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## Reading 4–7

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## Direct Revegetation of Coal Tailings at BHP-Saraji Mine (Central Queensland)

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### ABSTRACT

A direct revegetation strategy involving minimal capping for coal tailings is sought to reduce dust hazard and maximise the potential for later coal extraction. Coal tailings produced from washing mined material are composed of ca. 50 % coal and 50 % inorganics and are pumped as a slurry (c. 30% solids) to holding dams for disposal. On cessation of filling, surface crusting slows evaporation, and slow drainage limits consolidation and vehicular access. Studies were conducted on tailings dam #3 at Saraji Mine. The dam has a storage capacity of ca. 3,500,000 m<sup>3</sup> (20 m height, 23 ha) and was last used in 1985. The moisture content 1 m below the surface was, in July 1994, 10-30 %. Substrate characterisation indicated the material should allow growth of salt tolerant plants, with a pH<sub>1.5</sub> of 6.5-8.5 and a salt content (EC<sub>1.5</sub>) of 2.5 dS.m<sup>-1</sup>, except in the immediate area of the old inflows where substrate pH was low (pH<sub>1.5</sub> 2-4). Nutrient analyses indicated a low CEC (<20 meq.100g<sup>-1</sup>), with deficiencies in N (0.6 mg NO<sub>3</sub>:N.kg<sup>-1</sup>) and P (bicarb extractable; 6 mg PO<sub>4</sub>.kg<sup>-1</sup>). Plant available moisture was 20 %, but the material was poorly aerated where moisture content was high.

Germination trials were undertaken to establish the salt tolerance of 11 plant species, using salt extracted from tailings leachate. *Acacia harpophylla* germinated (>50 %) within 4 days, even at high salinity (EC<sub>1.5</sub> 20 dS.m<sup>-1</sup>). In contrast, salinity markedly delayed germination in other species (e.g. *A. salicina*). The effect of topsoil covering and mulching on germination and growth of 11 species was considered in a glasshouse based pot trial. Nil germination was recorded on bare tailings, a result ascribed to salinity and poor aeration. A 5 cm topsoil layer acted as a seed bed, and root growth into the tailings followed.

Field trials were established with respect to a wetland and a dryland zone using apparently saline tolerant species. Techniques were trialed to decrease surface salinity, evaporation, and to improve surface nutrition and water content. In the wetland zone, a factorial experiment (5 replicates) involved fertilisation at three levels (0, 650, 1300 kg.ha<sup>-1</sup> Osmocote™ 14 month plus) and three mulch levels (0, 10, 20 tonnes sugar cane-tops.ha<sup>-1</sup>). Each plot (2 by 2 m) was planted with *Vetiveria zizanioides*, *Sporobolus virginicus*, *Typha domingensis*, *Phragmites australis*, *C. glauca* and *Sarcocornia* sp. Vetiver grass gave excellent establishment and growth, particularly at the highest fertilisation level, and is recommended for wetland use. In the dryland zone, a factorial experiment (3 replicates) considered three mulch conditions (nil, 10 t.ha<sup>-1</sup> cane-tops, plastic), two levels of cultivation (nil, 15 cm depth) and irrigation (nil, T-tape delivering 1 L.plant<sup>-1</sup>.day<sup>-1</sup>) with respect to seed germination and *C. glauca* tubestock survival and growth. Each plot consisted of a row 22 m in length planted at 1 m centers. Germination occurred with bare tailings and cane mulch treatments. After 90 days, greater than 75 % survival of *C. glauca* was achieved in all mulched and irrigated treatments, however survival was less than 50 % in other treatments. Irrigation by T-Tape with mulching is recommended on the dryland area.

## INTRODUCTION

BHP Australia Coal Pty. Ltd. operate several large open-cut and underground coal mines in the Bowen Basin of Central Queensland. In such coal mining operations, coal tailings are produced as a fine waste when run-of-mine material is crushed, screened and washed to produce a product of market specification. The tailings are comprised of predominantly 0.002 mm to 0.006 mm sized particles and approximately 50 % coal and 50 % inorganic material (Williams and Morris 1988; Canibano and Leininger 1987). The amount of tailings produced is substantial, with the weight of tailings typically 7-10 % (dry weight) of the final coal product.

After production tailings are pumped as a slurry of approximately 30 % solids to tailings dams for disposal. In the Bowen Basin of Central Queensland, "turkey nest" style tailings dams to 20 metres in height and 100 hectares in area, with spoil or coarse reject dam walls, have traditionally been used for tailings disposal. In the tailings dam, the tailings are left to dry through surface evaporation and drainage from the dam walls and base. Surface evaporation is the dominant initial drying process, resulting in a dry consolidated surface crust with wet unconsolidated material beneath (Williams 1994). The surface crust develops to approximately 1 m in depth, limiting further drying by evaporation (Williams 1992a). Drainage of material beneath the crust is extremely slow due to the poor hydraulic conductivity.

