Developments in the use of spot-sowing as a remedial treatment for *Eucalyptus obliqua* wet forests in Tasmania

J.K. Dingle[1]*and B.S. Plumpton[2]
[1]Northern Research, State Forests of NSW,
P.O. Box J19, Coffs Harbour Jetty 2450
[2]Forestry Tasmania, GPO Box 207, Hobart 7001

Abstract

This paper describes experimental work carried out to develop a spot-sowing method to produce one tree seedling on each spot. The work has four parts: (a) a retrospective study of trees in spot-sown sites aged between three and 33 years at the time of assessment; (b) a long-term study of seedling development after spot-sowing over seven years; (c) a replicated short-term study of cultivation methods and seed weights of 0.38, 0.18 and 0.08 g/spot at three sites; and (d) calculations of the required sowing weight per spot.

Multiple-seedling spots generated by spot-sowing generally result in one dominant seedling and a number of smaller competing seedlings. Although over time competition appears to reduce the number of seedlings found on a spot, seedlings can persist for a number of years and this can lead to poor form. In some cases, there is fusion of the seedlings at the base.

*The weight of seed sown on a spot appears to be the most important criterion affecting the number of seedlings produced. A decrease in the sowing weight increases the percentage of single-seedling spots. However, it also reduces the percentage of stocked spots. Of the weights tested, the best sowing weight to establish single seedlings was determined to be 0.08 g (*Eucalyptus obliqua *Class-A seed), resulting in average rates of 48% stocking and 21% of spots being stocked with one seedling at about age one year. Clearly, to ensure satisfactory stocking, the density of spots established may need to be increased.*

Based on laboratory germination tests and a field success rate of 40%, a minimum sowing weight of 0.06 g of E. obliqua *Class-A seed was required to produce one seedling per spot. As site factors were also found to affect the number of seedlings on a spot, the minimum sowing weight of 0.06 g should be varied to suit site conditions.*

* Corresponding author
e-mail: JoanneD@sf.nsw.gov.au

Introduction

Spot-sowing is used in Tasmania as a remedial treatment when a high proportion of the seedbed is no longer receptive due to the surface soil being covered by light litter, lichens, mosses or liverworts (Forestry Commission 1992). It is mainly used when an initial broadcast sowing has failed or browsing has destroyed seedlings. It is not an appropriate technique to use when woody weeds have overtaken the site. The aim is to clear a small area, create fresh seedbed, allow newly sown seed to germinate, and for one seedling to become dominant and occupy the site.

Spot-sowing has been used as a remedial sowing treatment in Tasmania for over

30 years, particularly in the Murchison District in north-western Tasmania. Until 1995, spots were cultivated with a hoe, and seed was distributed onto the spot using a tin can with small holes drilled in the lid (hoe and salt-shaker method). The spots, approximately 30 cm in diameter, were placed at 2 m intervals along lines 3 m apart (approximately 1700 spots / ha) using between 0.2 and 0.4 g / spot of seed (Forestry Commission 1978, 1992). This method often resulted in a heavy application of seed on a large spot, resulting in multiple seedlings competing with each other for a long period of time. These clumps of seedlings, where no single seedling dominates, can produce seedlings of very poor form and in some cases result in fused stems. Ideally, after two years, when the seedlings are between 50 and 100 cm tall, there should be only one seedling occupying each spot.

Photo 1. The spot sower. Above: upper part of the spot sower showing the seed dispenser. Right: base of the spot sower showing the scarifying device and the hollow tube through which the seed falls.

At present, spot-sowing is being carried out using a 'spot sower', a device designed specifically for this purpose by Forestry Tasmania (Photo 1). The spot sower is a scarifying device on a hollow-handled tube with a seed dispenser (Weed-a-metre™, Macspread™) fixed onto the top. When released, the seed falls down inside the tube onto the scarified area. The tool dispenses an accurate amount of seed onto a spot size about 10 cm in diameter. The incorporation of the scarifying tool and sowing device into one unit makes it easier and quicker to use than the hoe and salt-shaker method.

