New Zealand Journal of Forestry Science

39 (2009) 5-13

http://nzjfs.scionresearch.com

Suitability of *Acacia longifolia* var. *sophorae* (Mimosaceae) in Sand-Dune Restoration in the Central Coast of New South Wales, Australia

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(Submitted for publication 28 July 2008; accepted in revised form 22 January 2009)

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Abstract

Persistent and strong wind, low nutrient and moisture levels in the soil, and mobile sands debilitate efforts to establish vegetation in coastal ecosystems. These difficulties can be overcome in some situations where either built structures (either dune-forming fences or individual protective shields) can be constructed in fore-dune locations or irrigation (either fixed or by hand) can be applied to protect and sustain new plantings. Because many restoration projects do not have adequate monetary resources to manage expenditure relative to built structures and/or irrigation, these efforts can experience up to 50% loss in the seedlings planted. Keeping these limitations in view, a field trial was conducted at Patonga Beach in (New South Wales, Australia) to test the suitability of the long-stem planting technique in restoring coastal sand dunes. Long-stem planting is a technique that utilizes plants grown in forestry tube-sized pots; plants of such stock can have vertical woody stems up to 1 m depending upon the application and an additional 10 cm of foliage. Plants suitable for this method of installation develop adventitious roots on the buried portion of woody stem, and mature in a manner consistent with seedlings without long stems. Placing of the nursery-grown root mass at a greater depth than non-long-stem plants at the time of planting is one of the advantages of this method of planting. *Acacia longifolia* var. *sophorae* (Labill.) F. Muell. is a native legume of Australia that occurs naturally in coastal ecosystems in New South Wales and Victoria and is a species recommended for use in stabilizing sand on the fore- and crest-dunes of beaches, due to its ability to withstand the poor soil and aggressive wind conditions. The trial reported in this paper, using *A. longifolia* var. *sophorae*, was undertaken to compare the survival rate and above-ground vigour between long-stem (LS) and non-long-stem (NLS) plants in the absence of either built structures offering protection or post-planting irrigation. Several LS plants of *A. longifolia* var. *sophorae* were installed concurrently in large containers (custom-made using PVC pipes) under similar climatic conditions at a nursery in Erina (New South Wales, Australia) to observe the development of adventitious roots on the buried stems of LS plants. Results from this trial have shown plentiful and healthy new roots, which are further supported by datasets demonstrating that 52% of root growth from LS plants was adventitious. A survival rate of 79% for LS plants compared with 53% for NLS plants during the field trial and the development of adventitious roots in the container-grown plants support the view that long-stem planting of *A. longifolia* var. *sophorae* is an effective and reliable method for use in the restoration of coastal sand dunes, overcoming the need for either built structures or post-planting irrigation.

Keywords: *Acacia longifolia* var. *sophorae*; Mimosaceae; restoration; long-stem planting; sand dunes.

ISSN 0048 - 0134

Introduction

Persistent and strong wind, low nutrient and moisture levels in the soil, and mobile sands debilitate efforts to establish vegetation in coastal ecosystems. These difficulties can be overcome in some situations where either built structures (either dune-forming fences or individual protective shields) can be constructed in fore-dune locations or irrigation (either fixed or by hand) can be applied to protect and sustain new plantings. Because many restoration projects do not have adequate monetary resources to manage expenditure relative to built structures and/or irrigation, these efforts can experience up to 50% loss in the seedlings planted. Keeping these limitations in view, a field trial was conducted at Patonga Beach in New South Wales, Australia to test the suitability of the long-stem planting technique in restoring coastal sand dunes.

Coastal ecosystems throughout the world are currently experiencing considerable damage as a result of human actions and activities. This damage includes extensive mobilisation of sand and disturbances to naturally formed sand dunes. One key technique used to stabilize drifting sand is to plant *Ammophila arenaria* (Linn.) Link. (Poaceae) [marram grass; European beachgrass], sowing seeds of *Lupinus arboreus* Sims (Fabaceae) [lupin; yellow bush lupine], and sowing/planting perennials (Gadgil & Ede, 1998). Use of perennials, and especially tree species, is gaining relevance in sand-dune restoration efforts (e.g., Yan et al., 2006).

