A Revegetation Guide for Mallee Woodlands

Australian Government
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Greening Australia

Landcare Australia

A REVEGETATION GUIDE FOR MALLEE WOODLANDS

Who this guide is for

This introductory guide is for people wishing to learn, or be reminded about, the basic principles and practices of planting trees and shrubs for revegetation of Mallee Woodlands in the southern regions of Australia. This guide describes eight key steps that need to be followed to help ensure a successful revegetation project.

The importance of Mallee Woodlands

Mallee Woodlands occur in southern Australia, from the coast to far inland, including north western Victoria, central and south western New South Wales, throughout South Australia and into southern Western Australia with small areas found in Queensland and the Northern Territory. Mallee Woodlands are usually associated with landscapes that receive 200 -400 mm of rain per year, but also occur in areas with up to 600 mm per year in south eastern and south western Australia. In arable areas, Mallee has been widely cleared for agriculture, a process optimistically repeated in marginal areas. Most intact remnants are located now only in conservation reserves and on pastoral land. Mallee Woodlands are dominated by low open eucalypt trees with multiple stems emerging from a ground level swelling called the lignotuber. The understory is variable from dense heath or salt bush to sparse grasslands (Photos 1, 2 & 3). Temperate woodlands are dominated by single trunk eucalypts and usually occur in areas of higher rainfall. These are dealt with in a separate revegetation guide.

STEP 1.

Assess site conditions

Revegetation is needed when there are local constraints that limit the natural return of woodland plant species. Constraints include:

Recruitment

- Lack of seed;
- Lack of suitable sites for seed germination (establishment niche);

Altered physical environment

- Temperature extremes - hotter and colder than within a natural woodland;
- Wind exposure that can quickly dry out young plants;
- Lack of fire or too frequent fire.

Photo 1. A mallee woodland with a dense and diverse understory.

Photo 2. A mallee woodland in a low rainfall area with a moderately dense understory.

Photo 3. A mallee woodland with a very sparse understory found in a low rainfall zone.

Hostile soil conditions for native plants

- Soil compaction from cultivation, vehicles and livestock;
- Soil erosion by wind and water;
- Nutrient enrichment (high levels of Phosphorus and Nitrogen – good for weeds but not most native plants);
- Carbon depletion causing poor soil structure;
- Rainfall runs off rather than infiltrating into the soil (water repelling soils);
- Lack of soil microbes that greatly assist native plant survival and;
- growth.

Threats to mallee plant survival

- Weed competition from pasture grasses and weed;
- Insect pest;
- Grazing by sheep, cattle, horses, goats and rabbit;
- Browsing by native mammals.

Examine your site to determine if you have any of these constraints. If you do, then active revegetation is likely to be needed, and you will need to address these threats to successful establish a diversity of Mallee plants.

STEP 2.

Set clear site objectives

There are many different reasons to plant locally native mallee species. These includes:

- Wildlife habitat and dispersal corridors;
- Shade and shelter for livestock;
- Salinity management ;
- Harvesting firewood and timber;
- Carbon sequestration; and
- Amenity value.

Historically the objective of restoration has been to fully recreate the native vegetation believed to have occupied the site before it was degraded. This has been done by Alcoa in Western Australia for Jarrah forest where vegetation was removed for bauxite mining and in Victoria by Dr. Paul Gibson-Roy where complex grasslands have been recreated. However, comprehensive restoration of hundreds of plant species is costly ($30-$70,000/ha). In contrast, revegetation usually only goes part way to re-establishing a diverse mallee indistinguishable from healthy native remnants. The greatest diversity of plants is found within the groundcover of high quality woodlands (grasses and wildflowers). A diverse mallee understory, including mosses and lichens can be difficult to restore so mallee revegetation tends to focus on trees and shrubs.

In many cases, where the site is so altered that the physical and chemical environment no longer matches that occupied by the original mallee vegetation, a compromise may be needed. You may have to use species that look like those that originally occupied the site but are much hardier – i.e. create a structural mimic of the original mallee woodland using species tolerant of the new conditions. In really tough sites, just getting a couple of species of trees and shrubs to thrive is a major accomplishment.

A decision on whether to attempt full restoration, or scale back to simple revegetation should be based on a cost vs. benefits, your objectives and the importance of the restoration in the bigger picture.

Landscape context

Ideally revegetation or restoration should buffer and re-connect existing high quality native vegetation remnants, particularly areas protected by covenants or in reserves.

In many landscapes wildlife, particularly birds, but can be used for prioritising connectivity between remnant mallee patches. Revegetation is then focused on buffering and re-connecting key woodland remnants to create 'stepping stones' or 'corridors' along these identified broad routes and may facilitate the movement of wildlife in response to climate change. Strategic revegetation of this sort provides resilience to climate change and improves biodiversity at both a patch and a landscape scale.

It is recommended that revegetation planners consult with the surrounding neighbours and local community to identify opportunities for linkages with adjacent revegetation work. This can achieve ecological benefits and some costs savings, but it is also a process that allows community concerns to be raised about possible increased fire hazards and pests.

STEP 3.

Site preparation

Mallee plantings are most likely to succeed if you've prepared the site well. The primary purpose of site preparation is to build adequate soil moisture before planting and control competition (weeds and browsing animals). These are the two most important factors in mallee revegetation.

Weed control

Access to moisture throughout the soil profile is essential for the survival and growth of newly germinated seeds or newly transplanted seedlings. Soil moisture must be built up in the 12-24 months prior to planting by removing plants that would otherwise use this moisture. Try to minimise soil disturbance because it will increase evaporation. The usual method for achieving this is to use herbicides to maintain a weed free soil surface after initial soil preparation.