Current tailings dam rehabilitation strategies involve the capping of exposed tailings material with a minimum of 1 m of overburden before vegetation establishment is attempted (Johnson 1992; Department of Minerals and Energy 1995). The low undrained strength and high compressibility of the underlying tailings result in a relatively low bearing capacity, limiting trafficability and the ability to support substantial capping load (Williams 1994). Large tailings dams such as those in the Bowen Basin may take 7-10 years to consolidate sufficiently to allow capping to commence. In the interim the fine nature of the dry surface material renders it highly susceptible to wind and water erosion. Additionally, the capping process is expensive, costing in the range of A\$ 15,000 to A\$ 20,000.ha<sup>-1</sup> (Williams 1992b). Mine operators are reluctant to cap tailings as this would increase the cost of coal recovery should improvements in technology render reprocessing economically viable. At BHP Australia Coal Pty. Ltd. Saraji Mine 100 ha of deep (approximately 20 m) tailings material has accumulated in three tailings dams.

Permissible tailings dam rehabilitation (decommissioning) alternatives include permanent water cover, consolidation with overburden (current practice), rock cladding, capping with an impermeable substance or amelioration and revegetation (Department of Minerals and Energy 1995). Decommissioning through amelioration and revegetation could result in large cost savings to industry and minimised offsite environmental impact, whilst maximising the accessibility of a potential resource. Deep rooted vegetation may act to dewater the tailings, and reduce surface wind velocity and erosion. Similar approaches have been used to dewater and reduce erosion in saline discharge zones (George 1990; Bari and Schofield 1991; Schofield 1991; Walsh *et al.* 1995).

The objectives of this study were to determine the ability of the tailings to support plant growth, by screening a variety of tree, saltbush and wetland species for establishment on the tailings surface, and to select amelioration procedures to facilitate the vegetation establishment. Germination, glasshouse and field trials have been used to meet these aims.

## METHODS AND MATERIALS

### *Study Site*

The study site selected was tailings dam no. 3 at Saraji Mine. Saraji (latitude, 22° 23' 52"; longitude 148° 16' 23") is located approximately 180 km SW of Mackay and 270 km NW of

Rockhampton in the Bowen Basin of Central Queensland. Tailings dam no. 3 was selected as it was representative of Saraji tailings and available. The dam has not been used for tailings disposal since 1985 and therefore was considered "drained". The dam has an area of 23 ha and a height of approximately 20 m. Due to the primary fill point being situated at the southern end, a topographical gradient of 1:300 from south to north was created. The southern end consisted of a dry surface crust 1 m in thickness with unconsolidated material beneath. In the north an ephemeral wetland area (perched watertable) attained to a maximum area of 10 ha, and depth of 1 m.

The climate of the Saraji area has been categorised as sub-humid and sub-tropical with high seasonal variability in temperature, rainfall and evaporation (Fitzpatrick 1967; Lloyd 1984; Kelly 1987). Annual pan evaporation rates of 1500-2200 mm greatly exceed the 600-700 mm annual rainfall (Fitzpatrick 1967; Lloyd 1984; Kelly 1987). Rainfall is unreliable and highly variable, both seasonally and annually. Intermittent summer rain of short duration is the dominant form of precipitation (Lloyd 1984). The winter mean daily minimum temperature is 3-7 °C and the summer mean daily maxima 34-36 °C (Lloyd 1984). Kelly (1987) reported that at Saraji Mine daily maxima were likely to exceed 38 °C for 27 days between November and March. Frosts were likely (>50 % probability) during June and July when overnight minima may drop below 2 °C (Lloyd 1984). Rainfall data collected during the field trial period have been presented (fig. 1).

#### Substrate Characterisation

Surface samples (0-10 cm) from a sampling grid at 50 m centres were also analysed for pH<sub>1:5</sub> and soluble salts (EC<sub>1:5</sub>) as outlined by Rayment and Higginson (1992). Substrate chemical and physical characteristics were determined for 9 bulked samples. The samples were obtained by dividing the dam into 9 cells of equal area (6 dryland, 3 wetland) and pooling ten 0-30 cm samples from each cell. A synopsis of the analyses and methods have been presented (Table 1 and 2).

#### Species Selection

Species were selected for their ability to colonise saline waterlogged substrates (Marcar 1988, 1992; Truong and Roberts 1992; Hoy *et al.* 1994); their success on tailings material of similar characteristics (Bell *et al.* 1989) or as known halophytes. The tree and shrub species used in dryland trials were *Acacia harpophylla*, *A. salicina*, *A. holosericea*, *A. stenophylla*, *Eucalyptus camaldulensis*, *Casuarina glauca*, *C. cristata* and *Melaleuca bracteata*. The saltbushes *Atriplex lentiformis*, *At. amnicola* and *At. lindleyi* were included as were the grasses *Cynodon dactylon* and *Chloris gayana* (c.v. Pioneer). Tree seed was obtained from Queensland Tree Seeds and grass seed from Selected Seeds. In the wetland *Vetiveria zizanioides*, *Sporobolus virginicus*, *Phragmites australis*, *Typha domingensis* and *Sarcocornia* sp. were trialed.

