4 kg ha^{-1}), cereal rye (44 kg ha^{-1}), Zulu sorghum (11 kg ha^{-1}), Rhodes grass (11 kg ha^{-1}) and sand plain lupin (11 kg ha^{-1}). A mixed (N,P,K) fertilizer was applied at planting and the following treatments were applied to plots (9 m x 4.5 m) randomly allocated within each of four replicates: brush matting (2.5 kg brush m^{-2}), straw mulch (0.62 kg straw m^{-2}), 'Terolas' (bitumen emulsion mixed with 5 volumes of water and sprayed at 0.28 l emulsion m^{-2}), 'Curasol' (poly vinyl acetate emulsion mixed with 30 volumes of water and sprayed at 0.05 l emulsion m^{-2}), straw plus 'Terolas' and straw plus 'Curasol'. Fertilizer to promote plant growth was broadcast over the treatment plots during the 90 week trial period.

Measurements of plant establishment, ground cover and resistance to wind erosion were used to assess treatment effect. Each treatment gave sufficient surface protection to allow vegetation to establish and stabilize the sand. The brush matting treatment provided better conditions for plant establishment and growth than did most of the other treatments. In all treatments annual plants (particularly cereal rye) were dominant early in the trial but after 7 months the perennial plants, Rhodes grass and sand spinifex grass, were dominant. Ground cover in all treatments improved generally over the term of the trial (Fig. 1). Early ground cover was provided mainly by cereal rye and was slightly better in the treatment plots where this species established best i.e. in the treatments where straw was used. At the end of the trial (after 90 weeks) ground cover on the brush matting treatment was not significantly different from that on those treatments containing straw but it was significantly greater ($P = 0.95$) than ground cover on the 'Terolas' and 'Curasol' treatments. Rhodes grass was the dominant ground cover component in the brush matting treatment at the end of the trial. Visual ratings showed that brush matting had the greatest resistance to wind erosion. The surface seal provided by straw mulch was the first to deteriorate. The 'Terolas' and straw plus 'Terolas' treatments lasted slightly longer than the 'Curasol' and straw plus 'Curasol' treatments. The 'Curasol' and 'Terolas' treatments showed signs of deterioration at 10 months after application.

(c) Mulch Trial 2

A similar trial to the one above was installed in the summer of 1974. The trial area (1.2 ha) was sown (broadcast) with spikelets of sand spinifex grass at the rate of 67 kg ha^{-1} and seed of Tamworth pearl millet at the rate of 11 kg ha^{-1}. A mixed (N, P, K) fertilizer was applied at planting and harrowed in with the seed.

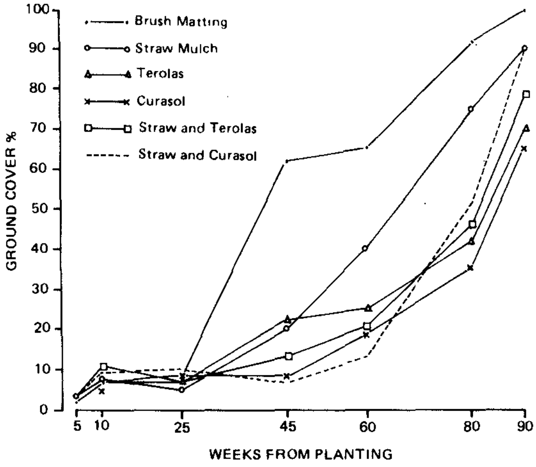

Figure 1. Ground cover on surface stabilization treatments.

Nine treatments were randomly allocated to plots (10 m x 5 m) within each of 4 replicates at 2 sites (each site 0.6 ha). The treatments applied were:-

Brush matting: 2.5 kg brush m^{-2}.
Straw mulch: 0.45 kg straw m^{-2}.
'Terolas': bitumen emulsion mixed with 4 volumes of water and sprayed at 0.36 l emulsion m^{-2}.
'Curasol': poly vinyl acetate emulsion mixed with 18 volumes of water and sprayed at 0.1 l emulsion m^{-2}.
'Unisol': synthetic latex and mineral oil emulsion mixed with 15 volumes of water and sprayed at 0.1 l emulsion m^{-2}.
Straw plus 'Terolas'.
Straw plus 'Curasol'.
Straw plus 'Unisol'.
Nil: bare sand without surface treatment.