Weeds compete with newly established plants for moisture and light. Many weeds are more efficient at drawing moisture from the soil than new seedlings, resulting in reduced growth or plant death. Plants which struggle in the first few years never reach their full potential or growth rate. Weeds should be controlled in an area at least 1m in radius around new plants for around 2 years to ensure the plants are vigorous enough to out-compete weeds. Weed control can be split into two categories; spot control (Photo 4) and strip control (Photo 5). Strip control is most suitable for dense linear plantings such as direct seeding and spot control is most suitable for patchy, random, plantings with seedlings (tubestock).

Photo 4. An area spot sprayed with a knock down herbicide, a weed control technique suitable for small areas.

Photo 5. A large site Strip sprayed recently direct seeded as well as seedlings hand planted and protected by tree guards.

Treat a mallee planting like a high value crop. Most herbicides should be applied to actively growing weeds. Getting to know the weeds on your site and when they are actively growing is recommended. Spraying when weeds are moisture stressed or after frosts or other stresses should be minimized.

Timing of herbicide application needs to be flexible and ideally occur 1-2 weeks after rain when new weeds have just germinated and older weeds are actively growing. Most importantly, herbicide applications should be applied well before planting or sowing.

Commonly, up to three applications of herbicide may be necessary:

1. Depending on the weeds present, a first spray may be applied in the late spring or early summer of the year prior to revegetation to help deal with warm season weeds such as kikuyu or couch grass and wireweed.
2. At least one spray should be applied in autumn and winter to control weeds which directly compete with small seedlings for moisture and light. Autumn application is suggested if significant rain falls in March or April that stimulate germination and growth of weeds. A further application can follow further rain in May-June. Ideally, the first application in the year of planting or seeding should be done 6-8 weeks before revegetation.
3. A further spray is often needed just prior to planting, particularly if planting or direct seeding in early spring.

Care must be taken in sandy soils, which are prone to wind and water erosion, not to leave bare soil exposed for extended periods. It may be necessary to retain some weed cover on the soil by using a selective herbicide or rope-wick applicator. This will slightly reduce moisture depletion and seed set whilst retaining soil binding benefits. Alternatively, reducing the width of the sprayed strip or spot can perform a similar function. Spraying strips at right angles to the prevailing wind or along the contour can also mitigate erosion from wind and water.

The first herbicide application should use just a knockdown chemical that kills all actively growing plants. Residual herbicides may provide longer term weed control and kill new weeds that germinate after spring rains. Generally, residual herbicides like Simazine will be in the second herbicide application as a cocktail with a translocated knockdown such as Glyphosphate. However follow the 30/30 rule. Wait until at least 30 mm of rainfall has fallen before direct seeding on soil treated with a residual. Such a rainfall will move the herbicide through the soil. Or wait until 30 days have past after residual herbicide application by which time, in the absence of rain, the herbicide will begin to break down. So in dry years, use of residuals may be wasted as they are only activated in the presence of soil moisture. A residual such as Simazine is ideally applied to bare moist soil.

Residual herbicides should not be used just prior to revegetation that relies on germination of native seed. These herbicides should not be used at all in sites dependent on natural regeneration. Residual herbicides can be particularly useful with direct seeding. All direct seeding machines (Photos 6 and 7) scalp a narrow strip of soil using a scalping blade or disc. The seeder also cultivates a seedbed in the scalped area into which seed is sown. One objective of the scalp is to remove any residual herbicide left from a previous spray. However, residual herbicides should generally be avoided in free-draining deep sandy soils. Residual herbicides are mobile and may move below the seeder scalping depth in deep sands.

In addition, the scalping blade or disc of a direct seeder clears away the weed seed bank in the topsoil and removes any germinated weeds leaving a 'clean' strip for mallee seed germination (Photo 8). This scalp results in at least a few months of reduced weed establishment post-sowing but only in the narrow scalped area.

Photo 6. A direct seeder with a large disc that scalps a clean seed bed. Note the single calibrated seed box on top and press wheel at the bottom rear. This disc seeder is particularly suited to lighter soils and requires little horsepower (e.g. a ute).

Photo 7. A 'V Blade' direct seeder is particularly suited to heavier or stony soils, but requires more horsepower (a tractor rather than a ute).

Photo 8. The scalped seed bed created by a direct seeder, then freshly treated with a 'Dustex strip' (bitumen emulsion) in the seeding row to reduce wind erosion and seed loss.

Make sure your equipment is appropriate to the size of the job. Backpack sprayers are suitable for spraying small areas or individual weeds, while a spray unit with a tank mounted on a ute or quad bike will be necessary for larger areas. For very large areas, a boom spray will be more efficient.

Where large woody weeds are to be controlled, it is more efficient to do so before revegetation commences, this reduces off-target herbicide impacts or physical damage which can result from weed control practices.

It may not be possible to meet these exacting weed control standards outlined above, but experience shows that the nearer your operation comes to meeting these standards and timing outlined above for weed control the better your mallee plantings will survive and grow.

Browse control

Regardless of the quality of weed control a mallee planting will fail if heavily browsed (eaten). Seedlings are particularly attractive to browsing animals and easily killed by them. Your assessment of site conditions (Step 1) should have identified which browsing animals pose a threat (e.g. livestock, feral goats and deer, rabbits and hares, snails, or natives like kangaroos and wallabies).

An ordinary stock fence is usually sufficient in areas where it is only domestic stock that have to be excluded, or the numbers of native browsing animals are low. However where plantings are established to buffer and connect healthy mallee remnants, animal proof fencing will be needed (consider hinge-lock wallaby fencing or rabbit proof netting). Fencing is a major cost to a revegetation project, but remember a mallee woodland is a high value 'crop'.

It is most important to implement an integrated pest control program for as long as possible in the lead up to revegetation to minimise grazing pressure. Integrated in this sense means using a broad range of control strategies in a co-ordinated manner in and around the planting site. Below is a table showing possible control options. Note that permits are required to conduct most of these activities and professional site-specific advice should be sought before implementing pest control. Although shooting is a common control technique it is usually not an efficient option for long-lasting control.