#### The Effect of Substrate Salt on Seed Germination

The effect of tailings salt extract on germination of the selected tree and saltbush species was studied in a petri dish germination trial. The salt extract was obtained from a representative sample of dryland surface material collected for substrate characterisation analyses. A 1 kg tailings sample was mixed with 5 L of deionised water and stirred for 1 h at 25 °C. The leachate was concentrated by heating at 70 °C until a stock solution (EC 20 dS.m<sup>-1</sup>) was obtained. Aliquots of the stock were diluted to obtain solutions of 10, 5 and 2.5 dS.m<sup>-1</sup> electrical conductivity (25 °C).

Three replicates of thirty seeds of each *Acacia* species and 100 seeds of the other genera were trialed at five salt concentrations (nil, 20, 10, 5, 2.5 dS.m<sup>-1</sup>). *Acacia* species (except *A. harpophylla*) were pretreated with boiling water (20 seconds) immediately before all trials. Seeds were placed on filter paper over vermiculite and 20 ml of salt solution or deionised water added. Plates were randomised and incubated at 25 °C (photoperiod 12 hours light 12 hours dark) under

high humidity conditions to reduce evaporation. Germination was assessed at 2 day intervals for 60 days. Seeds were scored as having germinated when a radical of 3 mm in length emerged. At each counting the dishes were re-randomised. Data analyses were performed using a completely randomised ANOVA. In all experiments a critical probability of 0.05 was used when hypothesis testing.

### *Dryland Germination, Growth and Ameliorant Trials*

#### Glasshouse trial

The potential of the tailings as a medium for germination and growth, and the influence of selected amelioration techniques on these parameters was studied in a glasshouse trial. The trial examined the selected tree and saltbush species, and topsoil and mulching treatments.

A tailings bulk sample was collected by pooling twenty-four randomly selected samples (0-30 cm) from the dryland area of the dam, and homogenised by mixing in a conventional electric cement mixer. A factorial experiment involving covering tailings with 5 cm topsoil and 10 t.ha<sup>-1</sup> mulch was conducted. The experiment was designed as a randomised complete block with five replicates. The topsoil consisted of 5 parts medium river sand, 2 parts perlite, 1 part coir fibre peat and the mulch, lucerne hay. Tailings and topsoil were fertilised with the equivalent of 150 kg.ha<sup>-1</sup> (incorporated to 10 cm in depth) Osmocote™ 14 month plus. Each pot (20 cm diameter, 20 cm height) was divided into thirds and species randomly assigned to each position. Pots were "bottom watered" by placing in level bays containing 50 cm deep deionised water. Seeding was undertaken four days after bottom watering commenced. *Acacia* species were pretreated as in the salt germination trial. Twenty five *Acacia* seeds and 50 seeds from the other genera were sown at approximately twice the depth of the seed diameter. Germination and growth measurements were made every two days for the first 14 days, and every 5 days thereafter until day 60. In all treatments germination was scored when the epicotyl was visible. After 10 days pots were thinned to 5 seedlings per species. Data analyses was performed using a randomised complete block ANOVA.

#### Field Trial

A field trial to screen tree and saltbush species, and amelioration techniques in the dryland tailings material was established in January 1995. Amelioration techniques to decrease salinity and/or increase surface moisture content were selected. Ten treatments involved mulching (cane-tops 10 t.ha<sup>-1</sup>, silver horticultural plastic), cultivation (nil, 15 cm) and watering (nil, 1 L.m<sup>-2</sup>.day<sup>-1</sup>) were trialed. With respect to cane-top mulch, cultivation and water the experiment was constructed as a factorial design. Plastic mulch was not used without cultivation as the mulch could not be secured. The experiment was constructed as a randomised complete block with three replicates. Treatments were constructed in rows of 2 m in width and 20 m in length. All treatments received a fertiliser application of 1 t.ha<sup>-1</sup> Osmocote™ 14 month plus. Preparation plant feed water (ca. pH 8, EC 3 dS.m<sup>-1</sup>) was used for T-tape irrigation as this water was readily available on site.

Tree and saltbush species were sown in all treatments except plastic mulch. Species sown were those used in salt germination and glasshouse trials with the exception of *A. stenophylla*, *C. cristata*, *At. lindleyi* and *A. amnicola*. On each plot 100 seed of each *Acacia* species, 500 *C. glauca*, 300 *At. lentiformis*, 2800 *M. bracteata* and 1000 *E. camaldulensis* seeds were sown, resulting in a seeding rate of 15 kg.ha<sup>-1</sup>. In all treatments surface seeding was undertaken and seeding on top and beneath mulch was evaluated by dividing each row in half and randomly assigning the seeding method. Seeding occurred 3 weeks after trial establishment and coincided with 70 mm of rainfall over the following 4 days. Germination and establishment was assessed by counting the number of germinants of each species in the central 1 m strip of each row at 10 days

and monthly intervals thereafter. Data analyses were performed using a randomised complete block ANOVA.

