ESTABLISHING TREES ON NON-ARABLE LAND TO CONTROL WEEDS

M.H. Campbell and H.I. Nicol
NSW Agriculture, Agricultural Research and Veterinary Centre, Orange, New South Wales 2800, Australia

Summary Investigations into the establishment of *Eucalyptus viminalis*, *Acacia dealbata*, *Casuarina cunninghamiana* and *Pinus radiata* by aerial sowing, direct drilling and planting seedlings to replace *Nassella trichotoma* revealed that all species established well from planting seedlings, *E. viminalis* and *P. radiata* established well from direct drilling and *E. viminalis* established well from aerial sowing. Treatments that assisted establishment were herbicide application to control *N. trichotoma* and other weeds, and burning to remove dead plant litter.

INTRODUCTION

In New South Wales some serious weeds have infested steep, rocky hill country which makes economic control by landholders using pastures impracticable. For example, Vere *et al.* (1993) have shown that it is unprofitable to control serrated tussock (*Nassella trichotoma*) by pasture improvement in non-arable areas with low rainfall and low soil fertility. Approximately 741 000 ha of land are infested with *N. trichotoma* and 188 000 ha with St. John's wort (*Hypericum perforatum*) of which a mean of 65% is non-arable. At present the main method used to control weeds in these non-arable situations is repeated herbicide application which kills the weed for short periods but often eliminates associated useful species leaving bare ground. The establishment of trees to control the weeds would be a more sustainable solution. *Pinus radiata* has been used to control *N. trichotoma* and *H. perforatum* over large areas of New South Wales (NSW). The trees were established by conventional planting of seedlings. However, by using aerial seeding or direct drilling large areas of weeds could be sown to trees quickly and relatively cheaply. Thus experiments were set down to examine methods of establishing *P. radiata* and other tree species to control weeds.

The experiments investigated germination in the laboratory, radicle-entry and emergence in the glasshouse and establishment and growth in the field. The basic principles of establishing pasture species by direct drilling and aerial seeding were applied to a number of tree species.

MATERIALS AND METHODS

Experiment 1 Seeds of five tree species and two pasture species were sown in petri dishes in the laboratory to examine the influence of low temperatures on germination (Table 1). Seeds were placed on two filter papers and one germination pad, 8 mL of deionised water was added and the petri dishes placed in controlled temperature cabinets for 19 to 30 days (Table 1). Four replications were used and dishes were arranged in randomized blocks.

Experiment 2 Seeds of 12 tree species (Table 2) were surface sown and direct drilled on a sterilised infertile

Table 1. Effect of low temperatures on germination capacity and rate of germination of tree and pasture species.

Species	Number of seeds to germinate					Time in days to 50% of final germination	
	From 0.1 g seed + chaff	From 100 seeds[A]					
	14–22°C 22 days	14–22°C 22 days	9°C 30 days	3°C 19 days	3 + 9°C 19 days + 9 days	14–22°C 22 days	9°C 30 days
C. cunninghamiana	35	15	20	0	13	5.8	12.7
E. camaldulensis	39	75	71	0	68	5.4	11.0
E. macrorhyncha	3	12	8	0	7	8.9	12.4
E. viminalis	82	94	89	0	95	4.8	9.8
P. radiata	2.7	90	85	0	75	9.6	19.6
P. aquatica	–	81	85	0	84	4.1	6.8
T. subterraneum	–	91	90	89	90	–	–

[A] Objects that clearly appeared to be seeds. Other objects in the chaff may have been seeds but it was not possible to determine whether they were or not.

clay loam soil from Kerrs Creek, NSW in a glasshouse kept at 20°C and establishment recorded after 27 days. Sufficient seed + chaff was sown to allow 25 viable seeds of each species the chance to establish. Surface sown seed was dropped on the soil surface and direct drilled seed sown 3 mm deep and covered with soil in plots 11 × 28 cm. No fertilizer was applied but each plot was sprayed with a fungicide (Thiram®) to prevent damping-off of seedlings. Moisture was applied from misting nozzles four times daily at a rate of 1.8 mm simulated rain per day. The watering kept the soil surface very soft (strength of 0.5 kg cm^{-2}). Soil strength was measured on a set of scales by recording the weight required to push a cylindrical penetrometer head of 1 cm^2 surface area 5 mm into the soil. The experiment had a randomized block design with four replications.

