Forestry Tasmania

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Eucalypt Seed and Sowing

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Division of Forest Research and Development,
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Contents

Part A: Prescriptions for Eucalypt Seed and Sowing in Tasmanian Native Forests.

1. Introduction

Regeneration is an integral component of sustainable forest management. In native eucalypt forest, seedling regeneration arises from natural sowing from standing trees or fallen crowns, from artificial sowing, or often from a combination of both.

Where a coupe has been clearfelled it is generally followed by a high-intensity burn to create a favourable seedbed. The coupe is then sown as soon as possible after the burn with adequate amounts of seed sourced from the same coupe or seed zone, using the pre-harvest species mix.

On partially-harvested coupes, seed crop assessments establish whether adequate seed, in the same pre-harvest species mix, is available to naturally sow the coupe.

Each District is responsible for the collection, allocation and sowing of their own seed. The Seed Centre is responsible for the extraction, cleaning, storage and subsequent release of seed to the Districts.

Part A of this bulletin details prescriptions relating to the broad-scale collection, handling and sowing mixes of eucalypt seed and the silvicultural techniques utilising natural seedfall in native eucalypt forests. Part B gives more comprehensive background material on which the prescriptions in Part A are based.

2. Planning for seed collection

2.1 District requirements

The collection of seed should be based on current and future seed requirements, as established by District Seed Coordinators and Native Forests Branch. The focus should be on coupes that are to be regenerated to native forest within the next three years, and on maintaining an adequate amount of seed in reserve. Where good seed crops occur and are not required by that District, adjoining Districts should be notified in the event they require additional stocks of that in-zone seed.

Regular monitoring of flowering and seed crop development is desirable to optimise collection opportunities, especially on coupes scheduled for logging or where seeding tends to be sparse or irregular. A simple field sheet designed to collect information on flowering and seed crops can be found in Appendix 1. Wherever possible, roading and coupe harvesting should be scheduled to maximise seed collection opportunities.

Districts should take every opportunity to utilise flight time on other operations, e.g. eagle nest searches and aerial fire detection, to identify flowering. Where a particular species, height class or zone is difficult to collect because of irregular or sparse flowering, flower detection flights during optimum flowering periods should be considered.

2.2 Sources of seed

Seed can be collected:

- during road construction,
- in conjunction with harvesting operations, and
- as a 'contingency' from seed zones when available to meet unplanned sowing needs, such as changes to logging schedules or wildfire damage.

While it is important to build up stocks of required seed in times of plenty, seed with little future demand should not be collected. Extra effort should be made to seek out sources of scarce seed.

Forestry Tasmania also pursues external seed sales. Seed that is surplus to corporate requirements is available for sale. Where heavy seed crops are observed that are surplus to District needs, seek advice from the Seed Centre Manager before collecting.

3. Collecting the Seed

3.1 When to collect

The ideal time for seed collection is shortly after a capsule crop reaches full maturity but before it has been significantly depleted by natural shedding. Seed capsules of most Tasmanian eucalypt species mature a year after flowering. Seed should be collected before the second summer after flowering. A guide to flowering and seed collection times is given in Figure 1.

The seed crop should be sufficiently mature before collection. Very immature seed will not germinate and the valves of immature capsules are not fully developed (Figure 2), so they will not shed their seed completely on drying. The crop is mature when no seed is retained within the capsules after drying, and the fertile particles are mid-brown or darker in colour (Figure 3).

Capsules that have only recently matured may still be greenish in colour as distinct from the grey/brown of older ones. There should be a well-defined valve visible on the ends of the capsules, indicating that the valves are properly formed and ready to retract on drying. If the seed appears immature or greenish, collection should be delayed a few months.

Prompt collection of seed capsules after felling is important, especially in warm weather. Failure to collect within one to two days may result in significant seed loss as the capsules begin to dry out and open.

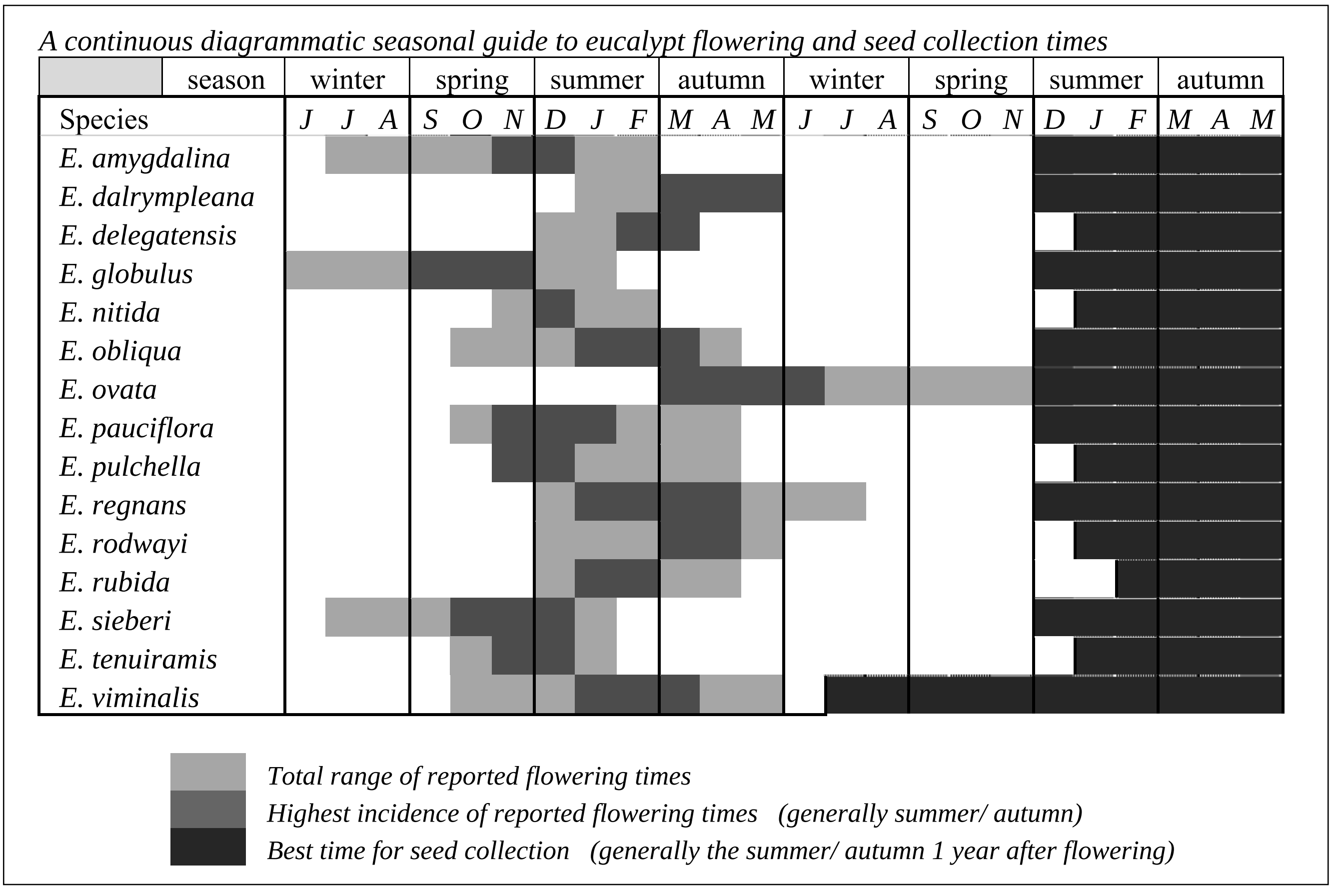


Figure 1. Reported flowering and seed collection times for some Tasmanian eucalypt species.

3.2 Which trees to collect from

The main objectives are to maintain genetic quality and to keep costs reasonable. The use of seed from inferior parent stock, or seed subject to a high incidence of inbreeding due to isolated flowering, may depress the quality of the new stand. Narrowing the genetic base by collecting from too few trees may be detrimental to subsequent generations. Collection of light seed crops is costly. These problems can be minimised by observing the following rules.

- **Spread the collection over the largest possible number of widely dispersed trees**
  Try to collect from at least 15 trees which are preferably 100 m or more apart.
- **Avoid sites where seed crops are sparse or heavy crops are restricted to isolated trees**
  Stands with numerous heavily laden trees are preferred.
- **Collect from vigorous trees of good form**
  Although defects due to physical damage (e.g. from fire or falling scars) can be ignored.
- **Collect across the range of site conditions**
  Such as ridges, gullies, soil types and aspect.

Very immature capsules shortly after flowering. The remains of the style and stamens are visible.

Immature capsules.
The faces of the capsules have not yet developed the 'star' or 'cross' shaped valve.

Mature capsules.
The clearly defined 'star' indicates that the valves are ready to open on drying. This is the best stage for seed collection.

Mature capsules after drying.
Most of the seed has now been shed from these capsules.

Figure 2. Capsule maturity in *E. viminalis*.

E. globulus
The larger, darker particles are fertile seed, the remainder are chaff.

E. amygdalina
The particles are smaller and there is a lack of size and shape differentiation between fertile seed and chaff, compared with *E. globulus*

E. globulus
The seed and chaff darken with age; in this case the seed has been in storage for 11 years.

E. delegatensis
This seed had been stored for 15 years after extraction from immature capsules which did not open fully. The seed was non-viable. The pale particles are indicative of immature collection.

Figure 3. Eucalypt seed maturity

3.3 How to collect seed-bearing material

The majority of seed collected on State forest will be from the heads of trees which have already been felled. For small scale collections or those from trees which cannot be felled (e.g. for aesthetic or rarity reasons) climbing, shooting off of limbs, pole pruners or saws may be used.

Capsules should be grasped in the hand and twigs and leaves clipped with secateurs about 5 cm either side of the hand. A protective glove should be worn on the hand holding the capsule material to minimise accidental injuries. The handful should be dropped onto a tarpaulin, or into bales or plastic bins. The collection of very wet material should be avoided.

Individual capsules are clipped only for *E. globulus*.

Bales of material should not be dragged over the ground because of snagging and holing, thus allowing capsules and/or seed to escape.

Collectors are responsible for the supply and maintenance of good quality bales. The Seed Centre will destroy a bale when it is likely to lose seed. All serviceable bales will be returned.

4. Transport, Extraction and Storage

4.1 Transport and care of seed-bearing material

Excessively high temperatures inside enclosed areas on hot days are to be avoided as this may damage seed. Avoid damp conditions as this may lead to fungal growth. To minimise the risk of loss or damage, the following guidelines should be observed:

- Seed-bearing material should be transported in seed-proof containers such as wool bales.
- Avoid compressing too much material into the bales. The maximum filled weight per bale is set at 30 kg for ease of handling and occupational health and safety reasons.
- Large amounts of twigs add to transport costs and increase the amount of moisture to be removed. Only include moderate amounts of non-productive twigs in collected material as this facilitates drying by improving aeration and reduces fungal damage.
- If there is a delay in forwarding seed material to the extraction centre, bales are to be kept in a dry, well-ventilated location protected from extreme heat with the bale flaps open.
- It is vital that seed is extracted as soon as possible after receipt at the extraction centre.

4.2 Collection information

Each bale or raw seedlot should be identified with two seed collection labels (see Appendix 2). One label should be inside the bale on top of the capsule material, and the other attached securely to the top flap. In order to use the seed appropriately, the seed centre needs to record specific information about the collected seed. The information to be written on each label is described below:

Information	*Comments and examples*
Supplier	e.g. Nigel Richardson
Date of collection	e.g. 01/09/2009
Species	e.g. *E. regnans* Note: individual bales *must not* contain multiple species.
Weight of bale	e.g. 29.2 kg
Collection zone	e.g. L18 Refer to seed zone map or consult seed coordinator.
PI type (Photo Interpretation)	• The *potential* height of the source forest. Note that this is not necessarily the actual height of the trees. • Refer to PI map or to seed coordinator. • PI types as follows: E1* greater than 76 m E1 55 – 76 m E2 41 – 55 m E+3 34 – 41 m E-3 27 - 34 m E4 15 – 27 m E5 less than 15 m
Collection Site	• The six character coupe source (e.g. BD017E). • When not off a coupe, a general locality indicator and grid coordinate (e.g. Franklin E: 498631 N: 5229039) will suffice.
Natural stand	• Tick if the source forest is a naturally regenerated stand (as opposed to trees regenerated from artificial sowing).
Number of trees for batch	• Number of trees that the *batch* is sourced from (*not the individual bale*). • e.g. 5
Maximum tree separation	An indication of the separation of trees in the seed batch collection, scored as follows: a) sourced from trees within 100 m each other b) sourced from trees more than 100 m from each other.
Bale no.	The individual bale no.: e.g. Bass 045
Batch information	An indication of the number of bales making up that collection. e.g. Bale number 2 of 5 (note that batches *must* be split by species).

4.3 Drying

The vast majority of seed is extracted in artificially heated kilns. The following principles should be applied.

- The temperature should not be allowed to exceed 45°C, especially in the early stages while moisture levels are high, otherwise the seed may be killed.
- Adequate ventilation is needed to remove moist air. A final relative humidity level of 15% is desirable to achieve maximum seed recovery and low moisture content of the seed.
- Good separation of different collections is essential.
- Ensure that the valves of capsules are fully open and that all the seed has been shaken free. Fertile seeds tend to be buried deeply within the capsule. Incomplete shedding can therefore not only reduce total yield but may also impoverish the recovered seed. Recovered seed generally constitutes 2 - 4% of the weight of the twig and capsule material before drying. For twig-free capsules of *E. globulus* this figure may be doubled.
- Seed is to be extracted by batches (a "batch" is a particular kiln loading of a given collection) based on collections of the same species from the same site. Seed extracted from each batch must be well mixed to aid homogeneity and placed in 'tins'.
- Reduce contamination between seed batches by thoroughly cleaning the extraction unit prior to the introduction of the next capsule batch.
- Where raw seed is purchased, an audit of the extraction and cleaning facilities will be carried out by the Seed Centre Manager. If the equipment or techniques are not adequate, the Centre may elect to only purchase capsules from that supplier.

4.4 Testing for moisture content

Moisture tests should also be carried out on all raw seed purchased before any payments are made so that seed can be dried if necessary. This may result in some weight reduction and a lower purchase cost. Stored seed should be moisture-tested at the same interval as germination retesting and any seed that is too moist should be dried.

Seed is tested for moisture content using a Protimeter Grainmini V or similar. For detailed information on seed moisture testing, refer to the article 'Moisture Content Measurement on Eucalyptus Seed for Storage (Lockett 1999).'

