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Seedling regeneration, growth and density of *Eucalyptus obliqua* following partial harvesting in the Warra silvicultural systems trial. 5. The second "clearfell, burn and sow with understorey islands" coupe, Warra 8H, age 3 years and a brief comparison with the first understorey island coupe Warra 8B.

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SUMMARY

At age 3 years Warra 8H is fully stocked with seedling regeneration. Seedlings growing on oxidised soil are growing faster than seedlings on burnt to mineral soil seedbed, which in turn are growing faster than seedlings on unburnt and disturbed, burnt to litter and undisturbed and burnt to litter and disturbed seedbeds. Seedlings on unburnt and compacted seedbed are growing very slowly.

The regeneration burn in Warra 8B, based on the post-burn assessment of the seedbed, was higher in intensity than the burn in Warra 8H. This is likely to be one of the factors contributing to more rapid early growth of the seedlings in WR8B compared to those in WR8H.

1. Introduction

Tall *Eucalyptus obliqua* forests are the most widespread and abundant commercial native forests in Tasmania, occupying some 425 700 ha (Public Land Use Commission 1996). The Warra long-term ecological research (LTER) site was established in 1995 in order, amongst other things, to focus research on this forest type (Brown 1998). Neyland *et al.* (2000) demonstrated that the tall *E. obliqua* forests at Warra are representative of many of the *E. obliqua* tall forests in Tasmania, particularly of those in southern and south-eastern Tasmania but also, with some qualification, of forests elsewhere in the State.

The Warra silvicultural systems trial (SST) was established in 1998 to explore alternatives to the 'clearfell, burn and aerially sow' method of wet eucalypt forest silviculture (Hickey *et al.* 2001). The second understorey island coupe to be opened in the SST was Warra 8H (WR8H), a 26 ha coupe which was harvested to a prescription of clearfell burn and sow with understorey islands. The prescription called for a routine clearfelling operation, except that four understorey islands, each 40 metres by 20 metres, were retained undisturbed within the coupe. Within each island two plots of 10 m by 10 m each were surveyed for all higher plants and dominant bryophytes prior to the commencement of harvesting. Four 'phantom' islands were also demarcated within the coupe. These islands were surveyed as for the retained islands but were harvested during felling of the coupe.

This report examines the post-burn seedbed, seedfall and seedling establishment and growth for the first three years following the harvesting and regeneration treatment.

The null hypotheses being tested here are:

- that the local intensity of the burn and /or disturbance of the soil arising from the harvesting has no influence on the establishment and growth of the eucalypt regeneration.
- that the understorey islands do not contribute to the regeneration of understorey species following harvesting and burning of the coupe.

2. Methods

2.1. Study site

The Warra SST is located within the Warra LTER site (latitude: 43° 04' S; longitude: 146° 40' E) which is situated at the junction of the Weld and Huon Rivers in the southern forests of Tasmania. The SST occupies south-east facing slopes above the Huon River and ranges in altitude from 50 to 350 m asl. Slopes are gentle to moderate (<20°) and rainfall is about 1450 mm per annum. Soils are variable throughout the SST, but are largely derived from Jurassic dolerite (Laffan 2001).

The pre-harvest vegetation in WR8H was mixed oldgrowth-regrowth *E. obliqua* tall wet forest, a number of regrowth-generating fires having burnt through the study area in the last 150+ years (Hickey *et al.* 1999) (Alcorn *et al.* 2001). The understorey vegetation varied within the coupe. On the upper slopes, the understorey was dominated by species typical of thamnic rainforest, notably horizontal scrub (*Anodopetalum biglandulosum*) but also including celery-top pine (*Phyllocladus aspleniifolius*), myrtle (*Nothofagus cunninghamii*), leatherwood (*Eucryphia lucida*) and sassafras (*Atherosperma moschatum*) together with smaller shrubs and ferns. On the lower portion of the coupe, the understorey was dense, comprising closed stands of tallow-wood, (*Nematolepis squameum*), prickly wattle (*Acacia verticillata*), tea tree (*Leptospermum* spp.) and paperbark (*Melaleuca squarrosa*) over cutting grass (*Gahnia grandis*) and bauera (*Bauera rubioides*) (Neyland 2001).

2.2. Understorey island establishment

Four understorey islands were marked out with flagging tape in the coupe. Each island was 40 m long by 20 m wide, with the long axis of the island orientated parallel to the western edge of the coupe. The islands were located so as to sample, in two islands each, the two dominant vegetation types in the coupe (ie two were in the thamnic rainforest understorey type and two were in the tea-tree cutting grass understorey type). In the central part of each island two adjacent 10 m by 10 m floristic plots were established and the cover abundance of all higher plants and common bryophytes was recorded. Four ‘phantom’ understorey islands were also established, in which all the same information was collected, but which were not marked out with flagging tape and which were harvested along with the rest of the coupe.

