PART III

RE-ESTABLISHMENT OF EUCALYPTS: PLANTATION ESTABLISHMENT

Mass tree planting at Malpas Dam - the water supply reservoir for Armidale - by the Armidale Tree Group Inc. in 1987, and monitored as part of this study.

Chapter 9

Direct Seeding

9.1 Literature Review

Direct sowing of native trees and shrubs has been extensively used by the mining industry to revegetate old mine workings (Middleton, 1980; Glossop, 1982; Gardner, 1985; Langkamp and Plaisted, 1987a,b; Brooks, 1987; Gunness and Lawrie, 1987; Connolly, 1987). Indeed in 1982–83 a total of 3 tonnes of native plant seed was used by the mining industry in revegetation of mines (Langkamp and Plaisted, 1987a). Many forestry departments also use it extensively to revegetate after logging.

Direct seeding has great potential as a technique to revegetate cleared agricultural land and eroded areas, where natural regeneration is not possible. It has the advantage over the planting of containerized seedlings of being potentially very cheap – eg. 2.4c per tree (Wells, 1981); 1.5% of planting costs (Weatherly, 1985) – and has been used extensively in parts of Victoria, Western Australia and South Australia (Venning, 1985b).

To date only limited success has been achieved in the harsher tableland environments. Prior to my study direct seeding had not been tried on the Northern Tablelands as far as is known. Certainly there are no published reports. The most thorough reviews on this topic are in Langkamp (1987b), Venning (1985b) and Venning (1988).[1]

Seed Sources

Seeds can be bought from a number of seed merchants, including some forestry services (C.S.I.R.O., ca 1983; Temple and Bungey, 1980). However seeds of eucalypts, acacias and other species suitable for direct sowing are easy to collect (Wrigley and Fagg, 1978; Kabay and Lewis, 1987; Langkamp and Plaisted, 1987b) and most direct sowers collect their own seed from their local area. This has the advantage of coming from genotypes adapted to the area to be sown (Temple and Bungey, 1980; Weatherly, 1984; Department of Conservation, Forestry and Lands, ca. 1986[2]).

Seed Treatment

Most eucalypts require no seed treatment to germinate (Chapter 7). This is also the case for other members of the Myrtaceae, Proteaceae, Pittosporaceae and many other species which are

[1] Because seeding commonly use species other than eucalypts, and because many of my trials included acacias and other species, this review includes information on species other than eucalypts.

[2] Hereon the Department of Conservation, Forests and Lands will be abbreviated to Dept. C.F. & L.

used for direct seeding (Petersen, 1987; Fox *et al.*, 1987; Langkamp and Plaisted, 1987; Turnbull and Doran, 1987a,b). Most leguminous plants such as wattles, and members of the Fabaceae, however, have hard seeds which must be treated in some way to break the coats (Petersen, 1987; Cavanagh, 1987). Methods include: putting seeds into near boiling water and allowing it to cool overnight; putting seeds into boiling water for a short period, withdrawing and then cooling (Clemens, 1984; Clemens *et al.*, 1977); putting seeds into a microwave oven for 160 seconds without a water load or 210–240 seconds with a 50cc water load (Cavanagh and Tran, 1980); manually chipping or abrading the seeds (Clemens *et al.*, 1977); washing the seeds in organic solvents, acids, alkalis, or alcohol; or by sowing green seed. Species respond differently to different techniques (Clemens *et al.*, 1977; Cavanagh, 1987).

Many of the forestry operations and others, have found that coating eucalypt seeds with kaolin clay, fertilizer and in some cases insecticide and fungicide, to form small pellets has greatly increased seedling establishment from broadcast seed and so use this technique extensively (Cremer, 1966b; Forests Commission of Victoria, 1977; Schuster, 1980; Annels, 1980; Middleton, 1980; Weatherly, 1984; Sharp, 1985; Wells, 1985), although success is by no means universal (Beswick and Moran, 1985).

Moisture holding hydrogels (deliquescent substances) are also used in pellets although with mixed success (Sharp, 1985; Wells, 1985; Grewar, 1985; Beswick and Moran, 1985). Weatherly (1985) reported that a combination of hydrogel and/or nutrient combinations derived from Leffingwell neutral spray-dried wettable nutrient powders gave good results for some species. A standard pelleting technique for all situations may not be possible and experimentation for each situation may be necessary (Wells, 1985).

Hydromulching involves mixing seed with a slurry of wood fibre, fertilizer and water, and spraying it onto the soil with a high pressure hose (Temple and Bungey, 1980; Middleton, 1980; Clemens, 1984).

Insecticide application to seed is sometimes recommended as it allows greater seed survival by reducing the effects of predators (Cremer, 1966b; Christensen and Schuster, 1979) but this is probably unnecessary when seeds are buried. Fungicide additions can decrease germination (Christensen and Schuster, 1979).

Seedbed Preparation

Just as it is essential for competing vegetation to be absent for good seedling establishment in natural seedling recruitment (Chapter 8), a good seed bed has to be prepared for successful direct seeding. There are many ways of achieving a weed free seed bed and which one is chosen will depend on the site itself and what is growing there already, the erosion potential, as well as the available technology.

Most forestry operations burn the site before sowing (eg. Floyd, 1960; Dexter, 1967; Manderson, 1985) which has the added benefit of converting existing vegetation into a nutrient-rich ash and may improve surface porosity. A suitable time for burning has to be chosen when sufficient dry fuel is available but when bushfire risk is minimal. This time will vary for different areas and sites. Whilst burning is often successful in native forest it is often unsuccessful in improved or natural pasture as it can encourage many annual weeds. In many mining operations also, weed control is not a problem as the soil is often left gravelly (or sandy) and relatively weed free (see references above). In such cases sowing is usually done following cultivation, or ripping or scarifying (eg. Glossop, 1982).

Ground preparation in native pastures, as with native forests, often presents few weed problems and in the 1890s to 1920s in south-west Victoria huge plantations of sugar gums were sown into areas which had been ploughed with mouldboard ploughs (Jamieson, 1947). In the sandy country of the Western Australian wheat belt great success has been obtained with cultivation. Grewar (1985) sowed native trees and shrubs in much the same way as he sowed wheat. That is, he cultivated in summer, left fallow for 8 months, reploughed and raked, and sowed in August-September through his combine, after his crops were sown. The seed was bulked with Agros fertilizer and harrows or a chain dragged behind the combine to cover the seed. A similar technique is described by Edmiston (1985) in parts of south west W.A., in newly cleared country which was burnt, cultivated, ripped (if the soil was heavy) and sown with a combine, the seed also being mixed with fertilizer.

With the advent of mass fertilizer application and the associated exotic pasture and weed species, direct seeding as a technique for plantation establishment on Australian farms, except as described above, virtually ceased until recent times when many new techniques developed. Site preparation for direct seeding these days usually incorporates removal of the top soil completely by grading, certain cultivation techniques or the use of knockdown or residual herbicides.

Removing topsoil by grading has been successful in some places, as weeds and their seeds are removed completely (eg. Chatfield tree planter; Venning and Croft, 1984; 1985; Venning, 1986; 1988). It is best when combined with chisel ploughing or ripping, which break up the hard surface left by the grader blade. Harrowing before and after sowing has also proved successful. A variation on grading a strip is niche seeding where a 1 m diameter depression is scooped out and seeds are spot sown (see below; Venning, 1988). Grading has its detractors, who cite erosion problems and poor seedling growth due to top soil removal as possible disadvantages (Marriot ca, 1987).

Herbicides are also used to avoid weed growth following cultivation (Venning and Croft, 1984; Venning, 1986; 1988). Cultivation using a mouldboard plough after first spraying with a knockdown herbicide has been successful in south western Victoria (Marriot ca, 1987; Potter Farmland Plan - Table 9.1). This plough turns the soil and buries weed seeds to a depth from which they have difficulty germinating. The Kimberley Seeds Contour Seeder (see below) cultivates in such a way that the top soil is removed and is used in conjunction with herbicides (de Salis, 1985).

The Dept. C.F. & L. (ca. 1986) recommends cultivation in the previous autumn for spring sowing and any weed germination be killed with a systemic knockdown herbicide (eg. glyphosate - Roundup) and/or a subsequent cultivation just prior to sowing. A similar technique is used in

Western Australian roadside revegetation programs. Roundup is sprayed in autumn (3 L/ha) following good rain and weed germination. The site is cultivated 2–4 weeks later with a 3 point-linkage disc plough, harrowed, and then sown with a sod seeder and lightly harrowed to bury the seed. Cultivation has been deleted in sandy soils, and metal drags or rollers have been substituted for harrows to prevent seed being buried too deeply (Beswick and Moran, 1985).

In the vast sowings by the Main Roads Department in the Albany district (W.A.) four techniques are used. On gravel side tracks where gravel has been spread for a side road, the area is chisel ploughed and sown, with excellent results. Roundup is sprayed in May after maximum autumn germination of weeds, chisel ploughed in early June and sown. Fusilade over-sprayed in mid September gives a good kill of annual grasses. In some places they scalp and chisel plough as a pre-treatment. In cuttings, coarse gravel is spread over the top, cultivated with spiked harrows dragged by hand or tractor, and the seed broadcast (Max Hordacre, 1989 pers. comm.).

The use of knockdown herbicides has been used extensively in south west Victoria (Sharp, 1985). Commonly Roundup (or Sprayseed or Tryquat) is sprayed in the autumn and spring before sowing (Table 9.1). Some add a further spray in the spring one year before sowing as well (eg. Bill Weatherly Table 9.1). These techniques have worked well but re-invasion of weeds sometime causes problems (Brown, 1985; Venning, 1988).

Knockdown herbicides have also been combined successfully with residual ones. The Department of Woods and Forests (1987) in S.A. recommend a combination of Roundup with a residual spray such as Oxyfluorfen (Goal), Propyzamide (Kerb), Oryzalen (Surflan), Propazine (Gesamil) or Simazine (Gesatop). These are sprayed in the same season as sowing (spring or autumn) or the Roundup can be sprayed in autumn with the residual to follow in spring just prior to sowing. They suggest that residual herbicides are only effective if sprayed on a site already made weed free by cultivation or herbicide. They also recommend that the herbicide contaminated soil be removed from where the seed is to be sown by making a furrow or trench using a furrow plough, grader blade steeply tilted, ripper with wings or a hoe. Weatherly (1985) also used Roundup in conjunction with the residual spray atrazine with good weed control and quite good germination.