4.5 Cleaning

Extracted seed should be sieved to remove particles of leaf, twig and dust while retaining chaff with the fertile seed. This process should not be confused with seed enrichment, where some of the chaff is sieved out before sowing to allow better control of seed spacing.

A guide to initial selection of sieves is given in Table 1. The particle size range of the seed concerned should be the ultimate determinant of the grade of sieves to be used.

Table 1. A guide to the selection of sieves for cleaning eucalypt seed.

	Approximate opening size required		
	E. globulus	*E. obliqua* *E. delegatensis* *E. sieberi*	other Tasmanian eucalypts
To remove large material Discard material *retained* by this sieve unless it includes any fertile seed, in which case use a coarser sieve	2.5 mm	1.5 mm	1.5 – 1.0 mm as appropriate
To remove small material Discard material *passed through* this sieve unless it includes chaff exceeding 10% of the cleaned seed weight, in which case use a finer sieve	0.5 – 0.7 mm as appropriate		

If an excessive amount of large foreign matter passes through the specified sieves for any species, a finer sieve should be used to separate it, provided that no fertile seed is retained with the rubbish. The smallest opening of 1.0 mm is only likely to be acceptable for fine-seeded peppermints such as *E. amygdalina* and *E. pulchella.*

All raw seed received by the Seed Centre will be cleaned with their equipment before a final weight for payment is determined.

4.6 Storage

To keep eucalypt seed in best condition during storage, the seed should be kept:

- dry,
- at a constant cool temperature, and
- protected from fungal and insect attack.

Dry seed is to be placed in airtight plastic bags and stored in numbered containers or tins. All extended storage should be in cool rooms at 2 - 4°C.

Insects are controlled with 2 calico bags containing 50 g of paradichlorobenzene in each bag of seed, one at ⅔ depth and the other on top of the seed.

With constant temperature and sealed storage, excessive humidity is avoided and fungal and insect activity is minimised.

Seed should be kept dry and protected from high temperatures once it has been removed from long-term storage, e.g. while awaiting sowing. If it is kept under refrigeration it is important to ensure that its container is moisture-tight. Any seed taken from the seed store that is not used within a month should be returned for holding at the regional seed store until it is required.

Seed stored under the above conditions and with low moisture content can be held for many years before germination percentages reduce.

4.7 Data management

The information recorded on the capsule tags, along with extracted seed weights and germination test results are recorded in the seed system. Information is recorded against a product number. The product number is independent of tin number as there can be potentially be more than one product number in a storage tin. A product number normally relates to seed no greater than 10 kg. In the situation of larger collections of seed, whilst they may have been extracted together are divided into 10 kg lots and each is allocated its own product number.

The seed system is subsequently used to provide seed inventories and to allocate, order and purchase seed from the seed centre. For instructions on how to use the seed system refer to the Seed System Manual on the Forest Management System.

5. Germination Testing

5.1 When to test

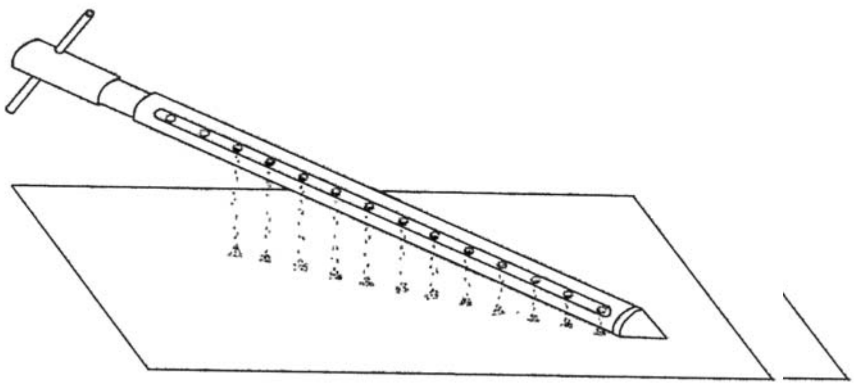
Each batch of seed is tested and classified after extraction or acquisition. Germination tests for Forestry Tasmania seed are conducted at the laboratory facility at Perth. The actual number of viable seeds per kilogram will be recorded on the seed system.

Seed held in store must be re-tested at a maximum interval of three years for *Eucalyptus delegatensis* and five years for all other eucalypt species. Seed requiring re-testing will be highlighted in the seed system. Each tin must be re-tested separately.

5.2 How to obtain samples

To ensure that a test sample accurately represents the seedlot, sampling should:

- be with a sleeve-type trier (Figure 4), taking a composite sample of at least 10 g weight (approximately two teaspoons full) from all tins of each seed batch,
- push the trier to the bottom of the container, then open and agitate gently, close and remove, and
- collect from all containers equally; multiple insertions spaced around each container should be used where necessary to provide sufficient seed.



Emptying a sample from a seed trier. The central shaft containing evenly spaced downward-angled collecting holes is rotated within the slotted outer tube to open or close off access to the holes. The end is pointed to ease insertion into a container of seed.

Figure 4. Sleeve-type trier

5.3 Germination test procedure

A more detailed description of the germination testing procedure can be found in the Seed Manual (available from the Forest Management System). To aid understanding, a brief description of the process is given here.

To prepare a germination test, a plastic container is lined with a moist cotton towel and then microwaved on high for 1 minute to eradicate any bacteria present. From the original sample, 4 sub-samples of a specified amount are obtained through repeated halving. The sub-sample size is determined by the species being tested. Each sub-sample is then placed onto a moist filter paper in the plastic container. The container is then sealed with plastic wrap and a lid placed on top.

5.4 Stratification procedure

Eucalypt seed requires specific environmental conditions to be met before germination will occur. This is an environmental adaptation to minimise the germination of seed in unfavourable conditions, such as during a cold winter. Subjecting the seed of species that occur naturally on cold sites to an artificial stratification in the cool store should promote germination. All germination tests are now subject to stratification before being tested.

The germination container is placed in the cool store at 4°C for 28 days. At the completion of this period, the container is placed in the germination room where the temperature is set at 20°C.

Once germination has started, counts of new germinants are made weekly for four weeks. These counts are recorded onto a tally sheet. Germinants are only counted when they meet the International Seed Testing Association (1985) germinant definition, which is 'when the primary root and hypocotyl together exceed four times the length of the seed, provided all structures which have developed are intact.'

At the completion of the four week period, each germination test is subjected to a squash test in order to determine if there are any un-germinated but potentially viable seeds.

5.5 Squash test procedure

The particles remaining on the filter paper from each sub-sample are scraped up and spread, a few at a time, on a clean sheet of slightly porous paper (e.g. duplicating paper). The particles are then individually squashed, using a metal tool with a narrow flat tip (e.g. the side of a scalpel) and the number of un-germinated full seeds is recorded. Full seeds contain a soft, moist white embryo, which leaves an oily smear on the paper when squashed. Chaff, on the other hand, is dry and woody. The number of full seeds and those that germinated are added to arrive at the total number of viable seeds for that seedlot. If this figure is low, then the reason for the low germination percentage should be investigated.

5.6 Test results

Under normal circumstances, at least eight weeks should be allowed to obtain a germination test result. It may be possible to obtain a provisional germination test at an earlier time, but this will involve the results of a squash test only and will give no indication of germination percentage.

The test result will include both a germinants/kg (result from germination test) and a viable seeds/kg figure (result from germination + squash test). These results are both reported as the lower 95% confidence limit (LCL) of the average of the four sub-samples assessed. That is, if the sample was taken correctly, it is 95% certain that the seedlot it represents would exceed the specified viable seeds/kg under laboratory conditions.

Seed has traditionally been allocated to one of four broad germination classes that have then determined the sowing rate of the seed. The classes were based on the number of germinants per kg that the seedlot would be capable of exceeding under laboratory conditions. In order to ensure that coupes are sown with sufficient seed that will germinate, seed is now sown at a designated rate of germinants/ha. This is explained further in section 6.3. To estimate the amount of seed required to sow a coupe, the average LCL for each species is used. However, the established use of seed germination classes means that they are still a useful indicator of seed lot quality. The minimum lower limit of these classes and the average LCL for the commercial Tasmanian eucalypts is shown in Table 2.

The average LCL figure should presently be used with some caution. This is because the figures are derived from both unstratified and stratified tests. It is therefore likely to be an underestimate of the true average. As more stratified tests are carried out, this table will be updated.

Table 2. Minimum lower limit of laboratory germinants ('000/ kg)

Species	A+ Class	A Class	B Class	C Class	Average LCL *
E. amygdalina	205	90	45	< 45	140
E. dalrympleana	250	110	55	< 55	219
E. delegatensis	125	55	28	< 28	84
E. globulus	120	50	25	< 25	80
E. nitida	205	90	45	< 45	140
E. obliqua	92	40	19	< 19	61
E. ovata	500	220	110	< 110	425
E. pauciflora	92	40	20	< 20	76
E. pulchella	205	90	45	< 45	236
E. regnans	145	61	31	< 31	114
E. sieberi	146	65	33	< 33	115
E. tenuiramis	170	75	38	< 38	95
E. viminalis	250	110	55	< 55	316

* *Average lower confidence limit of all seed of that species, as tested at the seed centre. This number is used for forecasting longer term seed requirements.*

The implications of germination test classes for field sowing are as follows:

Class A+ The number of germinants is well above normal for the species.

Class A The number of germinants is within the normal range for good seed of the species.

Class B The number of germinants is well below normal for the species.

Class C The number of germinants under laboratory conditions is so low that it is doubtful whether this seed would make a significant contribution to stocking under less favourable field conditions. This seed may be included in a sowing mix but only as a "bonus" on top of normal requirements. Its inclusion will increase the required sowing rate. No seed of this quality should normally be purchased. C class seed may be used to bulk up sowing mixes that are to be sown at a rate lower than that achievable by the sowing machine.

6. Sowing Mixes

The general aim of sowing is to ensure that sufficient seed is provided to allow each naturally occurring eucalypt species the opportunity to maintain its previous proportion in the new stand. Provisions covering species and seed source are designed to minimise risks to the stocking, health or vigour of the new stand.

6.1 What is the appropriate species mix?

Forestry Tasmania has a commitment to maintain local gene pools and species mixes on native forest sites. The species mix to be sown must represent the species proportions of the previous stand as determined by field assessment. This information should be recorded and used to determine the weight of seed for each species to be sown, as described in Section 6.3.

Where the coupe to be sown is homogeneous, in terms of its eucalypt species composition, the mix should be spread evenly across the coupe. Where major changes in species composition can be clearly delineated across a coupe, then species mixes or bags may be added to the seed hopper in a manner that better matches species to site. All seed should be given the opportunity to grow where it is genetically best adapted to perform - natural selection will decide final species distribution.

When allocating seed to a sowing mix, both the genetic diversity and provenance of the final seed mix should be considered. One should also consider the potential height of the original stand and the age of seed available.

Genetic diversity

Genetic diversity (or variation) drives natural selection. Individual seeds from any given population have a different genetic make-up and will exhibit different traits which may or may not be to their benefit with respect to the site or environment where the seed is sown. The more genetically varied the seed mix sown on any given site, the more likely that it will contain seeds with the potential to perform well on that site.

The genetic diversity of a seedlot will also influence future stands. Outcrossed seeds (produced from two non-related parents) are more likely to become vigorous, healthy trees than in-bred seeds (produced from single or closely related parents). In-bred individuals have a less varied genetic base, and as such are more likely to perform poorly or be susceptible to changes in the environmental conditions or parasitic attack. Stands created from genetically diverse seedlots, will produce genetically diverse seed in the future.

Genetic diversity is maintained by collecting seed from as many well distributed parent trees as practicable. As a guide, try to ensure that there is at least one parent tree/ha of forest to be sown. It is also important that provenance rules are followed as this increases the likelihood of the seed being adapted to the site.

Provenance

Seed provenance refers to the geographical location of a particular seed collection and informs the likely suitability of a seedlot to a site. Forestry Tasmania has developed a seed zoning system in order to promote the creation of appropriate seed mixes. The seed zoning system is based on an assessment of three environmental factors: altitude, dryness and coldness. It is aimed at minimising the risk of unhealthy or understocked regeneration due to the use of ill-adapted seed. Refer to Appendix 3 for a more detailed description of the seed zoning system.

Seed used in sowing mixes is categorised as follows:

- *On-Site Seed* (ONS) is seed collected from the coupe or from any immediately adjacent coupe that has similar topography, elevation, aspect, parent material and forest type. On-site seed is highly desirable as it maintains gene pools and ensures that regeneration is adapted to the site.
- *In-Zone Seed* (INZ) is seed collected from the same seed zone as the nominated coupe.
- *Out-of-Zone Seed* (OOZ) is seed collected from outside the seed zone of the nominated coupe.

Ideally, all harvested coupes should be sown with 100% on-site seed. The minimum standard for seed provenance is that the coupe should be regenerated using at least 10% on-site seed with the remainder being in-zone seed.

No opportunity to collect on-site seed should be foregone just because stocks from elsewhere are in hand.

If supplies of on-site and in-zone seed have been exhausted, out-of-zone seed should be obtained from the closest available similar seed zone, as shown in Appendix 3.

Seed should only be collected from silvicultural regeneration if the original seed source is known, and the seed used was all on-site and/or in-zone.

PI Class
PI (photo interpretation) class refers to the height *potential* of the stand. Seed should preferably be chosen from the same *mature* PI height class as the original stand. If this is not possible, one should attempt to use seed sourced from no more than one class above or below that of the site to be sown. Seed from an E2 stand should not be sown on E-3 sites or lower and E4 seed should not be sown on E+3 sites or higher.

PI type	*description*	*alternative PI types*
E1*	> 76 m	E1
E1	55 – 76 m	E1* - E2
E2	41 – 55 m	E1 - E+3
E+3	34 – 41 m	E2 - E-3
E-3	27 - 34 m	E+3 - E4
E4	15 – 27 m	E-3 - E5
E5	> 15 m	E4

Year
Subject to the above constraints, the oldest seed should be used first.

6.2 Broadcast sowing rates

The amount of seed to be sown on any given coupe depends on the:

- site conditions (the degree of difficulty expected in regenerating the site) [see Table 3].
- composition and proportion of the respective species present in the original forest, and
- germination test of the allocated seedlots.

Site conditions

The aim of broadcast sowing is to establish at least 2500 seedlings per hectare. For all species, a 4% establishment rate is assumed (4 established seedlings per 100 seeds sown). On fenced sites the rate is assumed to be 8%. The base sowing rate is therefore 62 500 viable seeds/ha for an unfenced coupe on a moderately favourable site.