The floristic data from the islands and from all the coupes within the trial will be reported separately. The impact of the harvesting and burning of this coupe on the islands is reported here.

2.3. Harvesting and burning

The harvesting prescription for WR8H called for the coupe to be clearfelled, burnt in a high intensity burn and sown, except that four understorey islands each of 40 m by 20 m were to be retained undisturbed through the course of the harvesting. The contractor was permitted to fell eucalypts out of the understorey islands if they could be felled clear of the islands without causing undue disturbance to the understorey.

Harvesting was completed on the 15th of March 2001. The coupe was prepared for burning in late March 2001, with the standard mineral earth firebreak cleared around the perimeter of the coupe. On the 7th April 2001 the coupe was lit by aerial drip torch and a high intensity burn was successfully achieved (Table 1). There were no escape burns into the surrounding forest. All of the four understorey islands were burnt.

Table 1. Weather conditions prior to burning (and attempted burning).

Date	Light-up time	Sticks (forest/coupe)	Temperature (°C)	Wind speed and direction (kph)	Relative humidity (%)
7 April 2001	16.51	39/11	20	NW <5	74

Following harvesting, but before burning, a bare mineral earth firebreak approximately 6 m wide was mechanically cleared around the perimeter of the coupe. The heaped fuels arising from the firebreak created a windrow which also extended around the perimeter. All subsequent references herein to 'the coupe' include the interior of the coupe, the windrow and the firebreak.

2.4. Aerial sowing

Seven days after the high intensity burn, WR8H was aerially sown with 24.5 kg of *E. obliqua* seed. All the seed was 'in zone' and 38% was 'on site'. 'In-zone' seed is matched regionally for altitude and climate as described in Forestry Commission (1991); 'on-site' seed was collected from the coupe.

Harvesting, production and safety issues are discussed in Hickey and Edwards (in prep) and are not considered further here.

2.5. Seedbed assessment

The seedbed assessment of WR8H was conducted on the 10th and 14th of May, following the regeneration burn which took place on the 7th of April. A randomly located grid, 100 m by 10 m was placed over the coupe. The seedbed was assessed at each intersection point of the grid. Each point was permanently marked with a tagged wire peg to assist relocation. A fixed size plot was not used for the seedbed assessment; the nature of the seedbed was assessed at the point at which the pin was located. In some cases this meant that the piece assessed was quite small, eg 10 cm by 10 cm, and in some cases the assessed patch was larger than 1 m by 1 m.

The intensity of the burn and impact of the harvesting disturbance on the soil at each point was classified as shown in Table 2.

Table 2. Seedbed: burn and disturbance classes.

B0	Unburnt (or burnt so lightly as to not affect the seedbed)	D0	Undisturbed
BL	Burnt but litter still present (minor soil heating but soil often not exposed)	D1	Revealed (litter removed from mineral soil or disturbed and aerated)
BM	Burnt to mineral soil (charcoal present over exposed and heated mineral soil)	D2	Compacted (litter removed and soil compacted, generally from machinery movement)
B2	Oxidised (intense soil heating, soil oxidation)		

The burning and disturbance impacts on the soil are not independent but have a combined effect in terms of the receptivity of the seedbed. Where the soil was burnt to mineral or oxidised soil, it was not considered possible to allocate the point to a disturbance class, partial or complete oxidation having altered the soil beyond the point at which disturbance could be reliably recognised.

The combinations of unburnt and undisturbed, unburnt and compacted, and burnt-to-litter and compacted seedbed were only very rarely observed and there were not sufficient seedlings in these classes to allow their use in the subsequent analyses.

The assessment determined the proportion of the coupe which had burnt and the intensity of the burn (where burnt), the extent of soil disturbance arising from the harvesting, the area of live vegetation remaining after the burn and the area of accumulated slash remaining unburnt.

2.6. Seedbed – understorey islands

The condition of each understorey island was assessed at the completion of harvesting and again following the regeneration burn. At the completion of harvesting, only a quick visual inspection was conducted for each island, and notes made about the general condition of the island. A more formal assessment of each island was conducted following the burn; for each plot, a cover class (Braun-Blanquet scale (Mueller-Dombois and Ellenberg 1974)), was assigned for each seedbed burn and disturbance class (Table 2).