The buffer strips between plots and all bare surrounding areas were brush matted to prevent wind erosion and sand encroachment onto treatment plots. Additional fertilizer was applied as required during the trial. Measurements of plant establishment, ground cover and resistance to wind erosion (longevity of surface seal) were used to assess treatment effect.

The nil treatment was completely ineffective and was brush matted to prevent sand blowing onto adjacent plots. All other treatments were initially effective in stabilizing bare windblown sand. Brush matting was again the most effective stabilizing agent and favoured establishment and growth of sand spinifex grass and Tamworth pearl millet. These plants also grew well in those treatments containing straw but establishment and growth were very poor in the 'Unisol' and 'Terolas' treatments.

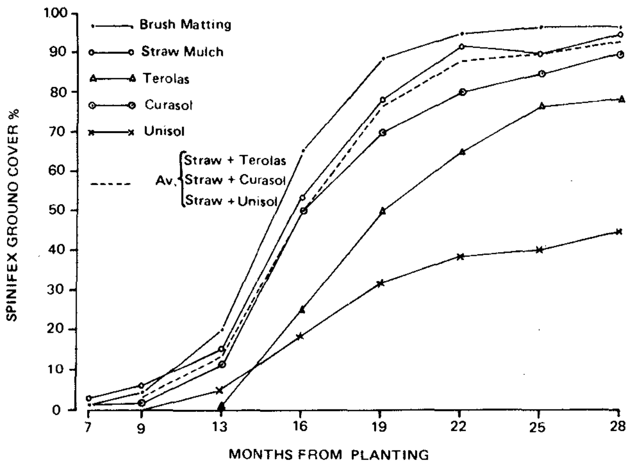

Figure 2. Spinifex ground cover on surface stabilization treatments.

The millet cover crop was the main ground cover component early in the trial and provided protection for establishing sand spinifex grass which was then the dominant ground cover for most of the trial. Development of spinifex ground cover during the trial period is shown in Fig. 2 and indicates that spinifex ground cover developed best in the brush matting treatment. Spinifex growth was also favoured by the 'Curasol' treatment and those treatments containing straw. There was poor development of spinifex ground cover in the 'Unisol' and 'Terolas treatments.

All mulch treatments (except nil) initially stabilized the sand surface but as the trial progressed the surface seal provided by the treatments either rapidly or gradually deteriorated. Visual observations of the treatments indicated that the surface seals deteriorated in the following order:

nil (after 2 weeks); 'Unisol' (after 3 months); straw plus 'Unisol', straw, 'Curasol', straw plus 'Curasol' (after 7 months); straw plus 'Terolas', 'Terolas' and brush matting (seal still effective at trial completion).

4. DUNE VEGETATION

As coastal sand dune stabilization is usually based on the use of vegetation, it is necessary to make the best use of available species if the stabilization program is to be most effective.

(a) Spinifex Growth Pattern Trial

Sand spinifex grass is the most widespread and important primary coloniser of coastal dunes in southern Queensland and in the winter of 1971 a trial was installed on a bare section of frontal dune primarily to obtain information on the growth pattern of this perennial species.

The grass was planted in plots (about 14 m x 5 m) either by seed or by stolon tip cuttings, with nil, medium (500 kg ha^{-1}), or high (1000 kg ha^{-1}) rates of a mixed (N,P) fertilizer. The trial design was that of a 3 x 2 factorial in a randomised tri-replicated complete block. After planting brush matting was spread over the plots and surrounds to prevent wind erosion. When the grass had established, at about 6 months after planting, regular ground cover measurements were used to assess treatment effect. Observations were also made on the requirements for good seed set of spinifex plants grown from seed and stolon tip cuttings. Additional fertilizer applications were made as required to maintain growth during the trial.