The Department of Environment and Planning (S.A.) has also tested residual herbicides. In particular they have had success using the "Quinn method" which uses Vorox AA. This spray contains a knockdown (amitrole) and residual (atrazine) component. The site is sprayed at the break of the season at the low rate of 3 L per hectare. When the weeds are under control 3–4 weeks later the area is ripped in such a way that treated soil is put to one site and the seeds are then scattered along the trench (Venning and Croft, 1984; 1985; Venning, 1986; 1988). This technique was also used successfully by Brown (1985) who sowed along ripped trenches and pressed the seed in with tractor wheels. The Department of Environment and Planning also examined the use of pre-emergent sprays Triallate (Avadex) and Trifluralin (Treflan) applied after cultivation, and cultivation-seeding-harrowing followed by post-emergent application of Roundup - both without much success (Venning, 1986).

Table 9.1: Direct seeding strategies of eight successful direct seeders in Victoria. From Curtis and Reeve, (1988b)

	BILL SHARP	CHRIS LANG	BILL WEATHERLY (Western Tree seeder syndicate)	POTTER FARMLAND PLAN 1.	2.	3.
SITE PREPARATION SPRING			Roundup	Roundup		
AUTUMN		Deep rip (March Add gypsum in heavy clay. Disc and mound	Roundup	Deep rip	Cultivate	
WINTER	Roundup (July)	Harrows monthly				
SPRING	Roundup (early Sept)	Roundup + Simazine (Sept)	Round up Rips sometimes	Roundup (early spray) Mouldboard plough	Roundup twice 10 days apart	Residual sprays Vorax, Simazine
SOWING TIME	Late August - early Sept.	Sept/Oct.	Spring	Spring	Spring	Spring
SOWING RATE	?	?	100gm/km mixture of 60 native species and provenances	75gm/ha River red gum 650gm/ha Acacia melanoxulon	<—	<—
SOWING METHOD	Scratch soil with combine. Sprinkle seed on top. Harrows.	Wester Tree Seeder or handseeder. Compress seed with 4 wheeler if using handseeder.	Western Tree seed coated with fertilizer.	Sprinkle by hand. Cover by dragging hessian bag.	<—	Seed drill
POST SOWING MAINTENANCE	None	Roundup just before seedling emergence. Weed control in following autumn- atrazine, Simazine or Fusilade and for 2-3 years after sowing.	Little follow-up necessary. Some Fusilade used.	Little follow-up necessary, but have experimented with over spraying with Fusilade (effective if done early in July/Aug) and Roundup at 1l/ha (some scorching of trees and some losses - not recommended at this stage.		
SOILS	?	Lighter soils. Has less success in heavier soils.	Clay-loam on basalt.	Varying from clay-loam to sandy -loams on sedimentary parent material.		
MAIN WEEDS	Improved pasture - phalaris etc.	Phalaris, Yorkshire fog Capeweed Perennial rye Vulpia bromo ides.	Wimmera rye Capeweed Phalaris, Sorrel annuals.	Yorkshire fog Capeweed Sorrel	Phalaris Perennial Ryegrian Subclovers.	

Ripping, as an aid to root development, is recommended for clay soils in particular and can be used in conjunction with many of the above treatments (Dept. C.F. & L., ca. 1986).

Whatever technique is used for site preparation the best results will occur in soil which is crumbly and weed free (Floyd, 1960). Sites which are lightly or heavily covered with weeds, dry, stoney, compacted, waterlogged, or covered with litter will give poorer results (Floyd, 1960; Annels, 1980).

Sowing methods

Seed may be broadcast or spot sown by hand (Floyd, 1960) or sown mechanically. Spot sowing may involve shaking seed from a "pepper pot" or screw-top jar with holes punched into the lid and calibrated to give a certain number of seeds per shake (Floyd, 1961). This is quite a good method for smaller areas. Another method of spot (or niche) seeding is given by the Department of Environment and Planning (1984) where a spot is prepared first by removing weeds for a diameter of 1 m and dishing out, sowing the seeds at the bottom of the basin and mulching lightly.

Another form of niche seeding (sometimes called "glob seeding") is where a "glob" of seeds, nutrient and mulch (eg. vermiculite) is dropped into a small furrow, and in some cases over sprayed with black paint and vermiculite (Temple and Bungey, 1980; Runciman and Malcolm, 1985), the furrow sometimes having been made by special machinery which slightly raises it.

Divot seeding is a further variation, where pockets of a certain micro-climate are chosen and sown. Covering the spot with a small guard made from an upended foam cup, cut to provide a suitable micro-climate has been tried successfully in Tasmanian (David Bennett, 1988 pers. comm.).

To cover the seed it is common for seed to be a broadcast on a prepared bed and lightly raked in or for a hessian bag to be dragged over the site to bury the seed (Clemens, 1984).

Mechanical sowing has been successfully used in many areas, for example the Western Tree Seeder developed in western Victoria by a group of graziers. The ground is treated with Sprayseed, Roundup or Vorox AA prior to sowing. The machine has a ripping tyne with adjustable depth control, two contra-angled cutting discs, and a shield disc to avoid side throw of soil. This gives a one pass single row cultivation. Seed is dropped through a fluted roller seed feeder and is lightly covered (Weatherly, 1984; 1985). Another example is Chatfield's tree planter which grades the top soil away and drops seed into a furrow made by a ripping tyne. Seeding is done with planting in the same operation (Chatfields, 1989).

Kimberley Seeds Pty Ltd. has developed a range of seeders for arid land sowing (Kimberley Seeds, ca. 1983). The Kimseed pitter seeder creates water catchment pits and is used on flat ground in low rainfall areas. The Kimseed contour seeder consists of two opposed discs which till the soil into furrows and mounds, and a central ripper (de Salis, 1985). It effectively removes a layer of top soil 5 cm deep and 1 m wide mechanically. Additional weed control is done with herbicides and the site is double ripped with rips 0.5 - 1 m apart and 1 m deep. Seed is placed in precise spots with fertilizer, hydrogel and a mulch of vermiculite. A similar machine has been developed by Runciman and Malcolm (1985), which sprays black paint over each spot as well.

Such specialized machinery can be by-passed however, and many sowers simply use standard crop seeders (Wells, 1981 - Chisel seeder; Dept. C.F. & L., ca. 1986). For small areas a vegetable seeder can be pushed by hand (Curtis and Reeve, 1988b). Alternatively brush containing fruit of, for example *Melaleuca, Leptospermum* and *Eucalyptus* can be laid on a prepared surface. As the fruit open the seeds are released and seedlings can become established (McDonald, 1979).

Sowing rates

Sowing rates depend on the density of trees required and the species involved. The amount of seed to be sown can be estimated using the formula:

Weight of seed required (g) $= \frac{Number\ of\ plants\ required}{Number\ of\ seeds\ per\ gram\ x\ survival\ rate}$ (Dept. C.F. & L., ca. 1986)

Most eucalypts have 100–500 viable seeds per gram (Scott, 1972; Boland *et al.*, 1980). A survival rate of about 1% one year after sowing is fairly normal for eucalypts although higher values are possible (Floyd, 1960; Dexter, 1967; Temple and Bungey, 1980; Wells, 1981; Clemens, 1984). Acacia seeds are much larger (on average 30-70 seeds per gram) and tend to have higher survival rates - 5% being common (Temple and Bungey, 1980; Clemens, 1984). Seed weights are given for a large number of species from a range of families along with seed treatments required by Petersen (1987), Turnbull and Doran (1987b), Cavanagh (1987), and Fox *et al.* (1987).

To establish 600 trees per hectare (trees would then be 4 m apart), and assuming a 1%

Table 9.2: Example of sowing rates

Examples of sowing rate		
3-20kg/ha	-	commercial operators (Temple and Bungey, 1980)
8kg/ha	-	Albany Main Roads Department (Max Hordacre, 1989 pers.comm.)
1-3kg/ha	-	Venning, 1985; 1988)
0.5-1.5kg/ha	-	(Woods and Forests S.A., 1987)
650g /ha	-	*A. melanoxylon* (Marriot, ca. 1987)
75g /ha	-	*E. camaldulensis* (Marriot, ca. 1987)
135-150g /km	-	(Weatherly, 1985)
100g /km	-	(Bill Weatherly, 1987 pers. comm.)
20,000seeds/ha	-	Karri (Annels, 1980 - yielded more than 1200 stems per ha.)

survival rate, about 60,000 viable seeds would be required. In the case of *E. viminalis*, which has about 350 seeds per g, this would amount to 170 g of seed per hectare. Seed viability must be estimated (Petersen, 1987; Ch 7) and seed batches with low viability need to be sown at higher rates. In practice many people sow at higher rates (Table 9.2) and where conditions are not favourable for seedling survival, much higher rates of sowing are needed to obtain satisfactory results (Floyd, 1960).

Sowing Time

The time of sowing depends on local conditions. In Victoria, spring sowing is usually favoured as autumn germinants are often choked by weeds due to high winter rainfall (Weatherly, 1985; Sharp, 1985; Dept. C.F. & L., 1986).

In W.A. April/May sowings are favoured because they coincide with good rain (Christensen and Schuster, 1979; Annels, 1980; Hordacre, 1989 pers. comm.). In Sydney autumn sowing is recommended (Temple and Bungey, 1980). Autumn–early winter sowings are better than spring sowings in S.A. (Venning, 1986).

As mentioned above, no work had been done on sowing times for the Northern Tablelands. However, based on the conclusions of Chapter 8, it could be postulated that both spring and autumn sowings could be successful as long as there is above average rainfall, (ie. 100 mm) in the 4 week period after sowing, with good follow up rain in the first 3 months of seedling life. Establishment is favoured by prolonged periods of drizzle, cloud cover, and mild weather, rather than wet days followed by hot or dry weather (Section 8.3; Clemens, 1984). As pointed out by the Dept. C.F. & L. (ca. 1986) soil moisture either alone or by interaction with other factors is the main factor determining survival in the first 9–12 months.