This paper describes the experimental work carried out over seven years to develop a spot-sowing method to produce one seedling on each spot. The work has four parts:

(a) A retrospective study of trees in spot-sown sites aged between three and 33 years at the time of assessment;

(b) A seven-year study of seedling development after spot-sowing;

(c) A replicated short-term study of cultivation method and the weight of seed sown on a spot (hereafter referred to as sowing weight) at three sites; and

(d) Calculations of the required sowing weight per spot based on laboratory germination tests and the germination success of the short-term study.

Note that sowing weights in this paper are based on Class-A seed where the number of germinants is within the normal range for good seed of the species (Forestry Commission 1991). The minimum number of laboratory germinants, based on the lower 95% confidence limit, is 40 / g for Class-A *Eucalyptus obliqua* seed (Forestry Commission 1994).

Table 1. Characteristics of six coupes in the Murchison District that previously had been spot-sown.

Coupe	Year of spot-sowing	Age at evaluation	Area (ha)	Altitude (m)	Rainfall (mm, av./yr)	Map Sheet (1:25 000)
Dip 023*	1991	3	13	260	1600	Tayatea 3445
Mt Bertha 046*	1991	4	73	300	2500	Bertha 3442
Sumac 030	1991	4	51	150	1600	Sumac 3244
Tipunah 006*	1986	9	33	210	1600	Tayatea 3445
Sumac 027	1983	12	70	100	1600	Sumac 3244
Folly Road	1962	33	110	160	1600	Tayatea 3445

* = Systematic stripline survey

Methods

(a) Retrospective study

Comparisons of the characteristics and form of stems on single- and multiple-seedling spots were made using six coupes which previously had been spot-sown using the hoe and salt-shaker method. The year of sowing, area, altitude and average rainfall for the six coupes are outlined in Table 1.

Three of the coupes were assessed using a systematic sampling system. Striplines were randomly located through each coupe and plots placed every 10 m. At the remaining three coupes, spots were subjectively selected because they appeared to be spot sown. Measurements were made of the number of stems on a spot, the DBHOB, the height of the tallest stem, and the height of the tallest competing stem.

(b) Long-term evaluation of spot-sowing

A long-term trial to assess seedling development following spot-sowing was established in 1993 at Russell 001A, a coupe located in the valley of the Russell River, 25 km west of Huonville. The forest was predominantly *Eucalyptus obliqua* with a scattering of *E. globulus*. The understorey consisted mainly of *Pomaderris apetala* and *Acacia dealbata*. The area was logged as part of a salvage operation after it was severely burnt in a wildfire in March 1990. Logging was completed in mid 1992 and the regeneration burn was completed in March 1993. In early September 1993, an inspection revealed that the area appeared to be understocked.

Forty spots were sown in a small section of the coupe in 1993 using the hoe and salt-shaker method. The tin shakers were calibrated to distribute 0.2 g of *E. obliqua* seed on each spot. Each spot was marked with a wire peg at the time of sowing. The number of seedlings found, the height of the dominant seedling and the height of the largest competitor on each spot were measured annually over seven years.

(c) Recent spot-sowing trials using the spot sower

A factorial trial at three sites using different cultivation tools (hoe and salt-shaker, spot sower, and garden tool) and sowing weights (0.08 g, 0.18 g, 0.38 g) was used to evaluate the spot sower and to fine-tune the amount of seed needed on each spot.

The trial was set up at one site in the Huon District and at two sites in Murchison District (Table 2). One coupe (Esperance 020B) had been aerially sown twice because of a wildfire when the regeneration was only one year old. The regeneration consisted of multi-aged seedlings and was patchy in some areas. The seedbed in Meryanna 004B had been lost to mosses and liverworts and was typical of a site requiring spot-sowing. Mt Bertha 043B was recorded as 100% unstocked at the time of the experiment due to heavy mammal browsing. The loss of seedbed due to mosses and liverworts indicated a need for spot-sowing.

