

# What are the chances of successfully replacing buffel grass with native plant communities in central Queensland's coal mine rehabilitation sites?

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## Abstract

It is sometimes desired to establish native plant species on rehabilitated minesites of central Queensland that are occupied by exotic pasture grasses such as *Cenchrus ciliaris*, which is more effective than native plant species in utilising the limited available soil moisture. Investigations were conducted on the hydrological characteristics of the mine site soils and on the water requirement for germination of selected native species. Rainfall simulation experiments using established pastures of different ages showed that pastures increased the infiltration rates and water retention capacities of soils as compared with bare surfaces. Germination experiments exposed non-dormant seeds of six native tree and shrub species and five grass species to decreasing osmotic water potentials (OWPs). Each species varied in its rates of imbibition, radicle elongation and germination, as well as their tolerance to dehydration during germination. Imbibing seeds of all species would germinate only if they reached critical minimum water contents, regardless of the OWPs imposed during imbibition.

Coupled with the knowledge on the rainfall characteristics of the region, this study demonstrates the possibility of increasing the success of native species establishment on rehabilitated minesites in central Queensland by identifying environmental conditions that must be provided in order to achieve successful germination.

## Key Words

Runoff, erosion, water content, bulk density, coal industry, grazing

## Introduction

While grazing may continue to be a practical option as a post-mining land-use in some areas, the mining industry in central Queensland has, in the past two decades, turned towards the establishment of native plant communities or bushland as one of the alternative post-mining land-uses (Emmerton and Elsol, 1998; Williams, 2001). Native trees and shrubs have been seen by many mine operators as useful in providing shade and shelter for native fauna, as well as potentially providing useful forest timbers and assisting in erosion control (Roe et al., 1996). It is assumed that once established, native vegetation communities can be self sustaining and maintenance-free. On the other hand, grazed pastures are thought to form plant communities that lack diversity and are less resilient to environmental disturbances (Walker *et al.*, 1999).

However, following reshaping of the mined land and placement of growth media to support vegetation, the slower growing native species are exposed to intense competition for water, nutrients and light from fast-growing weed species and exotic pasture grasses such as *Cenchrus ciliaris* (buffel grass), and thereby tend to be excluded from the site (Mulligan, 1993). Moreover, only limited work has been done where exotic pastures that have been established for two or more years were replaced with native species sown into media with much higher organic matter concentrations and vastly improved physical characteristics than would have existed if the pasture phase had not been established initially. Therefore, the replacement of well established exotic pastures under the relatively dry and erratic climate of central Queensland requires that the seeds of native species can germinate and become established before the limited available soil moisture is exhausted. This study examines three factors involved in seedling establishment: water characteristics of the soil, germination characteristics of the seeds of native species and the rainfall distribution of the region. Defining conditions under which these three factors were optimised at a site would allow 'windows of opportunity for sowing' to be selected for desired species in terms of water availability, which in this region will be largely determined by soil water retention and climatic conditions.

## Methods

### *Water characteristics of the replaced soils*

Three rehabilitated sites with similar reconstructed duplex topsoils and sown with exotic pasture grasses 2.5, 5 and 16 years previously were selected for treatment plots. Three additional sets of treatment plots were also established on a stockpile of duplex topsoil supporting a 5-year-old pasture. On each treatment site, two sub-

treatments were applied: grassed (undisturbed) and grass cut to ground level, created to reflect different seedbed conditions. Each sub-treatment was replicated three times. Altogether there were 27 treatment plots established and rain simulated. A field rainfall simulator (RFS) designed and developed at the Queensland Department of Primary Industries, Toowoomba, (Loch *et al.*, 2001) was employed to apply simulated rain events on the treatment plots. Runoff and erosion data customarily produced by this type of experiment were recorded, together with soil moisture changes by depth (0-2.5, 2.5-5, 5-10 and 10-20 cm) over several days after the application of simulated rainfall of approximately 100 mm over a period of one hour. Plant available water was determined as the difference in water content (mm rainfall equivalent) between field capacity and permanent wilting point (-1.5MPa).