The survival and growth of 6 month old *C. glauca* tubestock was assessed in all treatments. Seedlings were hardened by water stress for two weeks and trimmed to 30 cm in height before planting. Planting occurred 6 weeks after trial establishment. The row centres were planted with 20 seedlings per row at 1 m intervals. Survival and growth (height) was assessed on monthly site visits. Data analyses were performed using a randomised complete block ANOVA.

#### *Wetland Species and Ameliorant Trial*

A field trial to study the survival and growth of selected wetland species, and screen amelioration techniques was established in October 1994. The experimental evaluated 3 levels of cane-top mulching (nil, 10 t.ha<sup>-1</sup>, 20 t.ha<sup>-1</sup>) and 3 levels of Osmocote™ 14 month plus fertilisation (nil, 650, 1300 kg.ha<sup>-1</sup>). The nine treatment combinations were arranged factorially in a randomised complete block design with 5 replicates. The trial species *Vetiveria zizanioides* (vetiver), *Sporobolus virginicus* (marine couch), *Phragmites australis* (common reed grass), *Typha domingensis* (cumbungi) and *Sarcocornia* sp. were randomly assigned to grid positions (30 cm centres) and planted in the internal 1 m<sup>2</sup> of each 2 m by 2 m plot. *V. zizanioides* and *T. domingensis* were planted as 30 cm high slips, *S. virginicus* as 10 cm by 10 cm blocks, common reed grass as rhizome with 8 nodes and *Sarcocornia* sp. as 20 cm high plants. All planting material (except *V. zizanioides*) was collected from the lower reaches of the Fitzroy River three days prior to planting and stored in a cool humidified environment. *V. zizanioides* was sourced from stocks held at the Central Queensland University. Survival and growth were analysed during monthly site visits. The growth of *V. zizanioides* and *S. virginicus* were assessed by determining cross sectional area (largest height by width/2) and total area respectively. Survival data were analysed using the Kruskal Wallis test for randomised complete blocks. Growth data were analysed using a randomised complete block factorial ANOVA.

## RESULTS

### *Rainfall*

Rainfall over the trial period was below the 100 year median for eight months of ten (Fig. 1). Although for two months of the trial period rainfall was reasonable, falls were predominantly received as short duration storms. Over the trial period only one rainfall event (received in February 1995) lasted for greater than two days.

### *Substrate Characterisation*

Chemical analysis indicated the substrate was saline, highly sodic and extremely low in nitrogen and phosphorus (Table 1). The substrate contained high levels of soluble sulfur, magnesium and calcium. Plant available copper, zinc, magnesium and iron was high. Cation exchange capacity was low. Homogeneity of the substrate was high, as reflected by the low standard errors. Acidic tailings (pH 2-4) were found near the inflows (8 % of dam area).

Physical analysis indicated a specific gravity intermediate between coal and mineral material (Fig. 2). The tailings had good water holding capacity (20%) with wilting point at 20 %, field capacity 40 % and porosity 45 %. Surface moisture in the dryland was 10 % (below wilting point) to 50 cm in depth, reaching a constant 30 % below 1.5 m. In the wetland the surface material was saturated, however moisture content decreased to 30% at 1.5 m in depth.

### *The Effect of Substrate Salt on Seed Germination*

Germination was not significantly effected by the 20 dS.m<sup>-1</sup> tailings salt extract in most species considered (Fig. 2a). Germination of *A. salicina* was decreased by 11 % under high salt. Salt treatment increased the time to 50 % germination in all species with the exception of *A. holosericea* (Fig. 2b).

#### *Dryland Germination, Growth and Ameliorant Trials*

##### Glasshouse trial

Germination in all media was poorer than in petri plates (Fig. 2a). With the exception of *A. holosericea*, germination was not effected by mulching. Germination in tailings was poor in all species trialed with *A. harpophylla* and *A. holosericea* being the only species germinating in tailings. *A. harpophylla* germinated in all tailings media whereas, *A. holosericea* only germinated in 50 % tailings/50 % topsoil. Germination in 50 % tailings/50 % topsoil was significantly higher than in other tailings media.

Germination time in the topsoil media was similar to that in petri dish trials (Fig. 2b). Relative to the topsoil control, time to 50 % germination increased significantly in tailings media with a topsoil cover. With the exception of 50 % tailings/50 % topsoil, *A. harpophylla* germination time was greater in tailings than in other media.

Plant growth was significantly reduced in topsoil on tailings relative to the topsoil control (Fig. 2c). In tailings *A. harpophylla* growth was significantly less than in topsoil, and topsoil on tailings. *A. holosericea* however grew equally well in the topsoil on tailings and 50 % tailings/50 % topsoil media. On harvesting the pots, roots were found penetrating deep into the tailings. Mulching did not significantly effect the growth of any species on any substrate.

##### Field Trial

Due to a four day rainfall event (70 mm total) at the time of seeding, watering was found to have no effect on germination at 10 days (Fig. 3a). Germination at 10 days was significantly higher on bare tailings than in mulched treatments. Seeding on top of mulch was less effective than seeding beneath mulch, and cultivation had no significant effect on germination.

