TASK FORCE REPORT ON IMPROVING P. RADIATA PLANTING STOCK

August 1985

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1. INTRODUCTION

Over the last 6 months there has been increasing awareness of the benefits that tree breeding could provide to the P. radiata establishment program. Articles published in "Australian Forestry" and a paper by Arnold and Gleed at the May 1985 Institute of Foresters Conference stimulated operations staff to take a keener interest and start discussing possibilities with Research staff.

There are several reasons why it would be desirable to upgrade the quality of P. radiata planting stock as soon as possible.

1. A growing surplus of particleboard resource and the unlikelihood of utilizing first thinning material, particularly ex Southern Region plantings means that much lower initial stocking numbers can be used if stock quality is high. Currently 1330 seedlings are planted to provide 250 final crop trees.

2. Lesser initial stockings of seedlings that can produce good formed lightly branched trees will reduce pruning costs and significantly increase utilizable volume of mill log material.

3. Most of the future planting of P. radiata, (programmed to be about 3000ha/year for the next 20 years) will be on cleared, former pastured farmland. If initial stockings can be low, grazing can be maintained much longer into the rotation. This makes pine forests much more acceptable to the community.

4. The difficulties in acquiring land for pine planting make it essential that any land planted produces mill logs as effectively as possible.

5. The success of agroforestry is very dependent on the availability of top quality stock to increase utilizable volume and reduce tending costs. Without good quality stock the Department will find it difficult to get the concept of agroforestry accepted. Because of the lack of government funds for land purchase, private plantings will become much more important and growers need every encouragement, eg. availability of quality stock.

   On July 11th 1985 a meeting of Operations and Research Staff was held at Manjimup to discuss what action should be taken. The meeting agreed that the following action should be taken:-

   1. **Seed Orchards**

      New orchards should be established using the concept of hedged artificial pollinated seed orchards (HAPSO).

2. **Cuttings**

A 1 - 1.5 million cuttings from the best stock available to be produced by 1987.

3. A task force be set up to document the reasons for and the steps necessary to achieve this recommended action. The Task Force comprised the following people, D. Spriggins, P. Christensen, T. Butcher, C. Muller, J. Gilchrist and G. Chester.

This report is the result of the Task Force discussions. Policy Group approval is requested for the recommended action outlined in Section 5.

2. CURRENT & FUTURE DEMAND FOR P. RADIATA PLANTING STOCK

Yearly planting target

G.W.P. No. 57 lists a yearly planting target of 3500ha by the State and an additional 500ha by private plantings. The 3500ha/year of state plantings have been divided into 3000ha (P. radiata) and 500ha (P. pinaster). The P. pinaster yearly target has been consistently achieved in Wanneroo District, but lack of funds for land purchase and a change in policy on clearing native forest have prevented the P. radiata target from ever being attained. Private plantings reached 500ha/year in the 1970's but have varied considerably since then.

Additional area of Pine forest required

The W.A. Timber Supply Review Report (1984) recommended that W.A. establish an additional 60 - 70,000 ha of pine to ensure, in the face of the declining hardwood cut, that W.A. remains self sufficient in timber supplies. On this basis, establishment of P. radiata forests would need to continue at about 3000ha/year for at least the next 20 years.

Current Yearly Planting stock requirements

Most P. radiata stock in the past has been raised ex seed at Nannup Nursery. In August 1985 seed will be sown at Nannup and Gnangara to raise 3.24 million plants for 1986 planting (3.16 million, Nannup, 80,000 Gnangara). This is to cover initial plantings, 2nd rotation planting and private orders.

Quantity and quality of current and future stock Current

Current practice is to plant 1330 seedlings/ha. This has been considered necessary to give adequate selection for a final crop of 250 s.p.h.a. This initial stocking has usually resulted in canopy closure by age 5 - 6 which has been beneficial in former bush areas as scrub is controlled by low light penetration. Planting at 1330 spha also controls branch diameter growth - an important factor on high quality sites with current stock quality.

In practice, although the aim has been to plant 1330 spha, the actual number remaining after one year is about 1100 spha. This arises because in former bush areas, stumps and windrows reduces the effective area planted. Rabbits, drought and other factors reduce initial numbers and gaps can cause excessive branch development. Aiming to plant at 1330 spha has tended to offset this problem.

T. Butcher considers current existing seed quality ex Manjimup seed orchard would permit initial stocking rates of 1100 spha and this is what has been achieved in the Sunklands albiet by default.

Very recent experience in attempting to produce mill logs from second thinning operations in the Central Region has illustrated very well the deleterious effects which poor form has on mill log yield. The nett effect has been to reduce mill log yields in many cases from a predicted 40m3/ha to about 20m3. Had form, sweep etc. been a little less much of these rejected logs would have been acceptable. P. radiata seems to suffer more from form problems than species such as P. taeda.

Future:

Future plantings of P. radiata would benefit considerably if better stock was available. There are three reasons for this:-

1. A surplus of particleboard resource in existing plantations coupled with the intention of the plant to use more waste means there will be a decreasing need to plant at 1100 - 1330 spha to ensure a particleboard yield at first thinning, ie. about 11 years of age.

   In the Manjimup area and southern parts of the Central Region, it is most unlikely that first thinning material can be utilized. Consequently "sawlog regimes" are proposed that involve non commercial thinning to final crop densities by age 8 - 9.

2. Future planting will largely be on cleared and pastured former farmland, Many of these plantings are likely to be joint venture schemes when it will be desirable for grazing to continue as long as possible by planting fewer trees initially and reducing to final densities as soon as possible.

3. Interest in agroforestry involving P. radiata is increasing. The success of this system is heavily reliant on the availability of high quality stock, ie. excellent form, small branches and low taper. The difficulties in getting the system accepted are strongly influenced by the quality of stock currently available.

There are considerable savings to be made both in initial planting and tending up to year 8 if the quality of planting stock can be markedly improved. Hopefully initial planting rates could be reduced to 700 spha. N.Z. experience (Attachment 1), Tasman Forestry Ltd., has been that initial stocking using cuttings can range from 500 - 700 spha and that although cuttings are more than three times as expensive as seedlings, by year 7, discounted costs to that age are $200/ha in favour of cuttings due to lesser pruning costs/tree and the smaller number of trees involved. Over and above this is the marked increase in utilizable volume from superior stock.

Based on the above factors we consider one of our objectives in the P. radiata tree breeding scheme should be to produce by 1987 a minimum of One Million plants/year of sufficient quality to allow initial stocking rates to be reduced from 1330 to 700 spha.

The figure of One Million is derived from:-

1.	500ha/year Manjimup Region sawlog regime	-	350,000
2.	500ha/year Central Region " "	-	350,000
3.	330ha/year joint venture schemes other areas, eg. Albany, Mt. Barker, sawlog regimes		230,000
4.	100ha/year, Agroforestry plantings private land and Department	-	70,000
	TOTAL		1,000,000

3. CURRENT PROGRAMME FOR IMPROVING STOCK VIA SEED ORCHARD PROGRAMME

Historical

Manjimup seed orchard was established over the period 1969 - 72 using grafts of the best trees in the Australian breeding population for P. radiata.

Cones were first collected from the orchard in 1976, yielding 64kg seed. This was planted in 1978 forming 20% of the total radiata public planting.

Orchard has been in full production since 1978. Annual yields have fluctuated according to thinning and pollarding management; minimum yield was 147kg in 1979 and the maximum was 385kg in 1984. An average yield would be 250kg.

Good quality has also been variable. On the average, 11,000 plants have been produced per kilogram of seed but in 1978 (SN5099) and 1983 (SN8301) this reduced to 7 - 8,000 plants/kgm. This was coincident with very low ranfall in the previous year (time of cone fertilization) and high density of trees.

Since 1983, all public plantings of radiata pine have been of orchard origin.