Winter sowings may turn out to be suitable as seeds sown in winter would undergo natural stratification while lying in the soil. Grose (1965) suggests that stratification hastens the germination of many eucalypt seeds, even non-dormant ones. This more rapid germination would place seedlings at an advantage when soil temperatures increased in the spring. However the spring germination of weeds could be a problem.

Bulking Agents

Most seeders bulk the seed before sowing. Common bulking agents are dry sand, bran, dry sawdust, fertilizer (Sharp, 1985; Dept. C.F. & L., ca. 1986), chick crumbles (Marriot, ca. 1987), and rice hulls.

Sowing Depth

Most eucalypt seeds will not germinate from depths much greater than 20mm, with 4–10mm considered optimal for most species (Chapter 8). A good rule of thumb is to sow seed at a depth 2–3 times their diameter - ie. about 5–10mm. When sowing by hand this depth can be achieved by brushing the soil over the seed by hand, rake or hessian bag; for machine sowing a chain dragged behind each sowing tyne can achieve the same result (Dept. C.F. & L., ca. 1986). Trials reported by Venning (1988) found that seeds covered by harrowing had a higher level of germination than compacted or unburied seeds.

Post Sowing Treatments

Moisture retaining mulches applied after sowing can aid seedling establishment, particularly where moisture is critical, by modifying seed bed temperatures and preventing soil crusting. Mulches which have aided establishment in certain situations include: an emulsion of anionic-bitumen (Temple and Bungey, 1980; Clemens, 1984); straw (Temple and Bungey, 1980; Day and Ludeke, 1980; Clemens, 1984; Agar, 1984); chitter (Agar, 1984); hydromulching with a mixture of wood fibre, fertilizer and water (Temple and Bungey, 1980); sawdust (Free, 1951); coarse sand (Venning and Croft, 1984); vermiculite (de Salis, 1985; Runciman and Malcolm, 1985); and woodchips (Subsection 8.3). Austrasorb was tried without success by Agar (1984). Species respond differently to different types of mulch and small seeded species, in particular, can have difficulty penetrating a thick mulch (Agar, 1984; Clemens, 1984).

Irrigation improves seedling establishment, particularly in the early stages of growth. If used, it should be gradually reduced to harden seedlings rather than being cut off suddenly (Clemens, 1984). It is virtually never used in direct seeding in the field - rather seeding is timed to coincide with good soil moisture.

In some mining rehabilitation a nurse crop of a fast growing grass is often included in the seed mix to give rapid erosion control - often a sterile hybrid is used or an annual exotic grass. Excessive competition from the nurse species can result and some authors advise against this practice (Temple and Bungey, 1980; Clemens, 1984).

Control of weeds is necessary for good establishment. Where the pretreatment is good no followup is usually necessary. However if invasion of weeds do occur selective sprays such as Fluazifop (Fusilade) which kills grass and not broad leaf species, or non-selective knockdown sprays such as glyphosate (Roundup) are used (Venning and Croft, 1985; Dept. C.F. & L., ca. 1986). In the latter type protection of the seedlings is vital.

McMurray (1985) sprayed five herbicides over native (including eucalypt) seedlings 9–10 weeks after germination. All the herbicides are translocated and used to kill grass seedlings. Sertin and Fusilade were not toxic to native seedlings at the recommended rates but became toxic at higher rates and were persistent in the soil for up to 8 weeks. Hoegrass, 2,2-DPA and Treflan all showed toxicity to the native seedlings.

Fertilizer

Few direct seeders of native species use fertilizer. Quick release fertilizers release their nutrients before the seedling roots are down, and if stored with the seed for a long time reduce seed viability (Dept. C.F. & L., ca. 1986). It is likely such fertilizer application would benefit weeds more than the young tree seedlings.

Croft and Venning (1985) examined the nutrient susceptibilities of seedlings of a range of common South Australian *Eucalyptus, Acacia, Melaleuca, Callistemon, Leptospermum, Hakea, Cassia, Casuarina* and *Dodonaea* species. High phosphorus levels adversely affected germination of some species while high nitrogen levels favoured germination and growth rates. For most species root length was not significantly influenced by levels of phosphorus, but was promoted by high levels of nitrogen. On the basis of the trial, they deduced that nutrient levels common in South Australian agricultural soils would only limit seedling growth where an imbalance occurred and that the changes in nutrient status that have followed land clearance and agricultural development were not an impediment to direct seeding of native trees and shrubs. Fertilizer is actually added to the seed by some sowers (Grewar, 1985; Weatherly, 1985; Edmiston, 1985).

Direct seeding is a less predictable method of tree establishment than tree planting and although cheaper, the chances of failure are greater (Leggate, 1980). Commonest problems are low rainfall following seeding, and weed growth. Even when sowing is successful, plants are often irregularly spaced or clumped (Dept. C.F. & L., ca. 1986). This is one of the appeals of seeding, although such clumping may not always be desirable - eg. in a windbreak. The density of seedlings is often greater and over time the stands self thin as weaker individuals die. There is also the advantage that seeded trees can develop a better root system and do not suffer transplant shock (Weatherly, 1985; Dept. C.F. & L., 1986).

Twenty seeding trials were established from 1985 to 1987 testing a wide range of soil preparation and sowing methods, sowing rates and times, and some post sowing treatments. Because direct sowing was a completely new tree establishment technique for the Northern Tablelands when this study began, a large number of techniques were tried over many sites with little replication at first. As techniques became refined, replicated trials were established. The large amount of variation among treatments without replication made statistical analysis for many of the trials impossible. However considering the stage at which this research was, it was considered more helpful to try as many techniques as possible initially and then to test a few in replicated designs.

9.2 Methods

Species and Provenance

Thirteen species of eucalypts, five acacias, two *Leptospermum*, two *Casuarina* and one *Angophora* species were sown in the course of the trials. Species other than eucalypts were sown for comparisons of growth and survival. Virtually all the species were native to the area and most of the seed came from within 20km of the individual sites, if not the sites themselves.

Viability Tests

Numbers of viable seed per gram were tested for each seed lot using the method described in Section 7.5 (see Appendix VIII).

Seed Treatment

Acacia seeds were held in boiling water in a sieve for 10-20 seconds to break the seed coat and then withdrawn. Usually they were sown immediately but sometimes were dried and sown some time later. No treatment was used for any other species.

Site Preparation

Site preparation techniques were the major factor examined in the trials. Grading was done using front mounted grader blades on tractors, a type which was dragged behind the tractor, or a bulldozer. In some trials a rip line was run down the middle of the graded area or the area was chisel ploughed (Plates 9.3 - 9.8). Cultivation techniques involved several runs using discs or chisel ploughs in the six months prior to sowing. A ripping tyne fitted with a mulching blade was used at one site (Plate 9.10). Burning was used only once. The dry grass sward was ignited in October the day before sowing (Plate 9.16). The contact herbicides Roundup and Gramoxone were used; the site was usually sprayed twice before sowing (Plates 9.11, 9.13, 9.15). The residual herbicide Atrazine was used in one trial in combination with Roundup (Plate 9.15).

Sowing Methods

The sowing methods used were: sowing by hand (sprinkling seed along the rip line and covering lightly by hand, foot or hessian bag); spot sowing (also by hand - using a jar with holes in the lid, calibrated to give a certain number of seeds per spot); using the Williams' family direct seeding implement (Plate 9.1); Duncan 734 multiseeder, Gyral air seeder; Begg sod seeder.

Bulking Agents

The seed was bulked with dry sawdust, rice hulls, coarse sand, laying mash - Plate 9.2 (sometimes called chick crumbles), bran mixed with wheat or nothing. In one trial the water absorbent compound Terrasorb plus the insecticide Diazanone were added.

Sowing Rates

Sowing rates varied from 11-800 seeds per metre of row, equivalent to .02-3 grams of viable seed per metre.

Sowing Times

Most trials were sown in spring (ie. October), with some in early spring (September), late spring (November), late autumn (May), and winter (July or August).

Mulches

In some of the spot sowing trials various mulches were tested: sawdust plus Nutricote, woodchips, vermiculite, black paint, gravel, 50% shade cloth.

Weeding and Follow up Maintenance

In many of the trials no weeding was ever done. Various methods were used at others including: hand weeding, spot spraying with Roundup or using a shielded sprayer, over-spraying with Fusilade, mowing the grass on either side of the sown line (in one case this was followed up by wiping the weeds with Roundup using a squeegee mop). No insect control was done in any experiment. All experiments were protected from stock but not hares or rabbits.

Monitoring

Seedlings were monitored 1 to 3 times each year. Seedling numbers, heights, and reason for death (if discernible) were recorded as was the state of weed growth.

For each species the average number of seedlings per metre sown was estimated by dividing the total seedling number by the total length sown. The percentage survival of viable seed sown of each species was then calculated:

$$\text{Percentage survival} = \frac{Seedling\ number\ per\ metre}{Viable\ seed\ per\ metre}\ x\ \frac{100}{1}$$

Results were then graphed and tabulated. Details of each individual sowing are presented in Appendix IX except for those presented in Table 9.4 and 9.5.

9.3 Results

9.3.1 Site Preparation

The consistently most successful soil preparation technique was grading the topsoil in combination with ripping or chisel ploughing (Table 9.3).

In the Ruby Hills 1986 sowing, grading and chisel ploughing the surface gave spectacular results with a 60% strike of *A. dealbata* and 20% strike of the eucalypts 8 months after sowing (Fig 9.1). This dropped to 50% for *A. dealbata* and 10% for the eucalypts 18 months after sowing (Plates 9.4, 9.5). At other sites where grading was used, results were also good although perhaps not quite as spectacular.

In the Eastlake 1987 sowings, when totalled over all graded plots, *A. filicifolia* had 44% survival at site 1 and 39% survival at site 2, 22 months after sowing, compared with Roundup plus Atrazine – 4% (Site 1) and 32% (site 2), and Roundup plus Gramoxone – 10% (Site 1) and 41% (Site 2). In the Birrahlee 1986 sowing *A. dealbata* had 7.5% survival in the graded plot 18 months after sowing compared with 4.5% survival in the Roundup plot – this despite an initially higher strike rate in the herbicided plot (Fig 9.1).

