

## Mycorrhizas and Root Attributes of Plants of Coastal Sand-dunes of New South Wales

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### Abstract

Root samples of 41 sand-dune plant species in 28 families were collected from sites along the coast of New South Wales during spring 1987. Of the species, 36 had vesicular-arbuscular mycorrhizas, with vesicles and internal and external hyphae. Among these species there was great variation in the proportion of root length colonised by vesicular-arbuscular mycorrhizal fungi (from 1 to 96%); in 33 species over 10% of root length was infected. Of the vesicular-arbuscular mycorrhizal species, 21 showed arbuscules, and 16 had intracellular hyphal coils. In four plant species mycorrhizas were not found in the single samples examined; ericoid mycorrhizas were present in the remaining species, *Leucopogon parviflorus*, but its vesicular-arbuscular mycorrhizal status could not be assessed. The results, though preliminary, may reflect a high vesicular-arbuscular mycorrhizal status of vegetation of coastal sand-dunes of New South Wales. This would be likely to enhance plant nutrition and sandbinding, and to have implications for sand-dune management.

### Introduction

The coastal dunes of New South Wales consist of wind-blown marine quartzose sands formed into barrier ridges and transgressive dunes (Chapman *et al.* 1982). Much of the surface of these dunes is vegetated in a zonal pattern. About 150 vascular plant species are found on the foredune, of which 50 are widespread and common. Vesicular-arbuscular mycorrhizas (VAM) have been reported from beaches in the Sydney area (Koske 1975), Queensland coastal dunes (Jehne and Thompson 1981), and mined and unmined sand-dunes at Bridge Hill, N.S.W. (Brockhoff 1985), as well as from maritime sand-dunes in other countries (e. g. Nicolson and Johnston 1979; Koske and Halvorson 1981; Giovannetti and Nicolson 1983; Bergen and Koske 1984; Sylvia 1986). VAM, the commonest kind of mycorrhiza (Harley and Smith 1983), are expected to improve the capacity of plants to take up nutrients — an attribute likely to be important in sand-dunes. VAM may also assist in sandbinding on dunes (e. g. Koske *et al.* 1975). However, for the coastal sand-dunes of New South Wales the abundance, geographic extent, sandbinding capacity, efficacy in nutrient uptake, and taxonomic occurrence, of mycorrhizas remain largely unknown. In this paper we report a preliminary survey of mycorrhizal status in a range of vascular plant species; this is part of a project investigating the extent and effects of VAM in beach dune vegetation along the coast of New South Wales.

### Materials and Methods

Roots of 41 plant species, from 28 families, were examined. Root samples were collected during a field survey of 247 sites on New South Wales coastal beaches during October and November 1987. Beaches for root collection from dunes were initially randomly chosen in the northernmost quarter of

Table 1. Root attributes and mycorrhizal status of plant species of coastal sand dunes of New South Wales

SMALL, roots not extending beyond 25 cm from the base of the plant; MOD\*, rhizome extending to between 25 cm and 2 m; MOD\*, rhizome system extending beyond 1 m, with root systems up to 25 cm from nodes; LARGE, roots extending beyond 2 m. +, present; -, none observed; n.o., data not obtainable.