Good establishment occurred both from seed and stolon tip cuttings. Vegetatively established plants grew faster than the seedlings. However the two methods of plant establishment produced similar ground covers. The higher plant numbers produced in plots established from seed compensated for the slower seedling growth. The development of spinifex ground cover over a 3 year period is shown in Fig. 3. Growth was best during the summer months with gradual die-back in winter. Ground cover was similar on plots receiving medium and high rates of fertilizer and ground cover on the fertilized plots was much higher than on unfertilized plots. The fall-off in ground cover after June 1973 was caused by the plots being inundated with windblown sand which occurred during a storm in July 1973. While fertilizer increases growth, climatic factors largely govern the plants growth pattern. The dramatic increase in ground cover after October 1972 is associated with increasing temperature and also the fact that 460 mm of rainfall occurred in late October 1972. Maximum ground cover was initially achieved in the fertilized and unfertilized plots at about 20 months after planting. The results indicate that where rapid stabilization is required fertilizer should be added. Plants raised from stolon tip cuttings produced more inflorescences than plants raised from seed in the first few years after planting. The addition of fertilizer markedly increased seed yield from both types of plant. To obtain maximum seed yield in the shortest possible time stolon tip cuttings should be planted and heavily fertilized.

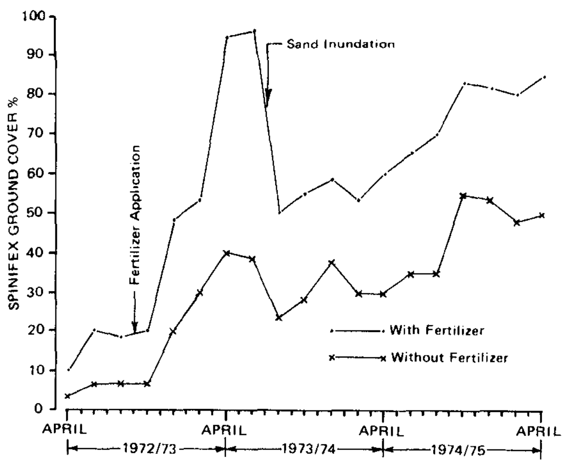

Figure 3. Development of spinifex ground cover over a 3 year period.

(b) Species Evaluation Trial

In 1974 a trial was installed to produce and compile information on the performance of important or potentially useful dune plants. Selected native and exotic species planted at 3 dunal sites of varying exposure are compared with sand spinifex grass (control species). Selected species are planted in duplicate 6 m long single rows at each site, either as seed or seedlings. Mixed (N, P, K) fertilizer is applied at 3 monthly intervals to all species except legumes (or other N-fixing species) which receive (P, K) fertilizer at 3 monthly intervals. Ground cover and vigour and persistance ratings appear to be the most useful measurements for comparing different plants.

The plants being studied include sea oats (*Uniola paniculata*), shoredune panicum (*Panicum amaralum*), beach grass (*Thuarea involuta*), green panic (*Panicum maximum* var. *trichoglume*), beach bean (*Canavalia maritima*), vigna (*Vigna marina*), vitex (*Vitex ovata*) and marram grass (*Ammophila arenaria*).

Ground cover, vigour and persistance of sand spinifex grass are generally superior to that recorded for all plants studied at each site. However sea oats, green panic, beach grass, vitex and beach bean may be suitable species for planting with sand spinifex grass on exposed frontal dunes. Sea oats, shoredune panicum, beach grass, green panic, vigna, vitex and marram grass have shown good growth at the less exposed sites but their vigour and persistance depends on season.

5. PLANT NUTRITION

Good establishment and rapid early growth of vegetation is required in order to improve the effectiveness of dune stabilization and to decrease costs by minimising the need for brush matting and repair work. Different combinations and rates of fertilizer were used in trials to improve establishment and early growth of dune stabilizing plants.

(a) Spinifex/Lupin/Nitrogenous Fertilizer Trial

In 1972 a trial was installed on the exposed seaward slope of the frontal dune to determine the effect of nitrogenous fertilizer on the growth of sand spinifex grass and sand plain lupin. Five rates of ammonium nitrate (34% N) fertilizer were applied to plots (9 m x 5 m) sown with spinifex and lupin seed. The rates used were 11.7, 23.4, 46.7, 93.4 and 186.8 kg N ha^{-1} applied at planting and then at intervals of 3 months for 2 years. All plots received a basal dressing of all other essential plant nutrients at planting and the plots and surrounds were brush matted to prevent wind erosion. Treatments were randomly allocated within each of four replicates. Ground cover and dry matter yield were used to assess treatment effect.

