infected material from soil. This may involve extensive excavation of root systems and may involve large machinery and considerable expense. No chemical control is currently available; however, biological control options using other fungi are being investigated. Host resistance is poorly understood but may offer some hope for control of the disease.

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Mycorrhizas and revegetation

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Much of Australia has extremely impoverished soil. Phosphate is particularly deficient. The major difficulty in revegetating these soils after severe disturbance is that plant survival and growth is unpredictable [1].

Mycorrhizas are associations between soil-borne fungi and the roots of plants. Of particular interest are the arbuscular mycorrhiza (AM) whose fungi form an internal colony in the roots of some 70% of all plant species. In AM, the fungi function as extensions of the root system, enabling the plant to increase uptake of non-labile minerals, especially phosphorus (P), from soil. The fungus gains its organic energy from the plant, and can only be maintained in the presence of living roots.

Experiments in the laboratory over many years have demonstrated the importance of mycorrhizas to plant growth [2]. However, as most Australian plants are adapted to impoverished soils, their growth response to mycorrhizas is difficult to detect in the laboratory.

Use of fertiliser improves survival and growth of most seedlings. If seedlings of Australian plants store minerals in their tissues, then we may be able to transplant fertilised seedlings in revegetation programmes, and expect them to thrive, albeit at slow rates of growth. However, much of Australia is also subject to regular fire. Seedlings are burnt back to the ground, releasing minerals to smoke and ash. Thus fertiliser may simply enable survival to the first fire unless the seedlings first become colonised by appropriate mycorrhizal fungi.

We set out to determine whether AM may play a role in revegetation of highly disturbed sites. We were particularly interested in whether inoculation with mycorrhizal fungi was necessary, whether the inoculated fungi would establish in disturbed soils, and whether we could provide a long-term benefit by inoculation.

The experimental site was a waste disposal area south of Sydney. The region is characterised by open vegetation typical of Hawkesbury Sandstone. In broad terms, the operators at the site move the bedrock and soil to one side, the waste is deposited and compacted, and then the crushed sandstone mixed with soil is placed over the waste (Figure 1). In addition, the local community expect the site to be returned to a state resembling the original vegetation when the site is returned. Results from initial plantings from seed by the operators indicate that a very limited number of plant species would grow. None of these formed AM. A much more effective approach to revegetation was required.

We germinated seed of four plant species collected from the site. Seedlings were either inoculated with AM fungi obtained from a similar soil, or fertilised to a similar size. We transplanted the seedlings to the site and followed survival and growth of the plants, and survival and spread of the AM fungi over 20 months.

Only fertilised or mycorrhizal seedlings survived to the transplanting stage, indicating that, unless fertiliser was continually applied to the soils, mycorrhizal fungi were essential for the long-term maintenance of vegetation at the site. At the field site, fertilised and mycorrhizal seedlings had a similar rate of

Figure 1. View of the experimental site following capping of the waste.

survival and growth for the entire experimental period (Figure 2). In the shoots of all plants, the concentration of P was extremely low, though similar to concentrations found in adjacent vegetation. We also attempted to harvest roots from the field site. However, roots were almost impossible to extract from the crushed sandstone.

We determined survival and spread of mycorrhizal fungi by using selectively placed trap plants in a field bioassay. The mycorrhizal fungi had thrived and readily colonised the trap plants. An additional AM fungus had dispersed into the site and established on about 40% of the non-mycorrhizal seedlings, though it rarely developed significant AM in trap plants, indicating low levels of adaptation to the 'soil' and the need for inoculation for long term retention of mycorrhizal fungi[3].

Several trends are evident, and we can speculate on their importance. First, we have been able to establish seedlings of native plants and mycorrhizal fungi in these extremely disturbed conditions. Thus it is possible to return the site to a state resembling the original, providing we know the nature of the plants and their mycorrhizal fungal associates[4]. Once the fungi are established, other organisms may return. Establishment of native mycorrhizal fungi provides a food resource for small native animals such as the bandicoot[5].

Further, mycorrhizal fungi are associated with stabilisation of the soil, especially between widely spaced plants. Soil stabilisation will reduce erosion, and increase the rate of formation of a 'real' soil through increasing soil organic matter content and complexity, microbial complexity and retention of products of microbial degradation of litter.

Humanity has generated many scars on the landscape. This work demonstrates that we can rehabilitate the surfaces, perhaps to a state resembling the original. However, we also need to be aware that valuable genetic resources are being lost from these sites during the disturbance events, resources we do not know we possess. It is better that we plan for the return of vegetation and the associated microbiota prior to disturbing the habitat, to reduce chances of significant losses.

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Figure 2. Plants after 20 months at one of the experimental plots.