2.7. Regeneration

Seedling regeneration was assessed in March each year for three years after the regeneration burn, following the methods of Forestry Tasmania (1996). A randomly located grid was placed over the coupe with lines 100 m apart. Plots were located every 20 m along the lines. At each sample point a circular 16 m^2 plot centred on the sample point was searched for eucalypt seedlings. The height of the tallest seedling on the 16 m^2 plot was recorded, if present, as was the mean height of the competing understorey vegetation. The number of eucalypt seedlings on both the 4 m^2 and the 16 m^2 plot was counted so that seedling density (stems per hectare) could be estimated. The nature of the seedbed (Table 2) in which the tallest seedling on the 16 m^2 plot (the 4 m^2 plot is a sub-set of the 16 m^2 plot) was growing, was recorded for the surveys in both the first and second years but it was difficult to separate BL (burnt to litter) from BM (burnt to mineral soil) seedbed by year two and by year three the condition of the seedbed was very difficult to judge accurately and this part of the assessment was discontinued. Mapping rules as described in Forestry

Tasmania (1996) were used to map the regeneration across the coupe. Portions of the coupe are mapped as stocked except where at least three unstocked plots occur in a row.

2.8. Browsing

A browsing transect of 50 seedlings was established in December 2001 to monitor browsing of eucalypt seedlings by native mammals, following prescribed operational procedures for monitoring mammal browsing of regeneration (Forestry Tasmania 1999). The transect followed an irregular line from the landing to the northern edge of the coupe. Where possible, seedlings were selected at approximately two metre intervals. In some places, due to lack of seedlings, distances between seedlings were much larger. The browsing transect was monitored monthly. The height of each seedling was measured and any browsing damage to the seedling noted.

2.9. Seedling establishment and growth – the single-tree plots

A set of single-tree plots was established to assess the influence on seedling establishment and growth of the seedbed, competing vegetation and the adjacent unharvested forest around the coupe. The plots were established in the second winter following burning (July 2002) when the seedlings were about one year old, from the same grid as used for the seedbed assessment. The plots have been remeasured at age three years (June 2004).

The nearest dominant seedling to each seedbed assessment point was identified, tagged with a numbered aluminium tag, and measured. Dominant seedlings were defined as seedlings that were healthy and at least as tall and preferably taller than the surrounding vegetation. As the plots were 10 m apart, the 'nearest' seedling was limited to a distance of 5 m. If no dominant seedling could be located within 5 m, nothing was recorded for that plot. The bearing and distance of the seedling from the plot point was recorded.

The height of each tree was measured to the nearest centimetre, the diameter of the root collar immediately above any basal swelling was measured to the nearest millimetre, the diameter of the stem either at one third of the height of the tree or 1.3 m, whichever was the least, was measured to the nearest millimetre (stem diameter), the spread of the crown in both the north-south and east-west direction was measured to the nearest centimetre. Measurements pertaining to the tree are hereafter referred to as stem variables. The nature of the seedbed in which the seedling was growing was recorded as in Table 2.

The cover-abundance of the surrounding vegetation on a plot of 16 m^2 centred on the seedling was recorded using the Braun-Blanquet scale (1 = <1% cover, 2 = 2 to 5% , 3 = 6 to 25%, 4 = 26 to 50%, 5 = 51 to 75%, 6 = 76 to 100%) (Mueller-Dombois and Ellenberg 1974) for each vegetation guild. The mean height of each guild was measured to the nearest centimetre. The guilds used were trees, shrubs, ferns, sedges and herbs. Grasses were originally included in the assessment but the cover and abundance of grasses within the trial is so uniformly low that they were considered of little consequence. Only eucalypts were defined as trees. The shrub layer includes tall shrubs such as dogwood, (*Pomaderris apetala*), tea tree (*Leptospermum* spp), lancewood (*Nematolepis squamea*), paperbark (*Melaleuca squarrosa*) but also includes low shrubs such as *Bauera rubioides*. In most instances plots were dominated by either tall or low shrubs. The species dominating the plot was noted. Measurements pertaining to the vegetation are hereafter referred to as vegetation variables.

The basal area of the retained trees, and the trees in the adjacent unharvested forest around each seedling, was assessed at age 1 using a prismatic wedge with a basal area factor of 2. At the age 3 measurement time each seedling was assessed as to its current crown class: dominant – taller than the surrounding vegetation including other trees, co-dominant – equal in height to the surrounding vegetation, sub-dominant – shorter than the surrounding vegetation but healthy, and suppressed – shorter than the surrounding vegetation.