\*\* Introduced species

Family	Species	Area covered by root or rhizome system	% of root length infected by VAM fungi <sup>A</sup>	External hyphae	Internal hyphae	Coils	Arbuscules	Vesicles	Latitude (°S.)	Comments
Dennstaedtiaceae	<i>Pteridium esculentum</i> (Forst. f.) Cockayne	MOD	68	+	+	+	+	+	35 19	Infection patchy in some roots
Comelinaceae	<i>Commelina cyanea</i> R.Br.	MOD*	26	+	+	-	-	+	30 22	
Cyperaceae	<i>Carex pumila</i> Thunb.	MOD*	0	-	-	-	-	-	35 00	
	<i>Isolepis nodosa</i> (Rottb.) R. Br.	SMALL	35	+	+	+	+	+	36 17	Thicker roots more densely infected
Iridaceae	<i>Gladiolus guineizii</i> Kunze**	MOD	20	+	+	-	+	+	36 00	Infection patchy
Liliaceae	<i>Dianella caerulea</i> Sims	MOD	4	+	+	-	-	+	36 28	Roots not well cleared
Poaceae	<i>Ammophila arenaria</i> (L.) Link**	LARGE	61	+	+	+	+	+	33 12	
	<i>Eragrostis interrupta</i> (R. Br.) Beauv.	MOD	78	+	+	+	+	+	30 08	Many coils in roots
	<i>Festuca littoralis</i> Labill.	MOD	96	+	+	+	+	+	34 07	Mostly vesicles
	<i>Imperata cylindrica</i> Beauv.	MOD*	52	+	+	+	+	+	32 01	
	<i>Spinifex sericeus</i> R. Br.	LARGE	55	+	+	-	-	+	31 37	
	<i>Zoysia macrantha</i> Desv.	MOD*	33	+	+	+	+	+	37 26	
Xanthorrhoeaceae	<i>Lomandra longifolia</i> Labill.	MOD	37	+	+	+	+	+	30 22	Mostly coils. Some non-infected cells stained
Aizoaceae	<i>Carpobrotus glaucescens</i> (Haw.) Schwantes	MOD	1	+	+	-	-	+	29 39	
Apiaceae	<i>Sesuvium portulacastrum</i> L.	SMALL	41	+	+	-	-	+	30 31	
Asteraceae	<i>Hydrocotyle bonariensis</i> Lamk.**	MOD	0	+	-	-	-	-	35 50	Some non-infected cells stained
	<i>Chrysanthemoides monilifera</i> (L.) T. Norlindh**	LARGE	57	+	+	-	+	+	36 02	
	<i>Cryptostemma niveum</i> (L.f.) Nichols**	SMALL	31	+	+	-	+	+	30 55	
	<i>Hypochoeris radicata</i> L.**	SMALL	55	+	+	+	-	+	36 28	
	<i>Senecio lautus</i> Forst.f. ex Willd. ssp. <i>maritimus</i> Ali	MOD	29	+	+	-	+	+	33 18	

Brassicaceae	<i>Cakile edentula</i> (Bigel.) Hook.**	MOD	14	+	+	+	+	+	+	28 32	+	Roots did not clear
Casuarinaceae	<i>Casuarina equisetifolia</i> Forst. & Forst. f.	LARGE	n.o.	+	+	n.o.	+	+	+	28 32	+	Roots did not clear
Chenopodiaceae	<i>Rhagodia candolleana</i> Moq.	MOD	26	+	+	-	+	+	+	31 55	+	Some non-infected cells stained
Convolvulaceae	<i>Calystegia soldanella</i> (L.) R. Br.	MOD*	66	+	+	+	+	+	+	35 01	+	Some non-infected cells stained
	<i>Ipomoea brasiliensis</i> (L.) Sweet	MOD*	0	+	+	-	+	+	-	29 39	-	Some non-infected cells stained
	<i>Ipomoea cairica</i> (L.) Sweet**	MOD*	33	+	+	-	+	+	+	30 22	+	Some non-infected cells stained
Dilleniaceae	<i>Hibbertia scandens</i> (Willd.) Gilg	MOD	78	+	+	-	+	+	+	28 58	+	Mostly vesicles
Epacridaceae	<i>Leucopogon parviflorus</i> (Andr.) Lindl.	LARGE	n.o.	+	n.o.	n.o.	+	+	n.o.	36 02	n.o.	Ericoid mycorrhizas present. Other roots did not clear.
Fabaceae	<i>Canavalia rosea</i> (Sw.) DC.	MOD	35	+	+	-	+	+	+	30 40	+	Roots not well cleared
Geraniaceae	<i>Pelargonium australe</i> Willd.	SMALL	43	+	+	+	+	+	+	37 16	+	Roots not well cleared
Goodeniaceae	<i>Scaevola calendulacea</i> (Andr.) Druce	MOD	57	+	+	+	+	+	+	35 01	+	Roots not well cleared
Menispermaceae	<i>Stephania japonica</i> (Thunb.) Miers	MOD*	19	+	+	+	+	+	+	36 02	+	Roots not well cleared
Mimosaceae	<i>Acacia longifolia</i> (Andr.) Willd. var. <i>sophorae</i> (Labill.) F. Muell.	LARGE	0	+	+	-	+	+	-	31 55	-	Roots not well cleared
Myrtaceae	<i>Leptospermum laevigatum</i> (Soland. ex Gaertn.) F. Muell.	LARGE	62	+	+	+	+	+	+	34 07	+	Roots not well cleared
Onagraceae	<i>Oenothera drummondii</i> Hook.**	MOD	31	+	+	-	+	+	+	32 48	+	Roots not well cleared
Oxalidaceae	<i>Oxalis corniculata</i> s.lat.	MOD*	12	+	+	-	+	+	+	36 02	+	Roots not well cleared
Proteaceae	<i>Banksia integrifolia</i> L.f.	LARGE	29	+	+	-	+	+	+	29 38	+	Roots not well cleared
	non-protoid:	non-protoid:	0	+	+	-	+	+	-		-	Roots not well cleared
	protoid:	protoid:	56	+	+	-	+	+	-		-	Roots not well cleared
Rosaceae	<i>Acaena novae-zelandiae</i> Kirk	MOD*	70	+	+	-	+	+	+	36 23	+	Arbuscules abundant
	<i>Rubus hillii</i> F. Muell.	MOD*	70	+	+	-	+	+	+	30 33	+	Mostly vesicles. Roots not well cleared
Rutaceae	<i>Correa alba</i> Andr.	MOD	49	+	+	+	+	+	+	36 09	+	Roots not well cleared
Stackhousiaceae	<i>Stackhousia spathulata</i> Sieber ex Spreng.	MOD	91	+	+	+	+	+	+	34 57	+	Roots not well cleared