Quality of planting stock

Yield trials have shown that 40% of seedlings planted ex unimproved source, will produce trees of reasonable form and vigour as compared with 60% ex orchard. However the number of exceptional trees resulting from orchard stock planting is less than 10%. Currently, initial stocking is 1,330 seedlings/ha to achieve 250 final crop trees/ha.

Improvement in quality

The Manjimup orchard consisted of 92 radiata clones. Progeny testing has identified some parents with inferior breeding values. These have been eliminated (culled) from the orchard. Only parents with superior breeding values remain in the Manjimup orchard. Current seed collections will produce better quality planting stock and will enable the planting of fewer seedlings/ha, ie: 1100 spha.

Phytophthora cinnamomi tolerance

Intensive screening has developed a radiata population that has high tolerance to *Phytophthora cinnamomi*, as well as other desirable tree traits. This population will not have the reduced growth, survival and stability problems associated with the normal radiata source, when planted on a dieback infested site.

The western area (6ha) of the Manjimup orchard was culled of *P.c.* susceptible clones in 1984 and will in future be collected as a "*P.c.*" tolerance radiata seed source until the future seed orchards are developed.

A specialized collection (D655) was made from outstanding clones having some degree of tolerance to *P.c.* in 1984.

Seed orchard programme

Seedlings from seed orchards are the main source of planting stock for all Australian programmes. Seed orchards are the means whereby the improved material resulting from the breeding programme is made available cheaply to the plantation manager and it is expected they will continue to have this role for the foreseeable future. A wider variety of radiata pine orchards can be expected in the future and the principal alternative, vegetative reproduction, will provide a small but significant fraction of Australian planting stock by the end of the 1980's.

The existing Manjimup seed orchard has an age range of 13 to 16 years. It has been culled from 360 down to 100 stems per hectare of the best clones and has been pollarded twice. Cone collection has been increasingly difficult and costly. It is overdue for replacement. Significantly better genetic material is available for new orchards, however the time needed to develop and obtain seed from new orchards is normally at least 6 years.

4. POTENTIAL FOR IMPROVEMENT VIA USE OF CUTTINGS

Essentially the advantages of clonal propagation are:-

(i) greater genetic gain through multiplication of the very best crosses in the breeding programme,

(ii) more rapid realisation of genetic gains as there is a considerable lead time for seed orchards between establishment and commercial seed production, and

(iii) development of more uniform forests than is possible with seedlings.

Coupled with these genetic gains are the potential gains associated with ageing. Trees grown from cuttings display growth characteristics distinctly different from seedlings grown trees of an equivalent age from planting. The cuttings have thinner bark, less taper, smaller branches, straighter stems and grow at the same rate as seedling trees. Cuttings from older trees (6 - 7 years) will have a slightly lower basic density which could be detrimental in agroforestry and sawlog regimes. The benefits of using cuttings are discussed very well in the paper by Arnold & Gleed (Attachment 1). The optimum maturation state is a balance between the easy rooting and rapid growth rates of the juvenile age, to the declining root regeneration, improved branching habit, lower taper and more vertical growth of the ageing state. Current thinking is that age 4 is optimal but this will be further explored by research.

Australian and New Zealand experience

South Australian and Victoria (APM) are currently raising several hundred thousand woody cuttings for production forestry plantings. Procedure is for a low intensity phenotypic selection (1 in 3) in 2 - 3 year old orchard stock plantings. Strike rate is about 50% and the cost to raise cuttings is probably close to 20c.

A new method developed by CSIRO and adopted by Francis Clarke in NSW is to multiply selected families by the fascicle shoot technique. Clonal gardens are established and maintained for the taking of fascicle shoots. Cost to produce these cuttings is probably 45c. (Attachment 2)

Tasman Forestry in New Zealand have a programme to raise 750,000 cuttings/year. (Attachment 1). Procedure is for a phenotypic selection (1 in 5) in 3 - 5 year old special pedigree stands, and setting of woody cuttings in open nursery-beds. Rooted stem cuttings are approximately five and a half times the cost of seed orchard seedling stock.

Western Australian experience

In 1981, we achieved a high strike rate (90%) with autumn setting of woody cuttings from trees aged 2 to 5 years. Survival of the outplanted cuttings in the Sunklands was similar to seedlings (85%) and the second year height increment was the same (1.4m) for cuttings and seedlings. The difference in shape and crown form of the cuttings compared with seedlings was very marked.

Some 55,000 woody cuttings of 3 and 4 year old trees originating from the Manjimup orchard were set at Manjimup in June 1985. High selection intensity (1 in 20) was used.

Development of a W.A. programme

There are two options. One option is aimed at multiplication of the best available genetic material at that time. The method requires rapid build up of donor plants and repeated multiplication from special clonal gardens leading to large scale production from elongated fasicle shoots.

The other option is to increase genetic gains by including selection and ageing of the donor in the field. The propagation technique would be by woody cuttings set in misted, open nursery beds.

The immediate limitation of either option is the lack of a superior genetic base and experience in these techniques. Both are being tackled. As we see it, both options should be included in the W.A. clonal forestry programme. The fascicle shoot option can be used immediately to develop clonal gardens of superior radiata families for future production and for multiplying stock of special seed lot D655. For the long term, the better option is for low intensity field selection in 2 - 4 year old trees of special family planting, and the setting of woody cuttings. Fascicle shoot production will still have a role in the multiplication of special radiata crossings; for example very high density clones crossed with rapid growth rate, good form, disease resistant clones. Details of this is given in (Attachment 3).

5. RECOMMENDED STRATEGY AND ACTION

Breeding population

As radical approaches are being recommended for the radiata production population (cuttings and seedlings) a concurrent commitment is also required for the radiata breeding population. The success of the intensive cutting and seed orchard programme will only be as good as is the genetic material. Both the cutting programme and seed orchards have cyclic designs to allow for a continuing upgrading in the quality of genetic stock. For this our radiata breeding programme must be active and efficient to develop the radiata resource.

Adoption of the HAPSO concept can also have a very significant effect on the radiata breeding plan (H/O 343/69, 8 February 1985). It is possible to create successive and improving populations without intensive control pollinations and to drastically reduce generation intervals to 9 - 10 years. The radiata breeding plan is being rewritten giving these options.

Considerable control pollination work will be necessary to create the selected families for the type 3a and type 3b cuttings. This requires high technical expertise. It is likely that this task will be performed by pine breeding technicians.

Completion of the radiata plus tree search (SEARCH 85) is required. New breeding population units will be sown at Gnangara nursery in 1986; this is critical to the long term development of the radiata plan. Forest Ranger John Ipsen should remain with research for another year, based at Busselton, with radiata improvement as his major task. There is also a backlog of progeny trials (ex NSW programme) that need to be assessed over the summer months so that this new material can be included in the 1986 cutting and orchard plans. The transfer of an additional operations Forest Ranger for one year to enable this work to be carried out is essential to the overall programme.

Seedlings ex seed orchards

Seedlings have been used almost exclusively in Australia and New Zealand for the establishment of pine plantations. Advantages associated with the use of cuttings have been known for a long time in Australia but it is only recently that new techniques for vegetative propagation have made it possible to mass propagate for production forestry. The interest and use of cuttings has been exponetial in the past two years but seedlings will probably remain the main source of planting stock in Australasian pine programmes. Cuttings are from three to five times the cost of seedlings to produce and require more qualified nursery personnel and intensive nursery practice for production. However as has been shown, initial cost of stock is only a small factor in the total production cost of the final product.

An intensive cutting programme is opportune at this time as there will be a serious shortfall in seed coming from the Manjimup orchard in 1986-88, because of culling and recent pollarding treatments. eg. 1986/87 we expect only 150kg, 87/88, 180kg, returning to the average 250kg by 1988/89.