Preliminary analysis of the distribution of the single tree plot data across seedbed classes revealed that the data was unbalanced, with some seedbed classes over-represented and some under-represented. To balance the data, a transect was set out to deliberately sample additional plots in the windrow on B2 (oxidised soil) seedbed and along the fireline on B0/D2 (unburnt/compacted) seedbed. In this case, a seedling was selected where the nearest dominant seedling within 5 m was on B2 or B0/D2 seedbed, or rejected if it was on any other seedbed class, every 50 m along the transect. The transect was started from the same randomly located point as used to establish the original grid. The additional transect was located a month after the original transect was established. Seedling growth in winter is very slow and any growth between the two measurements was considered minimal.

One hundred and ninety-one single-tree plots were established. No seedling could be located on three plots. Further post-establishment losses (five seedlings) due to drought death resulted in the age three year data set comprising one hundred and eighty-three seedlings.

2.11. Analysis

All analyses of the single tree plot data were conducted using Statgraphics Plus 2.1 (Statistical Graphics Corporation 1994-1996). A Pearsons product moment correlation matrix was prepared to examine the relationships between the stem variables, seedbed, the vegetation variables and the retained basal area. The correlation matrix showed that all the stem variables were significantly correlated with each other. For the purposes of this report all the seedbed analyses were conducted using height as the dependent variable ('height'). Tree volume, for example, could also be used as the dependent variable but in this instance height was considered sufficiently informative.

Analysis of variance and/or the Kruskal-Wallis test were used to compare the mean and median heights of the seedlings respectively, by seedbed class. To test for significant differences amongst the means of height for each level of seedbed, the multiple range test procedure, using Fishers least significant differences method to discriminate amongst the means, was used. The confidence level for the test was set at 95%.

3. Results

3.1. Seedbed assessment - coupe

Table 3. Results of the seedbed assessment. Figures in parentheses are percentages.

	D0	D1	D2	Total
B0	2 (1)	22 (9)	9 (4)	33 (13)
BL	60 (24)	59 (23)	n/a	119 (47)
BM	76 (30)			76 (30)
B2	27 (11)			27 (11)

n=255

B0 Unburnt
BL Burnt but litter still present
BM Burnt to mineral soil (charcoal present)
B2 Oxidised, intense soil heating

D0 Undisturbed soil, organic layer intact
D1 Revealed/lightly disturbed mineral soil
D2 Compacted bare soil, organic layer removed

3.2. Understorey islands

3.2.1. Post harvesting

Only the real islands were inspected at the completion of harvesting, however from the post burn assessment it is clear that all the phantom understorey islands had been clearfelled during the harvesting.

UI 13. Heads of felled trees had fallen into the north-west corner, the western side and the eastern side of the island, all were subsequently removed. A patch of horizontal on the western side had been flattened. Some regrowth eucalypt stems had been harvested, three from the south-east corner of the island and one from the east side of the top floristic plot. Rainforest species in the island were in very similar condition to UI 16.

UI 16. Very similar to UI 13. The north-west corner of the island had been hit by a eucalypt head which was subsequently removed. There were no standing eucalypts left in the island. There was almost universal windthrow of the rainforest species from west to east, most having raised large root plates. Prior to the burn and prior to clearing fuels from around the island the heads of these trees were trimmed off. Only scattered leatherwood and sassafras in poor condition were still standing at the time of the burn.

UI 106. Almost completely intact. The core floristic plots in this island were little altered by the harvesting, although noticeably open to the wind. An oldgrowth tree on the western edge of the island was harvested as was a regrowth tree on the north-east corner. Prior to the burn there had been no windthrow in this island.

UI 40S. While the core floristic plots were not impacted by the harvesting the outside portion of the island was significantly disturbed. An oldgrowth tree in the north-west corner of the island was harvested, as was a smallish regrowth stem in the north-east corner of the top floristic plot. Some tea-tree and Banksia stems had been knocked or blown down along the top edge of the island, and a snig track crossed the bottom edge. A large patch of Bauera in the north-west corner was noticeably dried out prior to the burn. The forecast before the burn was that this island would burn easily.

3.2.2. Post burning

All the islands burnt during the regeneration burn. The intensity of the burning varied considerably, as described below and summarised in Tables 4, 5 and 6.

Both top (UI 13 and UI 16) islands burnt moderately hotly on the ground (see tables – there was some ash-bed in both islands and small areas in UI 16 only of unburnt ground) and there were no green leaves left in the islands immediately after the burn. Many of the stems are still rooted in the ground and some have remained standing. It is likely that as in 8B there will be green shoots in time to come. There has been some further windthrow since the islands were first checked prior to the burn.