Site conditions reflect the regeneration difficulty for individual or groups of coupes (Table 3). Coupes should be classed as 'less favourable' where problems with obtaining good stocking are anticipated, e.g. poor climatic conditions, heavy browsing, etc. Fenced coupes can be sown at a lower rate as the losses sustained from browsing are likely to be lower.

All clearfelled coupes should be classified as moderately unfavourable and cable-logged coupes as very unfavourable in order to improve the chances of achieving successful regeneration.

Table 3. Base sowing rates (germinants per hectare) for calculating seed requirements for varying site conditions.

Site Conditions	*Target germinants/ha*	*multiplication factor or site weighting*
Fenced-intensive-blackwood	31 000	0.5
Partial harvest oversowing	40 000	0.6
Very favourable	50 000	0.8
Moderately favourable (base rate)	62 500	1.0
Moderately unfavourable	75 000	1.25
Very unfavourable	90 000	1.5
Extremely unfavourable	120 000	2.0

The number of germinants of each species required on the coupe can then be determined by multiplying the species proportion by the target sowing rate for the appropriate site conditions by the coupe area (Table 4).

Table 4. Determination of germinant requirements for sowing mixes.

Stand details	*Species*	*Proportion*		*Target germs (germs/ha)*		*Area (ha)*		*germinants required*
Coupe 1								
Moderately unfavourable 30 ha	OBL	0.7	x	75 000	x	30	=	1 570 000
coupe in M36, E2 stand,	REG	0.3	x	75 000	x	30	=	650 000
70% *E. obliqua*, 30% *E. regnans*								
Coupe 2								
Very unfavourable 67 ha coupe	OBL	0.6	x	90 000	x	67	=	3 618 000
in L9, E+3 stand, 60% *E. obliqua*	AMY	0.3	x	90 000	x	67	=	1 809 000
30% *E. amygdalina,*	GLO	0.1	x	90 000	x	67	=	603 000
10% *E. globulus*								

Seed should then be chosen in order to achieve the target number of germinants (Table 5). The actual amount of seed sown will therefore be determined by the number of germinants in the chosen seedlots.

Table 5. Determination of the amount of *E. obliqua* seed required on Coupe 1 in Table 4.

Species	*tin no*	*kg*	*germinants/kg*	*total germinants*
OBL	U23	7.2	88 000	634 000
OBL	416	9.8	46 000	451 000
OBL	315	9.8	49 500	485 000
Total		26.9 kg	Total germinants	1 570 000

Minimum sowing rates

Minimum sowing rates have been set for each species, based on the original A+ seed class sowing rates for a moderately favourable coupe (Table 6). This is the minimum amount (in kg/ha) that must be sown onto a coupe. In most cases, the minimum amount will be exceeded by allocating seed based on germinants/kg. However, in some cases it may be necessary to put additional seed into the mix.

The minimum sowing rate is used to reduce the chance of regeneration failure. In some cases germination tests reveal that a seedlot has an exceptionally high germination rate. When this occurs, a very small amount of seed may be sufficient to achieve the required number of germinants. However, it is possible that seed size is smaller than usual. Nursery evidence indicates that seedlings established from smaller seed particles are not as vigorous as those established from larger seed particles. In these cases the use of additional seed to achieve minimum sowing rates is justified.

Table 6. Minimum acceptable sowing rates by species for a moderately favourable coupe.

Species	*minimum sow rate (kg/ha)*	*Species*	*minimum sow rate (kg/ha)*	*Species*	*minimum sow rate (kg/ha)*
E. amygdalina	0.2	*E. johnstonii*	0.2	*E. risdonii*	0.2
E. archeri	0.2	*E. morrisbyi*	0.2	*E. rodwayi*	0.1
E. barberi	0.1	*E. nitida*	0.2	*E. rubida*	0.15
E. brookeriana	0.1	*E. obliqua*	0.35	*E. sieberi*	0.25
E. coccifera	0.2	*E. ovata*	0.1	*E. subcrenulata*	0.2
E. cordata	0.2	*E. pauciflora*	0.4	*E. tenuiramis*	0.2
E. dalrympleana	0.15	*E. perriniana*	0.2	*E. urnigera*	0.2
E. delegatensis	0.3	*E. pulchella*	0.2	*E. vernicosa*	0.2
E. globulus	0.25	*E. radiata*	0.2	*E. viminalis*	0.15
E. gunnii	0.2	*E. regnans*	0.25		

The minimum amount of seed required on a coupe can be calculated by multiplying the minimum sowing rate by the favourability multiplication factor by the species proportion by the area (Table 7).

Table 7. Determination of the minimum amount of seed required for Coupe 1 from Table 4.

Stand details	*Species*	*Min sow rate*		*Proportion*		*Favourability multiplication factor*		*Area (ha)*		*Minimum kg required*
Coupe 1										
Moderately unfavourable 30 ha	OBL	0.35	x	0.7	x	1.25	x	30	=	9.18
coupe in M36, E2 stand,	REG	0.25	x	0.3	x	1.25	x	30	=	2.81
70% *E. obliqua*, 30% *E. regnans*										

*Note that the amount of seed allocated in Table 4 was 26.9 kg. This exceeds the minimum sowing rate and no further seed is therefore required.

Seed allocation
The Seed Management System (located on the Citrix server) is used to allocate individual tins of seed to the seed mix for a coupe. The seed is allocated in consultation with the District Seed Coordinator, the Tasmanian Seed Centre Manager and Native Forests Branch.

For each coupe, the database calculates the required number of germinants of each species as well as the minimum sowing amount. It then allows the user to select appropriate tins to use in the seed mix of that coupe. to that coupe.

6.3 Mix preparation
When the seedbed in coupes has been prepared, the Seed Centre should be notified so that the previously agreed seed mix can be prepared and dispatched promptly. The bagged seed must be protected from moisture and excessive heat prior to sowing.

Bags should have two labels, one inside and the other attached sturdily to the outside. Two small packets of seed of approximately 7 g each should be included for the indicator plot.

If substantial quantities of a sowing mix cannot be sown when intended, they may be held over in a cool, dry place and protected from contamination and vermin. If the seed is unlikely to be used within a few months of preparation, it should be re-sealed in tins and placed in cool storage. Seed in calico bags should never be placed in the humid atmosphere of a cool store, as this permits easy moisture penetration to the seed.

Unused seed will not be accepted back to the store as part of formal stock. The seed remains the property of the District. Small amounts of left-over seed can be used productively on under-stocked areas.

7. Time of Sowing

The best regeneration will generally occur when seed is sown onto the most receptive seedbed. The earliest good sowing opportunity should not be missed.

Sowing should be timed to take advantage of the best seedbed conditions which allow the eucalypts to get away to a good start ahead of competing understorey species. This means sowing should be completed as soon as possible after slash burning or mechanical site preparation and at a time when conditions are likely to favour prompt germination. This is best satisfied by burning in March and sowing as quickly as possible. However, where seedbeds are created by mechanical disturbance during the winter, late winter/early spring sowing may be preferable.

Autumn sowing should be done early enough to allow the seedlings to establish before the onset of winter. Late autumn sowings run the risk of excessive loss of un-germinated seed due to fungal attack over winter and/or excessive loss of newly germinated seedlings which are particularly susceptible to winter browsing, frost heave and direct frost damage.

Sowing of coupes where the seedbed is created in winter can start in July and should be completed by mid-September or mid-August on drought susceptible sites, to allow the seedlings to become well established before the onset of summer drought. This applies even at high elevation where the advantage of the later arrival of summer may be offset by delayed germination due to dormancy of some seed. Early sowing on these sites will provide the cool, moist conditions (natural stratification) necessary to overcome any primary dormancy. Artificial stratification of seed is not currently recommended for field sowings.

7.1 Supplementary sowing

Re-sowing to rectify any understocking should be carried out without delay. This will reduce the development of excessive competition from understorey species and loss of seedbed to colonising plants. In most cases any re-sowing should be done by the autumn of the year after logging or burning (see Technical Bulletin No. 7. for remedial treatment details).

7.2 Wildfire areas

Where an area of silvicultural regeneration has been burnt by wildfire, it is better to mimic nature and sow as soon after the fire as possible. Experience has shown that seed sown on very dry soils does not germinate till moist conditions arise with the autumn rains. The seed tends to be buffered in the ashbeds and does not imbibe and begin the germination process until the soil is well wetted.

8. Sowing Methods

8.1 Aerial sowing

Aerial sowing is the preferred technique where there are large areas of suitable seedbed. Current aerial seeding equipment allows sowing mixes and rates to be easily varied. Helicopters can sow individual patches down to about 0.25 ha in area. Aerial sowing is the preferred technique for the majority of operations as it is flexible, efficient and effective.

Photo 1. Helicopters sow coupes efficiently and effectively.

Every opportunity should be taken to utilise any aircraft ‘down’ time during the regeneration burning program to sow any coupes that have been burnt.

The Sowing Boss should have a wind-speed gauge, hand-held radio and maps/photos of the sowing areas.

There should be a 1:100 000 scale map indicating the location of coupes, and a 1:10 000 map or photo for each coupe showing;

- grid north and grid references,
- sowing boundaries, hazards and distinctive ground features (e.g. high tension wires, stags etc),
- coupe area in hectares,
- sowing boss information (name, air-to-ground radio channel),
- quantity of seed to be sown, and
- sowing rate.

Helicopter Landing Site Specifications

The helipad should be approximately 20 m by 20 m and clear of foliage, loose rocks or humps. Road junctions or turning circles are ideal. The central touchdown area must be flat and be about 4 m x 4 m and capable of taking 4 tonnes.

Brohm Seeder

The Tasmanian Brohm Seeder transfers seed from the hopper by means of an auger and it disperses the seed through four hollow ‘spokes’ of a spinning disc.

The seed hopper fits inside the helicopter aft cabin held down by the rear seat belts. A light in the cockpit activates when the seed volume is low. The hopper capacity is 90 kg.

The auger unit consists of a nominal 30 cm long x 5 cm diameter auger, housed in a metal tube. Seed ingress is through slots in the auger tube. The speed control is through a variable speed motor with high efficiency fixed ratio gears, which maintain a constant speed regardless of the load applied to the motor.

From the auger, seed flows under gravity through an outlet pipe to the slinger which consists of a nominal 30 cm diameter x 1.5 mm thick aluminium disc. The disc is driven by a 24-volt electric motor at approximately 1000 rpm. Four radially arranged semi-flexible plastic discharge pipes of nominal 30 cm length x 15 mm inner diameter disperse the seed.

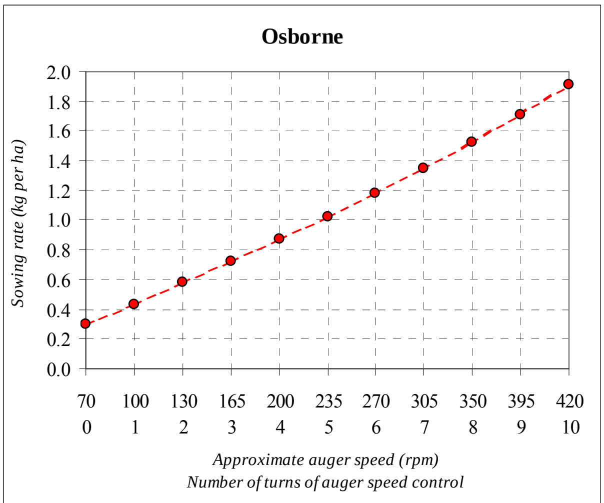
Calibration

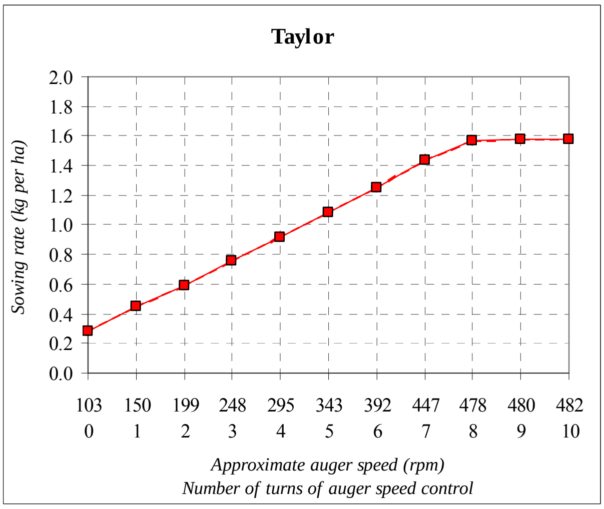
The calibration check is based on the time it takes to sow one hectare; with an average flying speed of 100 kph, this is 20 seconds.

Auger speed settings which gave satisfactory results last time are a good starting point, but regular checks are recommended. To check the calibration:

- Ensure about 5 kg of seed is in the hopper,
- isolate the slinger,
- remove the large cap nut on the base of the slinger,
- place container under this outlet,
- activate the auger and place a measuring container under the seed stream for exactly 20 seconds,
- weigh the collected seed.
- Adjust rpm if necessary to achieve required sowing rate.
- Repeat weighing test.
- Replace the cap nut on the slinger.

Figure 5. 2009 calibration charts





turns	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Osborne											
rpm	70	100	130	165	200	235	270	305	350	395	420
kg	0.30	0.44	0.58	0.74	0.82	1.02	1.19	1.32	1.58	1.71	1.91
Taylor											
rpm	103	150	199	248	295	343	392	447	478	480	482
kg	0.28	0.45	0.59	0.76	0.92	1.09	1.25	1.44	1.57	1.58	1.58

Seed Loading
Check the bags are tagged for the current coupe.

Seed for each coupe should have two small bags of seed for the indicator plot. There may also be bags of insecticide (paradichlorobenzene) which should be removed prior to loading.

Load required bags of seed into hopper.

Any foreign material in the seed, such as twigs, string or plastic bags will accumulate at the auger opening and limit seed flow. A partially blocked auger will distort the sowing and it will only be at the end that a problem will be identified. By this time, the point at which sowing was affected will be unknown.

Swathe Pattern
Seed distribution is asymmetrical with a slight bias to the left. Figure 6 indicates the distribution as if the helicopter is flying toward you. Using an 18 m swathe width allows for some overlap and more consistent distribution of seed. Seed distribution is greatly influenced by the ability of the pilot to fly uniformly spaced flight lines and the electronic flight time guidance system.