A working plan has been prepared detailing the immediate and continuing production of some one million cuttings. This will form approximately one half of the Department's planting requirements with the balance coming from seedlings. If adopted, seed requirements will be halved and smaller areas of new seed orchards will be needed.

Intensive management orchards or hedged artificial pollinated seed orchards (HAPSO) instead of conventional orchards have been recommended by this task force. HAPSO's will cost more to manage and require considerable technical expertise. However they have obvious advantages that are of special significance to Western Australia (H.O. 343/69, 26 July 1985). In adopting the HAPSO concept, intensive management is a must and a continuing commitment from operations is obligatory and because the concept has not been adopted elsewhere, a committment is also required from the Research Branch to pioneer and make it work. It should be noted that the male orchard will have a conventional design and will be a seed backup to the HAPSO.

Timetable for HAPSO development is given in Attachment 2. Glasshouses at Kelmscott and Wanneroo are being used for the annual grafting of 3,000 radiata clones. Three HAPSO blocks will be created over a four year period. Each block comprises "Phytophthora cinnamomi tolerant" clonal rows (1.5ha) and "general" clonal rows (2.5ha). The male orchard, probably area of 2ha will be developed on a separate site.

Cutting program

At this stage, the preferred cutting technique it not known. Trials commencing later this year using material from P. radiata plants growing in Nannup and Gnangara nurseries are aimed to evaluate the utility of fascicle shoots or woody cuttings from seedling shoots and their costs of production.

Propogation trials will be carried out at Wanneroo and Manjimup Nurseries commencing in November of this year. Wanneroo Research will be making use of their existing glasshouse to strike fascicle shoots, Manjimup are proposing to construct a greenhouse that could be used for pine or eucalypt cuttings. The financing of the latter will be of the order of $22,000 and hopefully funds can be obtained from within Southern Region and Central Region estimates to finance this construction and raising of trial stock.

Glasshouse facilities at Wanneroo can probably produce 100,000 fascicle shoot cuttings/year for transplanting into open beds at Gnangara Nursery. If by early 1986 it is considered that fascicle shoots are a preferred propogation technique one possibility would be to utilize private nursery glasshouses to strike the fascicle shoots (3 - 4 weeks) and then transplant into our own nursery beds. At this stage we believe that rooting woody cuttings in open misted beds is the cheaper preferred option and we should plan on a maximum of 500,000 fascicle shoot cuttings via heated propogation beds. Experience by early 1986 will give us a better guide.

Also at this stage we are not sure what would be the best nursery for striking either rooted fascicle shoots or woody cuttings in open beds. Manjimup nursery soils are rather heavy and the cold climate may be a problem. It may be that the well drained sands at Gnangara and the warmer climate may be very advantageous for cutting production. These are factors that we will be in a better position to evaluate by early 1986.

Assuming that the techniques for raising cuttings can be resolved by early 1986 a working plan has been prepared (Attachment 3) detailing the proposals for the immediate and continuing program of approximately one million cuttings as from 1987.

It would be extremely advantageous for one or more staff likely to be involved in the production of cuttings to visit the Eastern States and possibly New Zealand in the next two to three months to visit cutting production centres, eg. South Australia, Canberra and A.P.M. to glean practical information on propogation techniques we may otherwise take years to develop ourselves. I understand one private nursery sells radiata cuttings at 45c each. Unfortunately quarantine regulations would prohibit the importation of his material but inspection of this operation could be very valuable from an information viewpoint.

Staff requirements

The proposals represent a quantum leap in nursery and orchard management into an area where the Department has little expertise. It is wrong to think that this can be performed by (a changing) operations staff. Research involvement at a high level will be necessary for quite a number of years. To this end pinaster silvicultural research has been wound down and an Assistant Forester has been swung in to help with the radiata and pinaster breeding programme. Additional support is needed from operations; a request is included for the transfer of an operation Forest Ranger for one year to assist John Ipsen with this work at Busselton. This request should be supported in view of the large potential gains that are possible.

Finances

Discussions have commenced between the Southern & Central Regions on ability to finance the construction of a greenhouse at Manjimup from within existing estimates. Hopefully the required $22,000 can be found from within existing budget. If not a request for additional finance may be needed. As mentioned previously the greenhouse could also be used for a proposed cutting research program involving eucalypts. As with the pine program there are considerable gains to be made in this area and the sooner a start is made the better.

It is most unlikely there will be sufficient P. radiata material currently available for experimentation on fascicle shoot production to yield more than 20,000 cuttings maximum. (Both Wanneroo and Manjimup) by early 1986. Consequently the projected development costs for 85/86 listed for Manjimup Nursery could be considerably reduced below the $46,000 suggested in Attachment 6. Although trialing with use of container stock is worthwhile at this stage we are hopeful that raising in open beds will prove feasible and the most cost effective technique.

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Raising and Managing Radiata Pine Vegetative Cuttings for Production Forests

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SUMMARY 750 000 **P.radiata** D. Don stem cuttings were set out in Tasman's Forest Nursery in 1984. Methods including selection, collection and production rates are described. Nursery production of these rooted stem cuttings is shown to be five times more costly than one year old seedlings. Subsequent establishment and silvicultural operations are tabulated which indicate that at age 7 years, discounted costs per hectare are $200 in favour of cuttings. A 1970 planted stand of cuttings taken from 8 year old trees is described, including wood characteristics. Density and heartwood at 12 years of age are 7% and 4% less respectively than comparable seedlings. Tree form especially branch index and butt sweep are in favour of the cuttings. Growth of basal area and height at age 14 years are very similar to that projected for seedlings grown at similar stockings.

It is concluded that cutting grown plantations originating from the very best genetically superior phenotypes will have quality and financial advantages above stands grown from seedlings when established on the highly fertile forest sites currently being planted by Tasman Forestry Limited in the Bay of Plenty region of New Zealand.

INTRODUCTION

Establishment of forest plantations with rooted stem cuttings is practiced in many countries. **Cryptomeria japonica** and **Chamaecyparis obusta** cuttings have been used for plantation establishment since the 15th century in Japan (Toda, 1974). Norway spruce (**Picea abies**) in Europe, and Poplar species in Italy, are also commonly established with cuttings.

Vegetative propagation, including rooted stem cuttings, offers significant benefits in most breeding and establishment programmes. The very best genotypes, produced at any stage, can be rapidly replicated en masse, without the complication or time lag involved with seed orchards, (Wilcox et al, 1976). For **P.radiata**, these potential advantages are now being proven as both earlier stands of trees grown from cuttings, mature, and as large areas are established with cuttings which represent the best genotypes currently available.

Use of rooted stem cuttings for establishment of **P.radiata** plantations was first advocated by Jacobs (1937). Work in Australia by Fielding (1970) showed that trees grown from cuttings displayed growth characteristics distinctly different from seedling grown trees of an equivalent age from planting. The cuttings had thinner bark, less taper, lighter branching, grew straighter, and except for cuttings taken from old trees (15 years plus), grew at the same rate as seedlings.

Thulin and Faulds (1968) also considered the application of cutting grown **P.radiata**. Their work concentrated on the ability of stem cuttings to root, for reproduction of superior trees. From rooting trials conducted, production of commercial quantitites of plantable **P.radiata** rooted cuttings seemed both feasible and economic for cuttings taken from trees up to 15 years of age.

Subsequent to this work, trials involving selection of parent ortets, rooting of stem cuttings and their establishment, were conducted in Tarawera Forest. In 1969, cuttings were collected from parent trees selected for superior form and vigour in 7 year old stands (8 years from seed), and raised in the Te Teko Nursery. In 1970, 13 000 rooted cuttings from the previous years selection, were established in one stand. This stand of cuttings, now 15 years old (1985), is providing a striking comparison between seedlings and cutting grown radiata pine. The results of this trial in conjunction with various published work, prompted the initiation of a programme for the production of **P.radiata** rooted cuttings on a commercial scale by Tasman Forestry.