The bottom two islands (UI 106 and UI 40S) were both well-burnt as forecast and as above there has been additional windthrow since the original check, some of which has occurred after the burn. This is the source of the small amounts of D1 (revealed soil) in the tables.

Table 4. Vegetation groups and impacts of the harvesting and burning on the understorey islands.

Understorey island	Vegetation type	Impact of harvest and burn
Real islands		
UI 13a	T	100% scorched
UI 13b	T	100% scorched
UI 16a	T	100% scorched
UI 16b	T	100% scorched
UI 106a	G	100% scorched
UI 106b	G	100% scorched
UI 40Sa	G	100% scorched
UI 40Sb	G	100% scorched
Phantom islands		
UI 9a	T	Clearfelled and burnt
UI 9b	T	Clearfelled and burnt
UI 12a	T	Clearfelled and burnt
UI 12a	T	Clearfelled and burnt
UI 234b	G	Clearfelled and burnt
UI 234a	G	Clearfelled and burnt
UI 264a	G	Clearfelled and burnt
UI 264b	G	Clearfelled and burnt
UI 418a	G	Clearfelled and burnt
UI 418b	G	Clearfelled and burnt
UI 518a	G	Clearfelled and burnt
UI 518b	G	Clearfelled and burnt

Table 5. Seedbed assessment of the understorey islands (Braun-Blanquet scale)

	Burn code				Disturbance code		
Plot number	BO	BL	BM	B2	DO	D1	D2
UI 13a	0	5	4	3	6	2	0
UI 13b	0	4	5	3	6	2	0
UI 16a	1	5	3	3	6	1	0
UI 16b	3	4	3	3	6	2	0
UI 106a	0	5	3	2	6	1	0
UI 106b	0	6	2	0	6	2	0
UI 40Sa	0	3	6	1	6	1	0
UI 40Sb	0	3	6	1	6	1	0

Table 6. Seedbed assessment of the phantom understorey islands (Braun-Blanquet scale)

	Burn code				Disturbance code		
Plot number	BO	BL	BM	B2	DO	D1	D2
UI 9a	0	2	5	3	6	2	0
UI 9b	0	2	3	5	6	2	0
UI 12a	0	5	4	3	6	1	0
UI 12b	0	3	2	6	6	2	0
UI 234a	2	6	3	1	4	5	3
UI 234b	0	4	5	3	6	1	0
UI 264a	2	4	5	2	6	2	1
UI 264b	0	6	2	2	6	1	0
UI 418a	0	5	4	2	6	2	0
UI 418b	0	5	4	2	6	1	0
UI 518a	2	4	5	2	6	2	0
UI 518b	2	6	2	2	6	2	0

An assessment of the understorey islands floristics, and their recovery to age 3 years will be reported separately.

3.3. Regeneration

A summary of the results of the regeneration survey each March is shown in Table 7.

Table 7. Regeneration survey

Date of survey	% of coupe mapped as stocked	$16m^2$ stocking, whole coupe (%)	Seedling density (stems/ha)	Mean height of eucalypt regeneration	Mean height of understorey species
27/3/02	100	94	7600	0.41 m	0.28 m
26/3/03	100	95	9050	1.38 m	0.79 m
19/4/04	100	92	9950	1.92 m	1.11 m

The seedling density is based on the mean count of seedlings on the 16 m^2 plots.

The nature of the seedbed carrying seedlings on stocked plots as assessed during the regeneration survey of March 2002 is shown in the table below.

Table 8. Burn and disturbance proportions for seedlings on stocked plots (%), March 2002, with initial seedbed proportion (%) shown in brackets for each seedbed class.

	D0	D1	D2	Total
B0	0 (1)	8 (9)	2 (4)	10 (13)
BL	8 (24)	9 (20)	n/a	17 (47)
BM	42 (30)			42 (30)
B2	31 (11)			31 (11)

The seedlings in this coupe, as assessed during the regeneration survey, occur more commonly on BM (burnt to mineral soil) and B2 (oxidised soil) seedbeds than would be expected if the seedlings were randomly distributed; 47% of the seedbed in the seedbed assessment post-burn was found to be BL (burnt to litter) but only 17% of the seedlings are found on this seedbed type.

Only 11% of the seedbed was found to be oxidised soil, yet 31% of the seedlings are found on this seedbed type.

3.4. Browsing

Of the 50 seedlings sampled in the seedling browsing transect, none had died by January 2003 when monitoring ceased. Browsing in WR8H was rare, apart from through winter 2002 and had only a little influence on seedling growth. The chart (Figure1) shows that seedling growth slowed over winter 2002 and then improved in the summer of 2002/03. The coupe was not poisoned.