One innovative technique in ecological restoration efforts is the ‘long-stem planting’ of trees and shrubs, developed in the mid-1990s and tried along river banks in the Hunter Valley in New South Wales (NSW) (Hicks et al., 1999). These trials involved planting of 1–1.5 m tall plants from species of *Acacia* (Mimosaceae), *Eucalyptus, Callistemon, Leptospermum, and Melaleuca* (Myrtaceae). Plants were placed in approximately 60 cm deep pits along river banks using a water lance, which enabled the formation of deep, narrow pits and irrigation of the planting site. The long-stemmed plants, compared with the short-stemmed forest-tube plants planted ‘traditionally’ (*sensu* Hicks et al., 1999), exhibited better growth and survival rates, and root establishment (Hicks et al., 1999). The installation of plants with stems up to 1 m tall in a riparian zone ensured that those plants withstood floods and sheet erosion consequent to flooding; moreover, the depths at which roots were buried at planting time secured them below drier surface soils and closer to any ground water (Hicks et al., 1999).

The Australian Plants Society Central Coast Bushcare group trialled planting seedlings in Katandra Reserve (Gosford City Council local government area [GCC–LGA], NSW) using methods employed in river-bank restoration and long-stem plantings. The notable differences between the river-bank restoration project and Katandra Reserve trials were that a petrol-driven post-hole digger was used to dig pits, the plants were watered manually (up to 10 L) during installation and that the length of the woody stem (and, therefore, depth of planting) was reduced to between 50 and 60 cm. The reduced length of stem and depth of planting excavation was possible due to the texture and stability of the soil compared to riparian locations of previous trials. Table 1 describes the results of the initial trial of long-stem rainforest planting at Katandra.

TABLE 1: Results of rainforest trial at Katandra

Species planted	Number of plants	Mean survival rate
Acmena smithii	8	100%
Alphitonia excelsa	3	33%
Ceratopetalum apetalum	4	75%
Cryptocarya glaucescens	4	100%
Ficus coronata	5	100%
Ficus obliqua	3	100%
Glochidion ferdinandi	7	100%
Gmelina leichardtii	5	100%
Neolitsea dealbata	1	100%
Podocarpus elatus	5	100%
Schizomeria ovata	4	100%
Sloanea australis	1	100%
Synoum glandulosum	2	100%
Tasmannia insipida	6	100%
Trema aspera	9	89%

The long-stem planting trial at Katandra Reserve clarified that site preparation for pre-/post-planting and weed control were superfluous and that the plants required no follow-up irrigation to achieve acceptable survival rates (Australian Plants Society Central Coast Group, 2002). The success of the Katandra Reserve trial encouraged other Bushcare groups to trial further planting using seedlings of plants that usually grow in coastal areas, to support and restore sand dunes that were degraded because of human action.

Three Bushcare groups undertook long-stem plantings using a limited range of Australian native shrubs and trees in three coastal sites with an interest to restore sand dunes in GCC–LGA between 2002 and 2005. A pilot study indicated that *Acacia longifolia* var. *sophorae* (Labill.) F. Muell. survived better as long-stem plants, required limited irrigation and post-planting care, and had superior rates of foliage and stem growth (G. Bakewell, unpublished observations). *Acacia l.*

sophorae occurs extensively and naturally, especially along the coastline of NSW and eastern Victoria, where it grows as a low shrub (≥1 m) in the fore-dune areas and up to a small tree (≥10 m) in the hind-dune areas (Fairley & Moore, 2000; World Wide Wattle, 2004). *Acacia l. sophorae* performs best in higher rainfall areas and is frequently recommended for planting as a low windbreak agent and a sand-binder in both exposed and protected coastal areas and positions (The Electronic Flora of South Australia, 2001). Given its extensive distribution and characteristics such as the ease in propagation via seeds, rapid growth, and nitrogen-fixing capability, *A. l. sophorae* is a species of choice for use in coastal sand-dune restoration projects (Buchanan, 1994; Fairley & Moore, 2000; NSW Department of Land and Water Conservation, 2001; Bell, 2004).