The reason for the good performance of the graded treatments was the superior weed control - weeds did not reinvade sites for over a year and were not particularly competitive 2 and even 3 years after sowing.

Grading failed without some kind of disturbance of the soil. At Petali the surface was not ripped or cultivated and remained quite smooth and impenetrable to seedlings, resulting in zero germination (Plate 9.8). Similarly at Miramoona (1987) the central rip was too shallow, due to the implements used, and the soil surfaces remained quite hard. This was exacerbated as the surface baked in the sun.

Cultivation treatments performed poorly throughout the trials, even when the ground was worked four times and the soil had an excellent tilth (Table 9.3). The main reason for failure was the vigorous growth of weeds encouraged by the cultivation. At the Salisbury Court 1985 sowing, for example, initial germination of the acacias and eucalypts was quite good, particularly when spot sown (15% *A. baileyana* and 1% eucalypts, 5 months after sowing). This dropped to only 0.1% survival for the acacia and eucalypts 30 months after sowing because of competition from annual grasses and some dry weather. The same thing happened at that site in the 1986 sowing although initial germination was not as high. At Miramoona (1987 sowing) no germinants were ever found in the cultivated plots due to weed growth although at that sowing neither the graded nor the herbicide treatments did particularly well either (Table 9.4). The problem of weed growth in cultivated areas did not seem to be improved by mulches but was improved using herbicide (see below).

In the Belhaven trials a single tyned ripper was fitted with a mulching blade. This technique, used in native pasture, showed some promise, with a weed free zone being created near the seedlings for up to a year and survival rates of up to 1% for acacias being achieved. One of the main reasons for the failure at this site was possibly the species and provenances chosen, not the technique itself (Table 9.3).

The contact herbicide treatments gave some good results, (although not as good as grading) and were fairly consistent over different sites and seasons. In the 1986 sowings at Eastlake, Birrahlee and Yalgoo where Roundup was applied twice (once in autumn or winter, and once in spring shortly before sowing) acacia survival was 2–4% 1-2 years after sowing although eucalypt survival was not particularly good (0–0.2%) (Fig 9.1, Table 9.3). In the 1987 sowings at Eastlake (Table 9.4) where Roundup was sprayed in May and Gramoxone in spring, acacia germination was very good (10% at site 1, 41% at site 2 – 22 months after sowing), although again the eucalypts were low (only 0.03% at site 1 and 0.09% at site 2).

The main problem using contact herbicides was reinvasion of weeds in late spring - early summer (Plates 9.14, 9.15). This reinvasion had to be controlled to get success otherwise seedlings were completely swamped by thistle or grass growth. In the 1985 sowings when Roundup was used once or even twice, and when the seed was broadcast over a large area (Table 9.3 - Birrahlee, Yalgoo, Ruby Hills), failure was total as reinvasion of weeds made finding seedlings impossible. Thus the herbicide treatment, as with other treatments, seems to be best when seeds were sown in well defined rows (see below).

In the 1987 sowings at Eastlake and Miramoona, Roundup was combined with the use of the residual herbicide Atrazine. At Eastlake Roundup was sprayed in May and Atrazine in June; at Miramoona Roundup + Atrazine were sprayed in May and Roundup in October, two weeks before sowing (Table 9.4). At Eastlake the technique worked very well at site 2 with 32% survival of *A. filicifolia* 22 months after sowing. At site 1 it was less successful (3.9% for the acacia) possibly because of reinvasion of weeds or toxicity problems due to it having a lighter soil. Eucalypts responded at site 2 with a 0.13% germination after 22 months but not at site 1 (only 0.02%). Weed control was better in the Atrazine plots initially than in the plots which only had the contact herbicide Gramoxone and this was reflected in slightly better survival early on, although later these differences were not apparent (Plate 9.15, Table 9.4, Fig 9.1). At site 2 the Atrazine treatment had higher germination initially than grading. Here the graded plots baked in the sun reducing germination, while the Atrazine plots had a mulch of dead grass which seemed to aid seedling recruitment. After two years however the graded treatment had better results, possibly because of better long term weed control. At site 1 which was more gravelly, baking of the graded surface did not occur and seedling survival was better than Atrazined plots from the outset and was maintained over the two years of monitoring (Fig 9.1). The weed control in the Atrazine plots lasted until the end of the summer while the Gramoxone plots were rapidly reinvaded with weeds and the graded plots had good weed control for over two years.

At Miramoona the eucalypts had a 0.1% survival in the Atrazine treatment six months after sowing when meaned over all replications. This compared with 0.02% for graded and 0% for cultivated. No treatment was particularly good. No toxicity effects were evident from the residual herbicide. The furrows made from the sowing implements seemed to be sufficient for avoiding contact with the seed.

The burning trial at Europambela in 1986 (Plate 9.16) was disappointing as a virtual carpet of thistle (*Cirsium vulgare*) germination encouraged by the absence of vegetation after the fire swamped all but a few acacias and resulted in only 0.15% survival of *A. filicifolia* 17 months after sowing and no eucalypts (Table 9.3).

9.3.2 Sowing Methods

Results were best when the seeds were sown along clearly defined and marked rows. Follow up monitoring and maintenance was consequently easy. Where seeds were broadcast over a large area (in my trials this was done using conventional seeders) failure was total. In the trials where this method was used (Ruby Hills , Birrahlee and Yalgoo 1985, Table 9.3) the sites were boom sprayed twice with Roundup before sowing (except Birrahlee which was sprayed only the once). Weed reinvasion was swift. This, added to the very low sowing rates, made finding germinants impossibe and weeding impractible.

Sowing along rows made by a single tyned ripper (Plates 9.6, 9.13) or with a seeder with most of the outlets blocked leaving only 2–3 tynes (eg. Yalgoo 1986 – Plate 9.11) worked, as indeed did sowing along one furrow of a multi-rowed chisel ploughed area (eg. Ruby Hills 1986, 1987 – Plate 9.3). In small areas sowing by hand and covering the seed by hand, rake, or hessian bag was quite adequate, and more efficient than using a machine - even in rows several hundred metres long.

The Williams' sowing machine (Plate 9.1) performed well. In the first year sowing rates were too low and weed control inadequate - a dense weed growth grew directly in the row and 10cm either side, so although weed control was good further out, the immediate environment of the seedlings was unfavourable. In the 1987 sowings these problems were remedied and survival rates were much improved (Fig 9.1).

Table 9.3: Survival rates of all species sown over all sowing trials $1\frac{1}{2}$ –2 years after sowing. Full details of each trial are presented in Appendix IX.

	% GERMINATION GRADED									CULTIVATED							HERBICIDE										
Species	Petali 1986	Ruby Hills 1986	+ Ruby Hills 1987	Europambela 1984 (line sowing)	Europambela 1985 (spot sowing)	Birrahlee 1986	+ Miramoona 1987	+ Eastlake 1987 Site 1	+ Eastlake 1987 Site 2	Salisbury 1985	Salisbury 1986	Belhaven 1985	Belhaven 1985	Belhaven 1986 May	Belhaven 1986 Aug.	+ Miramoona 1987	Yalgoo 1986	Eastlake 1986	Birrahlee 1986	+ Miramoona 1987	+ Eastlake Site 1 Gramoxone	+ Eastlake Site 2 Gramoxone	+ Eastlake Site 1 Atrazine	+ Eastlake Site 2 Atrazine	Birrahlee 1985	Ruby Hills 1985	Yalgoo 1985
Acacia baileyana										.06																	0
Acacia dealbata		49	31	√		7.3						.03							4.4						0	0	
Acacia filicifolia				√	√			44	40		.44		1.0	1.0	0.4		2.6	1.5			10	41	4	32			
Acacia fimbriata													0.6	0.8	0.3												
Acacia melanoxylon												0	0	0	0												
Angophora floribunda						0				0									0						0		
Casuarina cunninghamiana				0	0							0															
Casuarina littoralis				0	0			0	0									0			0	0	0	0			
Eucalyptus blakelyi	0			0			.02			.03	.006		0	0	0	0				.05							0
Eucalyptus caliginosa		12	4					0.2*	.1 *				0	0	0						0*	.2*	0*	.2*		0	
Eucalyptus globulus bicostata					0																						
Eucalyptus laevopinea	0			0	0		0	0.4*	.16*							0		.09		.3	0*	.1*	.2*	.2*			
Eucalyptus melliodora										.28		.08															
Eucalyptus nicholii								0.1	.03												0	.03	0	.03			
Eucalyptus nova-anglica					0																						
Eucalyptus obliqua													0	0	0												
Eucalyptus pauciflora				√	0			.07	.03		0						.07				0	0	0	.25			
Eucalyptus radiata		9	0.7		0			.04	.02								0	.02			0	.02	0	.03	0	0	
Eucalyptus stellulata				0		0											0		0						0	0	0
Eucalyptus viminalis						.16	.04	.4§	.06§		.09					0			0.3	.1	.06§	.14§	.04§	.19§			
Eucalyptus youmannii			0.3																								
Leptospermum brevipes				0	0	0													0						0		
Leptospermum flavescens												0	0	0	0												0
‡Total	0	28	3.3	√	√	.4	.02	.5	.3	.08	.05	.01	.008	.08	.03	0	.42	.25	0.3	0.08	.08	.29	.04	.29	0	0	0

√ - establishment occurred; insufficient information to estimate % survival.
* - combined *E. caliginosa* - *E. laevopinea* count.
\+ - survival rates after 7-9 months.
§ - combined *E. viminalis* - *E. dalrympleana* count.
‡ - Total is estimated by the $\frac{\text{Total number of seedlings per m}}{\text{Total seed sown per m}} \times \frac{100}{1}$