Table 2. *Details of logging and sowing dates for three sites used for replicated spot-sowing trials.*

Coupe	District	Logged	Aerially sown	Spot-sown
Esperance 020B	Huon	1994	1994 / 1995	Mar 1996
Meryanna 004B	Murchison	Feb 1996	Apr 1996	Aug 1996
Mt Bertha 043B	Murchison	Feb 1998	Mar 1998	Sept 1999

Table 3. *Factorial experiment – method of cultivation, spot diameter and sowing-weight factors used at each site.*

Factors	Esperance	Meryanna	Mt Bertha
Cultivation method	Hoe and salt shaker (30 cm) Spot sower (10 cm) Garden scraper (1–3 cm)	Hoe and salt shaker (30 cm) Spot sower (10 cm) Garden scraper (1–3 cm)	Hoe and salt shaker (30 cm) Spot sower (10 cm) No cultivation
Sowing weight	0.38 g 0.18 g 0.08 g	0.38 g 0.18 g 0.08 g	0.38 g 0.08 g
No. of treatments	9	9	6
Replication	3	3	3

Table 4. *The measurement intervals of the replicated spot-sowing trials.*

	Measurement 1	Measurement 2
Esperance	3 mths	12 mths
Meryanna	8 mths	18 mths
Mt Bertha	4 mths	-

In the experiment (Table 3), the spot-sowing methods were blocked within each of the three replicates in a split plot design. Within each block there were 30 spots. The sowing rates were randomly allocated to each spot at Esperance and Meryanna, and systematically allocated to each spot at Mt Bertha. A nylon mesh fence was built around the experiment at Mt Bertha to prevent further browsing in the area.

Counts of the number of seedlings on a spot were taken at different intervals (Table 4). The percentage of spots stocked (stocking) and the percentage of spots stocked with either single or multiple seedlings were calculated for each of the treatments. The results for each site at the latest measurement and a comparison of the three sites using the initial measurement were analysed using an Analysis of Variance (ANOVA) (split plot design). In the comparison of the three sites, only the data from the hoe and salt-shaker and spot-sower methods and 0.38 g and 0.08 g sowing weights were used.

(d) Germination success and calculation of sowing weight

Calculations of the weight of *E. obliqua* seed required to get one viable seed per spot

Table 5. Stem characteristics of single- and multiple-seedling spots at six coupes in the Murchison District. Standard errors are given in brackets. (Coupe abbreviations: D = Dip 023, MB = Mt Bertha 046, S30 = Sumac 030, T = Tipunah 006, S27 = Sumac 027, FR = Folly Road)

Coupe		D	MB	S30	T	S27	FR
Age (years)		3	4	4	9	12	33
Single-seedling spot							
Average diameter (cm)		-	-	-	9.4 (1)	17.0 (1)	31.8 (1)
Average height (cm)		191 (26)	222 (21)	148 (37)	-	-	-
Number of samples		28	36	8	17	21	47
Multiple-seedling spot							
Dominant stem:	Average diameter (cm)	-	-	-	9.8 (1)	16.0 (1)	30.7 (2)
	Average height (cm)	376 (44)	345 (57)	230 (92)	-	-	-
Tallest competitor:	Average diameter (cm)	-	-	-	5.6 (1)	9.7 (1)	18.0 (1)
	Average height (cm)	305 (41)	235 (53)	213 (94)	-	-	-
Average number of stems		4.1	3.1	5.3	3.5	2.5	2.0
Maximum number of stems		15	5	9	6	5	3
Number of samples		18	8	3	25	26	13

were based on previous laboratory germination tests (Forestry Commission 1994) and percentages of germination success in the field trials.

Results

(a) Retrospective study

Table 5 shows the characteristics of stems found on both single- and multiple-seedling spots at sites aged 3–33 years. The average height of stems on single-seedling spots on the younger sites was generally one-half to two-thirds the average height of the dominant stems in multiple-seedling spots. In coupes older than eight years, the average diameters of the dominant seedlings on both single- and multiple-seedling spots are very similar (Table 5). The average number of stems and the maximum number of stems found on the multiple-seedling spots decreases with age.

At Dip 023, most of the stems on multiple-seedling spots had bad form, possibly due to the large number of stems on very small spots. However, most of these spots had a dominant stem of good form with the potential to suppress the other stems on the spot. Poor form at this site may also be due to the heavy browsing which occurred in previous years.

At Tipunah 006, most of the multiple-seedling spots had stems which were likely to compete with the dominant stem for a long time to come. It was noted that there was an obvious dominant stem but that the other stems were beginning to fuse together at ground level and some were developing quite severe butt sweep.