Tips

Try to control foxes soon after controlling rabbits and hares to prevent foxes from switching to native prey or stock.

The control of free-ranging pests usually requires the co-operation of surrounding landowners to prevent rapid re-invasion of the revegetation site.

Where plantings abut remnant vegetation and where mammal browsing control is problematic, tree guards can be placed around seedlings to prevent heavy grazing. In some cases this alone can deter grazing, but more often limits the extent of the grazing to the tips above the guard. Whilst this may not eliminate grazing it does allow seedlings to develop a healthy root system which prevents pulling the entire seedling out of the ground, and will allow the plant to reach greater sizes when grazing pressure is reduced.

Tree guards also protect planted seedlings from heavy frosts and provide some shade and wind protection during summer. Guard only those high value and costly seedlings that are particularly susceptible to pest and wind damage. Using tree guards on any scale is a time consuming activity and adds significantly to costs.

There are a variety of deterrents available (e.g. WR1 and D-Ter), that can be applied to the leaves of plants and, through various mechanisms, discourage browsing. However these can only be practically applied in a glasshouse or nursery and, once planted, any new leaves will be susceptible to browsing.

Even when all controls are in place, there will be some plant losses, so either plant more the first year, or budget to replant the second year.

Soil preparation

Ground preparation techniques are used to soften the soil, increase water infiltration, soil aeration and allow for easier root development. Ground preparation will vary according to soil type, site history and establishment technique being used. Many mallee plantings will

Pest	Shooting	Mustering	Baiting	Chaining	Fencing	Warren Destruction / Fumigation
Kangaroos / Wallabies	X				X	
Goats	X	X			X	
Deer	X					
Rabbits	X		X		X	X
Hares	X		X		X	
Snails			X	X		
Foxes	X		X			X

fail if proper ground preparation is not done.

Ripping on contours when the subsoil is dry is suggested for compacted soils to re-aerate these soils and allow for easy use of manual planting tools. It is not recommended for deep sands or calcrete. Riplines will allow ready absorption of moisture through the soil and often produce a reservoir of soil moisture, particularly if weeds that emerge along riplines are quickly controlled. If practical, rip and plant on level contours. This will improve water infiltration and reduce the risk of erosion on hilly country.

Rows are usually spaced at least 4 m apart to prevent over-crowding and to allow access in the future (especially for weed spraying). The most efficient method of direct seeding large flatter paddocks is to use cropping circles, starting along the outside edge of the paddock (or fraction of the paddock) and progressively seeding smaller and smaller "circles". This avoids constant lifting and lowering of seeders at the end of rows. It also avoids straight row look of seeding results. This obviously does not apply to paddock boundary revegetation belts and should be used with discretion in hilly areas with erosion-prone soils.

Ripping is also used when planting adjacent to established mallee vegetation because mature mallee trees have far reaching surface roots which will compete with the seedlings for moisture just like weeds do. Severing lateral roots with a ripper is a non-lethal way to reduce this competition. This type of ripping should be at least 5 m away from the base of mature mallee trees and should not be done around more than half of a single tree to ensure that it is not severely impacted.

There are many widely available soil treatments that can improve the structure and water-holding capacity of the soil, but they do add considerable cost to planting projects. Such products include water crystals, gypsum, compost, coconut fibre and TerraCottem®. Inoculants of soil biota, such as Wattle-Grow®, can be added to both direct seeding and seedlings to increase the nitrogen-fixing ability of Acacias and some pea species.

One simple way of maximising soil moisture in a seedling's root zone is to form a water bowl around the plant. This is a slight depression up to 1m in diameter around the root ball with a built up rim of soil, finishing at soil level. This prevents rainfall runoff from leaving the root zone and, if on a sloping site, can be constructed to gather nearby runoff. However, creating such depressions can only be justified for small sites planted to costly or rare species.
In areas where sand drift can blow seeds away or expose seedling roots, a seeding row can be protected by applying a bitumen emulsion to which secures the soil surface but doesn't prevent germination (Photo 8). These products can also create a barrier which prevents ants from removing seeds.Click here or here for more information.

'Dial before you dig'

Site preparation, even the shallow scalp of a direct seeder, could cause damage to cultural heritage, threatened species, pipelines, powerlines, or underground cables. First have a close look at the site you are going to revegetate. Get out and have a good walk. If in doubt contact the landholder and consult local authorities if necessary.

Insect control

Insects can entirely defoliate plants in the field. This is particularly a risk immediately after planting when seedlings are small and highly nutritious. In areas at risk (particularly near a healthy woodland remnant) a systemic insecticide tablet can be placed under the seedling or systemic insecticide can be injected into the soil around the root bowl before planting (usually in the nursery). Treating insect attack after planting is more difficult and more costly. Major problems arise with treating for insect attack when trees are more advanced and growing in the field because generally, any effective insecticide that kills the pest species will also kill desirable predator or pollinator species.

Some insects, particularly Red-legged Earth Mites, also consume roots of young plants. By the time the impact is evident above ground (whitening and leaf deformation), the damage underground is usually significant so it pays to look for signs before planting. Often signs of these pests are evident in surrounding crops and vegetation and should be inspected in the lead up to revegetation to ensure effective control. Control usually involves applying a soil active insecticide to the root zone of the seedlings. Ensure the entire area is treated to prevent the pests establishing in other areas of the revegetation.

Ants are often found moving

seeds, particularly Acacias, from direct seeding rows to their nests. This is rarely a significant problem as little seed is destroyed in the process compared to the amount sown. Sowing the seed to a suitable depth or mixing magnesium carbonate and other deterrents with the seed mix is usually sufficient to discourage ants.

STEP 4.