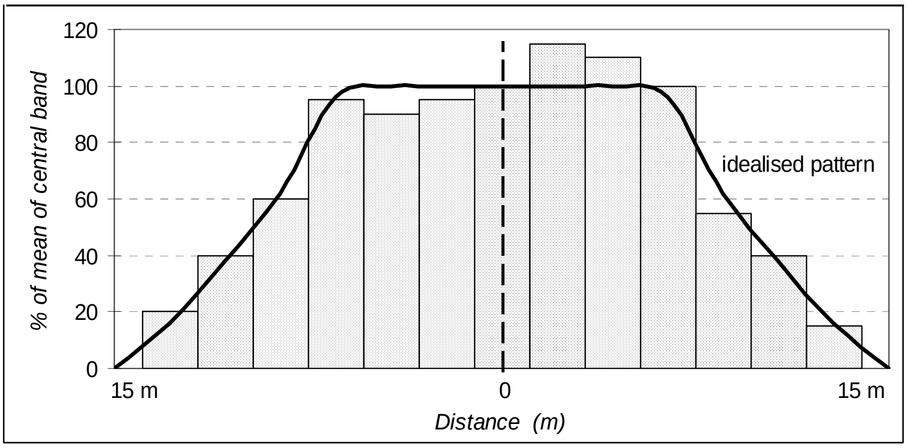


Figure 6. The distribution of seed from the heli-seeder.

Flying
Pilot briefing is normally carried out at the start of the day. A reconnaissance flight to confirm boundaries and hazards at each coupe is normally undertaken upon initial arrival at the coupe.

The general approach when working around helicopters is not to hurry – observe, then act. At the initial approach, first establish eye contact with the pilot and only move forward when indicated to do so. Obey the directions from the pilot at all times. After loading, ensure all catches and hatches are shut and secured. When all clear, give the pilot hand signals. Be aware that helicopters can throw up dust and small stones.

The carrying of a passenger is permitted for familiarisation of coupe boundaries, or between coupes. No observers are to be carried during sowing operations.

Seed Drift
A light consistent breeze will not affect seed distribution, but an allowance should be made for seed drift.

Wind gusts will have a marked effect on seed distribution and significant patches may be missed. The Sowing Boss should carefully monitor the aerial sowing and note where patches may be missed. A decision can be made whether to immediately re-sow any patches. Eucalypt seed drifts about 5 m for each 1 km/h of wind speed.
Sowing and Drift Guide

wind categories	*speed*	*action*
Nothing moves	0 km/h	no allowance for drift required
Smoke drifts	1-4 km/h	seed may be displaced up to 20 m
Leaves move	5-9 km/h	seed may be displaced up to 45 m
Twigs move	10-19 km/h	the offset is becoming too large and the pilot will experience difficulties in accurate positioning.
All branches move	>20 km/h	Do not attempt to sow.

The operation should be postponed when the winds are gusty or exceed 12 km/h. The pilot has the final decision on other operational flying conditions.

The Sowing Boss should at all times monitor seed distribution, by listening for seed falling onto a vehicle, safety helmet, clip board or onto a puddle.

Sowing rates

The quantity of seed in the hopper remaining after sowing should be weighed and recorded. If more than 10% of the seed remains at the completion of sowing, then the calibration or coupe areas were incorrect.

Difficulties will always be experienced in achieving consistently accurate calibration, as the distribution of seed from the aircraft relies on speed over-the-ground, centrifugal forces exerted by the slinger and forces exerted by aircraft pitch together with wind drift and turbulence.

A 10 km/h headwind will result in an 5% oversowing of the area, unless the airspeed is adjusted to compensate for the wind. A 10 km/h tailwind may result in an 5% undersow. The heavier rate when sowing into a headwind will be compensated for by the lighter sowing rate when sowing with a tailwind. A striated pattern of seed distribution may result, although it would be extremely rare that a direct head or tail wind would be experienced.

Where flight lines are long and the aircraft has to negotiate ridges or small humps the undulating flight path will induce forces which complicate seed distribution. The effect may be that over the crest of the hill negative forces result in less seed being sown. Conversely, as the aircraft pitches out of a gully, extra positive forces may result in oversow.

If the pilot flies higher to obtain a more level flight the seed has further to fall in the gully areas and thus is more prone to any wind drift, but over humps there may be a narrower swathe.

Sowing times should be recorded for each coupe on a master sheet. Any issues with the sowing should be recorded and referred to when assessing the distribution of seedlings.

Through constant monitoring, the Sowing Boss may suspect areas have been missed. If seed is left over at the end of sowing, it should be sown on suspected undersown areas, or generally around the perimeter of the coupe or retained for subsequent sowing on under-stocked areas defined in the regeneration survey.

If the Sowing Boss is satisfied that the whole coupe has been covered, but significantly undersown, it should be re-sown at a lower rate to make up the deficit. The nature of the site and any possible contribution from natural seeding should be considered. As a guide, there would be little justification for re-flying unless the coupe had received less than 75% of the sowing rate.

A printout from the aircraft GPS should be received from the company and stored on the coupe file as confirmation of sowing accuracy, and it can be consulted if there are any issues with the regeneration.

8.2 Hand sowing

Hand sowing is necessary where broadcast sowing would waste seed, such as:

- small and remote patches, or selective re-sowing of areas with patchy seedbed,
- occasions when lack of aircraft or unsuitable weather prevent aerial sowing.

Hand broadcasting
Broadcast sowing should be used where bare soil constitutes more than 70% of the ground area. It may also be used on areas with patchy seedbed for selectively sowing the better patches. Sowing rates within the sown patches should be as for aerial broadcasting.

The sowing rate of rotary hand seeders is affected by the:
- seed species,
- wind,
- the rate at which the handle is turned,
- the aperture adjustment of the seeder, and
- the walking speed of the operator.

The operation is conducted by systematically walking over the area, targeting the good seedbed and unstocked patches. A regular check of the seeders during the operation enables the seed usage to be roughly calculated to ensure that the area receives an even coverage of seed.

Spot sowing
Spot sowing may be used as a supplementary treatment on understocked moist sites where broadcast sowing is unlikely to succeed because of excessive ground cover, such as mosses and liverworts. It should not be used on dry sites or sites with dense understorey species already established.

Spot sowing is conducted using a spot sower. This tool consists of a scarifying attachment on the end of a hollow tube with a seed dispenser attached to the top. To operate, press the tool into the ground turning it from left to right until the surface crust is broken and fresh seedbed is created. Care should be taken not to make deep holes that can fill with water. Then remove the scarifying head from the ground to ensure that the seed is not buried. The dispenser will distribute a measured amount of seed, which falls down the pipe onto the scarified area when the trigger is pressed.

Spots should be created throughout the understocked area at approximately 2 m intervals along lines 3 m apart, or about 1660 spots/ha. Spots should not be created within 1.5 m of an established seedling. Selection of favourable seedbeds should have priority over regularity of spacing. Weeds should be removed from the sowing spot to a distance equalling their height.

The new germinants should be given every opportunity to establish prior to weed invasion and excessive competition.

Dingle and Plumpton (2003) determined that for Class 'A' *E. obliqua* seed, the optimum weight of seed per spot is 0.08 g. Their research showed that ‘the weight of seed sown on a spot appears to be the most important criterion affecting the number of seedlings produced.’ Where the sowing weight is too high, multiple seedlings can result, which significantly reduces the form of the growing seedlings. The rate suggested here is the best compromise between overall stocking and the incidence of multiple seedlings.

8.3 Natural sowing

Requirements for effective sowing
Natural sowing may be more variable but is generally cheaper than artificial sowing. Seed may be shed from fallen crowns, culls or from standing retained trees. An adequate quantity of sufficiently mature seed must be distributed over the coupe, at a time when both seedbed and ensuing weather conditions are likely to favour seedling establishment.

Where logging slash is left unburnt, the seed crop on fallen crowns will augment regeneration. The seed crop assessment field sheet is shown in Appendix 4. A capsule density of 4 or better on most trees should generally provide adequate seed.

Seed from retained trees
Partial harvesting systems are being used in both wet, dry, high and low altitude eucalypt forests. In high-altitude dry eucalypt forests, the retention of trees can have a number of benefits, including the reduction of frost severity and the maintenance of a continuous seed source (Keenan 1986, Orr and Todd 1992).

Seed tree retention is applied to open forests where a continuing seed source will maximise regeneration opportunities on harsh sites or where the retention is more cost effective than sowing. Seven to twelve well-spaced trees with good crowns and an adequate mature seed crop should be retained per hectare. Receptive seedbed must be prepared by burning or mechanical disturbance. Once a seed crop has matured it may be shed from standing trees within days after a hot fire or over a period of several years in the absence of fire.

For effective seeding from retained trees on moister sites where most receptive seedbed is lost to mosses and liverworts after a year, the seed crop must be at least approaching maturity at logging and must be fully mature before any slash burning which might scorch the trees. An indication of the stage of maturity can be derived from close inspection of a sample of capsules (Figure 2).

Seed crop assessment
Before relying on retained trees as a seed source, a seed-crop assessment should be carried out. It is important to retain seed trees in similar proportions by species to the original stand. The seed crop of all species must be mature and adequate to sow the coupe.

The seed crop assessment is a point-sampling system that predicts the likely intensity of seed shed. Most mature capsules on standing trees will be carrying seed, as capsules on a live tree are generally dropped within a short time of shedding their seed. Seed trees provide quantities of seed well in excess of artificial sowing rates. This does not negate the need to assess the current seed crop and to retain an adequate number of trees.

Seedfall patterns will be distorted on slopes > 15% as seed falls further down slope, than up slope.

Part B: Description and Background Material on Eucalypt Seed and Sowing.

Contents

1. Introduction

The process of sexual reproduction in eucalypts is characterised by extremely high outputs of reproductive material and extremely low success rates. The inflorescence buds initiated by a eucalypt over its lifetime have the potential to produce thousands of millions of seeds. The number of fertile seeds actually produced may be of the order of tens of millions. Only one of these seeds needs to germinate and grow to maturity to replace the parent tree.

When a stand is harvested, some seed losses mean that a higher sowing rate is required to perpetuate a new stand from seed. To achieve this we need to ensure that an adequate quantity of appropriate seed is available to be sown into a receptive seedbed and that the resultant germination is protected from damaging agents.

2. The Biology of Eucalypt Seed

2.1 Stages of development

The morphological development of the flowering and fruiting organs of eucalypts has been described in general terms by Cremer *et al.* (1978) and Boland *et al.* (1980).

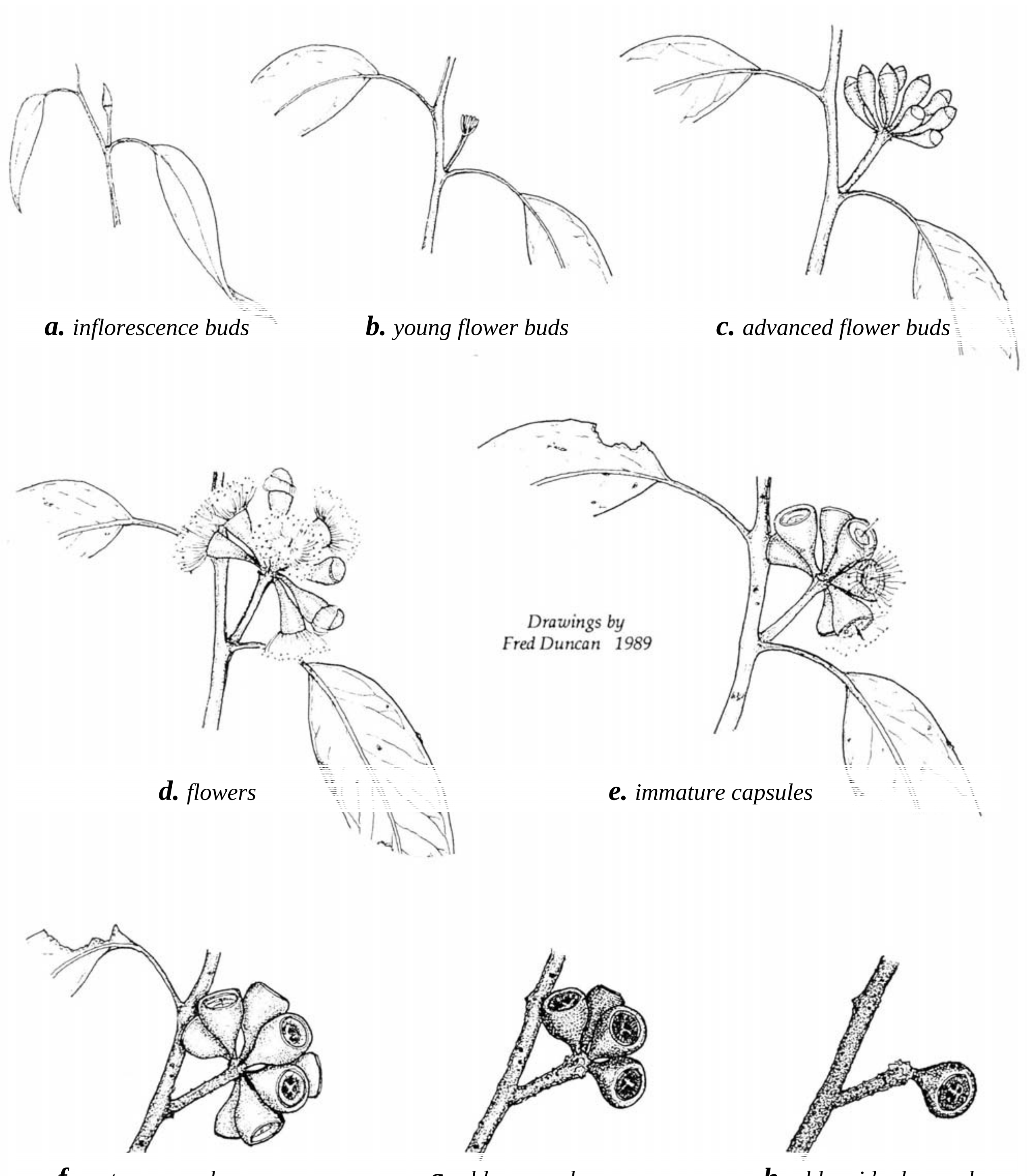
Detailed studies into seed production have been carried out on *Eucalyptus regnans* (Cunningham 1957, 1960; Gilbert 1960; Ashton 1975) and *E. delegatensis* (Fielding 1956; Grose 1957b, 1960). The general timing and duration of the different stages will vary somewhat between species but the process is exemplified by *E. regnans*.