Therefore, trials to assay the suitability of long-stem plants of *A. l. sophorae* in sand-dune restoration were carried out along the coastline of GCC–LGA, and sought answers to the following questions:

1. is there a measurable difference in the survival rates between long-stem (LS) and non-long-stem (NLS) *A. l. sophorae* in the field-planting trial?

2. is *A. l. sophorae* capable of producing new and healthy root growth on the buried stem? and

3. does development of new roots affect either above- or below-ground plant vigour?

Materials and Methods

To evaluate both the survival rate and the development of new roots by *A. l. sophorae*, an eight-month field trial measuring plant-survival rates and vigour, and a nursery planting trial measuring adventitious rooting were considered appropriate. This approach was designed to generate survival-rate data under field conditions, as well as to generate evidence of adventitious rooting without excavating well-established plants in the sand-dune trial sites.

Initial measurements of plants were taken immediately prior to installation. Over the duration of the trial, measurements of plants were conducted at six-week intervals culminating in a final inspection and measurement.

Nursery Plants

Nursery plants (seedlings) used in this trial was raised in local nurseries, (the GCC nursery and a local commercial nursery specialising in producing native plants for local restoration projects) from seeds of *A. l. sophorae* collected from coastal regions of the GCC–LGA, following Buchanan (1994) and Cremer (1990) who have recommended the use of seed-grown plants in any ecorestoration effort. Seeds for plants produced for this study were germinated in a commercially available seed-raising medium and then transplanted into a 300 mL forestry-tube container immediately after germination. Fertiliser and trace elements were either mixed in the potting mix, which was used as the substrate or applied as a top dressing at this time. Seedlings were raised over a 13-month period (May 2003 – May 2004) prior to the start of the planting trial in May 2004.

The following physical features characterized nursery-produced LS plants used in this trial: individual plants had a stem strong enough to support foliage in the upright position in a non-windy environment; bore several visible vegetative buds; and were 42–68 cm long. Nursery-produced NLS plants used in this trial were identical to the LS plants raised, except that individual plants with a stem length of 11–55 cm were used. ‘Circling’ roots that develop during the nursery phase, are considered to be a disadvantage to plants when the seedlings are meant to be planted in a landscape (Handreck & Black, 1986). Therefore, care was taken to prevent the development of circling roots during the production of these plants. This was achieved by: (a) using containers with internal ridges to direct root growth downwards; (b) placing the containers on racks to allow air pruning of roots; and (c) providing plants with regular irrigation.

Marking the Plants

To facilitate individual plant identification and data collection, aluminium-foil identification (ID) tags (5 x 5 cm) were secured to every plant, 24 h before installation either in the field or in the nursery. Identification tags for LS plants were secured to the stem of each plant at least 10 cm below the tip. Identification tags for NLS plants were secured immediately above the root mass held within the nursery container. Identification tag codes included details of: (i) whether LS or NLS plants; and (ii) serial number (e.g., 1, 2, 3, 4, …). Positions of these tags on the stems ensured that seedlings were planted at appropriate depth during installation. Moreover, these tags were useful as the reference point from which to obtain morphometric data pertaining to stem length and thickness.