At Folly Road, the 33-year-old multiple-seedling spots also had one stem that was obviously dominant but the competing stems were not moribund. The fusion of stems (some had died but were still fused to the main stem) had caused swelling and were a possible source of fungal infection (Photo 2).

(b) Long-term evaluation of spot-sowing methods

Seven years after spot-sowing, 94% of the spots at Russell 001A were stocked with

Photo 2. *Fusion of stems at Folly Road.*

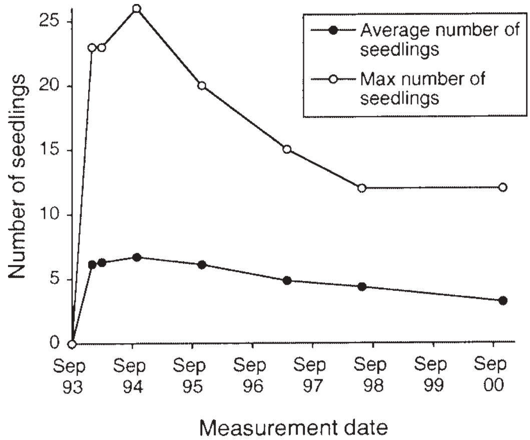

Figure 1. Average and maximum numbers of seedlings per spot over seven years at Russell 001A.

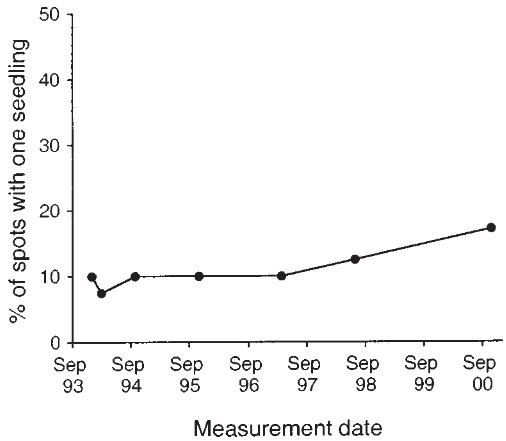

Figure 2. The percentage of spots that have one seedling on them over seven years at Russell 001A.

at least one seedling. Figure 1 shows the average and maximum seedling densities per spot over the seven years. The average number of seedlings peaked at year one (seven seedlings per spot) and then began to decrease at a slow rate to three seedlings seven years after sowing. The maximum number of seedlings (26) found on the spots also peaked at year one and had reduced to 12 at year five. Two years later (year seven) the maximum number of seedlings found on a spot is still 12 (Figure 1). The numbers of spots with one seedling rose from an initial 10% to 17% at year seven (Figure 2).

(c) Recent spot-sowing trials using the spot sower

All results presented show the main effects of sowing weight and cultivation method. There were no significant interactive effects of sowing weight and cultivation method at any of the three sites.

Mt Bertha.—Results from the Mt Bertha site measured four months after establishment are shown in Table 6. Sowing weight ($P < 0.01$) significantly affected the stocking. The spot sower produced the highest stocking; this was not significantly different

Table 6. The percentage of single-seedling spots, multiple-seedling spots and total stocking at Mt Bertha four months after sowing for both cultivation method and sowing weight. (NS = not significant)

Treatment	Single-seedling (%)	Multiple-seedling (%)	Total stocking (%)
Sowing weight (g)			
0.08	25	39	64
0.38	9	84	93
	$P < 0.01$	$P < 0.01$	$P < 0.01$
Cultivation			
Hoe and salt shaker	12	69 a	81
Spot sower	13	70 a	83
No cultivation	26	44 b	70
	NS	$P < 0.05$	NS

from the hoe and salt-shaker method. The highest stocking was achieved at the highest sowing weight ($P < 0.01$).

The number of single-seedling spots was significantly affected ($P < 0.01$) by the sowing weight, with the lighter weight producing the highest percentage.

The number of multiple-seedling spots was affected by both cultivation method and sowing weight. The no-cultivation method produced a significantly lower ($P < 0.05$) percentage of multiple-seedling spots compared to both the spot sower and hoe and salt-shaker method and the higher sowing weight produced a much larger percentage ($P < 0.01$) of multiple-seedling spots than the lighter weight (Table 6).