CURRENT PROGRAMME

To allow capitalisation of the maximum potential gain from Tasman Forestry's 1st generation seed orchards, two seed mixes from the annual harvest were segregated in 1977 and 1978. These mixes comprised open pollinated seed from the best 3, and the following best 5 clones, taken on progeny rankings at age 5 years. Seedlings from these seedlots were established on known high quality radiata sites in 1979 and 1980 (Gleed, 1982).

Phenotypic selection of the best 20% of trees in these stands has provided an excellent source of cutting material over the past 3 years. To meet an increasing demand for rooted cutings, additional material has been collected from forest stands, planted with seed orchard progeny from the full complement of clones.

Renewed annual production of rooted cuttings, by Tasman Forestry, commenced in 1982, with 60 000 being set that year. This increased in the two successive years to a total of 760 000 set in 1984.

PRODUCTION METHODS

Collection of the stem cuttings in the forest, and their setting out in nursery beds is carried out with contract labour. The 760 000 cuttings set in 1984 involved 30 contract workers, engaged in crews of 4 to 6 people and 3 supervisors from late May through till late July. Contracts were based on the number of quality cuttings set out in the nursery beds, plus appropriate travel allowances.

Forest

Ortet age significantly effects the rooting, growth and form of **P.radiata** stem cuttings. In the current programme, ortet age is restricted to a maximum of 5 years (6 years from seed). The worth of these early phenotypic selections is assured by stringent selection criteria. Achieving the right combination of ortet age and clearly expressed quality is fundamental to producing rooted stem cuttings that will perform superior to seedlings. The ortet selection is done on a subjective basis by each individual worker; it is an integral part of the collection operation. Careful and thorough instructions, close supervision, production penalties, including rejection of collected cuttings if necessary ensure ortet quality is maintained.

Within the appropriate age classes, stands for the collection of stem cuttings are selected using the following criteria;

i) there must be reasonable access both into and within the site
ii) any undergrowth must be easily penetrated
iii) terrain must be relatively easy
iv) trees must be sufficiently developed to allow phenotypic selection of the superior ortets
v) tree stock must be of seed orchard origin.

Criteria ii) and iii), whilst important to minimise collection costs and maintain productivity, were frequently compromised to maximise the yield of stem cuttings from better stands.

Outside of these criteria, a major limiting factor determining availability of suitable stands, is their distance from the nursery. Despite the proximity of a large forest estate managed by the company, younger plantings extend predominantly onto rougher and less accessible sites, where undergrowth is often prolific. The distance of collection areas from the nursery in 1984 ranged from 10 to 50 km, with over 70% of the cuttings collected in stands over 40 km away. To ensure rates of payment matched the work content involved, terrain and ground hindrance conditions were subjectively categorised into six categories;

1. Flat to undulating, moderate hindrance or less
2. Hilly to very steep, light hindrance
3. Flat to undulating, heavy hindrance
4. Flat to undulating, very heavy hindrance
5. Hilly to very steep, heavy hindrance or worse
6. Flat to undulating, extreme hindrance

Collections did not extend into areas of categories 5 and 6. Rates paid for each of the other four categories were derived using productivity figures from previous years in combination with time studies (Table I).

TABLE I

Terrain, Productivity and Rates of Payment
Cutting Collection and Setting Out
- Tasman Forestry Ltd, Te Teko

	SITE 1	2 & 3	CATEGORY 4
Average Daily Productivity (cuttings/manday)	1030	880	730
Rate Paid (Cents per cutting)	6.0	7.1	8.2

The cuttings are set out in nursery beds on the same day that they are collected. Crews work 5 hours in the morning collecting in the forest, and between 1½ and 3 hours setting out their cuttings in the nursery during the afternoon.

Each collector is issued with a planting frame, a pair of secateurs and 1m long wire hook. This hook enables cuttings to be obtained from higher branches. Cuttings are placed directly into a plastic seedling carton, carried in the planting frame worn at the waist.

Full cartons containing an average of 200 cuttings, are closed up and placed in the shade at designated collection points from where they are collected and transported to a central assembly point. Cuttings receive a thorough watering before being stacked in covered trailers which serve the dual role of field storage and transport to the nursery.

In the forest, each crew is allocated a separate and distinct stand which must be worked to the satisfaction of the supervisor before they are assigned a new stand. Frequent quality control checks to assess the crews ortet selection and thoroughness of collection, are carried out by the supervisor.

Nursery

Cuttings are taken directly from the cartons and set into freshly formed beds to which has been added a base dressing of Magamp fertiliser at 400 kg/ha. Precision spacing of cuttings, necessary for even root development and lateral root pruning, is achieved by pre-marking the beds with a special hand propelled bed roller; Figure I. This leaves imprints of crosses marking the points where cuttings are to be inserted. Crews are allocated separate lengths of bed in which they set out their previously collected cuttings. Quality control sample plots assess the percentages of acceptable quality cuttings that are satisfactorily set, and are the basis for calculation of crew payments.

Prior to root initiation, frequent irrigation is essential, particularly as the average day time temperatures increase during late spring and early summer. Although shoot elongation tends to commence in October, root development does not start until December following the formation of an adequate basal callus.

Development of an even, well formed, compact, fibrous root system is encouraged by regular conditioning. This includes an initial lateral root pruning using tractor mounted vertical discs in early February followed by frequent undercutting and wrenching as crop development and soil conditions allow.

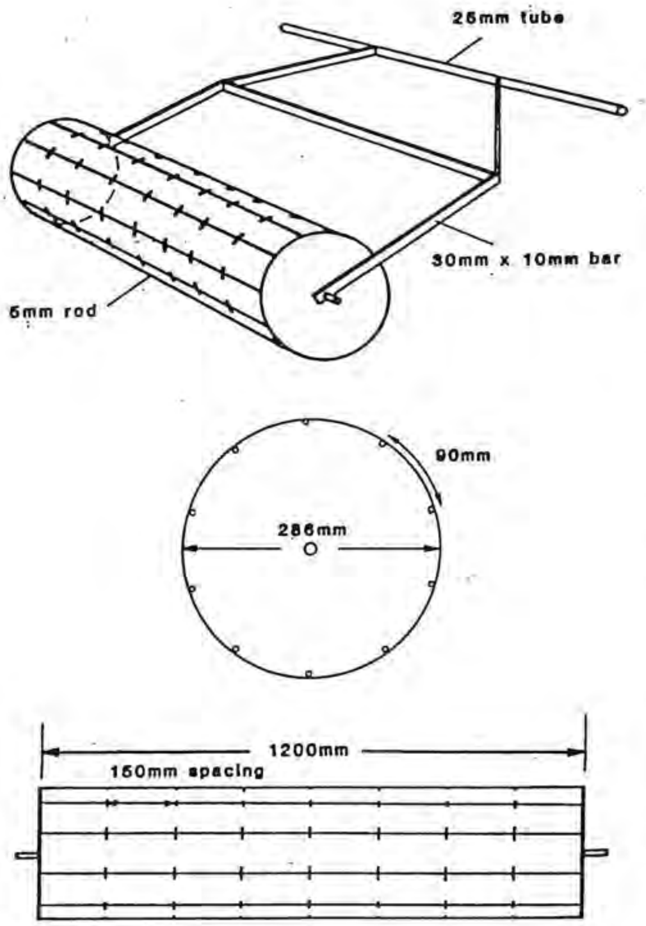

Fig. 1

Bed Marking Roller for Precision Setting of Cuttings in Nursery Beds

The rooted cuttings are lifted and despatched for planting during late May and June, after an average period of 12 months in the nursery. Just prior to lifting, they receive a final wrenching, and when lifted they are root trimmed with hand shears, packed in cartons and held in a coolstore until despatched to the planting site.