Commercially available survey-flagging tape was used as ‘stem tags’ (ST) to identify the buried woody portion of stems on nursery-trial plants. A piece of such a tape was secured to the stem immediately above the point where the stem emerged from the nursery-raised root mass. Stem tags along with identification tags acted as indicators of the length of stem that should be buried during the trial. Identification tags on field plants assisted in determining whether accumulation or removal of sand had occurred around the stem because of natural (wind or water-induced) activity or human activity during the trial. Measurements of stem length and thickness in both field and nursery trial plants were obtained from the point of attachment of the identification tags during monitoring, using a metal ruler and a pair of Vernier callipers, respectively.

Installation of the Plants

The nursery trial was carried out by installing plants in 160 long x 15 cm diameter containers (15 cm wide commercially available PVC pipes were adapted for use as containers) to demonstrate the response of *A. l. sophorae* planted as LS plants and to observe new root growth from buried stem portions. Development of new roots on the buried stem without any loss in plant vigour was noted as a visible expression of *A. l. sophorae's* ability to survive as LS planting and when the plant developed new roots close to soil surface, contributing to stabilization of coastal sandy ecosystem.

All plants received three identical watering treatments at approximately eight hour intervals, 24 h before installation. Irrigation involved the plants being placed in a water column of 15 cm while still in the nursery container for 10 min, thus providing adequate moisture to both the plants and potting media. Prior to installation, the plants were verified visually for pests and disease, and also for the foliage for consistent green throughout. Six LS and six NLS plants were randomly selected from the plants received from each nursery – a total of 24 plants. The remainder were used in the field trial. A total of 191 plants were used in the field trial. Planting was carried out in planting blocks 'A' and 'B', being 300 m^2 and 320 m^2 respectively. Thirty-two LS and 31 NLS from the commercial nursery, and 15 LS and 15 NLS plants from the Council nursery were planted in block 'A' located close to the western end of trial site; 49 LS and 49 NLS plants from the Council nursery were planted in block 'B' located close to the eastern end of trial site. Multiple planting was done to support the efforts of the Bushcare group in undertaking restoration work and also to avoid any possible vandalism impacting on the study.

Field trial planting was done with help from five volunteers in one day. Excavation was done using hand-held tools (trowel, spade, mattock, long-handled post-hole shovel). Water used for irrigation during planting was transported to trial sites in large containers and applied to plants using 1.1 L containers. Removal of non-native plants within a radius of 0.5 m of any plant was restricted to those required to provide adequate space for the installed specimen either as LS or as NLS, emerging perennial weeds (ground covers or shrubs) that necessitated constant monitoring, which was determined by the Bushcare volunteers. Plants in each block were placed in rows with LS and NLS arranged alternatively in each row. Individual plants within a row, and each row within a planting block, were spaced 2 m apart. Grouping the plants so was considered pragmatic to minimize any possible microclimate variations, and impacts of vandalism on one planting cohort within each planted block. This process ensured that all the plants were installed within the boundary of the trial site.

Trial Sites

For field trials, the coastline approximately 15 km south-west of the city of Gosford (Patonga Beach; GCC–LGA, NSW; 151° 27' E, 33° 54' S) was used. Trial sites had a southerly aspect and were exposed to the maritime influences of Broken Bay. Human activity for reasons of recreation and business, dating back to early 1920s (Smith, 1990), has reduced the extent of native vegetation at the trial site foreshore. In recent years, preference by local residents for views of Broken Bay has exacerbated the damage to remnant native vegetation along the coastline chosen as the trial site in this study. Quaternary Alluvium from the Narrabeen Group of soils that includes gravel, sand, silt and clay constitutes the trial site geology (Geological Survey of New South Wales, 1983). Soil is sandy with no organic material in the 'O' horizon. Climate is similar to that of Gosford City (Gosford City Council, 2005). The warmest months are December to March and the highest rainfall occurs between December and June. For nursery trials, GCC nursery (Erina, GCC–LGA, NSW; 151° 37' E, 33° 44' S) was used. The nursery experiences a similar climate to that described for the coastline field site.