\*Each value is the average of four counts of 50 root-grid intersections, expressed as a percentage.

the State's coastline, but this random selection was modified to allow for species distribution. In the remaining three-quarters of the State, beaches with species common to those selected in the northern quarter were sampled. Roots sampled were dug up from the surface 25 cm of sand, and were traced to the plant to identify their species. Each root sample consisted of more than 75 cm length of roots, with a bias towards fine and young roots; roots were put in clean plastic bags and stored for 16 h or less, washed in water, and then pickled in formalin-acetic acid-ethanol 1 : 1 : 18 (Brockhoff 1985). The extent of the root systems and the occurrence of root nodules and proteoid roots were recorded.

For the preliminary assessment reported in this paper, one sample of each of the plant species collected was randomly selected for analysis. Staining and assessment methods generally followed those of Brockhoff 1985 (see Brockhoff and Allaway 1988): subsamples of 75, 1-cm lengths (each root less than 1 mm in diameter) were cut, cleared in 10% KOH and most of them also in 10 volume-strength H<sub>2</sub>O<sub>2</sub>, stained with Chlorazol Black E (Brundrett *et al.* 1984), and then put in glycerine for analysis and storage. To assess mycorrhizal fungal infection, four counts, each of 50 grid-line intersections (Giovannetti and Mosse 1980), were made on each subsample, using a Wild Leitz Photomakroskop. Morphological characters were confirmed using a Leitz Dialux photomicroscope. For a sample to be regarded as possessing vesicular-arbuscular mycorrhizas (VAM), it had to be seen to have vesicles or arbuscules, and a grid-line intersection was only scored as VAM if the grid-line crossed one of these organs or mycelium that was clearly visible as being connected to one of them (Brockhoff 1985). Photomicrographs of *Pteridium esculentum* from this study are shown in Brockhoff and Allaway (1988).