Choose species to suit local conditions

Choose mallee species that occur in similar soil-landscape environments. Where possible, choose locally occurring plant species that match the relative abundance found in remnant mallee nearby on similar soils and slopes (Text Box 2). It is not realistic to restore all species that occur on a site because of limitations in seed collection, propagation, establishment and cost. Select a mix of species that provide multiple layers of vegetation (habitat structure). Include overstorey species (mallee eucalypts), medium sized trees (often Acacias), large shrubs (*Acacia, Melaleuca, and Senna*) and small shrubs (often chenopods). Multiple layers of vegetation provide food for pollinators, nesting sites for insectivorous birds and help resist the invasion of weeds. But most importantly choose native plant species that will survive in your site. Dead seedlings don't provide habitat nor fix carbon.

Seed for the chosen species should come from large and healthy populations (>500 individuals) growing on similar sites within the same region so they are naturally adapted to the environment of your site. Rainfall, soil, altitude, aspect, slope and position are important factors in plant adaptation (Text Box 1).

An exception to this principle is where the environment has changed to the extent that some local species can no longer survive. Secondary salinity, compacted soil structure, more frequent frost, increased aridity or waterlogging are reasons you may need to select alternative species that don't normally occur locally (for example salt bushes for sites that have recently become saline). A 'nursery' planting of non local species may first be required to reduce wind exposure, water logging, salinity or other factors hostile to restoration of locally native species.

Securing a supply of seed has to be considered at least a year in advance to sowing. The fruits of about 80% of native species in southern Australia are ripe only in summer. Fortunately, most mallee eucalypts have persistent fruits that are collectable all year round. Seed of other required species such as *Acacia, Dodonaea, Senna*, chenopods, and grasses may only be available for short periods in late spring through summer.

Planning has to be in place for seed collection (e.g. locking up paddocks for grass seed harvesting) or seed purchase. Seed suppliers need advance notice in order to collect quality seed and process it appropriately. Like any crop, native seed quantity varies from year to year based on rainfall. A drought one year can greatly reduce seed supply in some eucalypt species three years later. Ordering native seed is not the same as buying a packet of veggie seeds from the shops!

Seed Collecting Tips:

- Collect seed from the upper outer branches of a tree is more likely to be out-crossed (not inbred) than lower branches.
- Collect from trees separated by some distance (e.g. 100 m for eucalypts) because nearby trees will have a higher degree of genetic similarity (relatedness).
- Don't destroy or over-collect from a single individual. Collect seed from only a proportion of the tree or shrub and don't remove large numbers of branches because this tree may prove to be the best tree for future seed collection based on growth of seedlings in your restoration plantings.
- Record the position of plants, ideally with a GPS reference and keep a copy with the seed. If the seed is sown in a nursery, label the seedlings with the source location too. This information is important for knowing where quality seed (e.g. good survivorship) came from for future collecting.

Text Box 1.

Note, when seed collecting from public land make sure to obtain the required permits your relevant state agency responsible for conservation. Always obtain permission from the land owner when collecting from private land.

For uncommon species, seed is generally unavailable from seed suppliers and can require a special permit to collect. Sometimes, seed nurseries (orchards) have to be established specifically to grow rare plants for seed collection. Once plants reach maturity seed is collected and stored for use in restoration. The seed of these species is often so valuable that it is better to plant seedlings rather than use the seed for direct seeding.

Getting the right mix of seed for mallee revegetation is a complex task. The amount of each species required is dictated by the germination rate and the desired density of each species and it usually takes experience to get this balance right. The most important task is to ensure that you choose species which match your objectives and have the best chances of germination and survival.

A typical mallee revegetation site contains the following genera, which provide multiple layers (structure) and respond well to direct seeding: *Acacia, Allocasuarina, Atriplex, Banksia, Callitris, Dodonaea, Eucalyptus, Hakea, Leptospermum, Melaleuca, Senna, and Maireana.*

The Victorian Department of Sustainability and Environment's EVC Bioregion Benchmarks and the Nature Conservation Society of South Australia's Bushland Condition Monitoring benchmarks provide good guidelines for species composition in remnant vegetation. This can guide your species selection when trying to mimic naturally occurring compositions.

Seed quantity

Estimating the quantity of seed needed for a revegetation project is complex because there are so many variables to consider including:

- planting method – direct seeding or seedlings grown in a nursery;
- distance between planting rows (often 3-5 m);
- desired stem densities of trees, shrubs and ground cover;
- seed viability which varies; between species, seasons and whether germinated in the nursery or paddock; and
- size and longevity of species – short lived and small species are usually planted at higher densities than long lived and large trees.

Estimating seed and seedling quantities

Accurately calculating the amount of seed needed for a revegetation project takes considerable experience and knowledge of local planting conditions and plant species. If this local expertise is not available, the following equation and guidelines will provide a useful starting point.

Required seed (kg/ha) =

$$\frac{\text{Target plant density (plants/m}^2\text{) x (weight of 100 seeds, in grams) x 1000}}{\text{Germination percentage*(or nursery survival*) x establishment percentage}}$$

*Percentages must be listed as a percentage, not a decimal fraction

A working example for *Lomandra longifolia:*

$$\frac{\text{0.1 plant per m}^2\text{ x 21g (large seed) x 1000 (= 2100)}}{\text{50\% germination x 50\% establishment (=2500)}} = \text{0.84 kg/ha}$$

This is an example of a species with relatively moderate germinability and moderate survival of germinated seed. Germinability and survival data is scant or highly variable for most native species so the following rules of thumbs can are useful:

- For nursery seedlings (tubestock) assume seed germinability of 50% and 80% survival germinated of seedlings in the nursery;
- Establishment percentage (in-field) for tubestock: 85%;
- To plant one hectare using tubestock typically requires less than 100 g of seed.
- Tubestock is often planted at 500-1000 stems per ha depending on the proportion of large trees in the seedling mix.
- Establishment percentage (in-field) for direct seeding: 5%;
- Direct seeding often requires 200 g of mixed seed/km which equates to 660 g of seed/ha at 3 m between rows.
- Quantities of seed will need to be higher for establishing ground cover grasses and wildflowers

Text Box 2.

STEP 5.