Experiment 3 The site was an unploughed rocky hill 20 km north of Tuena, NSW heavily infested with *N. trichotoma* and lightly infested with *H. perforatum*. The soil had a pH ($CaCl_2$) of 5.2 with an available phosphorous level (Bray No. 1) of 10.3 µg g^{-1}.

The experiment had two burning treatments (unburnt, burnt) × 3 herbicide treatments (nil, one, two sprays) × 3 methods of sowing (aerial, direct drilled, planted seedlings). Four tree species (ribbon gum *Eucalyptus viminalis*, silver wattle *Acacia dealbata*, river oak *Casuarina cunninghamiana* and radiata pine *Pinus radiata*) were sown on each plot. *N. trichotoma* was burnt on 6 June 1995 after nil, one spray (on 24 November 1994) or two sprays (24 November 1994, 23 May 1995). The November 1994 spray to kill *N. trichotoma* and *H. perforatum* was a mixture of flupropanate at 2 L ha^{-1} product (75% a.i.) and glyphosate at 4 L ha^{-1} product (45% a.i.) and the May 1995 spray to kill annual weeds was glyphosate at 2 L ha^{-1}.

Ten seedling trees were planted per 5 m^2 sub-plot with a shovel and seeds sown on the aerial and direct drilled treatments by hand on 7 and 8 June 1995 (*E. viminalis* 2 kg ha^{-1}, *A. dealbata* 3.6 kg ha^{-1}, *C. cunninghamiana* 2 kg ha^{-1}, *P. radiata* 8 kg ha^{-1}). The direct drilled furrow (8 cm wide × 3 cm deep) was dug with a mattock and soil firmed by walking on the furrow after the seed had been sown on the cultivated surface. Seeds were treated with permethrin to reduce losses due to seed harvesting ants. Superphosphate containing 0.02% molybdenum was applied at planting at 200 kg ha^{-1}.

Plots (4 × 5 m with sub-plots 1 × 5 m) were in a randomized block design, blocked for burning and spraying, with four replications.

Results were recorded in late March 1996 by counting the number of trees per 5 m^2 sub-plot and measuring their height.

Table 2. Establishment (27 days after sowing) of surface-sown and direct drilled tree seeds in flats in the glasshouse

Species	Establishment of viable seed	
	Surface-sown (%)	Direct drilled (%)
E. viminalis	100 a[A]	100 a
E. camaldulensis	100 a	100 a
E. macarthurii	100 a	100 a
E. melliodora	100 a	100 a
E. aggregata	100 a	100 a
E. mannifera subsp. *maculosa*	100 a	100 a
E. fastigata	82 c	97 ab
E. obliqua	76 c	100 a
E. macrorhyncha	59 d	98 ab
P. radiata	43 e	99 a
A. dealbata	47 e	91 b
C. cunninghamiana	100 a	0 f (59)[B]

[A] Means in columns followed by a common letter do not differ significantly (P=0.05).
[B] Establishment between 27 and 55 days after sowing.

RESULTS

Experiment 1 The five tree species tested failed to germinate at 3°C in 19 days but germinated well when the 3°C treatment was followed by 9 days at 9°C (Table 1). *T. subterraneum* germinated at 3°C but *P. aquatica* did not, however *P. aquatica* germinated well when the 3°C treatment was followed by 9 days at 9°C (Table 1). Rate of germination of tree species was slower than that of *P. aquatica*, particularly at 9°C (Table 1).

Experiment 2 Of the nine eucalypts sown six established equally well from aerial seeding or direct drilling and three had higher establishment from direct drilling than aerial seeding (Table 2). Establishment of *P. radiata* and *A. dealbata* was higher from direct drilling than from aerial seeding; their establishment from aerial sowing was inferior to that of the eucalypts and *C. cunninghamiana* (Table 2). The latter established well from aerial sowing and had a delayed emergence, compared to the other species, from direct drilling (Table 2).