CURRENT ESTABLISHMENT PRACTICE

Seedlings grown from open pollinated seed, including seed orchard seed, display a wide range of variation in growth, branching, straightness and malformation. As it is not possible to select which seedlings will be of final crop tree quality at the nursery stage, considerably more seedlings, per hectare, must be planted in order to allow for selection of the required stocking of quality crop trees. At present a common practice in New Zealand is to plant 1 200 to 1 500 stems per hectare to provide a final crop of 250 stems per hectare.

All cuttings, in contrast, are potential final crop trees, due to the combination of ortet selection and growth form advantages associated with a degree of maturity. Consequently, the need for high initial stockings to guarantee sufficient quality tree trees for the final crop is eliminated. In Tasman's Forests, cuttings have been planted predominantly at 750 stems per hectare. Now, with several years experience in the establishment of cuttings, initial stockings on selected sites are being reduced to 500 stems per hectare.

These lower initial stockings, when established by Tasman Forestry, involve planting 250 groups of 3 or 2 stems at spacings of 6.25m between groups and 1.5m between trees within the group.

DISCUSSION

Tarawera Forest Cuttings

Twelve year old cuttings and seedlings, from stands in Tarawera Forest, were subject to detail-ed comparison in 1982 (Moffat, 1983). Twenty-five trees of each type were measured standing for diameter and bark thickness at breast height. Two increment cores and two pilodyn measurements were also taken at breast height for the calculation of average tree density. Ten out of the twenty-five trees of each type were then felled, and sweep, mean, branch size and diameters measured before removing discs for density calculations.

Though this comparison is unlikely to be conclusive for cuttings over the full range of sites on which **P.radiata** has been established, it is instructive to consider its results.

i) Morphology

The cuttings were significantly superior with smaller branch size, and less butt log sweep than seedlings. (Table II). They also had significantly thinner bark up to 2.75m height. These results concur with other comparisons conducted between seedlings and cuttings (Fielding, 1970; Libby et al, 1972; Sweet, 1973; Tuffor and Libby, 1973).

Taper over the length of the butt was lower for the cuttings than for seedlings, though the difference was not significant. Fielding (1968) reported cuttings to have definitely less taper than seedlings in the basal part of the trunk, based on studies in plantations aged between 4 and 27 years.

ii) Wood Properties

The cuttings in Tarawera Forest had lower average tree basic density and a lower heartwood content than seedlings (Table II). Analysis of density trends within trees revealed no significant differences between cuttings and seedlings above 10m height on the trunk, though the differences became larger in the lower portion of the trunk. As cuttings are primarily seen as trees for clearwood regimes, a reduction in their basic density below an accepted minimum could be detrimental to their value. However, marked variation in tree basic density also occurs at different elevations, particularly within the central North Island, which may be of greater significance to the grading of sawn timber than differences between cutting and seedling grown material.

As shown in Table II the average basic density of cuttings at 12 years is 7% below comparable aged seedlings. This lower density is no less than, that which exists between trees grown in Tarawera Forest and those grown in the extensive areas of Central and Southern Kaingaroa Forest, where in the latter areas, higher altitudes and lower mean annual temperatures lead to decreasing wood density. (Cown 1984).

TABLE II

Comparison of Cuttings and Seedlings
P.radiata 12 years old; Tarawera Forest

	CUTTINGS	SEEDLINGS
Mean Branch Index (cm)	3.4	4.5
Mean Sweep1) (mm)	22	49
Average Tree Basic Density kg/m^3	342	369
Heartwood %	5.4	9.5

(1) Sweep, over a specified log length is the maximum deviation of the log centre from the straight line between the log centre at either end. In this case, the sweep was measured on 5.5m butt logs.

ii) Growth

Height and basal area growth for the Tarawera Forest cuttings has been close to that predicted for seedlings by the Kaingaroa Growth Model (Figures 2 & 3). For accurate comparison, the growth model has been used in place of data from adjacent seedling stands due to significantly different regimes. These modelled values, generated using the site index derived from a permanent sample plot in the seedling stand combined with the cuttings stand regime, are compared to two separate samples of the cuttings. One is the growth of the crop elements (300 s/ha), in one sample plot, as reconstructed from increment cores and stem analysis, whilst the other represents annual measurements from a separate permanent sample plot.

To date (1984) growth measurements of the cuttings are similar to those predicted for seedlings but it is too early to say if such trends will continue through to rotation age. There is some evidence (see below) that diameter growth may drop below that of comparable aged seedlings. Should this occur it is expected that the improved stem form of the cuttings would yield greater utilisable volumes of higher valued timber and so help compensate for any loss in gross volume yield that may occur.

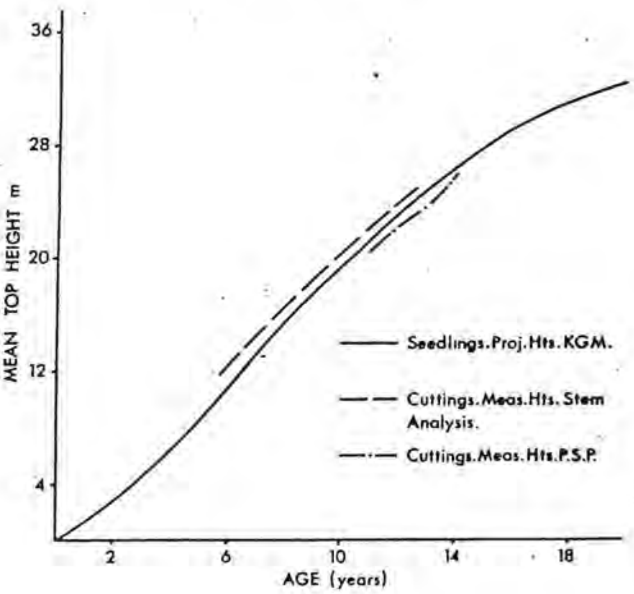

Fig. 2

Height growth trends Cuttings and Seedlings Tarawera Forest

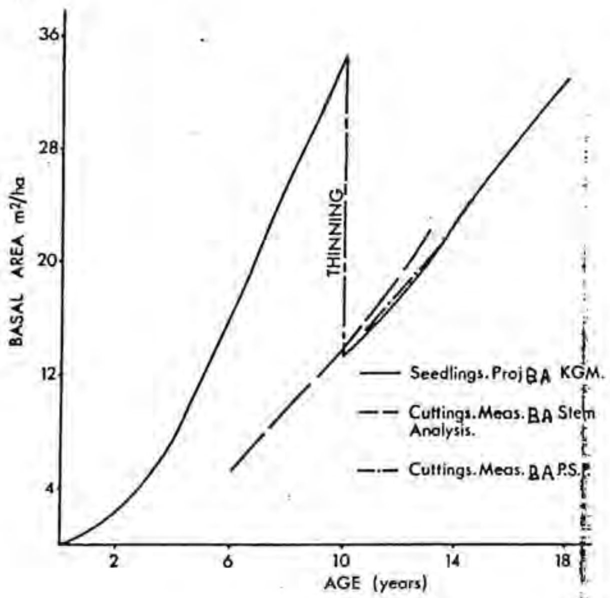

Fig. 3

Basal area growth trends
Cuttings and Seedlings Tarawera Forest

Numerous growth comparisons for cuttings and seedlings have been published, but results have not been consistent. In a trial reported by Shelbourne and Thulin (1974), the mean volume of cuttings taken from 6 year old ortets, was 89.5 dm^3 compared to 62.2 dm^3 for seedlings at age 6. Fielding (1970) found similar growth rates for cuttings and seedlings, with cuttings taken from ortets of ages between 4 and 7. Another trial involving cuttings from 1, 2, 3 and 7 year old ortets, described by Brown (1974), showed no significant differences between the early average growth rates of these cuttings and seedlings. In contrast, cuttings from 5 year old ortets planted in a trial at Kaingaroa Forest had signficantly smaller diameters at age 4 than 1/0 seedlings, of the same genetic origin, planted in the same trial (Anon, 1984).