Select quality seedlings

Only use healthy seedlings

The size and root structure of seedlings is critical to their survival after transplanting and to their long term survival. Poor root development in the nursery can result in dead plants in the paddock, slow growth, instability in windy conditions and in the long-term, self-strangulation by spiralling roots.

Nursery containers should be chosen to produce healthy roots with lots of strong growing tips. Lots of roots are more important than lots of leaves. Root development should be sufficient so that potting media does not collapse on removal of the seedling from the container. Nursery systems should allow for maximum air pruning of roots. Modern nursery tubes are fluted (rather than smooth and round) so that roots are directed downwards (Photo 9).

In addition, slots and holes in the sides of the tubes air-prune roots so root-binding does not occur. Seedlings should also be ordered or germinated with enough growing time to be able to meet specifications. This is usually a minimum of 6 months before planting, but can be up to 18 months.

A good quality seedling is generally 10-20 cm tall, not root bound, and has been hardened before delivery (Photo 10). Hardening involves exposing a seedling to more natural conditions such as wind, full sun and reduced nutrient availability.

	Pros	Cons
Tubestock	• Large root system • Large plants • Pots can be reused	• Most expensive • Slow to plant • Use lots of nursery and transport space
Hiko	• Intermediate • Pots can be reused	• Intermediate • Difficult to remove from pots
Cells	• Cheap to purchase • Use less space in nursery and transport • Fast to plant	• Small root system • Small plants • Pots usually can't be reused

Photo 9. Fluted nursery pots promote downward pointing roots, rather than spiraling roots that can develop in smooth and round tubes. Note also the air pruning of the roots at the bottom of the pot.

Photo 10. These well grown eucalypt seedlings are being hardened off to promote frost and drought resistance.

This is usually achieved by placing seedlings outside of hothouses or shade houses and ceasing fertilising. Seedlings that are not hardened properly will usually be set back or killed when transplanted.

Where ever possible get seedlings from a local nursery, so your plants have been hardened off to local conditions. It's tough to mimic a light frost in a nursery at the coast. It is important to ensure seedlings are well watered before leaving the nursery and being planted on site. Most nurseries take back the pots to be cleaned and reused, so don't leave them at your planting site.

Genetics

It is vital to use the appropriate seed source for restoration plantings (Text Box 3). A local native seed source has traditionally been the rule of thumb. However there are circumstances where this may not be the best choice:

1. Where the local seed source is in a different landscape position (e.g. from a gully when the planting will be on a ridge). It is better to match for site (ecological position) than to automatically choose the closest local native seed source.

2. Where the local native seed source is an isolated tree or scattered population. Out-

Genetic pollution
There is a **small risk** that mallee plantings may introduce new genotypes to an important local population of a species. In some cases genetic mixing can cause sterile hybrids. A judgement is required to assess the risk of diluting or changing the genetic make-up of a recognised important population of a plant species. Although it may be desirable to use seed from a provenance of hardy individuals of the species occupying a site a long distance away, this may compromise protecting the genetic character of a particular local population that is otherwise rare and only found in a nearby reserve. Genetic pollution is much less an issue in highly cleared landscapes.

Text Box 3.

breeding trees like eucalypts will have poor quality seed if the tree is an isolated paddock tree, regardless of the health of the trees. Self pollinated seed is weak and seedlings will grow slowly and there will be high death rates amongst seedlings. Collect seed from the nearest healthy intact population of the species containing at least 100 individuals in close proximity.

3. Where there is expected to be a shift climate in during the life of long-lived species such as eucalypt trees, it may be necessary to include in the seed lot seeds from lower altitude or drier sites than the local native to take account of climate change.

Poor quality seed will result in oor revegetation, so make sure it's healthy (Text Box 4). Once collected, it is important to conduct viability tests on your seeds so you know the sowing rates needed to germinate sufficient quantities of seed for your restoration plantings. See the Florabank web site for some simple techniques.

Getting the most from your seed
When ordering seed from a commercial seed supplier, ask these important questions:

- What is the viability (%) of the seed?
- Where has the seed come from (its provenance)?
- What is the age of the seed and how has it been stored?
- When comparing seed prices, remember that 1 kg of 90% viable seed is worth much more than 1 kg of seed with just 10% viability.
- Old seed may be OK, if it has been stored well. The moisture content of seed is key. Each percentage point decrease in seed moisture content between 15% and 5% **doubles** the life of the seed.

Text Box 4.

STEP 6.

Planting and sowing

When to plant

Mallee typically occurs in low rainfall areas with winter dominant rainfall. Just like a wheat crop, planting seedlings or sowing native seeds is dependent on soil moisture - timing is critical. Planting is usually conducted immediately after the first good rains of the season between May and June and ideally, before mid August. However rainfall can be irregular and planting plans must be flexible. If the season is too dry you must be prepared to put off planting until next year. A year delay in seeding is much easier than delaying planting seedlings raised in a nursery. Or consider an early spring planting to allow for build up of soil moisture over winter and warmer soil temperatures for quick germination and growth. If planting in spring, make sure weeds are well controlled over winter, though a spring planting may require watering seedlings over summer.

Techniques for planting seedlings

There is a broad range of approaches to revegetation and no single approach will necessarily work for every site. Usually a combination of direct seeding and planting of seedlings delivers the best value for money (Photo 11). This combination allows for the easiest establishment of the greatest diversity of species that form multiple layers of vegetation.

Photo 11. An example of a large site where seedlings from a nursery have been machine planted with alternate strips direct seeded. A combination of establishment methods are often needed to achieve high plant diversity at least cost.

For planting seedlings, some methods may reduce plant deaths, but the price to implement the method may outweigh the cost to replant dead seedlings. The right technique(s) depends on the size of your planting and the risks you're willing to take.