The first evidence of flowering is the appearance in early summer of the inflorescence buds found singly or in pairs in leaf axils near the ends of shoots. These buds develop slowly and nearly one year later, in early summer, the enclosing bracts fall, exposing an umbel of individual flower buds. These buds increase in size to flower in April to June, about 15 months later - just over two years from when the inflorescence buds first appeared (Cunningham 1967).

Pollination of *E. regnans*, like other eucalypt species, is effected almost exclusively by insects; wind plays only a very minor role (Cunningham 1967, Pryor 1976). After flowering, the immature capsules develop for another 9-12 months before maturing approximately three years after the inflorescence buds first appeared (Cunningham 1960, Ashton 1975). *E. delegatensis* follows a very similar pattern of development (Grose 1960) and is illustrated in Figure 7.

Due to this protracted development, individual trees may contain up to six consecutive crops of fruiting organs at various stages of development. The least advanced crop is located nearest the growing tips, and progressively more advanced stages occur farther back toward the trunk.

The conditions required for the initiation of floral organs in the eucalypts and for their subsequent development are only partially understood. Internal genetic and physiological influences as well as external factors such as the availability of light, moisture and nutrients are likely to be involved (Jacobs 1955, Cremer *et al.* 1978, Loneragan 1979).



Time scale and development stages

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*
OND	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJAS
	a	***b*** ***c***	***d e***	***f***	***g***	***h***

The letters (a – h) refer to the stages of development and their approximate time scale.

Figure 7. Development of *E. delegatensis* flowering and fruiting organs over time.

Knowledge of this process allows seed crops to be anticipated up to three years in advance. This facilitates the planning of collections to ensure that projected seed requirements are met at minimum cost, especially for localities or species with a history of poor or intermittent seed production.

2.2 Variability of flower and seed crops

The timing and intensity of flowering and seed production varies between eucalypt species, between localities, between years, between trees in a given stand, between trees on different sites within the same stand and even between different parts of the same crown (Ashton 1975, Florence 1964, Pryor 1976, Griffin 1980, Bridges 1983, Neyland *et al.* 2003). There is considerable variation in reported flowering times for Tasmanian species which may extend over several months. Figure 1 indicates the time of the year when flowering is most likely

Some factors affecting seed production

Eucalypts start producing viable seed from about 2-10 years of age (Eldridge *et al.* 1993). In pole forests, the annual production of viable seeds is estimated to be about 0.9 million per hectare, increasing to about 3.5 million per hectare in mature forests (Ashton 1975). An individual large tree can produce up to 100,000 viable seeds per year (Cremer *et al.* 1978). It is generally recognised that dominant trees have heavier seed crops than sub-dominant or suppressed ones (Jacobs 1955). Also, open grown trees are generally thought to produce more seed per tree than similar ones in dense stands (e.g. Hall 1960), although it cannot be assumed that sparsely stocked stands will produce more seed per hectare than more densely stocked stands (Loneragan 1979). Harrison *et al.* (1990) found that regrowth stands are unlikely to develop heavy seed crops due to high stocking levels, smaller crown size, and rapid ejection of mature capsules.

Neither a good initial crop of inflorescence buds, nor even a heavy flowering, will necessarily guarantee a good seed crop by the time the crop reaches maturity. The availability of pollinating animals, insect and fungal attack, or moisture stress will have an influence on the number of viable seeds produced (Gilbert 1958, Cunningham 1960, Loneragan 1979, Cremer *et al.* 1978, Boland and Martensz 1981). Ashton (1975) found that the proportion of *E. regnans* flowers setting fruit varied from 3% to 41% between different stands and seasons, whereas Cremer (1971) quotes average figures of 15% of buds and 30% of flowers producing fruits.

Close and Wilson (2002) found that there were inherently lower levels of seed viability in *E. delegatensis* as compared to *E. regnans*. Lower levels of seed viability can be attributed to reduced activity of insect pollinators at higher altitudes (Warren *et al.* 1988, Hessing 1989, Primack and Inouye 1993).

Seed production may also be affected by the prevailing fire regime. Jacobs (1955) observed that seed production in *E. fastigata* following a hot wildfire was depressed for ten years until the trees had regained their former vigour. Certainly, any fire which produced enough heat at crown level to damage any developing floral organs would depress seed crops for several years at least. Kimber (1978) noted that a jarrah *(E. marginata*) stand which had experienced a mild prescribed burn two years previously flowered fairly heavily, while trees on an area which had been deliberately burnt more intensely to produce crown scorch had a much lower incidence of flowering. Grose (1960) also observed a similar effect in *E. delegatensis*.

Seed/chaff ratio

Most of the ovules present in a eucalypt flower fail to be fertilised, producing on average 10% fertile seeds with the remainder being infertile, woody 'chaff' (Cremer *et al.* 1978). The fertile seed may be distinguished by larger size, fuller shape and darker colour. This distinction is much less clear for species of the *Monocalyptus* sub-genus (i.e. the ashes and peppermints) than it is for *Symphyomyrtus* species (the gums) (Figure 8). Most Tasmanian species have between one and four fertile seeds per capsule (Grose and Zimmer 1958b, Cunningham 1960, Boland and Martensz 1981).

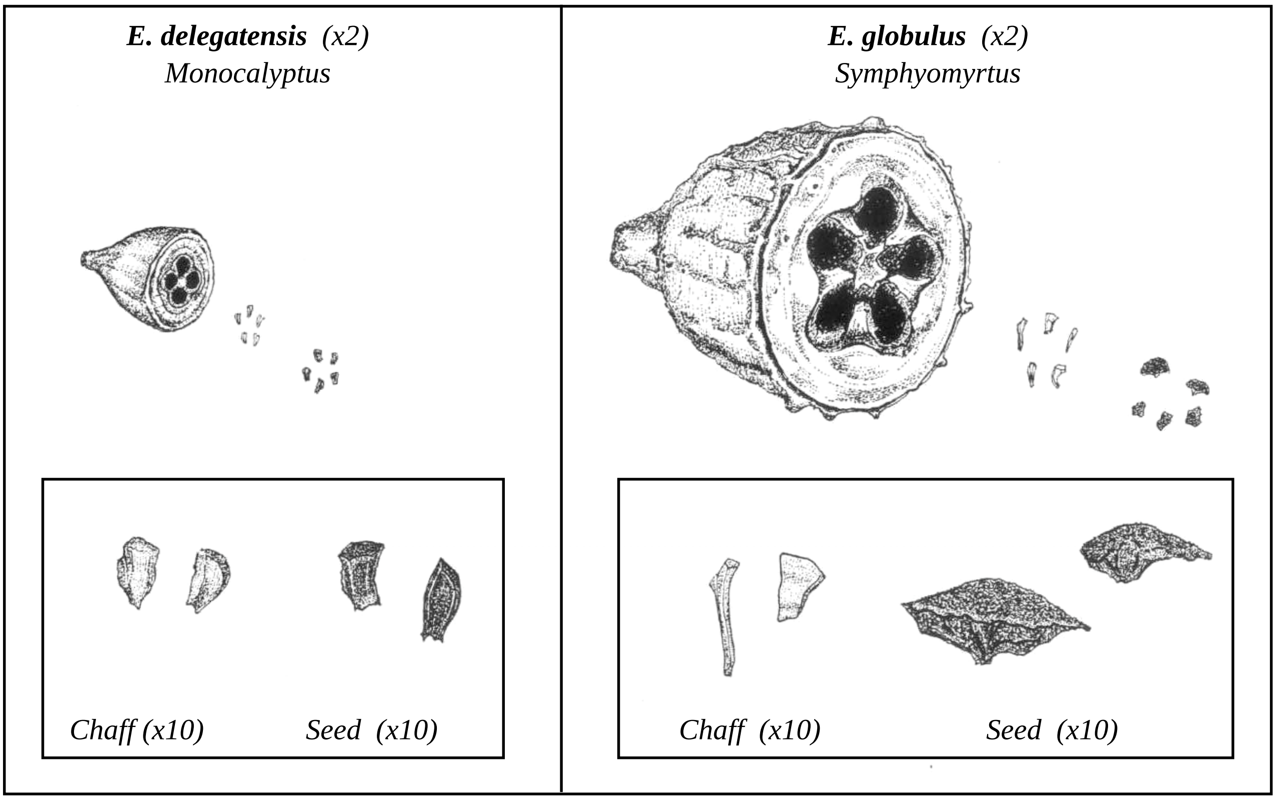


Figure 8. Open capsules, fertile seed and chaff of *E. delegatensis* (Monocalyptus) and *E. globulus* (Symphyomyrtus).

The size of the seed within the seed lot is also indicative of its competitive advantage. Laboratory studies have indicated that large seeds have an initial growth advantage (Grose and Zimmer 1958b, Green 1971). This rapid early growth may be important on wet forest sites, where seedlings must compete with a variety of understorey vegetation (Wilkinson 1995).

Controlled seed production

Eucalypt flowering is not always regular and in some instances the time between good crops of seed can be prolonged. The use of the growth regulator 'Paclobutrazol' to promote flowering is common in eucalypt seed orchards but has been trialled by Forestry Tasmania in native stands of *E. nitens* and *E. globulus* with no significant increase in seed crops. Roberts (1999) undertook a review of the potential for growth regulators to enhance seed crops in native forest and reports that ‘the concept of enhancing seed crops at a coupe level in an attempt to ensure supply for future regeneration is probably not feasible’. 'Paclobutrazol' produces an exaggerated flowering effect rather than inducing flowering so that in times of little or no flowering activity the use of such a growth regulator is unlikely to result in significant seed crops.

2.3 Seed-shedding and dispersal

The seed-shedding process

When mature capsules dry out, their seed is released by retraction of the valves and shrinkage of the enclosing structures as described by Cremer (1965c). The drying out of the capsules is a consequence of either the death of the twig to which they are attached or the formation of an abscission layer at the base of the peduncle or the pedicel, which cuts off their water supply. This mechanism does not work effectively on immature or very old capsules.

Abscission layers are formed naturally by live branches, and their formation may be promoted by damage such as crown scorch which is not severe enough to kill the branches. Within a few weeks of dropping their seed the capsules are themselves shed (abscissed) at the abscission layer (Cunningham 1967). Hence, most of the capsules present on a live twig at any given time will contain seed. Cremer (1965a) observed that in unburnt *E. regnans* 90% of capsules on living twigs are normally completely full of seed. By contrast, if a tree or a branch dies its capsules may remain on the twigs long after they have dried out and shed their seed. This is important when assessing seed crops on standing trees.

Between 16% and 49% of the total seed within a capsule may be shed within falling capsules (Grose 1957b, Gilbert 1958, Cunningham 1960, Cremer 1965a). This will not be as well dispersed as free seed. Also, much of it would fail to establish contact with a good seed bed, so it is unlikely to contribute to regeneration (Cremer 1965a).

In the absence of fire, the shedding of seed and capsules from *E. regnans* tends to peak in the autumn of the year after the capsules mature (i.e. approximately two years after flowering). However, diminishing quantities may be shed over several more years (Ashton 1975, Cunningham 1967). *E. delegatensis* behaves similarly (Grose 1960).

The effects of fire

Fire can have a big impact on seed-shed. Ground fires, especially on peaty soils, may kill trees by girdling, resulting in the slow drying out of the crowns and shedding of seed over a period of months. Alternatively, a fire too mild to scorch the leaves of standing trees may nevertheless initiate seed-shed through the formation of abscission layers (Cremer 1965a, Christensen 1971). Hotter fires may scorch crowns and directly commence the process of drying out the capsules, resulting in rapid and complete seed release. Cunningham (1960) observed very heavy seed-shed within two days of complete crown scorch in *E. obliqua*.

Scorching may kill some seed on standing crowns (Cremer 1965a) but seeds within capsules are fairly well insulated. In the event of a crown fire, seed is generally protected inside fire-resistant capsules which are located below the leaves thus reducing the heat flux received (Mount 1969).

Seed dispersal

When eucalypt seed is released, wind and gravity are its only means of dispersal (Cremer 1966). Because of the lack of ‘wings’ on eucalypt seed, its dispersal distance is fairly limited and tends to be greater downwind, downslope or from trees which are tall or exposed to wind.

Studies with *E. regnans* (Cunningham 1960, Cremer 1966) and *E. delegatensis* (Grose 1957b, Grose 1960) indicate that most seed falls within one tree height. About 5 - 30% falls from one to two tree heights. A small but significant amount of seed lands at distances of two tree heights or more. Cremer (1966) showed that, presumably due to the effect of wind velocity, dispersal distances increased with increasing openness of the stand. Cunningham (1957) noted that the fertile seed/chaff ratio declined with increasing distance from the tree.

Cremer (1977) measured the terminal velocities for a number of species of eucalypt seed in a wind tunnel and used this information to estimate likely dispersal distances. This study indicated that dispersal distances for *E. regnans, E. sieberi, E. obliqua* and *E. delegatensis* would be similar. The dispersal distance would be shorter for *E. globulus* seed, and greater for the fine seeded species like *E. viminalis*.

As a ‘rule of thumb’, a single tree is capable of seeding an area of radius equivalent to twice its height.

2.4 Genetics

The conservation of genetic diversity is an essential component of maintaining the evolutionary potential of a species (Frankel 1972). The Forest Practices Board (2000) requires that seed sourced for native forest regeneration should be on-site where available, to assist in the maintenance of the genetic resource.

Within areas devoted to production forestry, the use of 'on-site' seed can assist in maintaining a healthy and productive future stand.

The significance of seed source

As with other genera, many aspects of eucalypt survival and growth are genetically influenced. Research has provided ample evidence of wide variation between species, provenances and individuals in attributes such as:

- germination and establishment (Ladiges 1974a, Wilkinson 1995),
- growth rate (Griffin *et al.* 1982, Wilkinson 1995),
- form (Volker and Orme 1989),
- wood properties (Matheson *et al.* 1986),
- susceptibility to disease (Harris *et al.* 1985) and insect attack (Ohmart *et al.* 1984),
- resistance of coppice to mammal browsing (Wilkinson 1995),
- frost (Rook *et al.* 1980),
- water-logging (Ladiges and Ashton 1974), and
- drought (Ladiges 1974b).

Genetic adaptation to local site conditions may be important to the survival and health of a stand. Any mature eucalypt in a natural forest stand must have been well-enough adapted to its particular site to out-survive and out-grow many potential competitors. Also, there is generally a desire to perpetuate as far as possible, the nature of the previous stand, including its genetic resource.