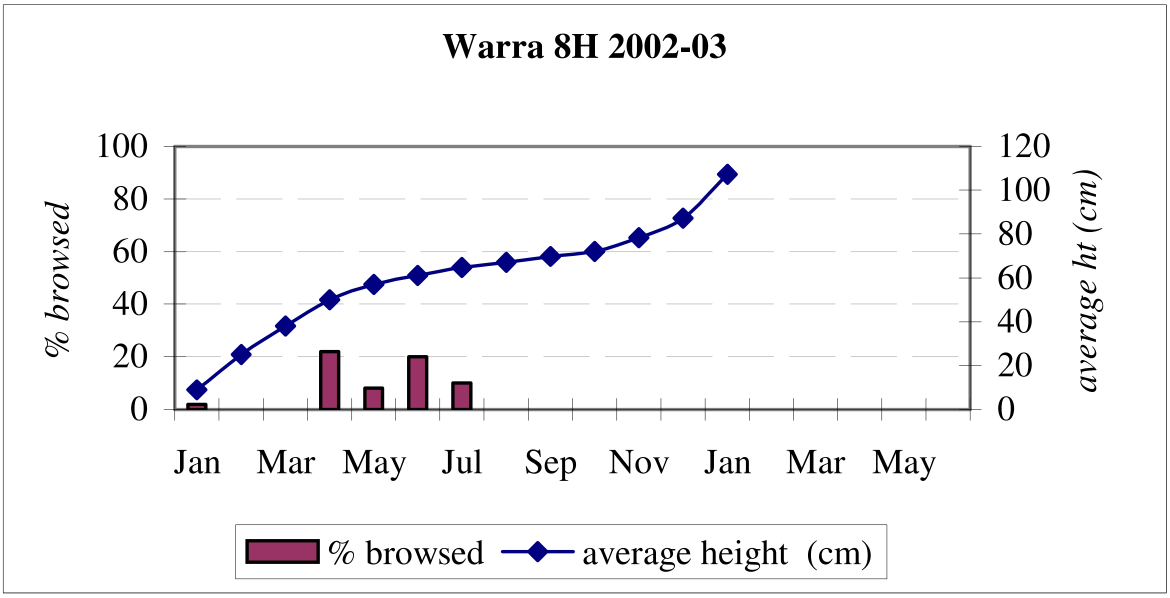

Figure 1. Average seedling height and incidence of browsing over time, Warra 8H

3.5. Seedling establishment and growth

The correlation matrix (Table 9) shows that all the stem variables (height, root collar diameter, stem diameter and crown width (both north-south and east-west) relating to the dominant seedling are significantly correlated, both to each other, and to seedbed class. The relationship between height and seedbed class is not as strong – partly this is a consequence of the fact that the seedbed classes are numbered arbitrarily. Later analysis (see the single tree plot section) explores the relationship between seedbed class and height more thoroughly. The relationships between seedling height and the other stem variables are very strong and in subsequent analyses, height is used as the key variable.

Table 9. Pearsons product moment correlation matrix. Only the most statistically significant correlations are shown ($P \leq 0.0001$).

	Seed bed	Ht	RC diam	Diam 1/3	N'th S'th	East West	Shrb cover	Shr ht	Sed cov	Sed ht	Fern covr	Fe rht	Herb cover	Herb ht	Tree cover	Tree ht	BA
Seedbed class	-------																
Height	0.5605	-------															
Root collar diameter	0.5471	0.9342	-------														
Diam 1/3 ht	0.5426	0.9415	0.9704	-------													
North-south	0.5147	0.9091	0.9216	0.9102	-------												
East west	0.4879	0.9011	0.9275	0.9058	0.9509	-------											
Shrub cover							-------										
Shrub height	0.3251	0.5254	0.4420	0.4816	0.4405	0.4050	0.3709	-------									
Sedge cover		-0.3541	-0.3866	-0.3584	-0.3702	-0.3901			-------								
Sedge height									0.6676	----							
Fern cover	-0.3297										-----						
Fern height											0.8239	------					
Herb cover													-------				
Herb height									0.3112				0.7740	-------			
Tree cover		0.3032							0.2968						-------		
Tree height	0.4609	0.6601	0.6033	0.6168	0.6254	0.5929	0.3684		-0.3599						0.5702	-------	
BA rtd trees	-0.4739						-0.3852	0									------
Dom class		-0.5250	-0.5192	-0.4926	-0.4982	-0.5411											

Sedge cover is negatively correlated with the stem variables. Where the plots were well burnt, the eucalypt seedlings are generally well developed and the sedge cover is generally low; such plots are typically dominated by *Pomaderris apetala* which tends to suppress the sedges. Shrub height is also correlated with the stem variables and seedbed class, which is also due to the fact that well burnt plots are often dominated by *Pomaderris apetala*.