Broad-scale planting (tens to hundreds of hectares) typically uses experienced forestry contractors to do the planting. Experienced planters will plant faster than novices and will also ensure that seedlings are planted in the correct manner including the correct depth, minimise root damage and construct effective water depressions. Planting machines can also be used to cover large areas rapidly and can be useful where manual planting labour is scarce. However, planting machines are only suitable in soils with little to no rock and cannot operate within rows that have also been direct seeded. In any event, planting machines will still require at least two people. Generally hand planting using planting tubes (e.g. Pottiputkis) and kidney trays or planting belts is more efficient and preferred.

Planting a site yourself can be a demanding process and may lead to delays in completion but will reduce costs. Volunteer planters can help given the right training and supervision, deliver excellent outcomes cost-effectively.

Traditionally, individual plants in small plantings have been protected using a planting bag, milk carton, coreflute guard or flexible netting and protected at the base using a hessian or newspaper weed mat (Photo 12). Large scale plantings are not normally protected with tree guards unless some really palatable species need to be protected near remnant patches of mallee. If guards are used they should be removed before they inhibit the plants and whilst they can still be easily removed. This is usually following the second summer.

If the topsoil is not moist at the time of planting, seedlings should be watered, but this can be impractical for large plantings, so wait for rain before planting. Experience shows that survival rates can be dramatically increased by applying a sea-weed extract solution to the roots before planting. It is believed this reduces root shock and promotes root growth. This is most efficiently applied prior to planting.

Another technique to reduce moisture loss and planting shock is to dip seedlings in, or spray on, anti-transpirants such as Envy® prior to planting. Click here.

Photo 12. An example of the use of tree guards and weed mats to promote seedling survival. This is a more expensive approach best suited for small sites or in-fill plantings.

Provenance – where seed should come from

Provenance should be considered in the following manner when collecting seed for revegetation:

Get the taxonomy right first

- Make sure you are dealing with the same species, sub-species, variety or cultivar
- Get the physical and genetic quality right
- Collect from over 100 plants when possible apart

Only collect from large populations or pool multiple collections from smaller populations

Store seed under best conditions from collection right through to use

Match the site condition
- Soil (texture and origin)
- Altitude
- Aspect
- Slope position
- Latitude (use bioregions as the boundary)

Text Box 5.

Method	Pros	Cons
Direct seeding	Low cost. Cover a large area in short time Healthier seedling growth Establishes a diverse, random mix of species Built in redundancy for poor seasons (seed dormancy) Scrapes away weed seeds Germinates a wider range of species	Requires large amounts of seed Not suitable in all soil types (e.g. heavy clay) or where understorey is intact May not be locally available Susceptible to grazing Limited control over germination density. Germinants establish in lines
Niche (hand) seeding	Low set up cost (no machinery or nursery required) Establishes a diverse, random mix of species Built in redundancy for poor seasons (seed dormancy) Control over plant density Easy to plant into remnant understorey Random seeding gives a natural appearance Healthier seedling growth	Requires relatively large amounts of seed for small areas Susceptible to grazing High cost to install
Planting seedlings	Control over plant density and composition Plant into most soil types Requires minimal seed Random plantings give a natural appearance Easy to plant into remnant understorey	High cost to supply and install. Vulnerable to complete loss in a poor season May not be able to source local provenance seedlings Poor root establishment Some species cannot be grown in a nursery
Plant yourself	Low labour cost	Slow planting rates. Improper planting technique. May need to purchase specialised tools
Planting contractor	Rapid planting rates Proper planting technique Already have specialised tools	High labour cost and may not be available locally
Planting machine	Rapid planting rates	Not suitable for stony soil types Not suitable with direct seeding May not be available locally
Tree guards	Prevent or reduce grazing pressure Prevent spray drift damage Reduce evaporation rate Some are reusable	Additional cost to supply, install and remove Can cause wind tunnelling in sandy soils
Weed mat	Long lasting weed suppression around base of the plant	Additional cost to supply and install
Soil conditioners / fertilisers	Improve soil moisture and nutrient content	Additional cost to supply and install Not suitable for all soil types
Water bowls (depressions)	Increases soil moisture immediately around seedlings	Additional labour cost to install
Anti-transpirant	Reduces transpiration and planting shock	Difficult to apply outside of a nursery Additional cost to supply and apply
Seaweed extract solution	Increases root vigour and decreases planting shock	Difficult to apply outside of a nursery Additional cost to supply and apply.
Watering	Increases survival and growth rates over summer	Not economical over large areas Additional cost of water, labour and/or irrigation May not environmentally sustainable
Ripping	Increases hand planting rates Facilitates faster root growth Increases soil moisture	Not suitable on highly rocky or sandy soils

Techniques for direct seeding

Direct seeding involves a machine sowing seeds at a predetermined rate directly into the soil drawn by a 4WD ute or ATV/quad bike (see direct seeding machinery below). Sowing seeds directly on-site has the potential to establish many more species than those propagated in a nursery. Direct seeding is often cheaper, but is generally a less reliable method for establishing trees and shrubs. Root development in directly sown seedlings is not at risk of poor root development that can occur in seedling raised in the nursery. Seedlings from direct seedling will generally also have much greater genetic variability than planted nursery-raised seedlings. The biggest problem associated with direct seeding mallee is that there is often insufficient rain in a single fall to satisfy the germination requirements for all species in the seed mix, or not enough to sustain seedlings over summer.

Large seeded species like *Acacias* and *Sennas* tend to germinate first and most reliably and dominate the site, whilst Eucalypts germinate later in warmer conditions. This can give plantings a skewed species composition. An experienced direct seeding operator can modify seeding rates to account for this, or you can use a combination of direct seeding and nursery seedlings, or be prepared to thin out seedlings. Another drawback is the need to collect large volumes of seed, although as direct seeding technology improves, the volume of seed required steadily decreases.

Niche seeding is a variation on mechanical direct seeding where seed is hand-sown in small patches rather than continuous lines (Photo 13), giving sites a natural appearance. This method uses less seed than mechanical direct seeding, but is more time consuming and best suited to small sites or in-fill plantings to enhance diversity.