Seedling survival at 90 days was low in unwatered treatments, and therefore density in watered treatments was presented (Fig. 3b). Establishment at 90 days was greatest in treatments where seeds were sown under mulch. Mortality in the unmulched treatments was high. The seeding rate of 15 kg.ha<sup>-1</sup> tree and saltbush seed resulted in an average of 19 stems.plot<sup>-1</sup> (20m<sup>2</sup>) or 9500 stems.ha<sup>-1</sup> when sown under mulch. The resultant species composition was 92% *Acacia* sp. (ca. 30 % each species) and 8 % *At. lindleyi*.

At 90 days *C. glauca* tubestock survival was significantly higher in watered treatments (Fig. 4a). In unwatered treatments survival was significantly increased by mulching. Cultivation had no effect on survival.

Growth of *C. glauca* tubestock 90 days after planting was greater in all treatments when watered (Fig. 4b). In unwatered treatments growth under plastic mulch was greater. Mulching and watering resulted in significantly taller plants than other treatments. Cultivation had no significant effect on growth.

##### *Wetland Species and Ameliorant Trial*

Complete mortality was recorded after 210 days for all species, except *V. zizanioides* and *S. virginicus*. *V. zizanioides* survival was significantly increased by mulching (Fig. 5a) but was



unaffected by fertilisation (Fig. 5b). Growth was improved by mulching at 20 t.ha<sup>-1</sup> (Fig. 6a) and fertilisation (Fig. 6b). Mean *S. virginicus* survival was 84 %, with no treatment effect found. Mulching and fertilisation however, resulted in a significant increase in *S. virginicus* growth (Fig. 7a,b).

## DISCUSSION

### *Characteristics of the Site*

The Saraji tailings material should be easily amendable to support plant growth, except in the limited areas of low pH (8 % of total dam area) near the inflows. Due to the low nutrient status and cation exchange capacity fertilisation with nitrogen, phosphorus and potassium as slow release fertiliser will aid vegetation establishment. Fertiliser application rate needs careful consideration however the nutrient requirements of many native species are unestablished (Aitken *et al.* 1984) and interaction between nutrients is common (Salisbury and Ross 1993). Fertilisation rate is therefore best determined from nutrient omission experiments. The electrical conductivity<sub>1:5</sub> of 2.5 dS.m<sup>-1</sup> indicated the tailings were mildly saline (Shaw 1988), a condition that may have resulted from the concentration of washery water salts by evaporation. The material has poor structure, resulting in low hydraulic conductivity as manifest in the perched watertable. Species tolerant to waterlogging and salinity are therefore recommended.

### *Species for Dryland*

A range of species were chosen for trial based on their reputation for salinity and waterlogging tolerance. Direct seeding is an option for species with a rapid germination rate allowing establishment after a rain event. *A. harpophylla* forms the dominant vegetation type in the Bowen Basin (Bell 1984) and is well adapted to the limited establishment opportunity, as reflected by its rapid germination rate and large seed size (Baker 1972). *A. harpophylla* is therefore recommended in this respect. The success of *Acacia* species may be attributed to a large seed size which is common of species from droughty environments (Baker 1972). *Atriplex* species have also been successful in direct seeding attempts on saline mined (Osborne and Lambert 1994) and agricultural land (Vlahos 1992) in low rainfall areas. The low viability commonly associated with *Atriplex* seed (Vlahos 1992) however, increases the cost of seeding. A seed mix of *A. harpophylla*, *A. salicina* and *A. holosericea* is therefore recommended.

### *Dryland Substrate Amelioration Techniques*

As a seeding regime, seed burial in the glasshouse performed poorly in comparison to surface seeding in the field (Fig. 2a; 3a). Moisture content, salinity and temperature were comparable between trials therefore, the result was consistent with poor substrate aeration. Surface seeding is therefore recommended. Mulch decreased the germination of *A. harpophylla* in the field but increased the survival of these seedlings (Fig. 3a; 3b). Additionally, in the field *A. salicina* and *A. holosericea* germinated under irrigation and mulch, a result ascribed to prolonged wetting and reduced evaporation. On the above we recommend surface seeding, mulching and irrigation for establishment of tree and saltbush species. Optimum fertilisation rates for the selected *Acacia* species will be determined in a glasshouse based nutrient omission trial. Further studies to investigate optimum seeding rates will be undertaken with the 3 species of *Acacia*. The potential of trees to dewater the tailings will be estimated after measuring the water use of established trees.

Tubestock survival (Fig. 4a) and growth (Fig. 4b) was also increased by mulching and irrigation, enforcing the value of this treatment. The high growth rate of seedlings in unwatered plastic mulch was attributed to the ability of a 5 cm depression in the rows centres to collect rainwater and deliver it to the seedlings, increasing substrate moisture and decreasing salinity. Therefore plastic

mulching is recommended over haymulch for tree species establishment from tubestock where irrigation is not applied.