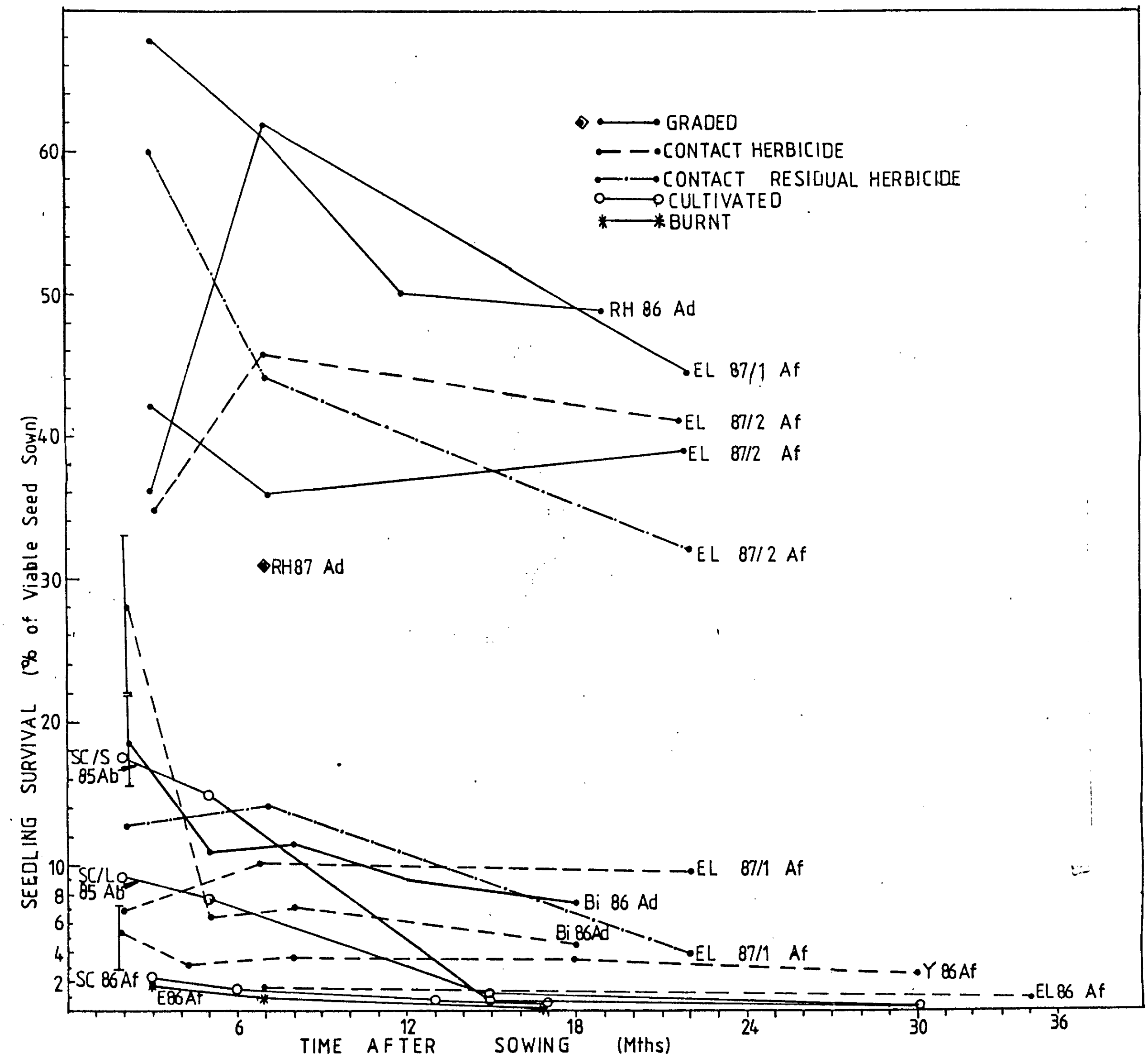

Figure 9.1: Survival of *Acacia* seedlings, over time from a selection of direct sowing trials. Ab = *Acacia baileyana*; Ad = *A. dealbata*; Af = *A. filicifolia*.EL 86 = Eastlake 1986 sowing; EL 87/1 and EL 87/2 = Eastlake 1987 sowings, sites 1 and 2; RH 86 and RH 87 = Ruby Hills sowings 1986 and 1987; Bi 86 = Birrahlee 1986 sowing; SC 85 and SC 86 = Salisbury Court 1985 and 1986 sowings; Y 86 = Yalgoo 1986 sowing; E86 = Europambela 1986 sowing.

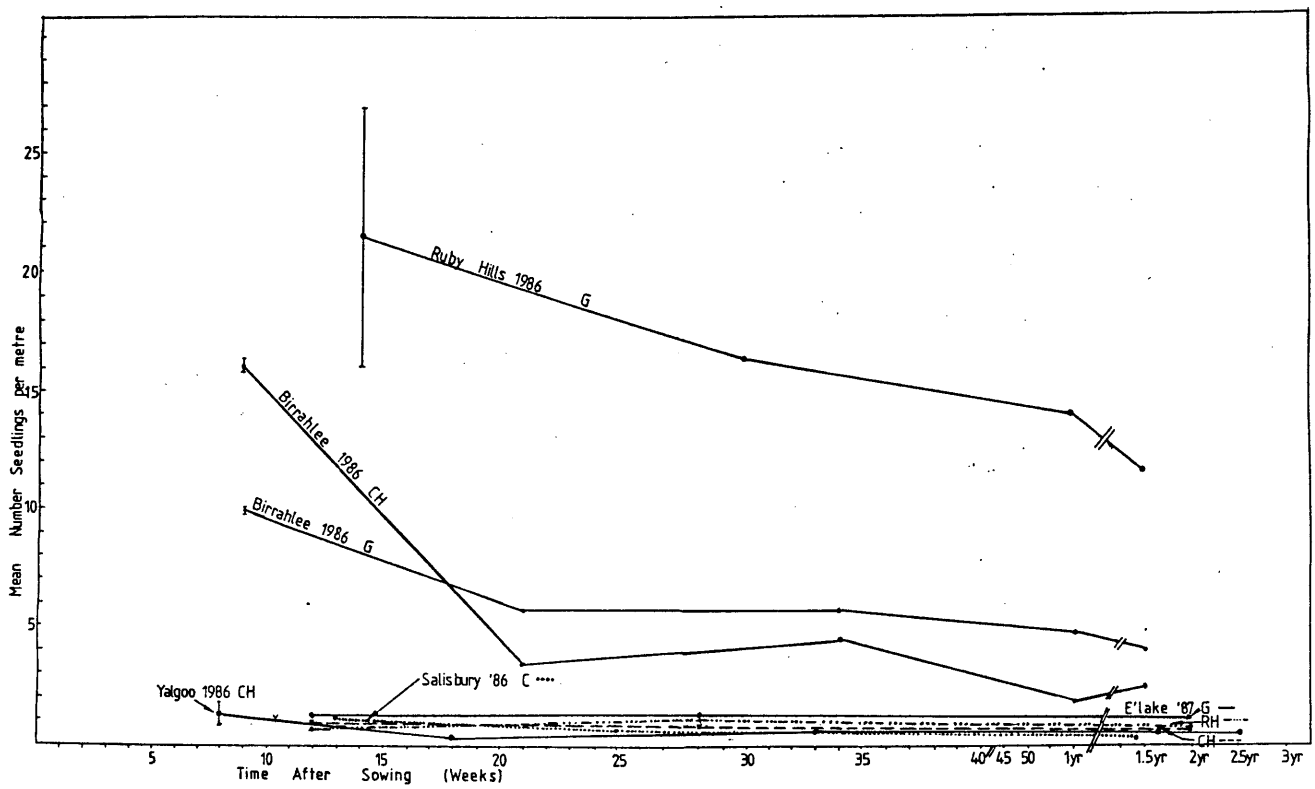

Figure 9.2: Seedling density: Direct Sowing Trials. Total seedlings per metre (over all species) for selected sites. G = Graded; CH = contact (knockdown) herbicide; C = cultivated; RH = residual herbicide.

Table 9.4: Sowing Trials: Comparisons between Graded and Herbicide Treatments

Site: Birrahlee (2a) - Improved pasture Sown: 7.10.1986

Preparation: 1. Graded using bulldozer; single ripline down middle, 75m x 3m.
2. Roundup in June and October, strip sprayed along rip line 60m x 2m.

Sowing: By hand. Sprinkled along ripline.

Bulked with: 10 L sawdust and fine gravel, mixed 3:1. Area: 70 x 5 = 350m² Total length: 135m

Species and Provenance	Sowing Rate g/m	Sowing Rate seed/m	GRADED 5 Months after sowing seed-lings/m	GRADED 5 Months after sowing % survival	GRADED 18 Months after sowing seed-lings/m	GRADED 18 Months after sowing % survival	GRADED mean ht.(m)	HERBICIDE 5 Months after sowing seed-lings/m	HERBICIDE 5 Months after sowing % survival	HERBICIDE 18 Months after sowing seed-lings/m	HERBICIDE 18 Months after sowing % survival	HERBICIDE mean ht.(m)
A. dealbata (Walcha 1986)	0.7	53	5.4	10.1	3.9	7.3	1.6	3.9	7.4	2.3	4.4	0.6
Angophora floribunda (Birrhalee 1985)	1.4	1.1	0	0	0	0	-	0	0	0	0	-
E. stellulata (Birrhalee 1985)	0.2	17.4	0	0	0	0	-	0	0	0	0	-
E. viminalis (Birrhalee 1985)	0.3	33.0	0.05	0.16	0.05	0.16	0.3	0.1	0.3	0.1	0.3	0.3
Leptospermum brevipes (Birrhalee 1985)	0.2	832	0	0	0	0	-	0	0	0	0	-
Total Eucalypt	0.5	50.3	0.05	0.11	0.05	0.11		0.1	0.2	0.1	0.2	
TOTAL	3.2	936	5.5	0.6	4.0	0.4		4.1	0.4	2.5	0.3	

Table 9.4 continued on next page.

Table 9.4 continued.

Site: Miramoona (6a) - Improved pasture. Sown: 14.10.1987

Preparation:
1. Graded strip 2m wide with single chisel plough down middle.
2. Ploughed with discs in April, May, June and October on day of sowing.
3. Herbicide Roundup 6 L/ha + Atrazine 4 L/ha - May; Roundup 4 L/ha October 2 weeks before sowing.

All rows ripped in May.
5 Replications of each treatment, randomly placed.

Sowing: By hand along ripline or (for ploughed treatment) down middle of plot. Covered lightly by hand.