Field Planting

All plants were removed from their nursery containers immediately prior to their installation in the planting pits. The installed LS plants (42–68 cm) had at least 10 cm length of foliage above the soil with stems displaying green pigmentation and no less than 3 mm in diameter positioned above ground level. The depth to which plants were installed was one that was practical for the resources available on site, as well as ensuring that the existing root structure was placed in a position where the soil profile was cool, moist and not prone to physical disturbance. To ensure that at least 10 cm of stem and foliage remained above ground, care was taken to install every plant in a manner that ensured the identification tag was located at the preferred ground level once back-filling of the pit was completed. Each plant was placed in its planting pit and received 1.1 L of water prior to backfilling. An additional 1.1 L of water was applied at the completion of backfilling and forming of a planting dish (Figure 1).

Non-long-stem plants were installed by digging a 14 cm deep pit to accommodate the length of the existing root structure (approximately 12 cm) and an additional 2 cm for a shallow planting dish around the stem.

Other procedures followed were identical to that described in the planting of LS plants. Installation of LS and NLS plants in this manner ensured that adequate moisture was available in the soil beneath and around the root mass, a shallow dish existed around each stem to gather rainwater, and planting was consistent with procedures recommended for field planting of plants (Cremer, 1990; Queensland Government, n.d; Thompson, 2005). No post-planting fertilisation or watering of either LS or NLS plants was done.

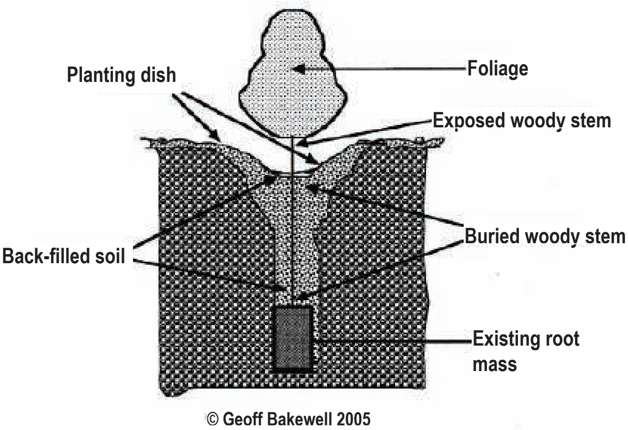

FIGURE 1: Longisectional view of LS plants when planted in the field *(not to scale).*

Nursery Planting

Plants installed as part of the nursery trial was identified and tagged consistent with field plantings and neither fertilised nor provided with any additional nutrients. This trial both prevented damage caused by excavating plants in the field, as well as, overcoming the logistical difficulties in collecting root growth from field plants.

Twenty four lengths of PVC pipe, each 160 cm long, were obtained and secured in a metal frame. The frame consisted of two sheets of 160 x 160 cm^2 wire mesh positioned one over the other with bricks and metal posts. Each PVC pipe length was stabilized in the frame by passing it through two sheets of mesh, with the bottom end of the pipe inserted gently into the soil up to a depth of approximately 5 mm. The frame and soil contact were necessary to stand the pipes upright and to ensure that contact between each pipe and the soil was sufficient to prevent the loss of sand through the open bottom end of the pipe during the 8-month trial period. Prior to installation, several drain holes were drilled in each pipe length (at 20 cm height from the bottom). The PVC pipes were filled with commercially available washed river sand. Careful back-filling and irrigation applied to the top of the pipe during filling prevented unconsolidated sand forming air pockets in the tube (Figure 2). In this trial, inspection for new roots was done after eight months, a time length recommended appropriate in any vegetative propagation trials (Hartmann et al., 2002; Blomberry & Maloney, 1994).

