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Revegetation of Gold-Processing Residue Storage Areas in the Eastern Jarrah Forest of South-West Western Australia

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Introduction

Gold-processing residue produced at Boddington Gold Mine (BGM) and Hedges Gold Mine (HGM), approximately 125 km south-west of Perth, is deposited in valley impoundments known as Residue Storage Areas (RSAs). These areas will be rehabilitated as part of the mine closure plans, though the rehabilitation prescription requires amendments to overcome those properties of residue that are unfavourable for plant growth. The residue generally has a very low hydraulic conductivity (2 x 10^{-2} m/day), high pH (9-10), salinity (EC 1:5 3-4 dS/m) and sodicity (62% exchangeable Na). Previous research by Murdoch University (Ho *et al.* 1999) was used to prepare a draft revegetation prescription aimed at generating a sustainable ecosystem in the RSA. The amendments chosen as essential in this prescription were the addition of a soil covering to the RSA surface for plant establishment, and the application of gypsum at a rate of 30 or 60 t/ha to decrease pH and sodicity, facilitate flocculation, and improve permeability and the leaching of salts. This paper describes a large scale field experiment established to determine the effectiveness of these treatments and some preliminary results.

Materials and Methods

The field site was established on a 5 hectare area along the north-west perimeter of BGM R4 RSA, where the depth of residue is generally less than 3 m. The main treatments being examined were three depths of a sandy ferruginous gravel substrate (0, 15, and 30 cm) overlying residue that had been treated with a broadcast application of 30 tonnes of gypsum per hectare. All plots subsequently received a surface application of 10 cm topsoil, with both the gravel and topsoil taken from stockpiles of the material sourced from the floor of the RSA before residue deposition. The treatments were replicated four times in a randomised block design. The plots were cultivated and seeded in May 1999, and 8 month old nursery grown seedlings were transplanted in mid-July 1999. All species included in the trial occur in the jarrah forest that surrounds BGM and HGM, or are salt and waterlogging tolerant Australian native species. Inorganic fertiliser was spread in late August 1999.

The topsoil, gravel and residue were sampled in January/February (residue only) 1999, May (just after topsoil and gravel spreading) 1999, October 1999, and February 2000, for chemical analysis. Monthly assessments of vegetation commenced in August 1999 and were conducted until March 2000. Monitoring of soil water content using gravimetric analysis and neutron probe measurements, and waterlogging, using shallow monitoring bores fitted with capacitance probes, was also conducted over this time.

Results

There was a decrease in surface residue pH and salinity from late January 1999, prior to gypsum spreading, to early February 2000. Exchangeable Na in the residue decreased greatly between 1999 and 2000 from 24 to 3 cmol(+)/kg, while exchangeable Ca increased from 0.9 to 3.1 cmol(+)/kg. These changes in chemical attributes have been attributed to the gypsum decreasing pH, and dissolved Ca replacing Na on soil exchange sites thereby decreasing clay dispersion and encouraging the leaching of salts through the profile. The salinity of topsoil and gravel layers over the residue increased between May 1999 and March 2000. Plots of Treatment 1, with no gravel layer, had the highest salinity level in March and these were classed as moderately saline at this stage.

It was hypothesised that with increasing depth of substrate overlying the residue, survival and vigour of plants established in plots would be higher. It was anticipated that a deeper substrate would provide a larger zone for roots to grow in before reaching the residue, which was thought to be possibly adverse to plant growth compared to the topsoil and/or gravel overlying it. Waterlogging in winter and drought in summer were expected to occur less on deeper treatments.

Waterlogging did induce mild stress symptoms in transplanted seedlings from July to September 1999, but overall did not appear to affect plant survival. No constraint to average plant vigour or survival due to salinity or drought was detected from July 1999 to March 2000. A quantitative assessment in March 2000 found that plants growing on 10 cm topsoil only (no gravel) were the most vigorous compared to those on treatments with a gravel layer overlying the residue in addition to 10 cm of topsoil (15 and 30 cm). Mean vigour, % cover, and seedling heights were all significantly higher ($p<0.05$) for no gravel plots compared to those with gravel. There were no differences in plant growth between the 15 cm and 30 cm gravel plots.

Preliminary excavations conducted in April 2000 found that plant roots are growing in the residue, but were growing preferentially in cracks and associated planes of weakness in the residue profile. The depth of root exploration and quantity of plant roots found was highest in the 10 cm topsoil only treatment.

Discussion

Current research is investigating possible causes of improved plant growth in the topsoil only treatment (Treatment 1) taking into account the observations of root growth in the residue profile. Three factors have been identified as the possible cause(s) of this response:

1. The majority of residue at or near the surface (0-50 cm depth) has a high gravimetric water content of around 25 to 35 %, even in mid-summer, while the gravel layer, with a much lower field capacity, dries out more in summer. If plant roots are accessing water held in the underlying residue they will fare much better than plants in thicker gravel treatments, where roots must grow further to reach the residue.

2. Gravel has lower concentrations of essential nutrients, such as nitrate N, K, Zn, and Cu, than residue. Complexes containing N, provided by the refining process, may be a potential nutrient source for plant growth. Plant roots would reach the residue faster and in greater abundance in topsoil only, and hence may be getting more nutrients, enhancing growth.

3. There are fewer macropores for root penetration in the gravel layer. This reflects heavy vehicle trafficking during spreading and the relatively low finer soil fraction in the gravel matrix. As a result, root exploration may be inhibited and plant growth depressed on these treatments.

Both hypotheses 1 and 2 depend on the concept that plant growth will be disadvantaged if none or only some of their roots reach residue. If either of these two factors are causing the enhanced growth in the no gravel treatment, it is possible that the effect is only short term and may not be noticeable after several years. It is also noted that at the time of assessment, the vegetation had not yet experienced a full winter or a typical dry summer for Boddington, therefore further vegetation assessments are required to determine the persistence of the observations.

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