At present, knowledge of cutting growth and performance is not complete. Whilst growth of cuttings has been shown to decline with ortet age up to maturity (Sweet, 1973), the growth of cuttings relative to seedlings still remains to be accurately defined over the range of sites where **P.radiata** is established.

Ortet Age

Maturation is the change from juvenile form to a senescent form and takes place in most perennial plants. Jacobs (1937) identified five phases in the maturation of **P.radiata.**

Upper Limit Of Age Years	Phase	Characteristics
1-4	Juvenile	Lack of a protected 'resting bud'.
4-8	Adolescent	Strong 'basket whorls,' thin leaders and other branch abnormalities such as heavy laterals. Steep branch angles are common.
6-10	Bulbous	Common in open grown trees, crooked internodes and long leaders.
20-40	Mature	Regular growth patterns
Variable up to 100	Senescent	Very slow growth rates.

The juvenile and adolescent phases will almost entirely be responsible for determining butt log form in seedling grown **P.radiata.** As the butt log can account for up to 70% of a trees's value, the defects associated with these two phases, particularly the adolescent phase, can be significantly detrimental to the total yields of both high quality logs and revenue.

Maturation effects within **P.radiata** are not reversed when it is propagated vegetatively. Ortet age therefore, will have significant effects on the growth and form of cuttings. In those studied at Tarawera Forest, the juvenile and adolescent phases had been avoided, resulting in superior formed trees to those derived from seedlings.

Significant growth, form and wood quality differences exist between cuttings taken from different age ortets (Sweet, 1973; Sweet and Harris, 1974 D.J. Cown, pers comm.). Associated with increasing ortet age through to maturity, characteristics of cuttings change as follows:

i) diameter and stem volume growth decline
ii) stem form improves
iii) branch diameter decreases
iv) bark thickness, at breast height, decreases
v) average tree basic density decreases
vi) difficulty of rooting increases

Vegetative propagation of **P.radiata** by cuttings taken from ortets into or beyond their adolescent growth phases, enables improvements in stem and branch form that are associated with maturity, to be expressed from the butt upwards. In seedlings, the desirable traits of maturity are predominantly confined to the upper logs. However, if the sum total of a cutting's performance is to be superior to seedlings, the degree of maturity has to be balanced against vital juvenile and adolescent properties, such as growth rate and wood density. The optimum ortet age to achieve this is yet to be defined, though trials have indicated that 5 years old could be the maximum (Anon, 1984).

Clearwood

Clearwood regimes enable full capitalisation of the inherent advantages of cuttings. To maximise the nett volume of clearwood produced in **P.radiata** it is important that the diameter of the pruned knotty core is kept to a minimum. This diameter is determined by the diameter over pruned branch stubs, commonly signified by D.O.S. (Diameter Over Stubs), in combination with the depth of the occulusion scars. The latter are primarily determined by branch diameter across the plane of abscission.

Significantly smaller diameter knotty cores can be achieved in cuttings than seedlings of equal Diameter at Breast Height (D.B.H.). This is due to the following attributes of cuttings:

i) reduced nodal swelling
ii) improved form (i.e. less sweep)
iii) lower taper
iv) smaller branch diameters

Alternatively, these attributes would enable cuttings to be pruned at a later age or with a larger D.B.H. than seedlings, to achieve the same diameter knotty core as the seedlings. Later pruning of cuttings could give them an advantage in diameter and stem volume growth.

Cost and Value Comparisons

Rooted stem cuttings, as planting stock, are approximately five and a half times the cost of seed orchard seedling stock; Table III. The extra expense of cuttings is associated with the following factors:

i) field collections, including ortet selection, cutting collection and transport
ii) setting out of cuttings in nursery beds
iii) density of plantable cuttings in the nursery beds
iv) the size of rooted cutting planting stock
v) Proportion of set cuttings making "plantable" stock

The cost of nursery weed control, tending and undercutting operations are largely determined by the ground area covered. On a 'per plant' basis, these costs are sensitive to the number of plants produced per square metre of nursery bed. On average, 50 plantable cuttings, compared to 84 seedlings, are produced per square metre of bed. Weed control costs are also affected by other factors. Firstly, the production period in the nursery, cuttings take approximately twelve months whilst seedlings take eight months. Secondly, cuttings provide an immediate and complete cover over the bed, resulting in poor penetration to the soil of pre-emergent weedicides and the consequent need for frequent hand weeding.

Cuttings are significantly larger in height, root collar diameter and root mass than are seedlings at the time of lifting in the nursery and planting out in the forest. With this larger planting stock, lifting times increase and cartons used for despatch hold only 75 cuttings versus 150 seedlings. Consequently the cost of lifting and despatch for cuttings are approximately double those incurred for seedlings. In addition the larger root mass of cuttings slows the wrenching operations further increasing the operational costs. The percentage yield of plantable stock from the total number of stem cuttings collected and set has a major influence on the final cost of rooted cuttings. Ortet age, genetic variation, nursery environment and the physical state of the stem cutting, including its degree of dormancy are the significant factors in determining the proportion of plantable stock achieved (Thulin and Faulds 1968). Careful attention to these details is necessary if costs are to be minimised.

Despite the higher cost of the planting stock, plantations established with cuttings and managed on clearwood regimes, accrue considerable cost savings in comparison to those established with seedlings. Table IV presents a comparison of the regimes in common use by Tasman Forestry Ltd, for forestry situations. **P.radiata** seedlings on fertile farm sites are usually fraught with adolescent growth defects including large nodal swellings, big branches, increased taper and poor stem straightness. High initial stockings required with seedlings lead to undesirable pasture shading, which is followed by problems of excessive thinning and pruning slash. Cuttings, in contrast, have fewer and lighter branches and lower initial stocking requirements, which minimise the problems of shading and slash. Furthermore, with group plantings, individual tree or group protection from animals is possible, allowing grazing to continue uninterrupted through the the establishment phase.

TABLE III

Production Cost Comparisons. Cuttings and Seedlings
1984/85

OPERATION	SEEDLINGS $/1000	SEEDLINGS % of Total Cost	CUTTINGS $/1000(1)	CUTTINGS % of Total Cost
Field Collection	-	-	102	47
Setting			41	18
Seed Orchard Seed including treatment	15	38	-	-
Seed Sowing including ground prep	2	5	-	-
Weed Control	5	13	19	8
Tending, including irrigation	1	2	26	12
Undercutting & Wrenching	1	2	5	2
Lifting & despatch	16	40	30	13
TOTAL	$40	100	$223	100

1) The costs presented are calculated per 1 000 plantable cuttings: not per 1 000 cuttings set. Approx. 80% of cuttings set make plantable cuttings.

TABLE IV

Comparison Of Cuttings And Seedlings Grown On Clearwood Regimes

Site: Average Slope
Rough Pasture
Medium Ground Hinderance

Interest Rate: 6%

	Age Years	Mean Crop Height	S.O. Seedling Stems/Ha	S.O. Seedling Cost $	Cost Discounted To Year 0.	Cuttings Stems/Ha	Cuttings Cost $	Cost Discounted To Year 0.
Plant	0		1 200	129	129	750	73	73
Cost of Stock				48	48		167	167
Spot Release Spray	0							
Application				44	44		26	26
Chemical				120	120		76	76
Low Prune 0 - 2.4m	4	6	350	184	145	250	98	78
Thin to Waste	4	6	700	94	74	250	38	30
Medium Prune 2.4 - 4.2m	5-6	8.5	250	181	128	250	148	104
Thin to Waste	5-6		0			250	51	36
High Prune 4.2 - 6.0m	7	12.0	250	234	156	250	145	96
Thin to Waste	7		250	59	39	0		
Silvicultural Costs Discounted to Year 0					883			686

these two types of tree stock. The establishment of fewer stems per hectare and the reduced pruning costs, due to the inherent lighter branching of cuttings, generate a discounted cost saving of $200 per hectare in favour of cuttings.