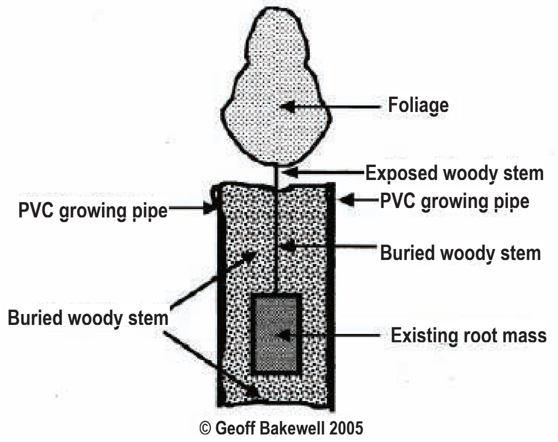

FIGURE 2: Longisectional view of LS plants in the PVC growing pipe used in the nursery trial (*not to scale*)

At the end of eight months, the supporting frame was removed and plants were removed from respective pipes and sand enabling inspection for new root growth. The frame in which the pipes were held, the absence of extensive sandy areas in the vicinity of the roots, and the limited rainfall trapping capacity all restricted the ability of nursery-trial plants to access soil water or rainwater and these were recognized as possible weaknesses in this comparison. Therefore, limited irrigation of the pipe-raised plants was necessary to ensure survival of plants. Weekly irrigation with a hand-held hose was done (approximately 3 L over 20 sec) at the top of the PVC pipe. Non-long-stem plants were also placed in PVC pipes using techniques similar to that described in the preceding section (Figure 2), but they were placed at the top of the PVC pipe.

Results

Field Trial

Survival rates

A plant was considered dead when it held no observable foliage, and when neither vegetative axillary buds nor green pigmentation existed. A plant was considered alive when any of these attributes existed. Long-stem plants had a significantly ($p<0.001$) higher survival than NLS plants at the completion of this trial (Table 2).

Stem elongation

At the completion of the trial period, LS plants achieved. greater stem elongation than NLS plants (Table 3)

Stem thickening

LS plants achieved greater stem thickening than NLS plants (Table 4). Analysis of stem thickening in field-planted plants was achieved by comparing the measured means of the diameter of stems of plants at the location of the ID tag at both planting and at the end of the trial period.

TABLE 2: Survival rate and significance of plants in field trial using chi-square tests (z^2)

	Specimen	
	Long-stem	Non-long-stem
Number of plants in each cohort at start of trial	96	95
Number of plants in each cohort that died during trial	20	45
Number of plants that survived the trial	76	50
Mean plant survival rate	79%	53%
Chi-square value	14.98	
Degrees of freedom	1	
Probability (null hypothesis)	$p<0.001$	

TABLE 3: Mean stem length (cm) including significance in field trial

Inspection	Specimen		Degrees of freedom
	Long-stem	Non-long-stem	
Start	28	30.5	0.102
1	27.8	30.3	0.070
2	26.7	29.3	0.064
3	29.3	30.3	0.462
4	35.9	32.1	0.027
5	47.2	38.5	>0.001

TABLE 4: Mean stem diameter (mm) including significance in field trial

	Long-stem	Non-long-stem	Degrees of freedom
Start	4.04	4.02	0.927
End	7.55	6.54	0.033

Nursery Trial

Survival for both LS and NLS cohorts was 100%. The nursery trial was carried out concurrent to the field trial.

Stem elongation

LS plants displayed significantly greater stem elongation than NLS plants by the end of the trial period (Table 5).

Stem thickening

LS plants displayed significantly greater stem thickening than NLS plants during the nursery trial (Table 6).