Area: Total length:

Species and Provenance	Sowing Rate g/m	Sowing Rate seed/m	6 MONTHS AFTER SOWING: POOLED DATA OVER 5 REPLICATIONS — Graded seedlings/m	Graded % survival	Graded mean ht.(m)	Ploughed seedlings/m	Ploughed % survival	Ploughed mean ht.(m)	Herbicide seedlings/m	Herbicide % survival	Herbicide mean ht.(m)
E. blakelyi (Miramoona, Petali 1985)				0.02		0	0	-		0.05	
E. laevopinea (Miramoona 1987)				0		0	0	-		0.3	
E. viminalis (Miramoona 1987)				0.04		0	0	-		0.1	
TOTAL				0.02	0.25	0	0	-		0.08	0.3

Site: Eastlake (3c, 3d) - Natural pasture. Sown: 24.9.1987

Preparation: All plots slashed in March and sprayed with Roundup in May. Both sites had the same treatment.
1. Graded: strip 1.5m wide June or September.
2. Contact herbicide: Gramozone (2 L/ha) in September
3. Residual Herbicide: Atrazine (4 L/ha) in June.

Each treatment replicated, and randomly placed.

Sowing: Using G. Williams' sowing machine (Plate 10.1).

Bulked with: 2 L of laying mash. Area: Site 1 233 x 2m = 470m²; Site 2 342 x 2m = 684m²

Total length: 577m

Species and Provenance	Sowing rate g/m	Sowing rate seed/m	SITE 1: 22 MONTHS AFTER SOWING: POOLED OVER ALL REPLICATIONS — Graded seedlings/m	Graded % survival	Gramoxone seedlings/m	Gramoxone % survival	Atrazine seedlings/m	Atrazine % survival	Total per site seedlings/m	Total per site % survival
(all from Eastlake) Site 1										
A. filicifolia	0.24	1.8	0.8	44.3	0.17	9.5	0.07	3.9	0.36	20.2
Cas. littoralis	0.04	12.8	0	0	0	0	0	0	0	0
E. caliginosa / *E. laevopinea*	0.04 / 0.21	5.9 / 4.7	0.03*	0.24*	0*	0*	0*	0*	0.01*	0.08*
E. nicholii	0.13	69.4	0.08	0.11	0	0	0	0	0.03	0.04
E. pauciflora	0.14	17.6	0.01	0.07	0	0	0	0	0.004	0.02
E. radiata	0.35	66.2	0.03	0.04	0	0	0	0	0.01	0.01
E. viminalis + *E. dalrympleana*	0.29	168.5	0.72	0.43	0.11	0.06	0.07	0.04	0.31	0.18
Total Eucalypts	1.20	345	0.86	0.25	0.11	0.03	0.07	0.02	0.36	0.10
TOTAL	1.44	347	1.67	0.48	0.28	0.08	0.14	0.04	0.72	0.21
Site 2										
A. filicifolia	As above		0.7	39.2	0.73	41	0.58	32	0.68	37.7
C. littoralis			0	0	0	0	0	0	0	0
E. caliginosa / *E. laevopinea*			0.01	0.1	0.02	0.20	0.02	0.20	0.02	0.20
E. nicholii			0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.03
E. pauciflora			0.01	0.03	0	0	0.04	0.25	0.01	0.08
E. radiata			0.01	0.02	0.01	0.02	0.02	0.03	0.01	0.02
E. viminalis + *E. dalrympleana*			0.11	0.06	0.24	0.14	0.33	0.19	0.20	0.12
Total Eucalypts			0.16	0.05	0.30	0.09	0.43	0.13	0.27	0.08
TOTAL			0.87	0.25	1.0	0.29	1.0	0.29	0.95	0.27

* Combined *E. caliginosa* and *E. laevopinea* due to difficulty of separating these two species in early seedling stages. *E. viminalis* and *E. dalrympleana* seed was mixed together accidentally so these two species are amalgamated.

Spot sowing was compared with line sowing in the Salisbury Court 1985 sowing (Fig 9.1). Although spot sowing doubled germination of acacia seed initially, after 2 years no difference could be detected between the two methods. With eucalypt seed no difference was evident at any time in the trial. Spot sowing was also used in the graded and burnt trials at Europambela (Table 9.3), where limited success was achieved. However spot sowing tended to give a less even distribution of seedlings than line sowing. If, as often happened, some spots had no germination large gaps appeared in the row whereas in line sowing, seeds were scattered fairly evenly along a row – and subsequent seedlings were also.

Standard seeding implements seemed to be adequate for sowing native seed. Because the seed has to be sown no deeper than 10mm (Chapter 8) it is important the implement used does not bury the seed any deeper – this was particularly critical for eucalypts, not so for acacias - and may have accounted for low eucalypt germination at some sites where seeding machinery was used (eg. Yalgoo 1986 – Table 9.3).

Bulking Agents

Of the bulking agents the one which flowed best through machinery was the laying mash (Plate 9.2). Coarse sand was too heavy for the air seeders and blocked them up, and was very abrasive. Rice hulls were extremely dusty to work with. Being high in silica they presented a real health risk and are not recomended. Bran did not flow well even when mixed with wheat. For hand sowing coarse sand or dry sawdust were both adequate bulking agents.

9.3.3 Species

Acacia species out performed eucalypts in all trials. Maximum survival 7 months after sowing was 60% for both *A. dealbata* and *A. filicifolia* on graded plots (Ruby Hills 1986, Eastlake 1987 sowings – Figure 9.1) and 45% was achieved in some herbicided plots (Eastlake 1987). More usual were rates of 2–5% in successful treatments such as the herbicide treatments. In unsuccessful treatments such as the cultivated plots rates of only 0.1–1.0% were achieved.

Eucalypt surival was very low generally (Table 9.3). A maximum of 10% was achieved at Ruby Hills on the graded plot in 1986, but this was exceptional and values of 0.05–0.2% were more common, with values of 0–0.05% being frequent. It is not really possible to make an objective comparison between species since different species were sown at all sites. Where germination was very good (eg. graded plots at Ruby Hills 1986, Eastlake 1987, Birrahlee 1986 – Table 9.3) it was species indigenous to the site that were the ones involved, perhaps indicating that local provenances are important as is selecting species for the specific site.

Table 9.3 tabulates all the species sown and most of the trials. *A. dealbata* and *A. filicifolia* were the best species and performed consistently well. The other acacia species (*A. baileyana, A. fimbriata* and *A. melanoxylon*) did not seem as good – interestingly all three species came from outside the area. Of the eucalypts, *E. viminalis* was possibly the most consistently successful. No germination was ever observed of *E. globulus* or *E. obliqua*, both of which came from outside the area. *E. stellulata* and *E. nova-anglica* never produced seedlings either, but neither species was ever sown in any quantity. Other eucalypts had germination at some plots but comparisons between them is not really possible.

The *Casuarina, Angophora* and *Leptospermum* species virtually never produced seedlings.

9.3.4 Sowing Rates

To define sowing rate success, it is first necessary to state the numbers of seedlings per metre desired. A sowing with 0.5–1 seedling per metre or more, 2 years after sowing could be considered successful. Typically seedlings are clumped and such a density gave a fairly even row of trees. Where seedlings were very dense (over 10 per metre) growth seemed to be inhibited in many of the seedlings. A process of self-thinning occurred as some more vigorous individuals dominated – this was observed in the 1985 Ruby Hills sowing (Plate 9.5) where germination was very good and seedlings came up at over 20 per metre.

Sowing rates are determined by the degree of mortality which occurs in the first year, which, as in natural recruitment (Chapter 8), can be very high. So although germination may be high initially, the ultimate numbers of seedlings may be much lower - eg. the successful Birrahlee 1986 sowing on a graded site had 15 seedlings per metre initially. This dropped to 4 seedlings per metre $1\frac{1}{2}$ years later (Fig 9.2).

Sowing rate is also determined by the numbers of viable seed per gram and the percentage survival. As mentioned above percentage survival can vary incredibly between and within species, as does the viable number of seed per gram (see Appendix VIII). Table 9.3 tabulates survival rates of all the species examined. Table 7.3 and Appendix VIII tabulate the numbers of seed per gram for each of the species sown.

In the acacias sowing rates of 0.2–3 g/m (2–50 seed/m) gave successful results while rates of 0.002–0.2 g/m (0.2–41 seeds/m) gave insufficient seedlings per metre. In the eucalypts no sowing rate tested produced a satisfactory density of seedlings - ie. 0.01 to 1 g per metre (or 0.4 to 400 seeds per metre). The only exception was the Ruby Hills 1985 sowing where 0.5 g per metre (only 22 seeds per metre) with a 10% survival of seed, resulted in 2 eucalypt seedlings per metre $1\frac{1}{2}$ years after sowing, but this was an exception (Table 9.3).

9.3.5 Sowing Times

Most of these trials were sown in October, however two trials addressed sowing times, with the same batches of seed being sown at 2 or more periods (Belhaven 1986 - Table 9.3; Miramoona 1986 - Table 9.5).

In both trials seeds were sown in May and August. At Belhaven neither sowing was particularly successful, mainly due to the species and provenances sown being unsuitable. However the May sowing seemed to be better than August, with twice the survivorship. In the Miramoona sowing (again not a particularly successful sowing trial due to factors other than sowing times)

Table 9.5: Sowing Trials: Cultivation and Mulching Treatments

Site: Miramoona (6a) - Improved pasture Sown: 30.10.1985

Preparation: Ploughed with discs immediately before sowing.

Sowing: Seed spot sown or sprinkled a long a line and covered with various mulches. Split plot design with 4 replications of each treatment. Results here are pooled over all replications.