The performance of mulched and watered treatments was maximised by the treatment design. Irrigation of the dry saline material ( $EC_{1:5}$   $2.5 \text{ dS.m}^{-1}$ ) with  $2.5 \text{ dS.m}^{-1}$  water would initially have diluted pore water salts. Over time however, pore water salt concentration should increase where evaporation concentrates salts at the surface, or irrigation rate exceeds hydraulic conductivity. Therefore minimal irrigation in combination with mulching is necessary, and watering at night preferred. Before ceasing irrigation a period of watering with low salinity water ( $0\text{--}1 \text{ dS.m}^{-1}$ ) is suggested to leach salt from the root zone. Irrigation should be necessary only for the first year of growth, until the tree roots penetrate the surface crust and access (and dewater) subsurface ( $> 1 \text{ m}$ ) moisture.

#### *Species for the Wetland*

Of the species trialed, *V. zizanioides* is recommended based on planting ease, survival and vigour on the site. This grass has been recommended by Truong and Roberts (1992) for the stabilisation of sheet, wind and drainage erosion and is due for release early in 1996 (Truong pers. comm).

#### *Wetland Substrate Amelioration Techniques*

*V. zizanioides* survival was improved in the presence of mulch (Fig. 5a). The mulch presumably acted to prevent evaporation and thus maintain substrate moisture and decrease salt accumulation as the wetland dried. *V. zizanioides* growth was greater at the high level of mulch (Fig. 6a), and *S. virginicus* growth increased with each level of mulch (Fig. 7a). The higher growth rates obtained with mulch again suggest mulch reduced surface evaporation. Mulching should therefore, prove advantageous in maximising survival and increasing the potential growing period. Higher mulching rates may have further improved survival and growth however, in the wetland, trafficability is limited and broadscale mulching at higher rates impractical. The effect of fertiliser on the growth of *V. zizanioides* (Fig. 6b) and *S. virginicus* (Fig. 7b) was marked. Fertiliser response had not plateaued at the highest rate ( $1300 \text{ kg.ha}^{-1}$  Osmocote), and consequently fertiliser omission trials are required to establish the optimal level of application and an efficient fertilisation regime. We recommend the planting of *V. zizanioides* slips with  $20 \text{ t.ha}^{-1}$  cane-tops mulch at a high level of fertilisation for stabilising the wetland tailings material.

#### ACKNOWLEDGEMENTS

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#### REFERENCES

- Aitken, R.L., Campbell, D.J. and Bell, L.C. (1984). Properties of Australian fly ashes relevant to their agronomic utilisation. *Aust. J. Soil Res.* 22, 443-453.
- Baker, H.G. (1972). Seed weight in relation to environmental conditions in California. *Ecology* 53, 997-1010.
- Bari, M. and Schofield, N.J. (1991). Effects of agroforestry-pasture associations on groundwater level and salinity. *Agroforestry Systems* 16, 13-31.