The development of spinifex ground cover at 3 rates of nitrogen application is shown in Fig. 4. Accelerated growth and ground cover of sand spinifex grass occurred at 5 months after planting continuing until maximum ground cover was achieved at 15 months after planting. Increased spinifex growth was obtained by increasing the rate of application of nitrogenous fertilizer up to 934 kg N ha^{-1} in 5 equal split applications over 15 months. Differences in spinifex ground cover in fertilizer treatments at 18 months after planting are shown in Table 3.

TABLE 3: SPINIFEX GROUND COVER IN TREATMENTS AT 18 MONTHS

Treatment (kg N ha^{-1} 3 $months^{-1}$)	186.8	93.4	46.7	11.7	23.4
Ground Cover (%)	74.1	65.8	61.9	48.6	44.3

Note: 1. Values underlined are not significantly different (P = 0.95).

The application of increasing amounts of nitrogenous fertilizer increased dry matter yield of spinifex from about 1000 kg ha^{-1} to over 4300 kg ha^{-1} after 15 months. More frequent applications of nitrogenous fertilizer during the growing season are likely to improve growth, ground cover and yield of this grass. Heavy and frequent applications of nitrogenous fertilizer may be detrimental to lupin growth. No short term beneficial effect of using lupin as a nitrogen source for sand spinifex grass could be detected in this trial.

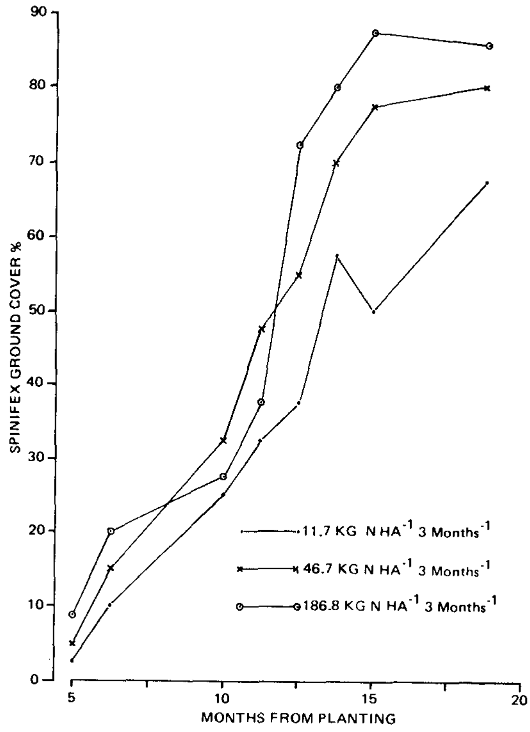

Figure 4. Effect of rate of application of nitrogenous fertilizer on spinifex ground cover.

(b) Spinifex/Superphosphate Trial

A trial was installed in 1972 on a bare section of frontal dune to determine the effect of superphosphate (9.2%P) on the growth of sand spinifex grass. Plots (9 m x 5 m) were sown with seed of sand spinifex grass at the rate of 112 kg ha^{-1} and the plots and surrounds were brush matted to prevent wind erosion. Superphosphate was applied at the following rates: 126, 251, 502, 1004 and 2009 kg ha^{-1}. Each treatment was replicated 4 times in a randomised complete block design. Each plot was split and at planting each half of each plot received the appropriate fertilizer rate. Repeated applications of superphosphate were made at 6 monthly intervals for 2 years to the same half of each plot. All plots received adequate nitrogenous fertilizer during the trial. Dry matter yield was the main measurement used to assess treatment effect and the grass was harvested at 9 and 15 months after planting. The results obtained for each harvest are shown in Fig. 5. Establishment and growth of sand spinifex grass seedlings was unaffected by applications of superphosphate ranging from 126 to 2009 kg ha^{-1} but the highest rate depressed early seedling growth. A yield increase at the 15 month harvest resulted from the application of superphosphate at moderate rates (502 kg ha^{-1}) when compared with the lowest rate (126 kg ha^{-1}). At each harvest date repeated applications of super produced marginally higher yields than the single application. An apparent yield suppression at the highest rate could not be confirmed statistically.