Agro Forestry

Additional benefits will accrue when cuttings, instead of seedlings, are established in agro-forestry situations. [continued above]

Future Values and Trends

The future stumpage value of cutting grown trees could exceed the value of seedling trees for the following reasons:-

i) Lighter branch characteristics may encourage additional high pruning because of the lower work content required, leading to higher clearwood volumes than that expected from "seedling" trees.

ii) · Less sweep, particularly in the butt log, yields improved sawn timber outturn. Using the values shown in Table II stumpage predictions via the Radiata Pine Task Force Silvicultural Model "PREVAL" indicate an increase in stumpage value at 30 years of approximately $500/ha.

iii) The possibility of planting "site specific" phenotypes is more likely with cuttings than seedlings and would maximise site potential.

iv) Using cuttings from selected older ortets (7-9 years) may allow short-rotation crops to be grown for specific end uses i.e. Horticultural or Construction poles.

v) Cuttings with inherent low density and heartwood percentages, of uniform diameter and little taper would make ideal mechanical groundwood. Billets would make maximum use of the groundwood hoppers and would require less power to separate the fibres and yield a pulp with minimum pitch content.

CONCLUSIONS

The use of vegetative cuttings for commercial afforestion is an accepted practice in Japan, Europe and Scandinavia. Encouraging results with radiata pine cuttings in Tarawera Forest have prompted Tasman Forestry Limited to undertake a progressively increasing forest establishment programme with them (1 000 hectares in 1985). Optimum site conditions and availability of superior genetic material are important factors in this decision.

It is predicted that their use will become and remain a profitable option for **P.radiata** forest establishment.

ACKNOWLEDGEMENTS

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Prospects for clonal forestry with radiata pine

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Summary

The advantages of vegetative propagation of forest trees are discussed. The history of the development of such techniques with radiata pine (*Pinus radiata*) is outlined and a new technique for mass propagation of cuttings of the species described. It is suggested large scale clonal plantations of this species are now possible.

Introduction

New techniques for vegetative reproduction of forest trees have made it possible to mass propagate selected and improved clones of some species for production forestry. This was not possible a few years ago, yet now one third of Norway spruce (*Picea abies* (Linn.) Karst.) plantings in the Federal Republic of Germany are clonal (Kleinschmidt[1], pers. comm.) and the Swedish company, Hilleshog, has a major clonal plantation programme with the same species (Bentzer 1981). The French are successfully producing rooted cuttings of *Pinus pinaster* Ait. for forest planting (Chaperon[2], pers. comm.) and clonal eucalypt plantations are being established on a large scale at Aracruz in Brazil (Campinhos and Ikemori 1980) and in the Congo (Delwaulle, Laplace and Quillet 1980).

The advantages of clonal forestry are so great it should be most seriously considered for radiata pine (*Pinus radiata* D. Don) in Australia. This paper outlines some of the advantages which accrue from the use of selected clones in production forestry, describes new techniques which are being used to mass propagate radiata pine and details a time frame within which the procedures could become widespread.

The advantages of clonal propagation

The benefits resulting from clonal propagation of improved material have been summarised by Zobel (1981), Libby (1983) and Burdon (1983). Essentially these involve (i) greater genetic gain, (ii) more rapid realisation of this gain and (iii) development of more uniform forests than is possible with seedlings. Libby (1983) detailed other advantages, which include (iv) utilisation of material whose good qualities would be lost if sexually propagated and (v) possible development of clone/site matching so that special clones can be used in particular circumstances.

Increased yield

The seeds produced in seed orchards are a mix of the different possible crosses between the breeding trees in the orchard. The resulting forests represent an average of these crosses. However, the very best crosses produce progeny much superior to this average as is demonstrated in data from a CSIRO progeny test of radiata pine in N.S.W. After eight years in the field the general seed orchard materials showed a 21% advantage over unselected material but the five best crosses a 57% advantage (Table 1). Mass vegetative propagation of the few super crosses could allow this increased advantage to be exploited in plantations.

Speed of realisation of the increased yield

Improved material can be established in the field much more quickly by using vegetative propagation than is possible with seedlings. With seed propagation and tree improvement by means of seed orchards there is a minimum lead time of

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Table 1. Comparative diameters (at 11 yr of age) and volume production (at 8 yr) of *P. radiata* trees of (i) unselected stock, (ii) general seed orchard origin and (iii) the mean of five outstanding control pollinated families in CSIRO progeny tests in N.S.W.

	Diameter (cm)	Volume (dm^3)	% advantage in volume
Unselected stock	15.5	56.7	control
Seed Orchard	17.3	68.7	21
Five outstanding families	19.1	89.1	57

Source: CSIRO Division of Forest Research and adapted from Clarke (1982).

eight to ten years between tree selection and large scale seed production with even the fastest growing species. Using vegetative propagation selected material may be established in a much shorter time. This has been demonstrated in Brazil where work on establishing cuttings of eucalypts (*Eucalyptus grandis* Hill ex Maid., *E. saligna* Sm. and *E. urophylla* S. T. Blake) commenced in 1975. Three years later the techniques were sufficiently well understood to allow clonal propagation to be done commercially. One million cuttings were planted in 1979 and five million in 1980 (Campinhos and Ikemori 1980). Thus, even including research and development time, the improved material (in this case with a 28% gain) was in the field within five years of commencement of the programme. The methods described below could achieve similarly rapid results with radiata pine.

Gain from uniformity

The uniformity of a forest affects the efficiency and cost of silvicultural, harvesting and processing operations. Consequently, substantially increased net gains will accrue with establishment of more uniform forests. Clonal material should produce uniform forests and if so these gains will be realised (Gleed 1983).

Special trees

Libby (1983) suggested it may be possible to exploit unique individuals by using clonal propagation. These special individuals combine attributes which do not usually occur together and Libby refers to such trees as 'correlation breakers'. Examples could be trees which combine (i) high volume and high density wood or (ii) fine branches and long internodes. Special trees of this kind may lose their desirable combinations when outcrossed and consequently they cannot easily be obtained using seed. Mass vegetative propagation could retain them and allow their widespread use.

Some outstanding trees may be difficult or impossible to propagate by seed. Many F_1 hybrids are in this category and one example of a valuable F_1 hybrid tree widely propagated clonally is provided by the Leyland cypress (x*Cupressocyparis leylandii* (Dallim. and Jacks.) Dallim.) in England. This originated as a spontaneous hybrid between Monterey cypress (*Cupressus macrocarpa* Hartw.) and Nootka cypress (*Chamaecyparis nootkatensis* (D. Don) Spach) and is now extensively used as a windbreak, hedgerow or ornamental tree. However all propagation has been by cuttings and generally from only two clones (Ovens *et al.* 1964).

Clone/site matching

Individual trees vary in the ability to cope with adverse situations. In radiata pine, individuals differ in their tolerance of low boron (Windsor and Kelly 1971, Snowdon[3] pers. comm.), low phosphorus (Burdon 1971) and resistance to *Dothistroma pini* Hulbary (Wilcox 1982). Similarly, eucalypts exhibit variation in disease resistance to *Diaporthe cubensis* Bruner in Brazil (Campinhos and Ikemori 1980), frost resistance and calcareous soil tolerance in France (Destremau *et al.* 1980) and salt tolerance in Australia (Blake 1981). It may be possible to find particular individuals unusually well adapted to specific soils, climatic types, regions, forests and, possibly in the very long term, to aspects and microsites. If so, clonal propagation of such individuals would allow the benefits of this adaptation to be realised in plantations (Libby 1973).