TABLE 5: Mean stem length (cm) including significance in nursery trial inspections

Inspection	Long-stem	Non-long-stem	Degrees of freedom
Start	26.8	31.7	0.161
1	27.9	33.00	0.110
2	30.1	31.7	0.680
3	38.6	35.4	0.479
4	68.7	52.4	0.065
5	119.00	81.5	0.005

TABLE 6: Mean stem diameter (mm) including significance in nursery trial

	Long-stem	Non-long-stem	Degrees of freedom
Start	5.00	4.17	0.236
End	14.58	11.17	0.002

Root development

Below-ground inspections analysing the development of adventitious roots, the mass of root system, and root elongation demonstrated that LS plants were as vigorous as NLS plants (Figures 3 and 4). Figures 3–4 are examples of the development of roots on a NLS and a LS specimen respectively. Every LS plant installed in the planting pipes developed adventitious roots on the buried portion of stem between the ID and ST tags. No adventitious roots were observed above the position of the ID tags at installation (indicated by the white paint on the stem above the roots) on NLS plants. Both LS and NLS plants developed non-adventitious roots from the existing root structure that was contained in the seedling nursery container.

To compare the total root mass generated by both LS and NLS plants during the nursery trial, the mean weights of air-dried (12 day treatment) adventitious and non-adventitious roots of each cohort were combined and compared (Table 7).

TABLE 7: Root mass development in nursery trial (g)

	Long-stem	**Non-long-stem**
Mean mass of adventitious roots	23.14	0
Mean mass of non-adventitious roots	20.97	29.15
Total mean root mass	**44.11**	**29.15**

Long-stemed plants produced a greater total mass of roots than NLS plants. The PVC planting pipes had impervious walls that restricted root growth in a lateral orientation to a maximum of 7 cm from the stem. Roots growing in a lateral orientation were observed growing in a downward direction once they had come into contact with the wall of the PVC pipe. The extent of this downward growth in some LS plants resulted in adventitious roots growing to a depth equal to that of the non-adventitious roots of the same specimen. The altered root orientation may differ from those of plants growing in a field situation. LS plants developed a longer root system than the NLS plants when grown in PVC pipes. Table 8 describes root elongation by LS and NLS plants during the nursery trial.

FIGURE 3: A - Root growth of NLS 6 depicting typical non-adventitious root development in NLS plants (Scale Bar = 0.5m);

B - Root growth of LS 6 depicting typical adventitious and non-adventitious root development in LS plants. Survey tape indicates position of stem tag. (Scale Bar = 0.5m)

TABLE 8: Root extension (cm) for plants in nursery trial

	Long-stem	**Non-long-stem**
Total mean extension	105.83	57.91
Buried stem	36.75	0
Mean root elongation	69.08	57.91

Discussion

This study reports the suitability of *A. l. sophorae* for installation as LS plants, tried in the restoration of sand dunes along the central coast of New South Wales. In this field-based trial, efforts mimicked the planting process, and the resource constraints usually experienced in similar projects. This trial particularly considered practical limitations for planting and replanting of failed plants, such as the lack of facilities to provide post-planting irrigation, adequate plant protection, and specialized tools.

The ability of any plant cutting to regenerate roots relies on the cuttings being in a favourable physiological state at the time of excision (Maynard & Bassuk, 1996; Southworth & Dirr, 1996) and the environmental conditions that support the expression of inherent rooting potential (Howard & Harrison-Murray, 1995). Although the precise physiological factors that determine the capacity for rooting of any shoot cutting are not clearly known, what is clear is that the rooting potential is influenced by age and the degree of lignification of tissues within the cutting and also by the age of the parent plant (Eshed et al., 1996; Brown et al., 1997). Nonetheless, the generic understanding is that cuttings from *Acacia* species are hard to generate (Wrigley & Fagg, 1998). In such a context, the ability of LS plants of *A. l. sophorae* to root and establish especially in sandy soils appears noteworthy because the LS plants of *A. l. sophorae* in planting pits (Australian Plants Society, 2002). Both riparian and rainforest projects have used as much as 10 L of water/plant during installation.the field planting trials responded positively (LS plants achieving a survival rate of 79% [p<0.001]). A survival rate of 79% in sand dune conditions represents a critical return value for the human effort and time invested. Not only did higher numbers of LS plants survive and become established at the trial sites, but also they generated greater biomass of stem tissue than NLS plants. Mean-stem elongation over the trial period for LS plants was 19.20 cm, a value far greater than what was achieved by NLS plants being 8cm.