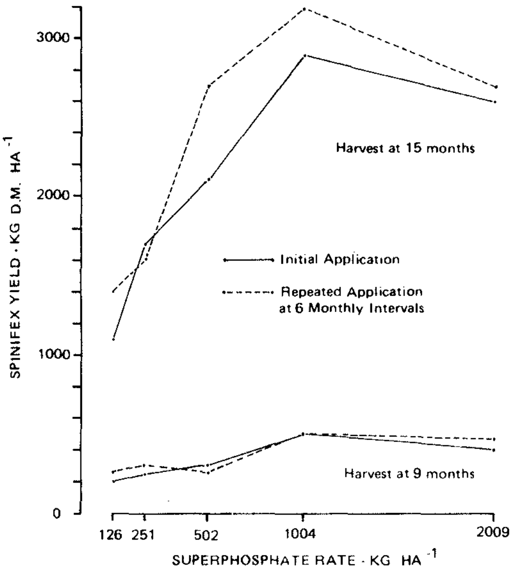

Figure 5. Effect of rate and timing of applications of superphosphate on spinifex dry matter yield.

(c) Millet Cover Crop/Fertilizer Trial

In 1973 a trial was installed in a semi-exposed bare area on the main dune to investigate the growth response of a cover crop of Tamworth pearl millet to different levels and combinations of potassium, sulphur and calcium fertilizers. Treatment plots (7 m x 7 m) were sown (broadcast) with millet seed at a rate of about 11 kg ha^{-1}. All plots received a basal dressing of nitrogen (40 kg ha^{-1}), phosphorus (30 kg P ha^{-1}), copper (10 kg ha^{-1} of copper sulphate) and zinc (10 kg ha^{-1} of zinc sulphate). The following rates (or levels) of nutrient elements were applied in factorial combinations: 0 and 26 kg K ha^{-1}; 4, 16, and 56 kg S ha^{-1}; 0 and 28 kg Ca ha^{-1}. Twelve nutrient element combinations were randomly allocated within each of 3 replicates. Statistical analysis of millet establishment counts indicated that there were significant differences between treatments in terms of plant establishment The treatment plots were harvested 10 weeks after planting and dry matter yield was used to assess treatment effect. The effect of levels of K, S and Ca on millet dry matter yield is shown in Fig. 6. The application of potassium at 26 kg ha^{-1} together with basal nitrogen and phosphorus increased dry matter production of Tamworth pearl millet. The application of calcium or sulphur had no significant effect on dry matter yield and there were no significant yield interactions between any of the levels of the 3 nutrient elements applied.

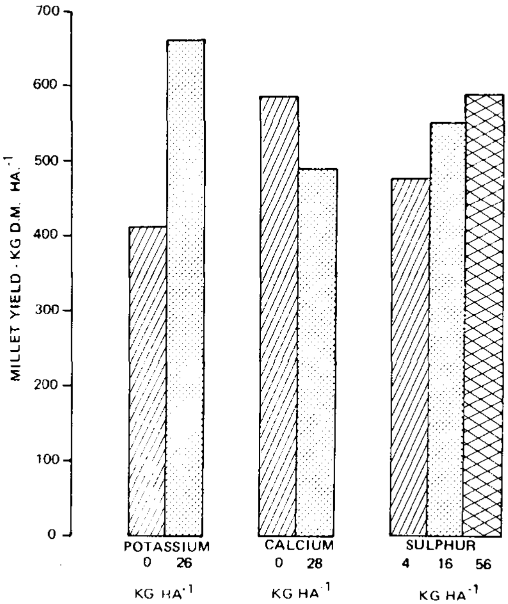

Figure 6. Effect of potassium, calcium and sulphur on millet dry matter yield.

(d) She-oak Nutrient Requirement Trial

In February 1975 a trial was installed at 2 sites on the main dune to investigate the nutrient requirements of horsetail she-oak seedlings. One site was exposed and the other was protected from onshore winds. The trial was an "omission" type with a randomised complete block design. Each site consisted of 24 plots (7 m x 7 m) in 3 replications of 8 plots. The plots and surrounds were brush matted to prevent wind erosion and planted with she-oak seedlings (about 20 cm high) on 1 m centres. The following fertilizer treatments were randomly allocated within each replicate at both sites: nil; complete (containing N, P, K, Ca, Mg, S and trace elements); complete minus N; complete minus P; complete minus K; complete minus Ca and Mg; complete minus S; and complete minus trace elements (Cu, Zn, Mo, B, Fe, Mn). The nutrients N, P and S were applied as split applications every 6 months and the remaining nutrients were applied annually. Tree height and basal diameter were the most useful measurements for assessing treatment effect. At the exposed site 15 months after planting there was no significant difference in height of trees in the following treatments: complete, -P, -K, -Ca/Mg, -S and -T.E (trace elements).