Esperance.—The Esperance site showed good stocking three months after sowing, with an average of 65% of spots stocked. Initial stocking (three months) was affected by sowing weight, with the highest stocking achieved with the highest sowing weight. One year after sowing, the average stocking had dropped to 37% regardless of cultivation method or sowing rate. The low stocking was attributed to the woody native plants that quickly colonised the area and overtopped the seedlings.

Table 7 shows the percentage of single-seedling spots, multiple-seedling spots and total stocking for each of the sowing weights tested one year after sowing at the Esperance site. The method of cultivation used did not result in a significant difference among the percentage of single-seedling spots, multiple-seedling spots or total stocking at any time during the experiment. The lowest sowing weight (0.08 g) had a significantly greater ($P < 0.05$) percentage of single-seedling spots than both the other sowing weights. The highest sowing weight (0.38 g) resulted in the most multiple-seedlings spots.

Table 7. The percentage of single-seedling spots, multiple-seedling spots and total stocking at Esperance one year after sowing. (NS = not significant)

Sowing weight (g)	Single-seedling (%)	Multiple-seedling (%)	Total stocking (%)
0.08	21 a	16	37
0.18	10 b	26	33
0.38	8 b	31	39
	$P < 0.05$	NS	NS

Table 8. The percentage of single-seedling spots, multiple-seedling spots and total stocking at Meryanna for both cultivation methods and sowing weights one-and-a-half years after sowing. (NS = not significant)

Treatment	Single-seedling (%)	Multiple-seedling (%)	Total stocking (%)
Sowing weight (g)			
0.08	17	28	44 a
0.18	20	26	46 a
0.38	21	46	67 b
	NS	NS	$P < 0.05$
Cultivation			
Hoe and salt shaker	23	43	67
Spot sower	19	37	56
Garden scraper	16	19	34
	NS	NS	NS

Meryanna.—Table 8 shows the percentage of single-seedling spots, multiple-seedling spots and total stocking for each of the sowing weights and cultivation methods tested one-and-a-half years after sowing at the Meryanna site. Stocking was significantly affected only by the sowing weight ($P < 0.05$). The greatest stocking was achieved using the hoe and salt-shaker method but this was not significantly different from the spot sower. Of the three sowing weights tested, the highest (0.38 g) produced significantly greater stocking than the others.

Comparison of all sites.— The stocking from the first measurement at each trial, when analysed over all three of the sites, was significantly different ($P < 0.01$) between sowing weights but not cultivation methods. The 0.38 g sowing weight produced the greatest stocking (83%) compared to the 0.08 g sowing weight (67%).

The percentage of single-seedling spots was significantly affected only by sowing weight ($P < 0.01$). Meryanna had a significantly larger percentage of single-seedling spots (23%) than Mt Bertha (13%) and across all sites the 0.08 g sowing weight produced the greatest percentage of single-seedling spots (23%) compared with the heavier sowing weight (12%).

The percentage of multiple-seedling spots stocked was also significantly affected only by sowing weight ($P < 0.01$). Across all sites, the 0.38 g sowing weight produced the most multiple-seedling spots (71%) compared with the lighter sowing weight (45%).

An average stocking and percentage of single-seedling spots was calculated for the 0.08 g sowing weight by using the latest measurement at Esperance (12 months), Meryanna (18 months) and Mt Bertha (four months). With this sowing weight, about 48% of spots will be stocked and 21% of spots will have a single seedling about one year after sowing.

(d) Calculating sowing-weight requirements using germination success

Table 9 shows the sowing weight, the resulting average numbers of germinants for each of the sites and the minimum number of germinants (based on laboratory germination tests). On average, 43% of the viable seeds germinated using the spot-sowing methods (both the spot sower and the hoe and salt-shaker method). The required weight of seed to result in a single-seedling spot is calculated to be 0.06 g / spot (using the weight of Class-A seed required to produce one germinant in laboratory conditions and a 40% success rate).

Table 9. Average number of field germinants (at the first measurement) for each seed weight at three sites, and the number of expected germinants for that seed weight (Class-A seed) from laboratory germination trials.