Greater survival rates of LS plants compared with NLS plants, supplemented by a greater shoot biomass, demonstrates that LS planting, while establishing, did not compromise on plant vigour in any way. Earlier LS planting trials have recommended the use of a water lance to scour planting pits (Australian Plants Society, 2002). Both riparian and rainforest projects have used as much as 10 L of water/plant during installation. However, the reality is that neither specialized machinery nor copious volumes of water are always available during a restoration project, especially in coastal ecosystems. The survival rate of 79% of LS plants in this trial was achieved using household tools (e.g. shovels or trowels) and a one-time application of small quantity of water (ca. 2 L). This field trial demonstrates how an improvement of nearly 26% in the survival rate and an increase in the mean-stem elongation of 16 cm of plants can be gained in a restoration project, using cheap tools and easily accessible material resources.

One critical outcome from this study was the extensive adventitious root growth achieved on every LS specimen (verified in nursery trials). Photographic evidence illustrates that LS plants of A. l. sophorae struck roots adventitiously which suggests that similar rooting may have occurred in the field trials as well. The mean mass of all root material indicates that LS plants produced nearly 15 g of root tissue more than that in the NLS plants. Nursery trials also indicated that the below-ground growth of A. l. sophorae was in no way hampered by installation as a LS specimen and striking of adventitious roots. By applying the measures of stem elongation, stem thickening, and root mass, it is evident that A. l. sophorae did not suffer any above- or below-ground vigour loss consequent to being installed as a LS specimen. In discussing the role of vegetation in slope stability, and erosion and sediment control, Phillips (1995) indicates the criticality of root and shoot biomass factors of native plants are key in stabilizing soil; in such a context also, *A. l. sophorae*, a native hardwood species of Australia (Lambert & Turner, 2000), scores high both in terms of hydrological and mechanical mechanisms, more so because the trails have been conducted in stabilizing loose sandy soil. The nursery trial achieved results similar to the field trial, where stem elongation was greater in LS plants, greater stem elongation was achieved in LS plants in the nursery trial than that in NLS plants. The mean stem elongation of LS plants in the Nursery Trial was 37.5 cm greater than NLS plants. This was despite the fact that all nursery trial plants received weekly irrigation and did not experience any of the normal vagaries of field conditions. In addition, LS plants achieved greater mean stem thickening than NLS (7.5 mm and 6.5 mm respectively), and greater root mass development (44.11 g and 29.15 g respectively).

At the end of the nursery trial, the buried stem between the ID and ST tags on every LS specimen developed a distinct wider top and a narrower bottom, which is considered as a step towards greater stability of vegetation and improved resistance to removal from the surrounding soil by mechanical forces (Stokes et al., 1996; Ennos, 2000). The nursery trial revealed that 52% of the root mass generated by LS plants was adventitious growth, emerging between ST and ID tags. Tapering of the buried stem and root growth emerging from both the buried stem and from the deeply planted original root mass, suggests that LS planting both improves plant stability and increases the depth of soil being stabilised by the root structure of the plant when compared to a NLS specimen.

In conclusion, the present study illustrates multiple short-term benefits of LS planting of *A. l. sophorae* and the trials have not revealed any adverse impacts. However, issues such as the longevity of the plant used as a restoration species in sand-dunes and its enhanced susceptibility or resistance to pests and pathogen, and a cost –benefit analysis of these efforts, and other corollary issues such as the reproductive phenology of *A. l. sophorae* need to be verified.

Acknowledgements

Geoff Bakewell is grateful to the University of Sydney for the award of the Faculty of Rural Management – Honours Scholarship, to the Australian Plants Society Central Coast Group, John Connor, the Patonga Bushcare group, Gosford City Council and Anne Matthews for their encouragement and support.

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