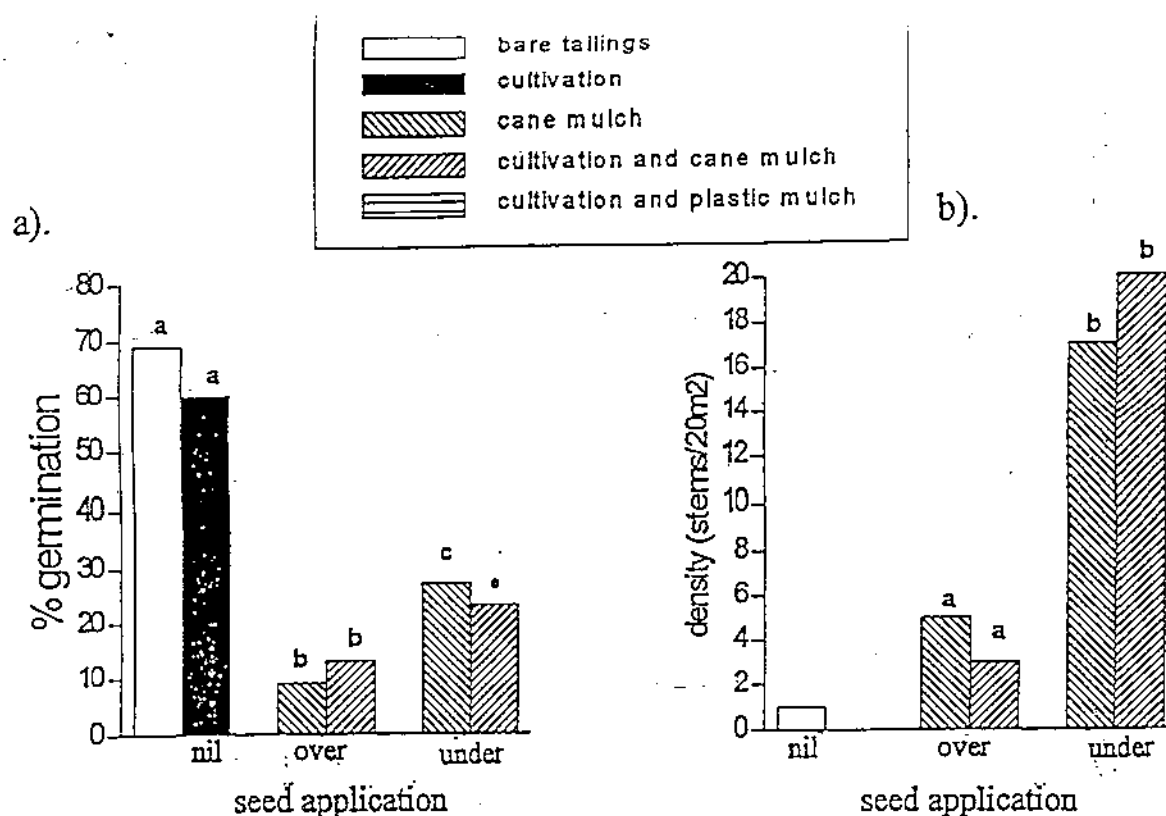


Figure 3. Broadcast seed under field dryland conditions. a) Percentage germination of *A. harpophylla* seeds 10 days after sowing onto tallings material, ontop and beneath cane-top mulch (data pooled from watered,unwatered treatments). b) establishment of tree species in watered treatments 90 days after seeding.

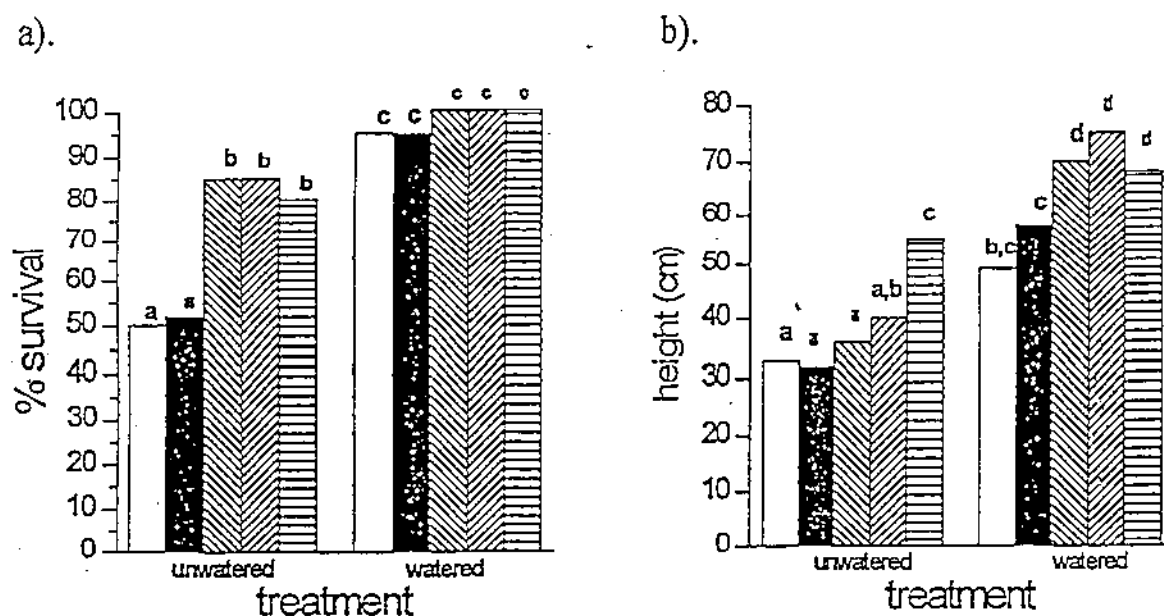


Figure 4. *C. glauca* tubestock under field dryland conditions. a.) survival; b). growth 90 days after planting.