Experiment 3 *Aerial sown and direct drilled seed.* Ten months after sowing, establishment of *E. viminalis* and *P. radiata* was higher from direct drilling than from aerial sowing (Table 3). Method of sowing had no effect on the establishment of *A. dealbata* and *C. cunninghamiana* failed to establish.

Table 3. Effect of aerial sowing and direct drilling on establishment of trees (m^{-2}) and height (cm) of the three species that established ten months after sowing.

Treatment		Species		
		E. viminalis	*A. dealbata*	*P. radiata*
Method of sowing				
Direct drilled	burnt	6.68 a	0.56 cd	0.88 cd
	unburnt	5.50 ab	0.22 d	2.00 c
Aerial	burnt	3.76 b	0.20 d	0.22 d
	unburnt	1.88 c	0.22 d	0.38 d
Height	(meaned for aerial and direct drilled)	24.8 a	20.3 a	11.1 b

Means for method of sowing and for height followed by a common letter do not differ significantly at P=0.05.

Burning assisted the establishment of aerially sown *E. viminalis* (5.2 seedlings m^{-2} on burnt and 3.7 m^{-2} on unburnt, meaned for the other treatments), but had no effect on the establishment of the other species. Herbicide treatment assisted establishment of *E. viminalis*, two sprays giving better (P=0.05) establishment than nil spray, but two sprays did not assist establishment of the other species (Table 4). The surprising feature of the herbicide treatment was the establishment of the trees on the unsprayed treatment despite heavy competition from *N. trichotoma*. The different treatments did not influence height of trees, the only difference being between species (Table 3). The slow growth of *P. radiata* was characterized by yellowish plants lacking vigour.

Table 4. Effect of herbicide treatment (meaned for other treatments) on the establishment of trees (number m^{-2}) ten months after sowing.

Herbicide treatment	Species		
	E. viminalis	*A. dealbata*	*P. radiata*
Two sprays	5.70 a	0.55 c	1.14 c
One spray	4.18 ab	0.24 c	0.52 c
Nil	3.48 b	0.44 c	0.96 c

Means followed by a common letter do not differ significantly at P=0.05.

Planted seedlings A high proportion of seedlings planted in June 1995 established and increased in height in the ten months after planting (Table 5). Treatments did not affect establishment or growth, the only difference being between species. Best establishment was achieved by *E. viminalis* and *P. radiata* whilst *A. dealbata* attained the greatest height. The height of *C. cunninghamiana* was influenced by tree health, 23% being dark green and healthy with a mean height of 105 cm whilst the remaining 77% had unhealthy yellowish leaves and a mean height of 48 cm. The reason for the unhealthy trees may have been that their roots were not infected with the actinomycete *Frankia* and thus they were not able to fix nitrogen.

DISCUSSION

The experiments showed that the best method of establishing trees was by planting seedlings but they also demonstrated that some tree species are well adapted to establish from aerial sowing or direct drilling. The accepted method of establishing pastures from aerial sowing and direct drilling is to sow the seed in late autumn or winter to take advantage of moist soil, low evaporation and generally reliable and effective rainfall (Campbell 1963, Campbell *et al.* 1996). The experiments presented here show that establishment of tree species can similarly take advantage of these conditions. Although tree species failed to germinate at 3°C they did germinate at 3°C followed by 9°C. *P. aquatica* demonstrated a similar pattern and this species has been established in practice from aerial sowing or direct drilling in winter for over 20 years. Therefore, the establishment of the tree species tested here should not be limited by lack of germination in winter in areas of NSW where the mean maximum daily temperature in winter is 9°C or greater.

Radicle entry and emergence are critical factors in the ability of pasture species to establish from aerial sowing and direct drilling. Experiment 2 demonstrated that tree species are well adapted to establishment from

Table 5. Establishment (%) of planted seedlings ten months after planting, and height (cm) at planting and ten months later.