Species and Provenance	At 3 months No. seedlings	At 3 months % of seed sown	At 30 months No. seedlings	At 30 months % survival	At 30 months Mean ht.(m)
Casuarina littoralis (Grafton Road 1983)	0	0	0	0	-
E. blakelyi (Miramoona 1985)	83	0.13	6	0.06	0.4
E. laevopinea (Petali 1985)	6	0.9	0	0	-
E. melliodora (Petali 1985)	53	0.42	12	0.3	0.4
E. pauciflora (New England N.P. 1983)	0	.0	0	0	0
Total Eucalypts	142	0.17	18	.02	
Lept. flavescens (Puddledock 1984)	0	0	0	0	0
TOTAL	157	0.1	18	0.01	
SOWING TECHNIQUE					
Spot sown	45		5		0.5
Line sown	112		13		0.4
TOTAL	157		18		
SEED COVERING					
Soil	6		3		0.4
Sawdust	21		2		0.3
Sawdust and Nutricote	35		1		0.6
Woodchips	2		3		0.3
Shadecloth	33		3		0.5
Vermiculite	13		1		0.7
Black Paint	7		2		0.3
Gravel	4		0		-
Straw	36		3		0.3
TOTAL	157		18		

Table 9.5 continued on back of this page.

the August and May sowings had virtually the same number of surviving seedlings after 2 years, although in the first growing season after sowing the August sowing seemed to be favoured.

The one sowing done in July (Europambela 1984 - Table 9.3) was quite successful for acacias. Sowings in September - October were successful (dependent on site preparation etc.). Late October - November sowings tended to have desiccation problems as the season warmed up and soil moisture became more critical.

9.3.6 Mulches

Addition of a variety of mulches were tested in some of the spot sowing trials (Miramoona 1985, 1986 - Table 9.5, and Terrible Vale 1985, 1986). In the Miramoona 1985 trial too few seedlings emerged to analyse statistically. Sawdust, shade cloth, straw and vermiculite seemed to improve seedling survival in the first sowing season while woodchips, gravel, and black paint had no obvious effect (Table 9.5). However $2\frac{1}{2}$ years after sowing so few seedlings survived (only 0.01% of seed sown or 18 seedlings) that no effect could be observed between mulched and unmulched seeds (Plate 9.9).

In the Miramoona 1986 trial (Table 9.5, Plate 9.17), effects from the mulches were evident in the first season. The shade cloth (Plate 9.18) improved germination considerably in both sprayed and unsprayed, May and August sowings but there was often many weeds and the seedlings themselves were often spindly. Sawdust (Plate 9.19) suppressed weeds well but very few tree seedlings penetrated, (except sometimes - Plate 9.20) and possibly it was too thick (1–2 cm and sometimes 5cm). Similarly, straw (Plate 9.21) suppressed weeds but few seedlings penetrated it. The suppressive action of these mulches against the sown species was apparent at both sowing times in sprayed plots but not apparent in unsprayed plots (Table 9.5).

Over the first summer there was heavy mortality in all treatments due to drought and grasshoppers and in the following winter goats got into the plots. When the seedlings were measured 2 years after sowing very few seedlings remained (only 135, representing 0.1% of the seed sown - Table 9.5). The controls had better results than any mulch treatments.

At the Terrible Vale 1985 trial sawdust seemed to aid establishment of acacias in the first season (Plate 9.22). However due to hare damage and weeds virtually all direct seeded seedlings were dead after one year and no benefit was observable from the mulch. In the 1986 trial the same pattern happened.

9.3.7 Post sowing maintenance

Little experimentation was carried out to test different weeding techniques. Weeding was done as was considered necessary, and the necessity for it depended on the site preparation. In the graded trials no weeding was ever required. Where contact herbicides were used follow up weeding was necessary in the late spring - early summer. Some weeding was also required in the trials using residual herbicides, but less so than where contact herbicides were used.

The selective herbicide Fusilade was tested at Miramoona in the trial of 1986 (Table 9.5) The sprayed treatments increased survival dramatically in the first growing season - with about 1,000 seedlings in the sprayed plots and only about 120 seedlings in the unsprayed. In the unsprayed plots a dense sward of rye grass grew which suppressed the seedlings (in both May and August sowings). The Fusilade successfully killed all the grass. By the end of the first summer the sprayed plots had been invaded by broad leaved weeds such as *Cirsium vulgare* (Plates 9.23 – 9.24) while the unsprayed plots had a thick sward of annual grasses (rye grass, barley grass) and thistles (Plate 9.25). Despite the invasion of weeds the difference between sprayed and unsprayed plots was still evident, with 113 seedlings in the sprayed plots and only 22 in the unsprayed plots.

Hand weeding was sufficient for small areas. Shielded sprayers were adequate. Roundup has the disadvantage that it must not touch the seedlings. Thus a band of weeds can result right

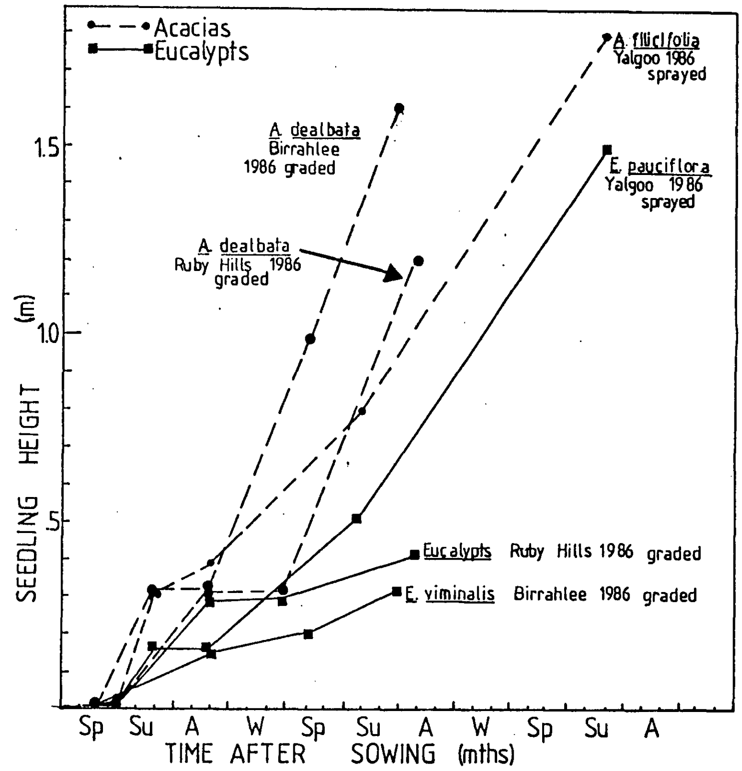

Figure 9.3: Seedling growth of *Acacia* and *Eucalyptus* seedlings in three direct sowing trials

next to the seedlings which can out-compete them. The method used by the Nivison s, novel though it was, gave surprisingly good weed control. They mowed either side of the seedlings in February (this followed hand weeding in December) and wiped Roundup on the weeds using a squeegee mop.

9.3.8 Seedling growth

Seedlings arising from September – October sowings tended to grow to about 10 to 30 cm over the first growing period in optimal conditions (Fig 9.3). In the second season the fast growing acacias (*A. dealbata* and *A. filicifolia*) typically grew to 1.5 to 2.0 m high while the eucalypts tended to be slower, growing to about 0.5–1.0 m by the end of the second season.

9.4 Discussion

My direct sowing trials confirm the results of other authors, namely that direct sowing is potentially a very cheap method of tree establishment (Weatherly, 1984). In the successful sowings (eg. Ruby Hills 1985, Birrahlee 1986, Eastlake 1987) the cost per tree was about $0.10-0.40. These costs included seed costs, site preparation and sowing costs, but not maintenance or fencing costs since these were deemed comparable with planting. Planting in comparison costs $3.00–4.00 per tree (Armidale Tree Group contract rates which include site preparation, planting, milk carton guard, mulch and fertilizer).

Direct seeding is a technique which can be used successfully on the Northern Tablelands to establish native trees. However results are variable and depend on the season, and even more than planting, on good site preparation. It is, therefore, a technique to be approached with caution by landholders. It certainly bears more investigation and experimentation.

My results did nothing to dispel the notion that seed collected from trees growing near to the site and from a site very similar to it in climate, geology, soil type, and position on the slope have advantages over seed collected from different soil types, climatic zones etc. Direct seeders elsewhere in Australia stress the need for local provenances (eg. Weatherly, 1984 etc.) and my data, limited though they are, seem to bear this out.

In terms of seed treatment, the method I used of lowering acacia seed into boiling water for 20 seconds and then withdrawing, (after Clemens, 1984) worked very well for both *A. dealbata* and *A. filicifolia*. Seeds so treated can be dried, stored and used some time later (possibly even one year) without reduction in viability, or they can be sown immediately. The technique has the advantage, compared with seeds which have been soaked overnight, that treated seeds can be stored and used when conditions suit, and remain viable in the soil until soil moisture is good. If the seeds are soaked overnight following boiling they will have imbibed water and thus be prone to moisture stress in the field and cannot be stored.

Because of the ease of my technique there seems no real justification for using chemicals to break seed dormancy. Other seed treatments such as pelletizing mixtures, hydrogels and so on were not tested in these trials but should be investigated locally.

Insecticide was added only in the Eastlake sowings and no objective comparison was made between presence or absence of insecticide. Where seed is to be buried (as should be the case in all sowings - see Chapter 8) there does not seem to be a need for insecticide addition. No comment can be made on addition of Terrasorb to the seed mix as it was only used once.

Preparation of the seed bed was considered to be the most important factor influencing success of seeding - the challenge being to get a good weed free seed bed for the first year after sowing. As other authors have found (eg. Venning and Croft, 1985), removing the topsoil by grading is a good treatment if it is accompanied by scarification, chisel ploughing or ripping. The erosion potential could be a problem and might be avoided by designing a machine that turned or removed a smaller width of soil. No problems were evident, as mentioned by some detractors of the method, in the actual growth of the seedlings.

Cultivation, as a pre-treatment for direct sowing, does not seem to be an appropriate technique on the Tablelands, unless as is done elsewhere, it is followed by weed control through regular scarification or herbicide application. These results confirm those of others in similar situations (Venning and Croft, 1984; Venning, 1986).

Knockdown herbicides were not nearly as successful as found by Sharp and others in Victoria (Table 9.1), because of weed re- invasion. Where weeds were controlled, seedling establishment was quite good. The excellent weed control using Roundup achieved by Bill Weatherly (Table 9.1) was not achieved in my trials. It is interesting to speculate whether better weed control would have been achieved if we had included the extra spray that he does, in the spring one year before sowing.