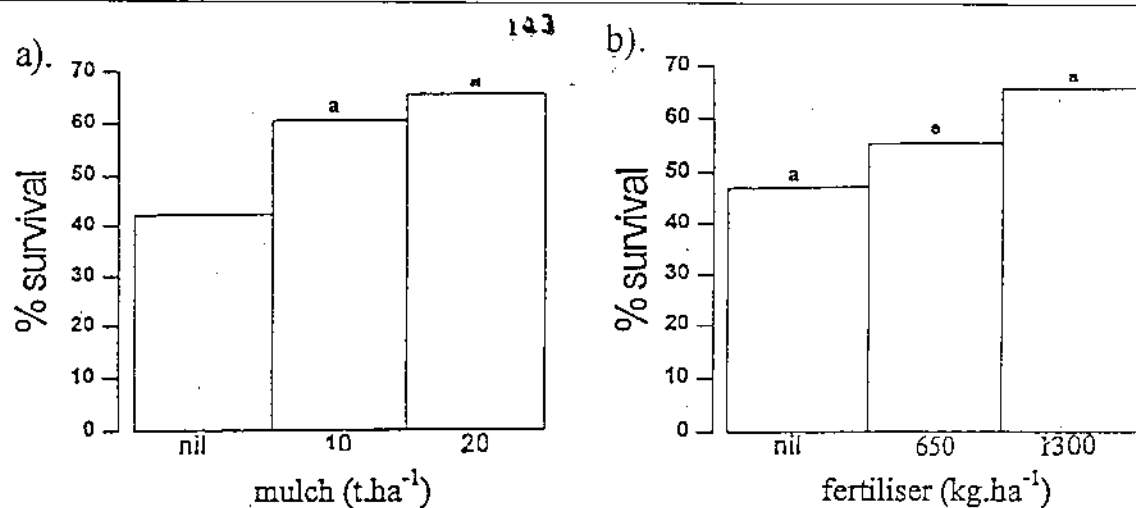


Figure 5. Survival of *V. zizanioides* under field wetland conditions 210 days after planting. a). cane-top mulch treatments b). fertilisation treatments.

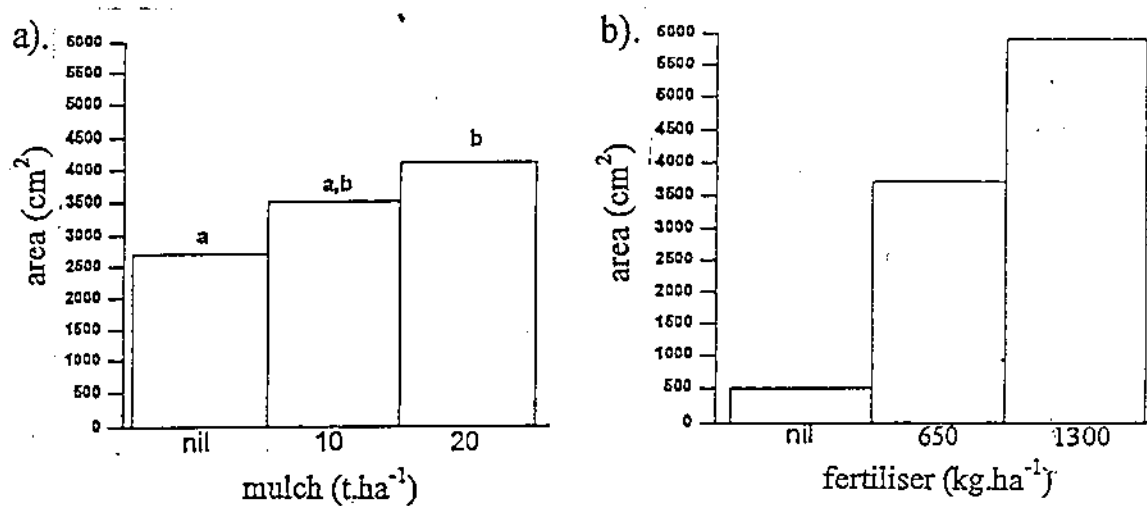


Figure 6. Growth of *V. zizanioides* 210 days after planting a). cane-top mulch treatments b). fertilisation treatments.

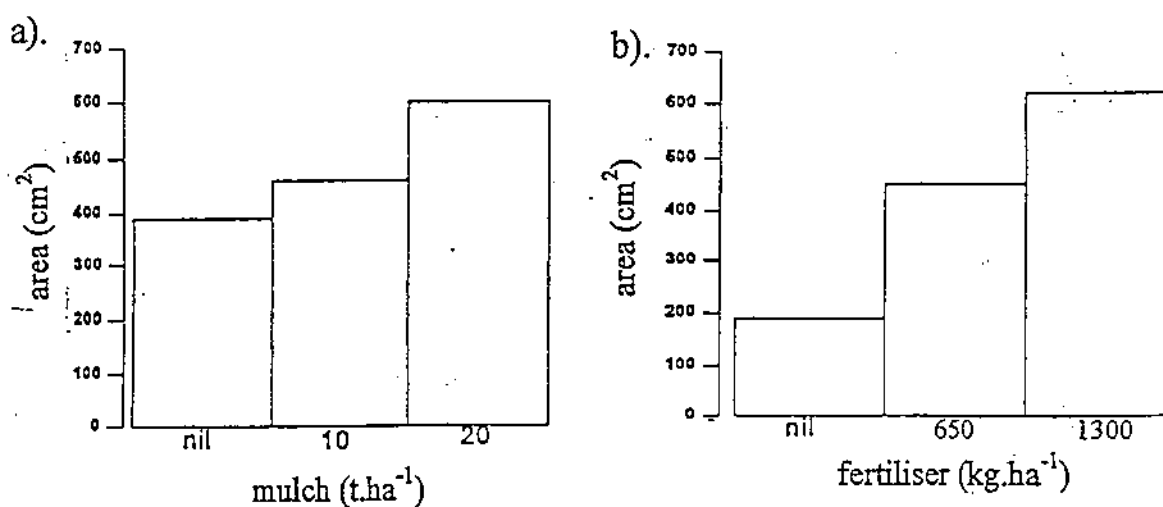


Figure 7. Growth of *S. virginicus* 210 days after planting in the wetland trial a). cane-top mulch treatments b). fertilisation treatments.