	E. viminalis	*A. dealbata*	*C. cunninghamiana*	*P. radiata*
Establishment (%)	98.3 a	70.8.c	89.2 b	97.5 a
Height (cm) at planting	36.4 a	13.5 c	40.4 a	28.4 b
Height (cm) ten months later	77.7 b	95.8 a	57.5 c	78.2 b

Means in rows followed by a common letter do not differ significantly (P=0.05).

either method of sowing. Eucalypts established well from aerial sowing because they all have hairs on their radicles which facilitates anchorage to the soil surface and assists radicle entry (Campbell and Swain 1993a, 1973b). *P. radiata* and *A. dealbata* do not have hairs on their radicles and have much larger (broader) radicles and thus their radicle entry on the aerial sown treatment was lower than that of the eucalypts. The larger seeded eucalypts, with broader radicles, (*E. fastigata*, *E. obliqua, E. macrorhyncha*) had a lower establishment from aerial sowing than did the smaller seeded eucalypts. *E. cunninghamiana*, which has hairs on its radicle, established well from aerial sowing but was slow to emerge from direct drilling possibly because of low seedling vigour.

In Experiment 3 all tree species established well from planting as seedlings. *E. viminalis* and *P. radiata* established well from direct drilling whilst *E. viminalis* alone established well from aerial sowing. Growth of *P. radiata* from direct drilling and aerial sowing was very slow due, possibly, to the lack of mycorrhiza in the soil which leaves only *E. viminalis* as suitable for aerial sowing or direct drilling. The two spray treatment assisted the establishment of *E. viminalis* by controlling *N. trichotoma*, *H. perforatum* and annual weeds. The one spray treatment did not control annual weeds which smothered tree seedlings in spring 1995. The beneficial effects of the two spray treatment was not evident on the other species at the time of measurement. The ability of *E. viminalis* to establish amongst unsprayed *N. trichotoma* needs further investigation. Burning assisted the establishment of aerially sown *E. viminalis* by removing the horizontal mass of dead tussock leaves that occurred on the soil surface of unburnt treatments.

The best method of establishment was planting seedlings. However, the establishment achieved by direct drilling and aerial seeding of *E. viminalis* exceeded the recommended density of trees necessary for weed control (one *P. radiata* per 10 m^2, Hans Porada, State Forests of NSW, personal communication) and for ground water recharge and agroforestry timberbelts/shelterbelts (1 m^{-2}, Bird *et al.* 1990).

Of the species used here, only *E. viminalis* established well enough and grew sufficiently quickly to be considered for sowing by direct drilling or aerially seeding. Further research is needed to examine the establishment ability of other eucalypts and to reduce the costs of establishment by minimizing herbicide, fertilizer and seed inputs. For *P. radiata* and *C. cunninghamiana* to establish successfully from aerial sowing and direct drilling methods are needed to introduce, respectively, mycorrhiza and *Frankia* with the seed at sowing. In addition, for planted seedlings of *C. cunninghamiana* to establish successfully it will be necessary to sow them with *Frankia* already established on their roots.

ACKNOWLEDGMENTS

This research was funded by the Rural Industries Research and Development Corporation.

REFERENCES

Bird, R., Cumming, K.N. and Kearney, G.A. (1990). Research in direct seeding of trees in the 500–800 mm rainfall zone of western Victoria. Proceeding Direct Seeding and Natural Regeneration Conference, Department of Agriculture and Rural Affairs, Victoria, pp. 65-74.

Campbell, M.H. (1963). Establishment of pasture species on unploughed ground. Proceedings 3rd Australian Grasslands Conference, Warburton, Victoria, Paper 4-3.

Campbell, M.H. and Swain, F.G. (1973a). Effect of strength, tilth and heterogeneity of the soil surface on radicle-entry of surface sown seeds. *Journal British Grassland Society* 28, 41-50.

Campbell, M.H. and Swain, F.G. (1973b). Factors causing losses during the establishment of surface-sown pastures. *Journal Range Management* 26, 355-9.

Campbell, M.H., Watson, R.W. and Vere, D.T. (1996). Pasture establishment using aerial techniques. NSW Agriculture Agfact P2.2.2.

Vere, D.T., Auld, B.A. and Campbell, M.H. (1993). Economic assessments of serrated tussock as a pasture weed, *Weed Technology* 7, 776-81.