Studies of genetic variation have usually focussed on the difference between provenances of eucalypts (Green 1971, Brown *et al.* 1976). Provenances can have large geographical separation. Wilkinson (1995) has determined that there are genetic differences between populations of *E. obliqua* over the scale of hundreds of metres. This emphasises the need to collect seed from a diversity of trees within the area to be sown, and from different site conditions. Collections should be made from a large number of trees as this can increase the genetic diversity. Collecting seed from a small number of trees, especially if these trees are isolated or related, will produce a high proportion of potentially poor quality seed (Pederick 1987).

While eucalypt form is certainly a partly heritable attribute, it should be recognised that many old-growth trees have defective form for reasons unrelated to their genetic make-up. These include open growing conditions during their youth, fire or mechanical damage.

Inbreeding and hybrids

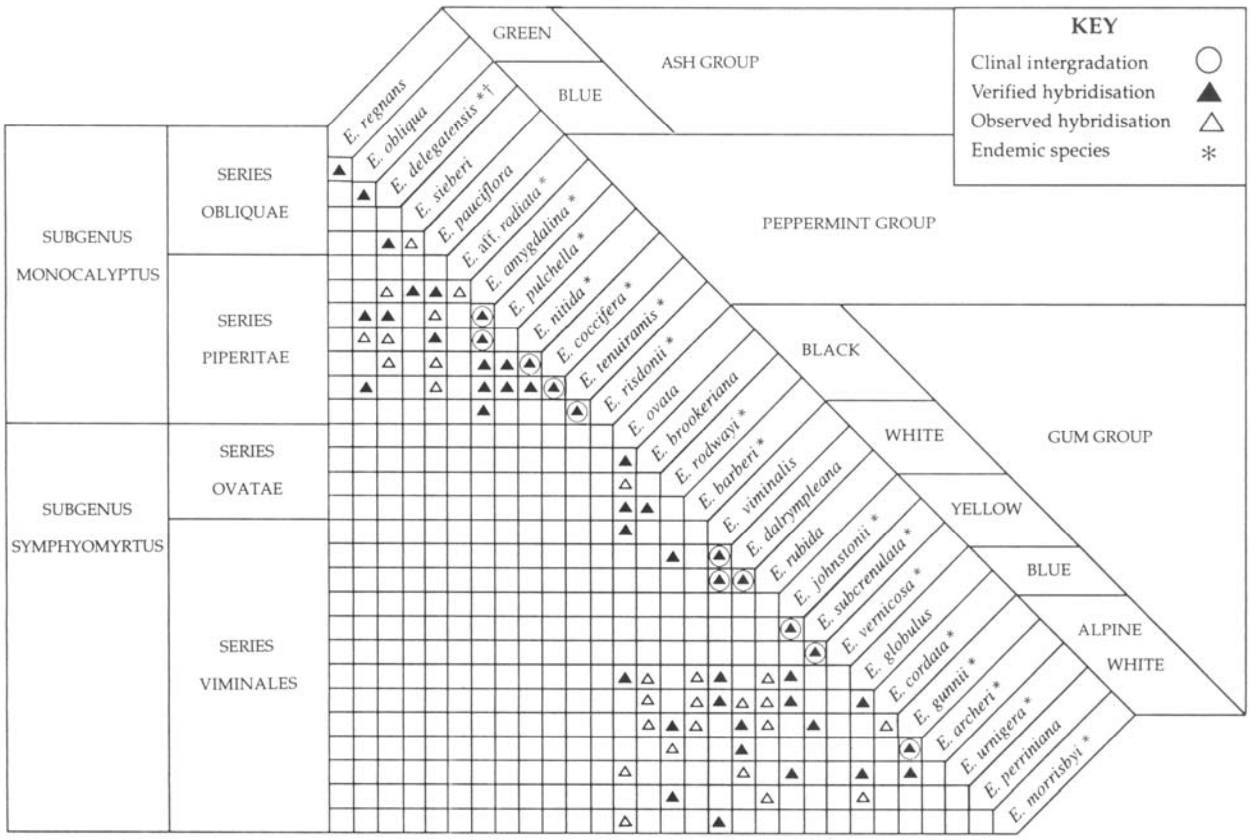
Inbreeding occurs to a significant but variable extent in natural eucalypt stands. The incidence of inbreeding is limited by various mechanisms including fewer fertilised ovules (Pryor 1976, Griffin 1987, Hardner and Potts 1995). Variation in flowering time within a canopy provides the opportunity for self-pollination (House 1997) and even the availability of outcross pollen does not preclude self-fertilisation (Griffin 1987).

The incidence of self-pollination in eucalypts has been variously reported at between 8-40% of all seeds (FAO 1979). Selfing may result in:

- reduced seed set (Hodgson 1976a, Pryor 1976, Griffin 1987, Potts and Savva 1988, Sedgely and Smith 1989, Sedgely *et al.* 1989, Tibbits 1989, Hardner and Potts 1995),
- lowered germinative capacity (Eldridge 1978, Eldridge and Griffin 1983),
- increased frequency of abnormal phenotypes (Hodgson 1976b, Potts *et al.* 1987),
- reduced field growth in offspring (Hodgson 1976b; van Wyk 1977, 1981; F.A.O. 1979; Eldridge and Griffin 1983; Potts *et al.* 1987; Griffin and Cotterill 1988; Jordan *et al.* 1994),
- reduced field survival (Eldridge and Griffin 1983, Potts *et al.* 1987).

Natural hybrids between related species have often been observed in Tasmanian eucalypt forests (Figure 9; Duncan 1989). Trees of compatible species can act as a pollen source. Where the seed is to be sown back on-site, the inadvertent inclusion of hybrid material is unlikely to have much effect on future overall stand quality.

Where off-site seed is sown, there is the potential for these 'foreign' genes to spread as mature trees provide a pollen source for nearby stands (Wilkinson 1995).



Species of Eucalyptus native to Tasmania, showing species which form clines and natural hybrids. Hybrids only occur within subgenera. For each species, follow horizontal and vertical axes. For example, E. barberi *is known to hybridise with* E. brookeriana *and* E. ovata *(horizontal axis) and possibly with* E. globulus, E. gunnii *and* E. cordata *(vertical axis).*
† E. delegatensis *is represented in Tasmania by an endemic subspecies. (Williams and Potts 1996)*

Figure 9. Genetic relationships between Tasmanian eucalypts. (adapted from Duncan 1989)

Canopy position
Patterson *et al.* (2001) have found that the canopy position from where *E. globulus* seed is harvested can markedly affect the outcrossing rate of the seed collected in self-compatible trees. Outcrossing rates from the top of the canopy ranged from 74 to 94%, while the rates for the lower canopy ranged from 27 to 66%. These results indicate a marked decrease in selfing at the top of the trees and the importance of preferential collection of seed from the upper canopy.

Seed should also be collected from dense stands where possible. Hardner *et al.* (1996) have determined that there is a correlation between the density of a stand and the rate of outcrossing. The less dense stands of *E. globulus* had a higher selfing rate, which is significant as inbreeding depression in *E. globulus* can result in affected trees being 25% smaller in diameter after 4 years than those which have resulted from outcrossing (Hardner and Potts 1995).

A study by Borralho and Potts (1996) determined that the levels of outcrossing were affected by the stand density and that the progeny from isolated trees showed higher levels of abnormality.

3. Seed Extraction

3.1 Kiln drying
The vast majority of eucalypt seed collected in Tasmania is extracted by drying seed capsules in artificially heated kilns.

Christensen (1971) observed that karri capsules, which are similar in size and shape to those of *E. delegatensis*, shed no appreciable amount of seed until their moisture content was below 20-25% (fibre saturation point). The initial moisture content of the collected material may vary widely for a given species, depending on the time of the year and the amount of natural pre-drying which has already occurred. Loneragan (1979) noted that the moisture content of karri capsules varied from 150% to 50% of dry weight between winter and summer.

It is important that the material in kilns is well aerated and there is good circulation and exhausting of moist air, particularly in the early stages of drying. Felton (1976) stated that for complete extraction the final relative humidity in the kiln must be reduced to 10%.

The drying regime must be efficient in achieving complete seed release and be safe for the seed. Excessively high temperatures may kill seed and less extreme temperatures may induce secondary dormancy. Seed mortality increases with increasing temperature, duration of heating and the initial moisture content of the seed (Boden 1957, Cunningham 1960, Grose 1963, Loneragan 1979). Harrington (1972) also noted that high, but sub-lethal temperatures may reduce the germinative energy of the seed and its longevity.

Where the climate permits, artificial kiln heating may be supplemented or replaced by passive solar heating, either under cover or in the open air. Such techniques are described by Boland *et al.* (1980) and Willan (1985). Small collections can be dried within calico bags in a warm room.

3.2 Sieving
Foreign matter such as fragments of twigs and leaves cause blockages in the sowing equipment and must be removed. This is achieved by passing the seed through a sieve of appropriate mesh (see section 4.3 of Part A). It is vital that the mesh is coarse enough to avoid removing any of the largest seed particles as these tend to produce large vigorous seedlings (Grose and Zimmer 1958b, Grose 1963). Fine sieving should be used to remove dust but not excessive amounts of chaff.
Symphyomyrtus species display a fairly clear size difference between fertile seeds and chaff. The seed can be enriched by further sieving with a finer mesh which allows the smaller chaff particles to be removed.

With *Monocalyptus* species only the very largest particles are predominantly fertile, so much intermediate sized material, including a substantial proportion of all the fertile seeds, would have to be removed to substantially enrich the remainder. Other devices such as blowers or specific gravity separators (see Boland *et al.* 1980) have been used to separate fertile seeds from lighter chaff and debris.

Seed destined for storage and field sowing is not enriched as the selective removal of some of the smaller fertile seeds along with the chaff may cause an undesirable narrowing of the genetic base.

4. Storing the Seed

4.1 Longevity

Eucalypt seed is relatively long lived. Grose and Zimmer (1958a) cited the observation by Ewart (1908) of some germinations from seed up to 37 years old. However, like seeds of other species, the viability of eucalypt seed does decline over time and the rate of decline depends on the initial state of the seed and the storage conditions. (Boland *et al.* 1980, Grose and Zimmer 1958a)

Harrington (1972) noted that immature seeds of many species which are capable of germinating if sown while still moist may not withstand drying. He also found that immature seeds have an inferior longevity to mature seeds and that a loss of vigour precedes a decline in germinative capacity. He observed that "physiological maturity" is usually defined as occurring when dry weight of the seed reaches its maximum.

In an unpublished study by E.J. Lockett, even seed collected from *E. globulus* and *E. delegatensis* capsules which were barely mature enough to open showed little decline in germinative capacity over five years of sealed storage away from extreme temperatures. In fact, there were some indications of an improvement in germinative capacity over the first six months of storage which may have been due to an after-ripening process as occurs with some other tree species (Willan 1985). Gilbert (1958) cited an observation by D. Ashton that *E. regnans* seed becomes viable before the capsules are mature enough to release it.

When eucalypt capsules are capable of opening fully, the seed should store well in the short to medium term, even though it may be paler in colour than usual. Because of the uncertainty about the timing of physiological maturity in eucalypt seed, it would be wise not to attempt the prolonged storage of initially pale-coloured seed.

Willan (1985) observed that seed dormancy is sometimes associated with longevity. This is not surprising as dormancy may be accompanied by a lowering of the metabolic activity which causes seed deterioration. Nevertheless, given the problems involved in inducing, and perhaps later breaking, dormancy and the adequate storage life of non-dormant eucalypt seed under favourable conditions, the deliberate induction of dormancy cannot be recommended as a measure to increase storage life.

4.2 Deterioration in storage

It is important to protect seed from fungal and insect attack during storage. Fungal and insect activity can be minimised by keeping the seed cool and dry (Harrington 1972). Fumigation (see Boland *et al.* 1980), or the addition of an insecticide such as paradichlorobenzene to each container, also reduces insect damage.

For seed which is mature and free from fungi and insects, a loss of viability is due to the natural ageing process which is largely governed by the rate of respiration. This process can be regulated by controlling oxygen availability, moisture content and temperature.
Oxygen reduction measures such as vacuum sealing or the replacement of air with other gases may extend storage life but are probably not warranted for routine seed storage. Simpler measures are to ensure that containers are airtight and to avoid frequent opening.

4.3 The effects of moisture content

Constant low seed moisture content can greatly prolong storage life, not only through its effect on fungal and insect activity but, more importantly, by reducing respiration rates (Willan 1985). The amount of moisture may be restricted by keeping initially dry seed in sealed containers.

Although the lowering of air temperatures in cool stores raises the relative humidity and tends to allow moisture to pass from air to seed, the moisture holding capacity of air is much lower than that of seed. Hence, in sealed containers, unless the air volume is many times greater than the seed volume this will cause only a negligible rise in seed moisture content (Harrington 1972).

Harrington (1972) gave a 'rule of thumb' for seed that, over a moisture content range from 5% to 14% of fresh weight, each 1% increase halves storage life. Eucalyptus seed appears to be less sensitive than that, which is probably due to the mixture of seed and chaff being tested. The seed moisture content may remain quite low, even when the overall moisture content is high, due to the high amount of chaff which may act as a moisture sink (Lockett 1999). Willan (1985) and Boland *et al.* (1980) recommended a moisture content between 4% and 8% for adequate storage life. Measurements on a sample of seed from all Forestry Tasmania storages (see Lockett 1981) indicated that about 87% of all seed held at that time had a moisture content below 8% of moist weight (8.7% of dry weight). This indicates that the usual practice of storing kiln dried seed in containers lined with polythene bags and equipped with neat fitting lids generally maintains acceptable moisture contents in storage.

4.4 The effects of storage temperature

Storage temperature is another factor which has a major impact on seed longevity. Harrington (1972) also gave a rule of thumb for temperature which states that storage life is halved for each 5°C increase in temperature.

The effect of temperature is due in part to its influence on respiration rate. To a large extent low temperatures can compensate for higher moisture contents and *vice versa* (Willan 1985). Fluctuating temperatures or moisture contents are particularly undesirable (Stein *et al.* 1974). Sub-freezing temperatures may be used to maximise storage life provided that moisture contents are low (Willan 1985) but should not be necessary for routine storage of eucalypt seed. Seed should be protected from extreme temperature fluctuations at all times and is best held in cool storage at a constant temperature around 2°C.

4.5 Storage requirements

No adverse effects on field germination in Tasmania are known to have resulted from the use of eucalypt seed routinely stored for periods of five years or more. Harrington (1972) observed that loss of vigour and inability to germinate at the extremes of a species' environmental range are among the first signs of ageing. These effects may not be detected by a germination test carried out under optimum conditions. Grose and Zimmer (1958a) found that some old seed germinated readily on filter paper at constant temperature but failed to do so outside in soil. It is therefore important to take all reasonable measures to delay the deterioration of stored seed.