#### *Germination characteristics of selected native species*

A series of experiments was conducted in controlled temperature chambers at the University of Queensland on selected native species of trees (*Acacia holosericea*, *Acacia leiocalyx*, *Eucalyptus citriodora*), shrubs (*Lysiphylum carronii*) and grasses (*Astrelba lappacea*, *A. pectinata*, *Dicanthium sericeum*, *Themeda triandra*) from central Queensland region, as well as the exotic pasture grass *Cenchrus ciliaris*. The following parameters were investigated in petri dishes under a range of water potentials from 0 to -1.5 MPa imposed by solutions of polyethylene glycol:

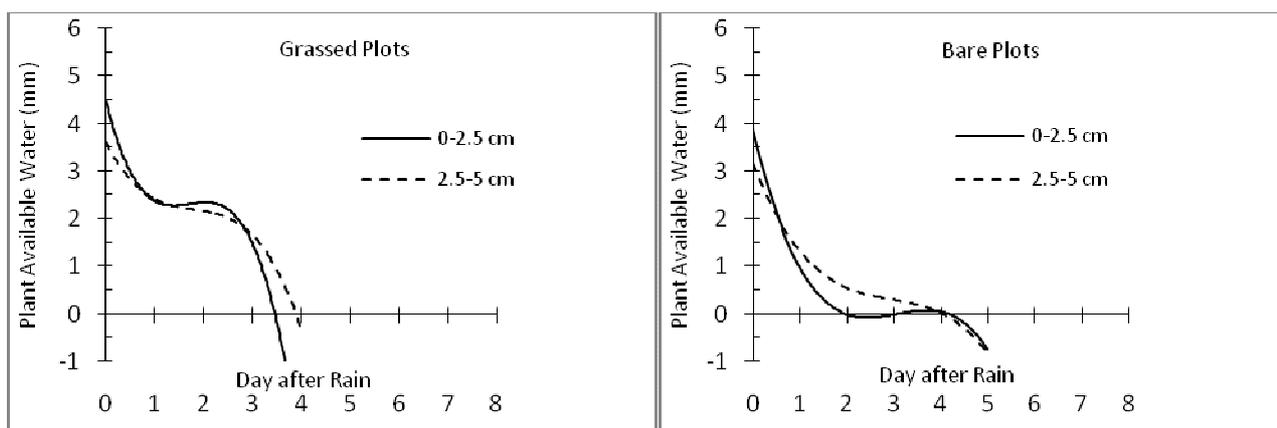
- *Imbibition*: to establish the rate and extent of water uptake by seeds.
- *Germination*: to determine the rate and completeness of germination.
- *Hydropedesis*: to determine the germinability of partly imbibed seeds that had been exposed to dry conditions for 1 to 5 days.
- *Radicle elongation*: to estimate the rate of radicle growth rate in germinating seeds.

However, only results from the first two experiments are reported in this paper.

## Results

### *Moisture availability in surface soils*

In this paper only results from rainfall simulation run on topsoil stockpile are discussed. Plant available water in each of the two uppermost soil layers (0-2.5 and 2.5-5.0 cm) varied between 3.5 and 4.5 mm after application of simulated rainfall (Figure 1). On the bare soil, the plant available water (above -1.5 MPa) in the 0-2.5 cm layer had been exhausted within two days after the simulated rainfall event. Most of the plant available water in the 2.5-5.0 cm layer had been lost in the first two days, but some remained until four days after rainfall. In the grassed treatment, the rate of water loss during the first day after simulated rainfall was similar to that on the bare plot, but the rate of loss slowed between 1 and 3 days and then accelerated in both the 0-2.5 and 2.5-5.0 cm layers so that plant available water was exhausted about four days after the rainfall application (Figure 1).



**Figure 1. Moisture availability in the top 5 cm of stockpiled topsoil that had been under pasture for 5 years, showing the comparison between bare plots and grassed plots. Bare plots were prepared by removing the top 15 cm of the soil. Grassed plots were undisturbed.**

### *Imbibition responses to water potential*

The germination experiments showed that the process of germination in all species was delayed and inhibited at reduced osmotic potentials. For most species, it was possible to identify the three phases of germination

as postulated by Bradford (1995). Phase I (imbibition) is associated with a relatively rapid increase in seed water content and the measurements were taken to determine any reduction in the rate of imbibition at the end of Phase I. A failure or substantial retardation of imbibition is likely to affect the eventual success of germination. Phase II is a period during which seed water content changes slowly but important metabolic changes are occurring in the seed. The end of Phase II was taken to be the time at which germination first occurred or when the rate of imbibition increased again. The results of these interpolations for the species examined are set out in Table 1. The estimates of the duration of Phase I and the resulting rates of imbibition are approximate but non-dormant seeds of all species exposed to continuous saturation (~0 MPa) readily imbibed water and reached a water content of 45% or more within 12 hours. Two tree species (*E. citriodora* and *A. leiocalyx*) reached water contents of about 100% in that time, demonstrating the most rapid imbibition rates for the experiment.