Tree height is correlated with the stem variables and is negatively correlated with sedge cover. Plots with tall seedlings tend to have tall adjacent seedlings and as discussed above plots with tall seedlings tend to have a low cover of sedges.

For shrubs, sedges, ferns, herbs and trees there is a correlation between height and cover; ie as the height increases the cover increases. This is readily apparent for the ferns, which at low heights are often small establishing seedlings, but which readily move into higher height classes with much greater abundance.

Fern cover is negatively correlated with seedbed class - ferns occur mostly on poorly burned wet sites. Herb height is correlated with sedge cover – herbs occur in this coupe more commonly on the wetter sites which also carry sedges.

Dominance class is negatively correlated with height and the other stem variables. The dominance class system is dominant (1), co-dominant (2), sub-dominant (3) and suppressed (4). The relationship shows that the dominant trees at age 3 are taller and larger than the sub-dominant and suppressed trees. The single tree plot analysis (below) was undertaken both with the full data set and with the sub-dominant and suppressed trees removed.

The retained basal area is negatively correlated with seedbed class; seedlings on compacted seedbed are predominantly those on the fireline which is adjacent to the uncut forest, so the local basal area is high. The weak relationship between shrub cover and retained basal area is considered a coincidence.

3.6. Single-tree plots

Table 10. The percentage of seedlings on each seedbed class for the single-tree plot data, with initial seedbed proportion (%) shown in brackets for each seedbed class.

	D0	D1	D2	Total
B0	0 (1)	16 (9)	11 (4)	27 (13)
BL	10 (24)	11 (23)	n/a	21 (47)
BM	33 (30)			33 (30)
B2	18 (11)			18 (11)

There is an obvious disparity between the abundance of the different seedbed types as assessed immediately post-burn and the seedbed types upon which single-tree plots were established. Unburnt seedbed is over-represented and burnt to litter (BL) seedbed is under-represented. This is despite the various efforts that were made to spread the single tree plots across the range of seedbed types. This shows that, for this coupe at least, BL seedbed is poorly receptive, and that the dominant seedling on the 5 m radius plot was rarely found on that seedbed type. Seedlings on BM and B2 seedbed are in broad proportion to the availability of those seedbed types. Compacted (D2) seedbed is over-represented, but this is because the additional transect set out around the fireline deliberately captured this seedbed type along with B2, both of which were under-represented within the coupe proper.

The crown class assessment at age 3 years showed that of the 183 trees assessed as dominant at age 1, when the plots were first established, 153 are now rated as dominant or co-dominant, 28 as sub-dominant and 2 as suppressed. On a small number of plots it is clear that the plot seedling will be out-competed by surrounding stems despite the fact that it was the dominant seedling at age 1. The analyses described below were undertaken using both the full data set and the data set with the suppressed trees removed, but only the results for the full data set are reported, as removing the subdominant and suppressed trees had little influence on the results.

Preliminary analysis of the whole data set found that the standardised skewness and the standardised kurtosis were outside the acceptable range for ANOVA. Removing a single outlier, (a 4.2 m tall tree on B0/D1 seedbed) from the data set brought the standardised kurtosis and skewness within the acceptable ranges, but the variance check found that there was a statistically significant difference amongst the standard deviations of height over the various seedbed classes. Square root transformations of the seedling heights normalised the distribution of heights.

Multiple range tests of square root (height) by seedbed class found that the seedlings growing on oxidised (B2) seedbed were significantly taller than those on burnt to mineral soil seedbed, which were significantly taller than those growing on the other seedbed types. Seedlings growing on unburnt and compacted seedbed are growing more slowly than the others (B2 > BM >B0/D1, B1/D0, B1/D1 >B0/D2).

Table 11. Mean height (cm) and height range by seedbed class

		Whole coupe	Outlier included
BO/D1	mean	145_b	
	range	53 – 250	
B0/D2		79_a	
		7 – 190	
B1/D0		131_b	147
		55 – 200	55 – 420
B1/D1		122_b	
		40 – 230	
BM		193_c	
		35 –390	
B2		332_d	
		150 – 540	

Subscripts indicate homogenous groups

4. Discussion

At age 3 years, WR8H is fully stocked and the seedlings on most seedbed types are growing steadily. BM (burnt to mineral soil) and BL (burnt to litter) seedbed dominates the coupe, with oxidised seedbed (B2) and burnt to litter and undisturbed being the only other common seedbed types. Oxidised seedbed is largely restricted to the perimeter of the coupe, under what was the windrow created by tracking of the coupe.