5. Germination Testing

No seed batch ever achieves anything like its full germinative potential in field sowings. Germination in field sowings can be affected by water, temperature, light, seed harvesting, pathogens, allelopathy, overstorey density and seedbed (Stoneman 1994). The aim of testing is to find whether seed has the potential, after allowing a reasonable margin for poorer field germination, to generate an acceptable initial stocking from normal sowing rates, or whether these rates are likely to result in understocking or seed wastage.

5.1 Test procedures

Formal rules for seed testing have been set down by the International Seed Testing Association (ISTA 1985). For most agricultural and tree species, germination tests are conducted on pure seed and the results are expressed as the numerical percentage of seeds germinating under specified test conditions. The particular nature of eucalypt seed, however, has necessitated special test provisions by the ISTA.

Because chaff is not completely separable from fertile eucalypt seed, it is invariably present in samples and cannot be definitely distinguished from the fertile seed. It is therefore necessary to test weighed samples of eucalypt seed and to express the results as the number of germinants per unit of seed and chaff weight. Differences in particle size, seed/chaff ratio and moisture content (through its effect on seed weight) thus provide further sources of variation in these test results.

These procedures are similar to those set down by the I.S.T.A., but the size of our samples would rarely satisfy their minimum test sample size requirement of "approximately 400 seed units". To do so would involve an approximate doubling of sample size and a substantial increase in testing costs. Nevertheless, to ensure that the estimate of each seed lot's germinative capacity is as unbiased and precise as possible, careful sampling and setting up of germination tests is required. It is important that the sample tested is fully representative of the seed to which the results will be applied. Sleeve type triers (Figure 4) are used for sample taking to ensure that the sample includes seed from all levels in each container. Sampling procedure is described in section 5 of Part A.

Germination tests are conducted under standardised conditions designed to give viable seeds every opportunity to germinate. For convenience, Forestry Tasmania has used a single temperature regime of 20°C, although the most recent recommendations by Turnbull and Doran (1987) specified temperatures of 15°C or 25°C for some Tasmanian species. Deviations from their recommended optima have been generally compensated for by using a longer test duration to allow for slower germination and/or using stratification to broaden the temperature range favouring germination (see Grose 1965).

5.2 Dormancy

Seed of some eucalypt species belonging mainly to the sub-genus *Monocalyptus* (ashes and peppermints) may be subject to a degree of primary dormancy. Dormancy is a state in which viable seed is unable to germinate even though external conditions favour germination. This is presumably a survival mechanism which ensures that, by having their germination delayed until the spring, at least some seedlings will avoid being at the susceptible recently-germinated stage during the worst rigours of winter. Dormancy is removed by stratification, which involves subjecting the seed to cool, moist conditions for a period of time.
The data of Grose (1963), based on Victorian seedlots, suggest that primary dormancy may be strengthened by handling and extraction procedures, as well as by exposure to high temperatures after sowing. High-temperature-induced dormancy may offer natural protection against germination during moist periods in summer which are likely to be followed by sufficient drying of the surface soils to be lethal to new germinants (Cunningham 1960). Battaglia (1993) studied the germination capacity responses of *E. delegatensis* from different seed zones around Tasmania and found that the proportion of dormancy varied according to the environment from which the seed was collected. The study found that 'seed from the warmest seed zone, L17, was least dormant while seed from the coldest seed zone, M50, was most dormant,

suggesting that winter mortality may be a selective influence on the proportion of seed dormancy within the seed population.'

Seed testing and storage.


Photo 2. *Freshly extracted seed.*

Photo 3. Germination testing.


Photo 4. Seed is stored in plastic bags and tins.


Photo 5. Seed tins are stacked in a cool store.

6. Sowing Mixes

The use of on-site seed for sowing is preferred for two reasons:

- it contains the genetic makeup most likely to be adapted to the site, thus minimising the risk of poor regeneration, and
- it contributes to the conservation of local gene pools.

6.1 Modifying species composition

Even without introducing new species it may sometimes be tempting to try to ‘upgrade’ mixed species stands by weighting the sowing mix in favour of the more desirable species.

The final species mix in regenerated forests is often largely a result of ecological factors rather than as a consequence of the species mix sown on the coupe (Duff *et al.* 1983, Elliott *et al.* 1991, Lutze 1998).

Typically more than 99% of sown seed fails to produce a final crop tree, and very small site-mediated variations in survival rates can completely overwhelm the effects of sowing mix composition.

Lutze (1998) shows that physiological differences between the seed sown on a mixed site will also influence the final species composition. For example, small seed can penetrate the seedbed more effectively, while larger seed has more reserves to enable faster growth.

Florence (1981) postulated that natural species composition may be due to sensitive responses to quite small changes in environmental factors. Any attempt to shift the species mix at the time of sowing to favour the preferred species is unlikely to succeed in the long run.

It follows that unless there is good evidence that the natural mix in a eucalypt stand has already been distorted by past management practices, little is likely to be gained by weighting the sowing mix in favour of the preferred species. The sowing mix should approximate the species proportions in the previous stand. Natural processes will ultimately determine the precise final composition of each patch of forest.

6.2 ‘Insurance’ trees

It is sometimes argued that the permanent retention of live ‘insurance’ trees to act as a seed source should the new crop be destroyed by a wildfire on some future occasion is desirable. It should be recognised, however, that as much of the site’s resources as is devoted to maintaining those trees is lost to the regeneration. If the trees are themselves producing valuable growth this may not be a problem. If they are not, then keeping them alive rather than killing them involves an annual cost in lost production, perhaps for the whole of the rotation, whereas the ‘insurance’ is only needed until the regeneration is old enough to survive a fire or to re-seed itself.

Furthermore, depending on how reliable a seed producer the species is, there is no guarantee that there will be an adequate seed crop present if and when it is needed. It may be cheaper and safer to carry our 'insurance' in the form of harvested seed safely in storage.

7. Time of Sowing

Stone (1980) recorded that autumn burning and sowing was favourable for *E. obliqua* seedling establishment as it gave emerging seedlings a competitive advantage over understorey regrowth. She also showed that up to 50% of the seed stayed dormant in the soil and was available for spring germination.

7.1 Seedbed preparation

Eucalypt seed germinates more readily where a seedbed has been prepared by disturbance (such as scarification or burning), than on undisturbed sites (Grose 1960, Cunningham 1960). Field germination is substantially improved if the seed has a shallow covering of loose soil (Pederick 1955, Cremer 1965b). Gibson and Bachelard (1986) attributed the increased germination to seed-surface contact, determining that it is important in maintaining internal water relations. Seed-surface contact is enhanced by sowing immediately after the seed bed has been prepared, so that the seed can penetrate slightly into minor crevices before these are filled by rain wash and the surface is hardened by the sun. The availability of different microsites has an impact on the effective germination of different species, with protected sites increasing survival time under conditions of limiting soil moisture (e.g. Battaglia and Reid 1993, Facelli *et al.* 1999).

Sowing soon after seedbed preparation also reduces the harmful effects of weed competition, especially on moist sites (Campbell and Bray 1987). Tall, fast-growing understorey species may smother late-germinating eucalypt seedlings. If sowing is delayed for too long on wet sites, much of the seedbed may be overgrown by ground-hugging plants such as mosses and liverworts which prevent the seed from establishing contact with the soil. Cremer and Mount (1965) achieved little success sowing *E. regnans* sites more than one year after a burn. This factor is of less importance on drier sites where the soil remains bare for longer and understorey species competition is less vigorous.

Effective sowing is also important to reduce the amount of seed which is foraged by ants. Ashton (1979) estimated that, in a stand of *E. regnans*, the total number of ants exceeded 5-6 million per hectare. Such populations of ants can remove 60-95% of the seed fall in a normal year (Cunningham 1960, Dexter 1965, Andersen 1987). A prepared seedbed (especially by fire) is thought to temporarily interfere with their foraging activity. Several studies have shown that the natural seed fall following fire, or artificial sowing, saturates ant feeding requirements and allows higher germination rates (O'Dowd and Gill 1984; Andersen 1987, 1988; Neumann 1991, 1992). Bashford (1993) showed that, where seed trees are retained, seed harvesting ants congregate around their bases, with 86% of ants collected within 15 m of a retained tree. Stoneman and Dell (1994) found that seed removal by invertebrates and other seed-harvesters was insignificant when the seed was covered by 5 mm of soil. This further highlights the importance of good seedbed preparation, which allows the seed to penetrate the soil surface.

The level of mortality is also affected by the method of seedbed preparation. Stoneman *et al.* (1994) found that *E. marginata* has significantly higher survival rates on a disturbed seedbed than on undisturbed sites. Mortality has been found to be lower on ashbeds than on other seedbeds due to factors including the reduction of seed-harvesters, an increase in available nutrients and better penetration into the seedbed by the seed (Grose 1957b, O'Dowd and Gill 1984). While sowing soon after seedbed preparation is recommended, a study by Lacey and Line (1994) found that slash burning elevates the soil pH to a potentially toxic level in up to 10% of the area burnt. Germination and subsequent survival of *E. regnans* was reduced on these sites. The coupe had elevated pH levels for only a few months.

Floyd (1962) found that, for *E. pilularis*, burnt seedbeds favoured germination, although these seedbeds may be subject to leaching and may dry out faster than mechanically prepared seedbeds. These factors can contribute to the deaths of growing seedlings.

Where a coupe has been harvested to a seed tree retention prescription, the seedbed should be prepared as soon as feasible after harvesting. However, Dooley *et al.* (2006) have found that, where seedbed preparation is ‘carried over’ for up to 12 months, most seed trees will remain standing and retain crown size during that period. It is advisable to monitor seed crops where seedbed preparation has been delayed to ensure that adequate seed is available over the coupe.

7.2 Effects on seedling survival

Dry seed is very tolerant of low temperatures but as seed is imbibing and germinating it becomes susceptible to cold conditions. Cotyledonary stage seedlings are particularly at risk due to their sensitive tissues and close position to the soil surface, where temperatures are often lowest. Battaglia and Reid (1993) found that the mean lethal temperature for *E. delegatensis* varied from -1 to -3.5°C over the first six months of seedling growth. Larger seedlings are also more tolerant of photoinhibition (Close *et al.* 2000). Once the roots are below the soil surface, damage is less likely, but death due to frosting of above ground parts is still possible (Cremer 1985).

Frost heave which exposes the roots of small seedlings may increase their susceptibility to subsequent drought or direct freezing damage to the roots. All these problems become less severe as the seedlings increase in size. Therefore, if seed is sown in autumn on frost prone sites, it is advantageous to sow early to ensure that seedlings are well advanced prior to any severe frost which may occur later in the season. Dormancy-susceptible species should be sown to experience at least one month of cool conditions on the ground prior to the spring warming, otherwise only partial spring germination may result. The remaining ungerminated seed will then be subject to insect predation and may become more deeply dormant over summer, rendering it unable to germinate until late in the following autumn or winter, after the next extended period of cool weather. By that time, little seed may remain alive (Grose 1957a).

7.3 Delayed germination

Although anecdotal reports of germinants appearing as late as during the third year after sowing sometimes arise, no firm evidence is available for germination later than the spring of the next year after an autumn sowing. This is consistent with the statement by Cremer *et al.* (1978) that very little germination occurs after 12-18 months and with observations by Fagg (1981). It is possible that some seed may remain viable on dry sites for slightly longer, but reports of more delayed germination are probably largely attributable to the detection of earlier germinants which had previously been overlooked because of their small size and/or the germination of natural seed which was shed after the sowing.

If slight understocking is detected one year after sowing on dry sites where weed growth is slow, it is acceptable to delay supplementary treatment for another year in expectation of further germination. On moist sites no reliance should be placed on further germination beyond the autumn of the year after sowing.

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Appendix 1. Eucalypt seed spotting form.

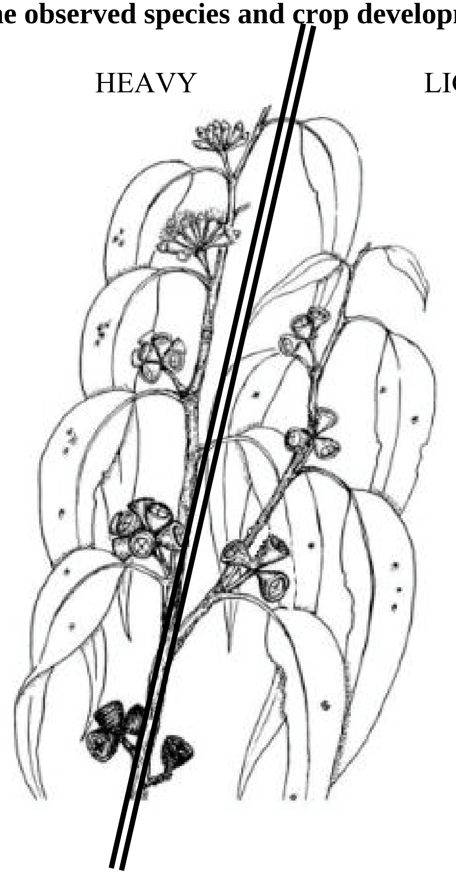
Eucalypt Seed Spotting Form

Coupe: __ __ __ __ __ __ Date: __ __ / __ __ / __ __

Location: ____

Circle the observed species and crop development.

Species HEAVY LIGHT



AMY

DAL

DEL

GLO

JOH

NID

OBL

OVA

REG

VIM

Action Plan: ________________________ Observer: ______

____

____

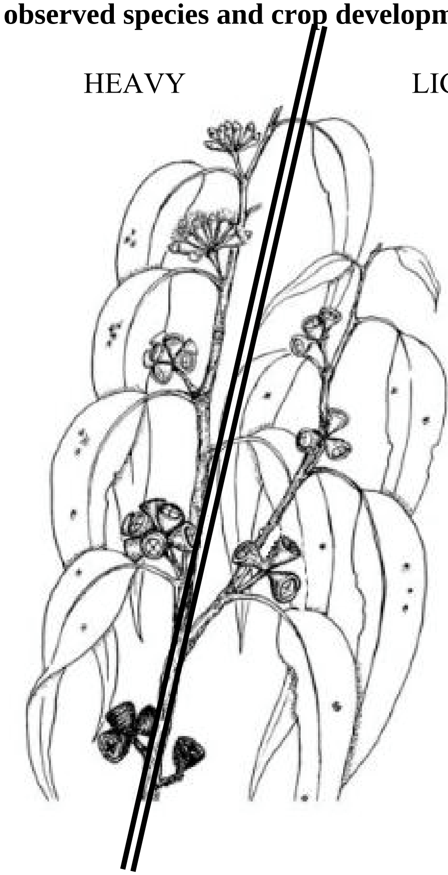
Eucalypt Seed Spotting Form

Coupe: __ __ __ __ __ __ Date: __ __ / __ __ / __ __

Location: ____

Circle the observed species and crop development.