Site	Sowing weight used	Average number of field germinants	No. of expected germinants (Class-A seed)	Quantity of seed that germinated (%)
Mt Bertha	0.08	1.7	3.2	53
	0.38	8.5	15.2	56
Esperance	0.08	1.9	3.2	59
	0.18	2.6	7.2	36
	0.38	5.5	15.2	38
Meryanna	0.08	1.6	3.2	50
	0.18	2.1	7.2	29
	0.38	3.5	15.2	23
Average				**43**

Discussion

The retrospective study indicated that multiple-seedling spots generally result in one dominant seedling and a number of smaller competing seedlings. This arrangement can persist for several years and can lead to poor seedling form and in some cases fusion of the seedlings at the base. Although the dominant seedling of a multiple-seedling spot seems to gain a height advantage over single-seedling spots, this is less evident in the older sites and the resulting bad form counteracts any benefit.

The long-term study supported this finding: although competition appears to gradually reduce the number of seedlings found on a spot, this process continued for at least seven years, over which time seedlings were likely to develop poor form. Continual competition for resources with other stems on multiple-seedling spots may eventually impede the development / growth of the dominant tree (Curtin 1964). The maximum number of germinants on a spot that resulted in one seedling two years after establishment was two seedlings.

The cultivation / sowing weight studies showed that sowing weight appears to be the most important criterion affecting the number of seedlings on a spot. The optimal weight must produce a reasonable stocking without producing a large number of multiple-seedling spots. An increase in sowing weight increased the stocking and increased the percentage of multiple-seedling spots.

The hoe and salt-shaker and spot-sower methods of cultivation produced similar results when used with known sowing weights. The spot sower has proven to be more time efficient, ergonomic and easier to use (S. Jennings, pers. comm.). Operationally, the hoe and salt-shaker method becomes problematic due to the inaccurate dispensing of seed compared with the cultivation method. The salt-shaker method of seed dispensing generally results in over-seeding which would increase the number of multiple-seedling spots.

The weight of *Eucalyptus obliqua* seed which produces one germinant under laboratory conditions is 0.025 g (Class-A seed) (Forestry Commission 1994). On average, aerial sowing results in 5% of the viable seeds becoming established seedlings (Forestry Commission 1991). The spot-sowing method would be expected to have a higher success rate than aerial sowing as seed is placed onto a cultivated spot. Aerial sowing does not guarantee that the seed will fall onto receptive seedbed.

The most important aspect in successful spot-sowing is to ensure it results in one seedling per spot stocked. The factor that has the most impact on this is the quantity of seed that is sown onto each of the spots. From the trials and calculations of the sowing weight, it appears that the appropriate sowing weight to use is between 0.06 and 0.08 g for Class-A *E. obliqua* seed.

Recommendations

- The use of the spot sower for remedial treatment of Tasmanian sites should become general practice as it increases both efficiency and accuracy.
- 0.08 g/spot of *E. obliqua* Class-A seed should be used.
- Spacing of spot-sowing lines will depend on how many successful spots are required. On average, 48% of spots will be stocked.

Acknowledgements

As the majority of this work was initiated and carried out by many predecessors, assistance has been given by many people. In particular, the authors wish to thank Sue Jennings and John Hickey whose advice and assistance throughout this study have been invaluable. We would also like to thank Jason Bolch, Tiina Kuusisalo and Leigh Edwards for technical assistance, and John Hickey, Ann LaSala and Mark Neyland for their input and editing of the draft manuscript.

References

Curtin, R.A. (1964). Stand density and the relationship of crown width to diameter and height in *Eucalyptus obliqua*. *Australian Forestry* 28 (2): 90–105.

Forestry Commission (1978). Silvicultural manual. Unpublished internal document. Forestry Commission, Tasmania.

Forestry Commission (1991). *Eucalypt Seed and Sowing.* Native Forest Silviculture Technical Bulletin No. 1. Forestry Commission, Tasmania.

Forestry Commission (1992). *Remedial Treatments.* Native Forest Silviculture Technical Bulletin No. 7. Forestry Commission, Tasmania.

Forestry Commission (1994). *Seed Manual.* Forestry Commission, Tasmania.