The results of the regeneration surveys at ages one, two and three years show that the coupe continued to stock up after the first season. Delayed germination may have contributed to the increase in stocking, and the standing trees in the adjacent uncut forest almost certainly also contributed additional seed and hence seedlings (this is particularly noticeable in places around the fireline, where there are clusters of seedlings around oldgrowth trees on the edge of the adjacent uncut forest). Seedlings assessed during the regeneration survey were found to be distributed predominantly on BM and B2 seedbeds; BL seedbed occupies nearly half of the coupe but only 17% of the seedlings were found on this seedbed type.

All of the understorey islands were burnt during the regeneration burn. At age three years, the islands are greening up, both with vegetative and seedling regeneration. Full analysis of the floristic plots was not undertaken at this stage. In the longer term, the interesting question will be whether the vegetatively reproducing late successional species in the islands (ie rainforest species) result in seedlings of these species establishing in the coupe sooner than they would have done were the islands not retained.

The single tree plot data shows that seedlings on oxidised (B2) seedbed were significantly taller than those on burnt to mineral soil seedbed, which were significantly taller than those growing on the other seedbed types. Seedlings growing on unburnt and compacted seedbed are growing more slowly than the others (B2 > BM >B0/D1, B1/D0, B1/D1 >B0/D2).

5. Comparison of Warra 8H and Warra 8B

Warra 8H and Warra 8B were harvested to the same prescription, which called for a clearfell, burn and sow harvest with four understorey islands each of 40 m by 20 m to be retained within each coupe.

High intensity regeneration burns were planned in both WR8H and WR8B. The tables below indicate that the burn in WR8H was not as hot as that in WR8B. The proportion of B2 (oxidised soil) seedbed in WR8H (11%) is lower than the 28% B2 recorded from WR8B. Conversely, the 47% of BL (burnt to litter) seedbed is higher than the 30% recorded from WR8B. Both coupes had similar proportions of BM and BO seedbed.

Table 12. Weather conditions prior to burning (and attempted burning).

Coupe	Date	Light-up time	Sticks (forest/ coupe)	Temp (°C)	Wind speed and direction (kph)	Relative humidity (%)
WR8H	7/4/01	16 51	39/11	20	NW <5	74
WR8B	26/3/00	12.56	22/16	19	NW 0	52

Table 13. Results of the seedbed assessments of the two coupes (8H (8B)).

	D0	D1	D2	Total
B0	1 (3)	9 (5)	4 (1)	13 (9)
BL	24 (21)	23 (9)	n/a	47 (30)
BM	30 (34)			30 (34)
B2	11 (28)			11 (28)

Seven of eight understorey islands were burnt during the regeneration burns. Future research will indicate whether the islands serve the planned purpose of providing an in-coupe source of seed of later successional species.

The single-tree-plot data from both coupes indicates that seedlings on oxidised soil are growing more quickly than seedlings on burnt to mineral soil seedbed, which in turn are outgrowing seedlings on burnt to litter and unburnt and disturbed seedbeds. Seedlings on unburnt compacted seedbed are growing very slowly. The seedlings in WR8B (overall mean height 2.85 m) are generally growing more quickly than those in WR8H (1.86 m).

Table 14. Mean height (cm) and height range by seedbed class and coupe

		WR8H	WR8B
BO/D1	mean	145_b	209
	range	53 – 250	30 – 450
B0/D2		79_a	n/a
		7 – 190	
B1/D0		131_b	n/a
		55 – 200	
B1/D1		122_b	289
		40 – 230	130 – 700
BM		193_c	293
		35 –390	50 – 700
B2		332_d	353
		150 – 540	100 – 680

6. Conclusion

Two null hypotheses were tested in this study. The first hypothesis, that the local intensity of the burn and /or disturbance of the soil arising from the harvesting have no influence on the establishment and growth of the eucalypt regeneration, can clearly be rejected. Seedlings on oxidised soil are outperforming (in terms of early height growth), seedlings on other seedbed classes. The second hypothesis, that the understorey islands do not contribute to the regeneration of understorey species following harvesting and burning of the coupe, cannot yet be challenged due to a paucity of data. Further time and research is required in order to be able to address this question properly.

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