Photo 13. A cluster of eight Acacia pycnantha seedlings emerge from a spot treated with herbicide then hand sown with seed. Thinning may be useful in this example.

Species that are widespread and have seed that is easily collected (hence relatively cheap) and germinate well are particularly suited in direct seeding mixes. Nursery raised seedlings are particularly suited to species that are rare or threatened, or those with seed that is difficult or time-consuming to collect (hence expensive) or those species that germinate poorly in the paddock.

Melaleucas and Leptospermums do not have robust root systems and will generally only be successful in direct seeding in wet years in low rainfall Mallee areas. In Victoria, successful sowing of mallee Eucalypt species has been mainly with the larger seeded species. Similarly, Buloke and Blackbox (*Eucalyptus largiflorens)* have been generally unsuccessful in direct seeding and are usually established in sites by planting nursery-raised seedlings.

Direct seeding machinery

There are many different types of direct seeding machines (see photos 6&7) however they all consist of three elements;

1. A blade or disc that removes the top soil to a depth of 30-60 mm;
2. A seed box, or boxes, full of native plant seeds, and possibly a filler (sawdust or sand) to help the seed flow evenly down a tube that delivers the seed to the middle of the scalped area; and
3. A wheel that presses the seed onto the soil surface to prevent it being blown away and it ensures seed to soil contact which reduces the rate of harvesting by ants.

Basic direct seeders have only one seed box and can be towed behind a quad bike or ute. Several machines are mounted on tractor linkage. More complex seeders have multiple seed boxes each delivering a different seed mix, so that in a single pass a complex structure can be created.

These bigger machines are generally towed behind a four wheel drive ute or tractor.

A consistent feature of direct seeding is to scalp (scrape) away topsoil. Scalping is an effective technique to control weeds, remove excess nutrients that are concentrated in the topsoil and remove water repelling soil crusts, as well as creating a channel in which to capture and concentrate water around the seeds. However, scalping may remove too much soil nutrient. Recent research in Western Australia has shown a benefit from a small dose of fertiliser being included in the direct seeding mix. Click here. The main variation in common direct seeders is the type of scalping disc; either a circular disc or a V blade. A circular disc cuts a shallow narrow scalp making it suitable for shallow or heavy soils (Photo 6). A "V blade" cuts a deep wide scalp (Photo 14). V Blades are robust machines making them suitable for areas with large loose rocks. The 'Rolls Royce' direct seeder is a modified turf making machine used for bowling greens (Photo 15). It creates diverse native grassland in a single pass, after the top soil has been removed from the whole paddock. This approach to re-establishing the grassy or herbaceous understory of mallee could be applied to smaller areas within a large planting of trees and shrubs.

Photo 14. A V blade seeder mounted on a tractor creating a suitable seed bed for native species. This robust machine is particularly suited to stony sites such as this one.

Photo 15. A turf seeder modified to sow a diversity of grasses and wildflowers.

Seed preparation

Some seeds will require treatment before seeding to overcome natural germination inhibitors and increase the chances of germination. There are many forms of treatment, for example, hard-coated seed species such as Acacia and Senna should be scarified (cutting or sanding) or placed in boiling water (most Acacias) or very hot water (e.g. native peas and some Acacias, e.g. *A. salicina, A. oswaldii*) then rinsed in cold water. A soak in diluted smoke water for 20-30 minutes can also help break dormancy. Water treated seeds should then be dried to at least a flowable state to allow easy transport through the seed box.

Other species may need to have awns, wings or appendages removed in order to travel through the seeder. The CSIRO Publishing book *Growing Australian Native Plants from Seed* (details below) is one of the best sources of pre-germination treatment information. The Australian Native Plants Society also has an informative website on seed preparation for sowing, click here for further information. In addition, CSIRO Australian Tree Seed Centre Operations Manual has comprehensive information on the germination and treatment of many Acacia, Eucalypt and other Australian tree species. Click here.

Acacias, just like other legumes such as Lucerne have a symbiosis with nitrogen fixing soil bacteria. However, bacteria specifically co-evolved with Acacias may be missing in long cultivated soil. Studies have shown superior germination, survival and growth in Acacias inoculated with specific strains of bacteria. A mix of these bacteria (Wattle Grow™) may be available.

STEP 7.

Maintenance

After planting, the new seedlings are vulnerable to weeds, browsing and insect pests. They will need to be closely monitored to ensure high survival and good growth. In dry periods supplementary watering may be needed.

All revegetation sites should be regularly inspected post-planting. Check for any problems such as browsing by livestock, damage from rabbits, red-legged earth mite infestation, or an over abundance of weeds.

If weeds are mainly grassy weeds, grass-selective herbicides (e.g. Fusilade™) may be applied as an overspray using a boom if the newly emerged broad-leaf native seedlings are considered hard enough. A follow up spray is often necessary in the first year to control summer weeds which can compete with the new seedlings for the scarce moisture at this time of year. Seek advice from a herbicide specialist if in doubt.

Weed control is usually not necessary once seedlings have established above the height of surrounding weeds. However, if the season is poor it may be advantageous to implement control work to maximise soil moisture levels. Shielded equipment will be an advantage in this situation.

STEP 8.

Monitor to Learn and Improve

Follow a five-year project cycle for maximum success, with 2 years of preparation before planting and three years of monitoring and maintenance afterwards. Monitoring should start at the beginning of a project. Monitoring should record what is done at each step of any revegetation project (Figure 1). Successful restoration projects show that effective monitoring benefits from setting clear objectives and goals and these can be easily forgotten a few years later. Too often monitoring starts at the wrong end of this sequence (Figure 1).