Species HEAVY LIGHT



AMY

DAL

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REG

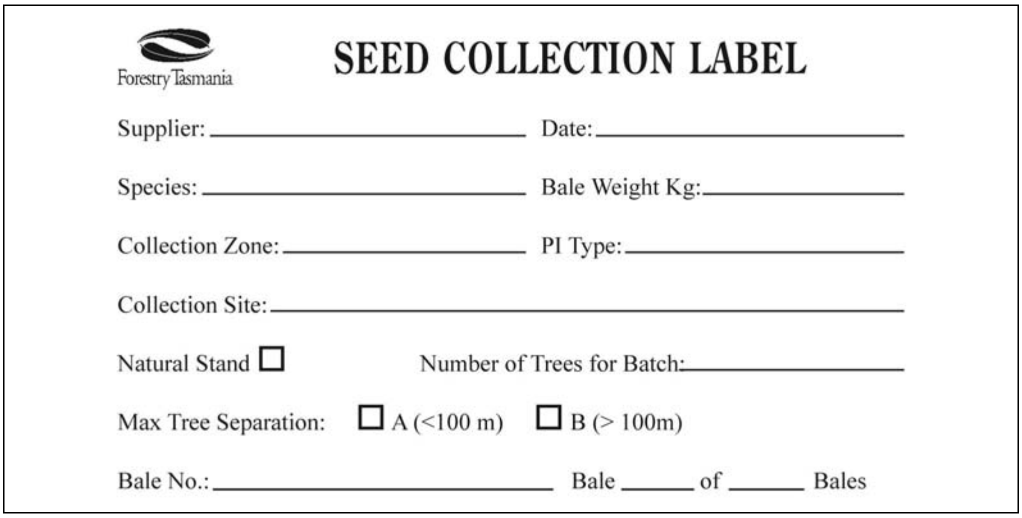
VIM

Action Plan: ________________________ Observer: _____

____

____

Appendix 2. Seed collection label.


Forestry Tasmania

SEED COLLECTION LABEL

Supplier: ______________ Date: ______________

Species: ______________ Bale Weight Kg: ______________

Collection Zone: ______________ PI Type: ______________

Collection Site: ______________

Natural Stand ☐ Number of Trees for Batch: ______________

Max Tree Separation: ☐ A (<100 m) ☐ B (> 100m)

Bale No.: ______________ Bale ______ of ______ Bales

Photo 6. A seed collection label

Photo 7. A seed label should be inside the bale, and another attached to the closed bale.

Appendix 3. Eucalypt seed zones for Tasmania.

Eucalypt Seed Zones for Tasmania

These notes are to be read in conjunction with the map 'Eucalypt Seed Collection Zones'.

Introduction

Wherever possible, harvested coupes should be sown with seed collected from that coupe. Natural fluctuations in seed production in eucalypts mean that this is not always possible; on-site seed is not always available. In such cases, the zoning system as described below is used to identify the most suitable alternative seed source.

Basis of the seed zones

The seed zones are based on an assessment of the prevailing environment: altitude, dryness and coldness are the principal attributes used to distinguish between zones. Zones have been drawn up for all parts of Tasmania except for the Tasmanian Wilderness World Heritage Area.

Altitude

Altitude is used for the primary subdivision of Tasmania into three classes as follows.

High	(H)	above 700 (occasionally 800) m.
Middle	(M)	300 m to 700 (800) m.
Low	(L)	less than 300 m.

The actual importance of altitude lies mainly in its effect on local climate. Therefore some flexibility has been used in positioning the boundary between the 'Middle' and 'High' classes to compensate for other factors such as topography and latitude which tend to modify this climatic effect. Hence the boundary follows the 800 m contour on the escarpment of the Western Tiers, varies between 700 m and 800 m according to topography in the N.E. Highlands and the upper Mersey/Forth area and follows the 700 m contour elsewhere.

For simplicity, some smoothing of boundaries based on contour lines has been done and some small isolated areas of higher or lower elevation have been incorporated in a surrounding zone with an appropriate dryness/coldness rating.

Dryness

Five dryness classes have been recognised as follows.

Dry	Deaths of young seedlings of non drought-tolerant eucalypt species likely in most summers (less than 650 mm annual rainfall).
Intermediate	Drought stress will commonly slow growth, with deaths of non drought-tolerant eucalypt seedlings occurring in drier than average summers (650 – 900 mm).
Moist	Trees occasionally subject to drought stress which may slow growth in some summers but will rarely cause seedling death (900 – 1200 mm).
Wet	Mild drought stress occurring in dry summers only, and mainly affecting small seedlings (1200 – 1600 mm).
Very Wet	Trees rarely, if ever, subjected to drought stress (more than 1600 mm).

The rainfall figures quoted are indicative only. Some allowance has been made in the zoning for factors such as the seasonal distribution of rainfall and the likely summer evapotranspiration levels, which affect moisture availability during the critical period. In some cases (e.g. zone H57, S.E. Central Highlands) the rainfall gradient is such that a particular zone extends across more than one dryness class. Where this occurs the rating that fits the majority of the area has been adopted.

The difference between classes at the dry end of the range, although smaller in terms of rainfall, is more critical than at the wet end. Hence there would be little objection to the use of seed from a ‘very wet’ zone on a ‘wet’ site but the use of seed from an ‘intermediate’ zone on a ‘dry’ site should be avoided. In general, seed movement from a drier to a wetter zone is more acceptable than movement in the other direction.

Coldness

This classification relates to the frequency and severity of frosts. Lack of hard data for forest sites make it a subjective classification based on experience and local knowledge. There are four classes as follows.

Very cold Prolonged severe frosty periods in winter with moderately severe frosts possible at any time of the year.

Cold Frosts frequent and moderately severe in winter and occasionally occurring out of season.

Cool Moderate frosts normally confined to winter months.

Mild Light winter frosts only.

In matching the zones to coldness ratings some allowance has been made for topography which may aggravate cold air pooling or exposure to chilling winds.

In general, seed movement from a colder to a milder zone is more acceptable than in the other direction.

Selection of alternative seed sources

Where on-site or in-zone seed is not available, alternative sources of seed will be required. Table 8 outlines in preferential order appropriate seed zones that can be used in these cases. Each identified source is also rated for goodness of match, as either ‘good’ or ‘fair’, with ‘tolerable’ matches also noted.

The order of precedence used for selecting alternative seed zones is (1) altitude, (2) dryness, (3) coldness, (4) geographical proximity. For example, the low altitude, dry, cold zone L16 (Derwent Valley.) would be better sown with seed from the distant, low altitude, dry very cold zone L5 (Northern Midlands) than the nearby, high altitude, wet, very cold zone H61 (Mt. Field etc.).

Table 8. Seed Zone Classification

good match | fair match

zone	*locality*	*dryness*	*coldness*	*best alternatives*				
	LOW ELEVATION - < 300 m			*1st*	*2nd*	*3rd*	*4th*	*5th*
L1	Flinders & Cape Barren	intermediate	mild	L7	L9	L2	L11	L12
L2	Tamar Valley	intermediate	cool	L4	L11	L12	L6	L5
L3	Deloraine, Mole Creek	moist	cold	L4	L6	L5	M30	M32
L4	Hagley, Bracknell, Poatina	intermediate	cold	L6	L5	L15	M33	M38
L5	Northern Midlands	dry	very cold	M40	M41	L6		
L6	Fingal, South Esk & St Pauls Valleys	intermediate	very cold	L5	M40	M41	L4	L15
L7	North-East Coastal Plain	intermediate	mild	L1	L9	L2	L11	L12
L8	Lebrina, Scottsdale, Winnaleah	moist	cool	L10	L26	L2	L3	L11
L9	Anson’s Bay	intermediate	mild	L7	L1	L11	L12	L2
L10	Lower George, Scamander, Avenue catchments	moist	cool	L8	L11	L12	L13	L18
L11	Bicheno, Coles Bay	intermediate	cool	L12	L6	L2	L15	L4
L12	Cranbrook, Swansea, Triabunna	intermediate	cool	L11	L6	L15	L2	L16
L13	Nugent, Forestier & Tasman Peninsula	moist	cool	L18	L12	L11	L10	L8

L14	South Arm, Cambridge, Carlton, Saltwater River	dry	mild	L16	M40	M41	L17	
L15	Buckland	intermediate	cold	L16	L6	M38	M33	L5
L16	Derwent Valley, Elderslie, Campania	dry	cold	M40	M41	L5		
L17	Hobart, Channel, N. Bruny, Lower Huon	intermediate	mild	L14	L15	L16	L12	L11
L18	Geeveston, Southport, S. Bruny	moist	cool	L13	M46	L12	L15	M39
L19	Upper Huon & Tributaries	wet	cold	M47	M43	L18	M44	L13
L20	South-West coastal Lowlands	very wet	cold	L21	L22	M48	M49	M51
L21	Central West Coast Lowlands	very wet	cold	L20	L22	M49	M51	M48
L22	Pieman drainage basin	very wet	cold	L21	L20	M51	M49	M50
L23	Temma, Sandy Cape	wet	cool	L25	L26	L24	M52	M32
L24	Arthur & Horton River drainage	very wet	cool	L23	L25	L22	L21	L26
L25	Far North West	wet	cool	L23	L26	M52	L24	L22
L26	North-West Coastal Lowlands	moist	cool	L3	L8	L2	L4	M30
L27	King Island	moist	mild	L26	L25	L23		
	MIDDLE ELEVATION - 300 – 700 m							
M30	Dazzler Range, Reedy Marsh	moist	cold	M34	M33	M36	M37	M38
M31	Upper Mersey & Forth Valleys, Smiths Plain	very wet	cold	M32	M49	M50	M51	M35
M32	Northern escarpment of Central Highlands	wet	cold	M33	M35	M34	M36	M37
M33	Eastern escarpment of Central Highlands	intermediate	cold	H57	M40	M41	M38	M39
M34	Westerly slopes of North-Eastern Highlands	moist	cold	M36	M37	M38	M35	M33
M35	Northerly slopes of North-Eastern Highlands	wet	cold	M34	M36	M37	M32	M30
M36	South-Easterly slopes of North-Eastern Highlands	moist	cold	M37	M34	M38	M33	M30
M37	Mt. Nicholas, Fingal Tier, Mt. St John	moist	cold	M36	M38	M34	M33	M39
M38	Snow Hill, Mt. Connection, Tooms	intermediate	cold	M33	M37	M40	M41	M39
M39	Woodsdale, Bluestone Tier, Brown Mt.	intermediate	cool	M40	M38	M41	M33	M37
M40	Oatlands, Rhyndaston, Lemont	dry	very cold	M41	L5	H57	L6	
M41	Bothwell, Dromedary	dry	very cold	M40	L5	H57	L6	
M42	Tarraleah, Black Bobs	moist	very cold	H57	M41	M40	H59	M44
M43	Florentine, Styx & Tyenna Valleys	wet	cold	M44	M45	H61	M47	M42
M44	Ellendale, Moogara, Collinsvale	moist	cold	M45	M42	H59	M46	M43
M45	South & East slopes Wellington, Snowy, Jubilee Ranges	moist	cold	M44	H59	M43	M46	M42
M46	Grey Mt., Snug Tiers	moist	cold	M45	H59	M44	M42	M41
M47	Mountain slopes south of Weld Valley	wet	cold	M43	M45	M48	M44	M46
M48	Lake Gordon catchment	very wet	cold	M43	M47	M49	H61	H62
M49	Western mountain slopes	very wet	cold	M50	M51	M48	M31	M43
M50	Parrawee, Guildford, Waratah	very wet	very cold	H64	H63	M51	M49	H55
M51	Mt. Bertha, Norfolk Range, Luina	very wet	cold	M50	M49	H64	H63	M31
M52	North-Western hill country	wet	cool	M53	M32	M31	M30	M35
M53	Slopes of Mt. Roland, Gog Range, Standard Hill	wet	cool	M52	M32	M30	M31	M35
	HIGH ELEVATION - >700 m							
H55	Maggs Mt., Borradaile Plains, Mt. Roland	very wet	very cold	H56	H64	H63	H62	H58
H56	North Central Highlands	very wet	very cold	H55	H64	H63	H62	H61
H57	South-East Central Highlands	intermediate	very cold	M42	M41	M40	H62	H59
H58	NE Highlands (Mts. Arthur, Barrow & Blue Tier)	wet	very cold	H56	H55	H61	H62	H64
H59	Wellington Range	moist	very cold	H61	H57	H62	H60	
H60	Mountains south of Weld Valley	wet	very cold	H61	H59	H62	H63	H64
H61	Wylds Craig, Mt. Field, Snowy, Jubilee, Maydena Ranges	wet	very cold	H62	H60	H59	H63	H64
H62	Clarence, Navarre	wet	very cold	H61	H56	H63	H55	H64
H63	Eldon and West Coast Ranges	very wet	very cold	H64	H55	H56	H62	H61
H64	Black Bluff, Middlesex, Granite Tor	very wet	very cold	H55	H63	H56	H62	H61

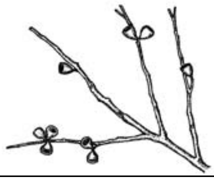
Appendix 4. Seed crop assessment.

1. Crown size and capsule density ratings

crown size rating

			
A - large	**B- medium**	**C - small**	**D- very small**

capsule density rating

				
1 - very dense	**2 - dense**	**3 - moderate**	**4 - sparse**	**5 - virtually none**

2. Seed crop points scores

At each point, do a 360° sweep recording the tree species, crown size and capsule density rating, and the angle of elevation to the top of the crown.
Calculate the point score for each species at each point from the table below.

Angle to top of crown		***crown size rating***			
'High' crowns (> 45°)		**A or B**	**C**		**D**
'Low' crowns (>30° <45°)				**A or B**	**C**
	1	**60**	**30**	**20**	**10**
capsule	**2**	**40**	**20**	**13**	**7**
density	**3**	**20**	**10**	**7**	**3**
rating	**4**	**8**	**4**	**3**	**1**
	5	**4**	**2**	**1**	**1**

3. Seed crop assessment

Point scores greater than 20 provide sufficient seed to satisfactorily sow that section of the coupe.

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