Trees in the nil and -N plots were significantly smaller in height than trees in other treatment plots. This marked difference in height was evident throughout the trial and is shown in Fig. 7. The -K, -Ca/Mg, -S amd -T.E treatments are not shown as they are not significantly different from the complete and -P treatments.

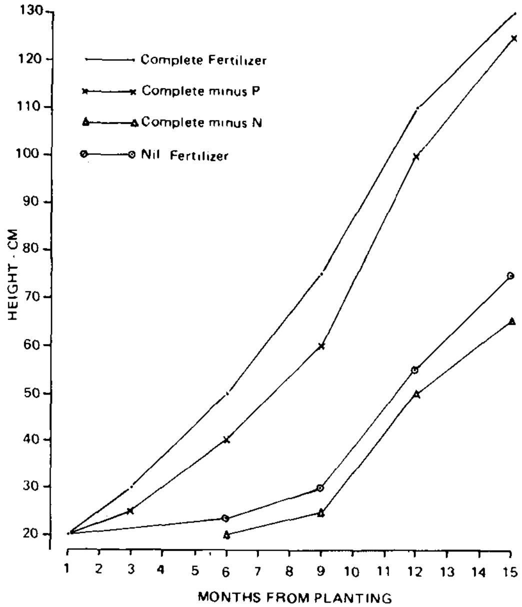

Figure 7. Effect of fertilizer treatments on the height of horsetail she-oak tree seedlings.

Similar trends for tree height within treatment plots were evident at the protected site. Results for basal diameter of trees within treatment plots at both sites showed similar trends to those for tree height. The trial has shown that nitrogen was the most important plant nutrient required for establishment and rapid early growth of horsetail she-oak seedlings.

(e) She-oak/Nitrogenous Fertilizer Trial

The she-oak nutrient requirement trial showed that nitrogen was the most important nutrient for growth of horsetail she-oak seedlings. Because of this a trial was installed in August 1975 on an exposed section of frontal dune to investigate the effect of different forms and rates of nitrogenous fertilizer on establishment and growth of she-oak seedlings. A randomised complete block design (with split plots) was used and consisted of 15 plots (18 m x 6 m) in 3 replicates of 5 plots. The plots and surrounds were brush matted to prevent wind erosion and planted with she-oak seedlings (about 20 cm high) on 1 m centres. The following fertilizer treatments were randomly allocated within each replicate: urea (46%N) plus basal P, K and T.E; blood and bone (4%N) plus basal K; di-ammonium phosphate (19%N) plus basal K and T.E; urea formaldehyde (38%N) plus basal P, K and T.E; and sulphur coated urea (36%N) plus basal P, K and T.E. Each nitrogenous fertilizer treatment was applied to split plots at rates equivalent to 100, 200 and 400 kg N ha^{-1} yr^{-1} in split applications every 6 months.

Tree height and basal diameter were used to assess treatment effect. Average height per tree in three fertilizer treatment over a period of 15 months from planting is shown in Fig. 8. At 15 months from planting the height of she-oak seedlings in the sulphur coated urea treat-

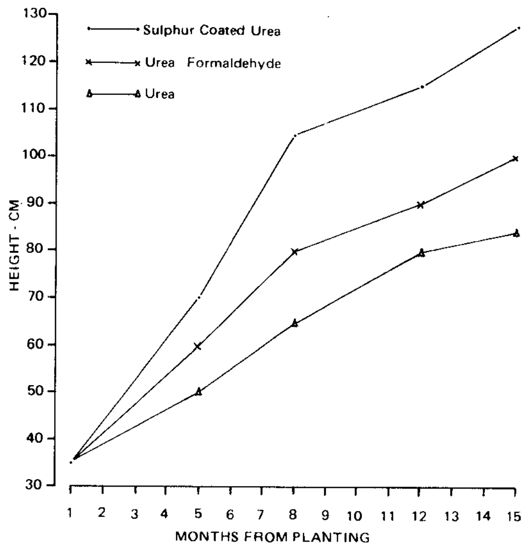

Figure 8. Effect of different forms of nitrogeneous fertilizer on the height of horsetail she-oak tree seedlings.