**Table 1. Summary of imbibition characteristics of nine tree, shrub and grass species at osmotic potentials of 0 MPa. Values are mean  $\pm$  s.e. (P=0.05)**

Species	Initial wc%	Phase I			Phase II			Phase III
		Dur. hr	Rate wc%/hr	Final wc%	Dur. hr	Rate wc%/hr	Final wc%	Begins hr
Tree								
<i>Acacia holosericea</i>	2.7 $\pm$ 0.8	24	2.7 $\pm$ 0.2	73 $\pm$ 4.9	24	2.2 $\pm$ 0.5	125 $\pm$ 0.1	48
<i>Acacia leiocalyx</i>	7.6 $\pm$ 0.5	24	6.4 $\pm$ 0.3	162 $\pm$ 6.7	24	0.6 $\pm$ 0.3	178 $\pm$ 1.5	48
<i>Eucalyptus citriodora</i>	9.7 $\pm$ 0.7	12	6.8 $\pm$ 0.3	91 $\pm$ 23.4	36	0.3 $\pm$ 0.4	101 $\pm$ 3.6	48
Shrub								
<i>Lysiphyllum carronii</i>	10.5 $\pm$ 0.6	24	4.5 $\pm$ 0.7	118 $\pm$ 2.9	48	0.1 $\pm$ 0.1	153 $\pm$ 5.6	72
Grass								
<i>Astrelba lappacea</i>	22.5 $\pm$ 0.1	24	2.8 $\pm$ 0.3	90 $\pm$ 1.7	24	0.1 $\pm$ 0.3	109 $\pm$ 8.6	48
<i>Astrelba pectinata</i>	21.6 $\pm$ 0.9	24	3.1 $\pm$ 0.4	98 $\pm$ 3.4	24	0.6 $\pm$ 0.2	105 $\pm$ 4.5	48
<i>Cenchrus ciliaris</i>	15.0 $\pm$ 0.7	12	3.1 $\pm$ 0.1	52 $\pm$ 1.7	12	2.9 $\pm$ 0.3	87 $\pm$ 5.5	24
<i>Dicanthium sericeum</i>	15.0 $\pm$ 0.7	12	2.5 $\pm$ 0.1	45 $\pm$ 0.8	12	0.1 $\pm$ 0.4	46 $\pm$ 4.1	24
<i>Themeda triandra</i>	13.7 $\pm$ 0.5	12	2.4 $\pm$ 0.3	42 $\pm$ 1.3	>84	n.a.	n.a.	n.a.

Abbreviations:

wc%: seed water content per cent dry weight; Dur.: duration; n.a.: not applicable.

The commencement of Phase III can be taken as the time of detection of germination. It is clear that *Cenchrus ciliaris* and *Dicanthium sericeum* would be likely to commence germination well before the surface soils in the field study had reached the permanent wilting point. It is likely that a substantial portion of the seed population may have begun to germinate by this time. In contrast, the other species would have just commenced germination by the time the available water had been exhausted. In addition, the germination process in most species was retarded at reduced osmotic potentials (data not shown) so it would be less likely that successful germination would have occurred on bare soil by the time the available water had been exhausted.

## Conclusion

This study shows that it may be possible to replace well established exotic pasture grasses such as *Cenchrus ciliaris* with native plant species in central Queensland. However, plant available soil water must be maintained for several days after a rain event if that is to happen. For seedling establishment under natural rainfall conditions, this means that several rain events must follow in quick succession over at least a week so the seedling roots can penetrate below the first 5 cm of soil. The most likely result is that without serious management intervention, *Cenchrus ciliaris* will become established sooner and more abundantly than the desired native species, reinforcing the dominance of this exotic species on mine rehabilitation sites.

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