## Results and Discussion

Thirty-six species of vascular plants were found to have at least vesicles and internal and external hyphae, identifying them as possessing vesicular-arbuscular mycorrhizas (Table 1). Of these species, 21 showed arbuscules in addition, and 16 showed intracellular hyphal coils (Table 1). In these circumstances — VAM in 90% of all species sampled, 85% having more than 10% of the root length infected by VAM fungi — it is difficult to find trends in the results. There seem to be no trends by plant family, and contrasting VAM status was found even in species within the same genus (*Ipomoea*, Table 1). There seems to be no evidence of a latitudinal trend. There is little discernible relationship between the niche occupied by plant species and VAM status (compare species of the thinly vegetated seafront part of the foredune, *Ammophila arenaria*, *Festuca littoralis*, *Spinifex sericeus*, *Carpobrotus glaucescens*, *Hydrocotyle bonariensis*, *Cakile maritima*, *Ipomoea brasiliensis* and *Canavalia rosea*, with the others found in more densely vegetated areas). Introduced species were in the ratio 9 with VAM to 1 where VAM was not observed, similar to the overall proportions. The average proportion of root length with VAM fungal infection, taken over 38 samples, each of one plant species, was about 40% (Table 1, omitting *Casuarina equisetifolia* and *Leucopogon parviflorus*, where the roots did not clear well enough, and *Banksia integrifolia*, where proteoid and non-proteoid roots were assessed separately and therefore no overall proportion was available).

In four species we did not find evidence of VAM (*Carex pumila*, *Hydrocotyle bonariensis*, *Ipomoea brasiliensis* and *Acacia longifolia* var. *sophorae*), although failure to find VAM in these single samples cannot be generalised to an absence of VAM from those species. Brockhoff (1985), who examined many samples, found variable, low levels of VAM fungal infection in *Acacia longifolia* var. *sophorae* in sand-dunes at Bridge Hill, also on the New South Wales coast (Brockhoff and Allaway 1988). *Acacia longifolia* var. *sophorae* possessed root nodules.

In *Isolepis nodosa* (Cyperaceae), we found extensive VAM with arbuscules, vesicles and coils, but we did not find VAM in *Carex pumila*, a member of the same family. Powell (1975) reported endomycorrhizas in about 37% of species and 18% of samples of Juncaceae and Cyperaceae in New Zealand, and our results are consistent with this. Unexpectedly, vesicles as well as internal and external hyphae were recorded in non-proteoid roots of *Banksia integrifolia*. Apparently this species can simultaneously

employ two root specialisations — one symbiotic, and the other the proteoid roots (Lamont 1982) more characteristic of the Proteaceae. Further results on this species will be reported elsewhere. Again, unexpected was the presence of extensive VAM in the strand-line brassicaceous species *Cakile maritima*. Brassicaceae had been thought of as a non-mycorrhizal family (Harley and Smith 1983), although the occurrence of VAM is becoming more widely recorded [see Peterson *et al.* (1985), in whose study VAM was not, however, observed in *Cakile edentula* growing in a calcareous sand].

*Casuarina equisetifolia* was observed to have both root-nodules and VAM. This is consistent with the observations of VAM in this species by Peterson *et al.* (1985). However, the roots of this species did not clear sufficiently, to allow the extent of VAM to be quantitatively assessed. Roots of *Leucopogon parviflorus* (Epacridaceae) also did not clear well enough for assessment, although it was possible to detect ericoid mycorrhizas in the hair-roots of this species. Apart from *Carpobrotus glaucescens* and *Dianella caerulea*, in which very little VAM was found, all the remaining species had more than 10% of the root length infected by VAM fungi (Table 1).

The samples assessed so far have been only one sample of each species, and they thus form a checklist rather than a quantitative estimate of a representative or random sample of the vegetation of N.S.W. coastal dunes. However, the relatively high proportion of species in which VAM was detected may reflect a high mycorrhizal status in the plants of the dunes (cf. Koske *et al.* 1975, Koske and Halvorson 1981). Sand-dune soils are likely to be initially poor in plant nutrients, subject to severe leaching, and to have a poor water-holding and nutrient-holding capacity; in these circumstances the possession of VAM may be an important factor in plant survival (Koske and Polson 1984). Additionally, vesicular-arbuscular mycorrhizal fungi can be involved in formation of soil aggregates in sand-dune soils (Koske *et al.* 1975; Sutton and Sheppard 1976; Forster and Nicolson 1981) and this is likely to have significance for the management of beach dune vegetation. Maintenance of the mycorrhizal nature of the plants is likely to be very important in management of dunes, and practices such as continuing fertiliser application — which may result in high phosphate levels, which tend to suppress mycorrhizal infection (Mosse and Phillips 1971) — may be counterproductive in this respect.

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