The residual spray Atrazine seemed to give better weed control than the knockdown ones, although in our trials weeds did reinvade over the first season, and by the end of the summer were quite dominant again. Further work needs to be done on such chemicals to work out best ways of using them on the Tablelands.

Table 9.6: Recommended sowing rates for the Northern Tablelands of some local species. Assumed survival rates and seed weights are given. Values are estimated for a desired spacing of 1 seedling per metre 2 years after sowing. g per metre is equivalent to kg per km.

Species	Assumed survival (%)	Mean seed per g	Recommended sowing rate	
			seed per metre	g per metre
A. dealbata	2	70	50	0.7
A. filicifolia	2	50	50	1.0
E. blakelyi	.1	430	1,000	2.3
E. nicholii	.1	540		1.9
E. melliodora	.1	140	1,000	7.0
E. radiata	.1	180		5.6
E. stelluata	.1	120		8.3
E. viminalis	.1	280		3.6
E. caliginosa	.1	120		8.3
E. laevopinea	.1	40	1,000	25
E. pauciflora	.1	80		12.5

*** From Appendix VIII, rounded to the nearest 10.**

The "pepper pot" technique of sowing, described by Floyd (1960) did work, but not ultimately as well as sprinkling seed along defined rip or chisel ploughed lines, and so may not be appropriate for on farm sowings on the Tablelands. Also little luck was achieved with niche seeding (Department of Environment and Planning, 1984) although perhaps it bears further work. My one attempt at simulating Runciman and Malcolm's (1985) niche seeding technique of "mulching" the seed with vermiculite or black paint, was not successful as neither of these substances were effective against weeds and dry weather.

No real problems were encountered using standard seeding equipment except to find a good flowable bulking agent (chick crumbles was found to be the best). It was found better to block most seeder outlets and have only 1–3 rows sown, to aid later weed control.

The only attempt at laying brush to get seed recruitment from the fruit (McDonald, 1979) was not a success due to weed problems and may only be suitable for areas not prone to weed invasion.

To estimate optimal sowing rates for local conditions, I based my calculations on a likely survivorship of 2% for acacias (*A. dealbata* and *A. filicifolia*) and 0.1% for eucalypts (Table 9.6). In both cases higher or lower values are possible but such values are not unreasonable to expect without being overly optimistic. In the eucalypts, as is obvious in Table 9.3, values of only 0.01% may occur, even in relatively successful sowings – sowing rates should be altered accordingly. The values in Table 9.6 were calculated using the formula above (Literature Review 'Sowing Rates').

Compared with sowing rates elsewhere (eg. Table 10.2) the rates in Table 9.6 are quite high, although some people are reported to use similar rates. With improvements in techniques it is conceivable they could be reduced. The acacia rates could be reduced where a higher survival rate is expected eg. a 5% survival rate would more than halve the rate given above, and rates of 10% or even more are possible locally.

For the eucalypts, until techniques are improved to the extent that higher rates can be expected (rather than fluked), the rates given here are reasonable. Clearly for any sowings on the Tablelands a high proportion of acacia seed should be included to firstly ensure success, and secondly to reduce the amount of seed required.

The optimal time to sow native seed on the Tablelands is still perhaps an open question until much more detailed trials are carried out. Based on the natural recruitment data in Chapter 8 we could expect spring sowings to be best, and autumn sowings to be possible. Certainly the data from my direct sowing trials support this idea, with mid-September to mid-October being perhaps the optimal period for sowing. Sowings in late October to March would be unwise due to increased chances of hot dry weather and unsuitable soil mositure. Sowings in April – May, depending on soil moisture conditions and the likelihood of bad frosts, may be successful. Seedlings originating from autumn sowings have the disadvantage of being very small in the winter and thus subject to frost damage, and also being small in early spring when weed growth is usually vigorous. Spring sowings, on the other hand, are usually 10-30cm high by the time winter arrives and fairly resistent to frost and hare damage. Even if frosts and hares cause severe damage the seedlings are often sufficiently strong to recover the following growing season – this occurred in the Yalgoo 1986 sowing (Fig 9.1, Plate 9.12) where the seedlings recovered from severe hare and frost damage and produced thick, vigorous growth up to 3 m high $2\frac{1}{2}$ years after sowing (Figure 9.3).

Spring sowings still require good weed control. If the sites are well prepared however, and the late spring germination of weeds is controlled, (this may not be necessary if site preparation is good) seedlings should be relatively unaffected by weeds until the following spring, by which time the seedlings should be quite well established.

Late winter sowings (ie. July – August) remain a possibility and bear further investigation. As with autumn sowings provision has to be made for weed control in the spring. Thus mid-September to mid-October seems to be the best time to sow. Such a period normally has good soil moisture levels, reasonable rainfall and optimal temperatures for germination and growth (Chapter 7) which is very similar to the Victorian situation (Table 9.1). July to August, and April to May are possibilities but require further work to confirm.

The addition of mulch was shown to improve seedling survival in some conditions in the recruitment trials (Section 8.3). It might have been expected to aid establishment in the sowing trials. Except for sometimes aiding establishment of acacias mulch was not shown to be of much benefit in the sowing trials.

Mulches are probably of more benefit where soil moisture is a problem. For example in arid areas the vermiculite/black paint mulch has been found to be useful (Runciman and Malcolm, 1985). However, because mulches are generally difficult to work with and since excellent results were achieved in the absence of mulch there seems no good reason to use it on the Tablelands with the possible exception of spot seeding/niche seeding of *Acacia* species.

The main causes for failure in the seeding trials were low sowing rates, poor site preparation, poor weed control, poor species choice, and poor soil moisture. Where all these were good, success followed. The 1985 Ruby Hills sowing and 1987 Eastlake sowings were both examples of successful sowings. Rainfall was good over the summer periods at both sites (Figure 5.2), sowing rates were good, indigenous species were sown, and site preparation and weed control were good.

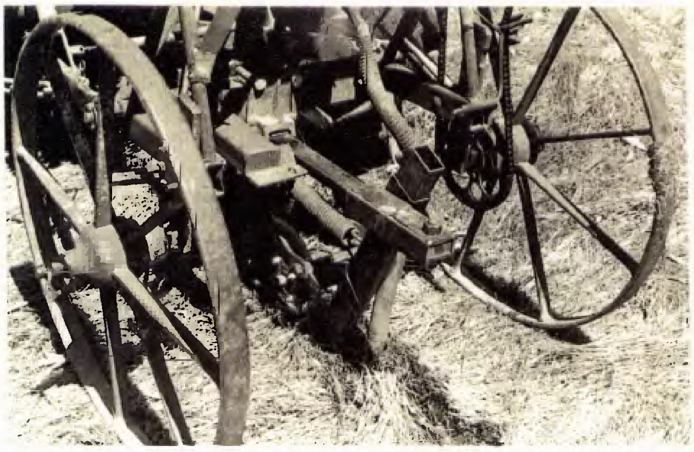

Plate 9.1. Williams' family direct seeding implement, designed and built by Gordon and John Williams. This single row sowing implement has a Coulter blade to make a cut, a flange to open the trench, a Baker's Boot seeding foot, a bolt dragged behind to cover the seed and a seedbox on top.

Plate 9.2. Chick crumbles/laying mash.

Bulking agent for seed, mixed with acacia and eucalypt seed.

Plate 9.3
Graded and chisel ploughed. Seed sown along one furrow and line marked with stakes. Ruby Hills 1986. Sown September 1986.

Plate 9.4
Same plot in March 1987, 6 months after sowing, showing good establishment (about 20 seedlings/metre) and good weed control.

Plate 9.5
Same plot in February 1989, $2\frac{1}{2}$ years after sowing. Seedlings up to 2m high.

Plate 9.6
Graded and ripped - Birrahlee 1986 (Table 9.4). Sown October 1986.

Plate 9.7
Birrahlee graded plot one year after sowing. Seedlings to 1m high and good weed control

Plate 9.8
Graded plot, Petali 1986. No germination due to hard surface (no ripping or scarifying).

Plate 9.9
Miramoona sowing (1985 - Table 9.6) one year after sowing showing severe weed problems from improved pasture.

Plate 9.10
Ripping with mulching blade attachment - grass either side of rip line killed. Belhaven 1986 sowing.

Plate 9.11
Two sprays of Roundup prior to sowing, sowing done in 3 rows, using sod seeder. Yalgoo 1986, sown October 1986.

Plate 9.12
Hare and frost damage of *A. filicifolia* in first winter - Yalgoo 1986 sowing. September 1987. Despite this initial setback the acacias achieved thick growth up to 3 metres high $2\frac{1}{2}$ years after sowing.

Plate 9.13
Two sprays with Roundup and central ripline - Birrahlee 1986 sowing (Table 9.4).

Plate 9.14
Birrahlee 1986 sowing, poor follow up weeding suppressed good initial germination.

Plate 9.15
Eastlake 1987 sowing, 3 months after the September sowing. Foreground left - graded, foreground right - Atrazine, background left - Gramoxone (Table 9.4).

Plate 9.16
Burnt and spot sown (Europambela October 1986). Despite good initial burn, weed growth subsequently dominated completely.

Plate 9.17
Miramoona 1986 sowing (Table 9.6). Cultivated and 5 coverings on spot sown seed. Species and coverings randomized within each block. Also tested sowing times and post sowing treatments.

Plate 9.18
Shade cloth mulch Miramoona 1986 sowing.

Plate 9.19
Sawdust mulch, spot sown seed Miramoona 1986.

Plate 9.20
E. viminalis spot sown seed, mulched with sawdust and sprayed with Fusilade, Miramoona 1986 sowing.

Plate 9.1
Straw mulch, Miramoona 1986 sowing.

Plate 9.22
Coarse sawdust mulch encouraged initial germination of *A. dealbata* spot sown. Terrible Vale niche seeding trial 1985, 4 months after sowing.

Plate 9.23
Miramoona 1986 sowing cultivated, May sowing - over sprayed with Fusilade. Grasses killed but thistles thriving.

Plate 9.24
Miramoona 1986 sowing. Cultivated. August sowing over sprayed with Fusilade - grass killed but thistles thriving.

Plate 9.25
Miramoona 1986 sowing. Cultivated. May sowing, unsprayed. Thick growth of annual grasses.