ment was significantly greater than the height of seedlings in all other treatments. There was no significant difference in height of trees growing in the urea formaldehyde, blood and bone, di-ammonium phosphate and urea treatments. Increasing the rate of application of di-ammonium phosphate, urea or blood and bone did not result in any significant increase in tree height. However, sulphur coated urea and urea formaldehyde applied at the rate of 400 kg N ha^{-1} yr^{-1} produced trees that were significantly taller than those resulting when each fertilizer was applied at the rate of 100 kg N ha^{-1} yr^{-1}.

The trends in basal diameter of she-oak trees are similar to those described for height. The application of sulphur coated urea or urea formaldehyde in split applications every 6 months at rates from 100 to 400 kg ha^{-1} yr^{-1} significantly increased growth of established she-oak seedlings. Both these fertilizers appear to be more beneficial to the nutrition of she-oak than the other forms of nitrogenous fertilizer. This is probably because forms of available nitrogen (eg. nitrate) are released from these fertilizers at a slower rate than they are from other fertilizers, and the nitrogen, which is easily leached from the root zone, is available to the trees over a longer period of time.

(f) Spinifex/Mycorrhiza Trial

In 1977 a small pilot trial was installed at a protected site on the main dune to investigate the effects that indigenous soil micro-organisms (mycorrhizas) may have on the phosphorus uptake and growth of sand spinifex grass. Data was collected but the results obtained were inconclusive.

(g) Spinifex/Superphosphate/Urea Trial

A trial to investigate the effect of various combinations and rates of superphosphate (9.2%P) and urea (46%N) on the growth of sand spinifex grass was installed on a bare section of the main dune in December 1977. The treatments consisted of 4 rates of superphosphate (0, 125.4, 250.8, and 501.7 kg ha^{-1} yr^{-1}) applied in two ways, viz. "all-on" at planting and every 6 months, combined with 2 rates of urea (0 and 250.8 kg ha^{-1} yr^{-1}) split into quarterly applications.

Ground cover of sand spinifex grass is being measured at intervals of 3 months. Early results clearly indicate the beneficial effect of quarterly applications of the nitrogenous fertilizer urea on growth and ground cover of sand spinifex grass. However the application of superphosphate did not seem to improve spinifex growth or ground cover.

(h) Spinifex/She-oak/Fertilizer Trial

In 1978 a trial was installed on a bare section of the main dune to determine optimum rates and timing for the application of nitrogenous and phosphatic fertilizers to horsetail she-oak tree seedlings planted into an established stand of sand spinifex grass. The trial will also determine the effect of competition between the trees and the grass on their respective growth rates. Data collection is still in progress.

6. INFORMATION GAINED FROM THE RESEARCH PROGRAM

The research program has produced quantitative and specific information on:

(a) The rate of dune formation that can be expected using semi-permeable fences or brush matting.

(b) The effectiveness of the recommended procedure for dune stabilization in immediately stabilizing base mobile coastal dunes and allowing rapid establishment of vegetation.

(c) The relative effectiveness of organic mulches (eg. brush matting) and spray-on materials (eg. bitumen emulsion) in temporarily stabilizing bare coastal dunes and allowing establishment and growth of vegetation.

(d) The likely value of a number of introduced and native sand colonising plants tested under field conditions for possible inclusion in dune management programs.

(e) The growth patterns and nutrient requirements of sand spinifex grass and horsetail she-oak tree seedlings which are the two main species used in planting programs for dune stabilization in southern Queensland.

7. USING RESEARCH INFORMATION

Information gained from the research program is used to improve management of coastal dunes in Queensland as one means of decreasing rates of coastal recession. The information is used in the following ways:

(a) It is progressively incorporated into a series of advisory leaflets on the vegetation and management of coastal dunes.

(b) It is used by the Beach Protection Authority to provide free advice to coastal Local Authorities on establishment and management of dune vegetation.

(c) It is tested and demonstrated in Field Trial Areas implemented on frontal dunes in co-operation with coastal Local Authorities.

Current and future trials in the research program will be aimed at improving all important aspects of coastal dune management in Queensland, and refining where necessary the information gained to date and presented in this paper.

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