There is a common desire to monitor restoration outcomes. However, it is also prudent to first monitor (record) the Objectives and Strategies of a restoration project, followed by a record of the Actions implemented (e.g. species planted), then the Results of those actions (e.g. dead or alive plants). Finally, assess the long term ecological outcomes of your planting such as the wildlife that has colonised your site, if wildlife habitat was one of your objectives. It makes no sense to unfairly judge the habitat quality of a site if the original objective was simply to establish a windbreak with some hardy native trees and shrubs.

Horses for courses

There are no universally applicable methods for monitoring outcomes, because the right method depends on site objectives. There are standard methods for monitoring birds if the site objective is to provide bird habitat. Similarly there are methods to assess the reduction in salinity and erosion risks if these are site objectives. Objectives should define monitoring. However, the table below provides a guide to the 'generic' kinds of monitoring data that need to be collected for any type of planting. Click here to download key monitoring data for revegetation sites (adapted from CSIRO/ABARES research).

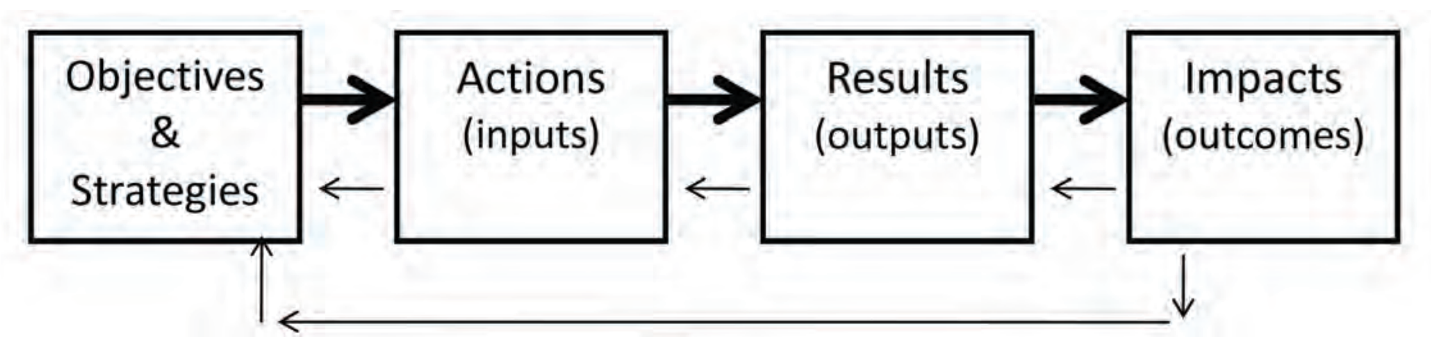

Figure 1. A framework that identifies the multiple points at which monitoring is needed to improve revegetation practices and identify outcomes. The thick arrows indicate the consequences of implementation and the thin arrows indicate key interpretation and learning feedback loops (from Freudenberger 2012)

Data type	Details	Definitions
Site Data		
1. Data record	Unique identifier for the site	The site is the area of the revegetation work for that season
2. Date	Day/Month/Year	Date of primary observation
3. Data source	Name of observer Contact details	Data collector's name and contact details including agency or business name
4. Site location	Nearest Town & State GPS coordinates for a site access point Tenure of Site Owner of land	Google Earth can be used to determine the coordinates (Lat/Long) of an access point like a gate if a GPS is not available.
5. Site area	Hectares	Google Earth can be used to measure the area of a site
6. Existing land cover	Describe the pre-planting vegetation cover or type of land use	Include dominant plant species covering the site pre-revegetation
Establishment Data		
7. Revegetation objective(s)	Improvements in: shade & shelter wildlife habitat seed production riparian health or water quality soil stability carbon sequestration etc.	If more than one objective, specify primary and secondary objectives
8. Funding source and resources invested	Agency or person supply funding Dollars spent per site (grant and in-kind) Hours of labour Materials (fencing, herbicide, total kg of seed or total number of seedlings)	Include multiple funding sources. Dollars spent includes site preparation, planting and maintenance to date.
9. Site preparation	Dates Weed control technique (e.g. glyphospate at X ml/ha) Soil preparation (e.g. rip and mound, or scalp with direct seeder)	Describe the dates and methods used to prepare the site for planting and/or direct sowing of seeds
10. Species planted or sown	Species name (Latin binomial) Seed provenance (source location)	Specify species of seed or seedlings used and where the seed was collected from (when known)
11. Planting or sowing rate	Kg of seed/ha/species directly sown Nursery seedlings planted/ha/species	List the planting or seeding rate for each species
12. Revegetation methods	Direct seeding Nursery seedlings Tree guards Mulches Watering Stimulate natural regeneration (e.g. fire or ripping) etc	Describe what was done to establish more native plants on the site
Monitoring and Maintenance		
13. Monitoring frequency	None Occasional-opportunistic Regular (planned)	If regular, list how often per year
14. Monitoring method(s) for revegetation	Casual look around Plots and formal surveys What measured	Describe the method(s) used to monitor the status or health of the planting
15. Revegetation monitoring results	Date Names (Latin binomial) of surviving species % of species planted that have survived Density of surviving species (number/ha) % of seedlings planted still surviving General health or vigour of the reveg Species of weed Cover of weeds (e.g. low, medium, high)	Describes and quantify the success rate (results) of the revegetation at this site
16. Site Management	Date Observed threats to the revegetation Management activity Effectiveness	Lists management activities on the site post revegetation (e.g. weed and pest control) and describe how well they worked
17. Methods to measure outcomes	None Bird surveys Habitat Hectares Carbon sequestration Salinity etc	Describe methods used to measure or estimate the outcomes of the planting. Outcomes are the consequences or environmental ***impacts*** of the revegetation.
18. Results of outcomes monitoring	Date Survey or observational data	What found and what it means
19. Other observations/notes	Date Text or data	Other observations conducted at the site

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Further Assistance

For further assistance or advice we suggest you try contacting:

Greening Australia
ph 1300 886 589
or find us on the web page

Your Regional NRM (catchment) Organisation

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