Simplicity of breeding strategy

A tree improvement programme based on vegetative propagation would be simpler to manage and document than a seed-based programme. Indeed, the strategies used or advocated for programmes using seed orchards seem overwhelmingly complex. They may require numerous parents with detailed pedigrees, intricate crossing programmes and replicated progeny tests with complex lattice designs using single tree plots. Considerable expertise must be committed to the management of such programmes and may need to be maintained over a long period, at least 10-20 years.

[3] Snowdon P. Division of Forest Research, CSIRO, Yarralumla, Australia.

There could be a marked reduction in programme complexity if the work were primarily with clones. The number of selected trees could be fewer and the crossing programmes and testing designs simpler because of the reduced variation. The programme would still require a large data base plus detailed documentation of pedigrees and of the results of trials on various sites, but flowering and seed production would only be important on an experimental scale.

The quicker realisation of gain means management commitments would not need to be long term. Indeed, given reliable propagation techniques, any one commitment might only need to be of the order of five years. After this, tangible returns might be apparent and the commitment could be reviewed. Such an arrangement must be more attractive to management than the 10-20 year requirements of the present seed-based programmes.

The history of vegetative propagation of radiata pine

For many years it has been possible to produce rooted cuttings from radiata pine. There are reports of the species being struck in the 19th century and Jacobs produced them in considerable numbers in the 1930s (Jacobs 1939) and Fielding (1954) developed the procedures further. Up to 1983, however, cuttings had only been used for limited trials and demonstrations and for the establishment of seed orchards and clone banks.

Early attempts to produce large numbers of clonally identified cuttings were unsuccessful because of a decline in success rate with maturation of mother plants and the consequent difficulty of obtaining high multiplication rates sufficiently quickly within a clone. As a tree ages it becomes increasingly difficult to produce rooted cuttings. The percentage of successful strikes drops markedly in radiata pine at about four years of age and further reduction in rooting ability occurs as the tree ages further.

One successful means of countering the maturation effect is to hedge the plant at about one metre high (Libby *et al.* 1972, Matheson and Eldridge 1983). Small areas of plantation can be established with this technique as these hedged plants can produce between 100 and 150 lignified stem cuttings per square metre of hedge per year (Libby *et al.* 1972). However, these hedges have high space and maintenance requirements and lignified cuttings require a long period of many months to become established. A more efficient procedure is desirable for large scale production forestry.

Some large scale production commenced in 1983 in New Zealand. The N.Z. Forest Research Institute and Tasman Forestry Ltd. struck close to 300 000 cuttings (Wilcox[4] pers. comm.) and private nursery interests there also commenced production. The procedure used is to select vigorous young seedlings in the field, between two and four years old, which have originated from the best seeds available. Lignified stem cuttings are taken from side branches of these seedlings for 2-3 years after which they are allowed to grow on as normal forest trees. This system is cheap and effective as no attempt is made to identify particular families and the identity of individual clones is not maintained, Consequently the genetic quality and composition of the forests is unknown and the forests could not form part of an ongoing breeding programme. Specialised procedures such as clone-site matching and the use of special trees are also not feasible with this procedure.

Another approach that has been considered in New Zealand is to micro-propagate from seeds of the best controlled pollinations (Smith *et al.* 1982). Multiplication rates using this method are extremely high and clonal micro-plants can be stored at low temperatures for many years, while clonal trials are proceeding. The major problem with this method is the high cost. Each micro-plant in the multiplication medium must be regularly separated manually in the laboratory and, at multiplication, micro-plants must be manually transferred to rooting medium. A further manual transfer of the rooted plantlet to solid medium must be followed by hardening off and out-planting in the nursery where the plantlet is then treated in the same way as a seedling. These costs are currently too great to allow large scale propagation by this method. Probably in the long term automation will be introduced into micro-propagating systems with reduced cost and the method will be considered for the production of forest planting stock.

The new procedures

A new method for production of clonally identified radiata pine cuttings in large numbers is in

[4] Wilcox M. D. Forest Research Institute, Rotorua, New Zealand.

use at the senior author's nursery at Tarago near Canberra. It is based on the techniques developed in France for *P. pinaster* by Franclet (1979) and Chaperon (1979) and uses soft tissue cuttings 3-5 cm in length from very small mother plants. Large quantities of suitable material can be produced as fascicle shoots on decapitated mother plants maintained at high growth rates by intensive watering and fertilisation in a "clone garden" (see Figures 1, 2 and 3). The shoots are removed, treated with hormone and placed in artificial rooting medium under plastic with an intermittent mist system and bottom heat. Rooting occurs from day 20 onwards and strike rate is close to 100% provided the mother plants are in good condition (Figures 4 and 5). Six or seven rooted cuttings can be struck from each mother plant during the first year and can then be used as mother plants themselves during the second year when they can each produce 100 cuttings. This can be repeated for several years.

As noted, multiplication rates of x100 are possible from a single mother plant each year. Consequently, provided any logistic difficulties can be overcome, one thousand original seedling mother plants could reliably produce ten million rooted cuttings per year four years after the original sowing.

The nursery and clone garden sizes are not excessive. Production in the clone garden at Tarago with five mother plants per square metre

Figure 1. The clone garden at Tarago, showing mother plants of three different ages. The plants on the right were taken as cuttings 12 months previously and established in the garden 6 months previously. They are now suitable for decapitation to provide cuttings. In the centre are plants established in the garden 12 months previously and to the left some established 18 months previously. The left and central rows are now providing large numbers of cuttings.

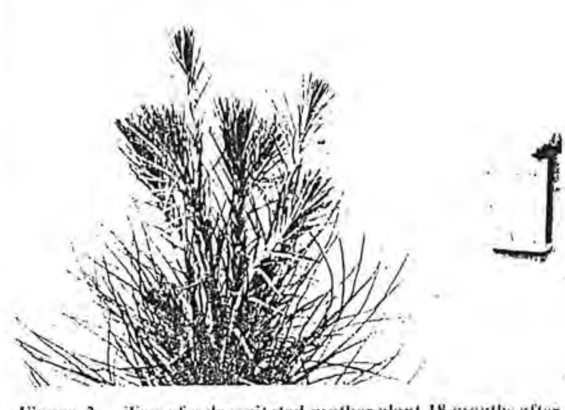

Figure 2. Top of a decapitated mother plant 18 months after establishment in the clone garden with several shoots suitable for use as cuttings.

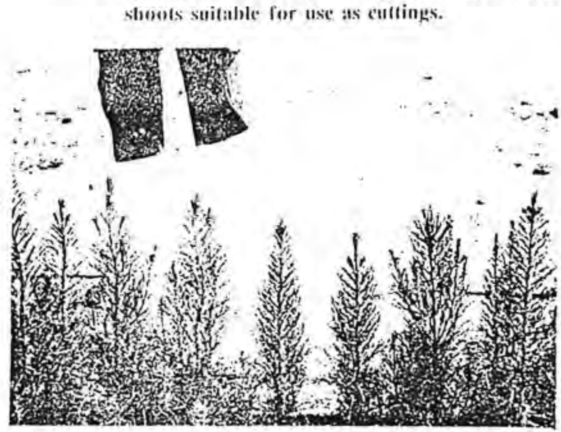

Figure 3. Young, six month old, mother plants now suitable for decapitation to provide material for cuttings.

is approximately 500 cuttings/m^2/yr and cuttings can be established in propagation beds at a density of 550/m^2 (Figure 4). However, if large, advanced growth, planting stock is required this density has to be reduced.

It has not yet been established how long individual mother plants can continue production at a very high rate and whether any physiological ageing and loss of rooting ability occurs. It is, however, anticipated that at Tarago the clone gardens will be re-established on a serial basis every 3-4 years and loss of rooting capability in this period should not be serious. Hedged radiata maintain high rooting ability for 6-7 years (Libby *et al.* 1972) and seedlings should have a similar performance.

Future strategies and research

Commercial acceptance of clonal forestry requires confidence in the knowledge that the clones

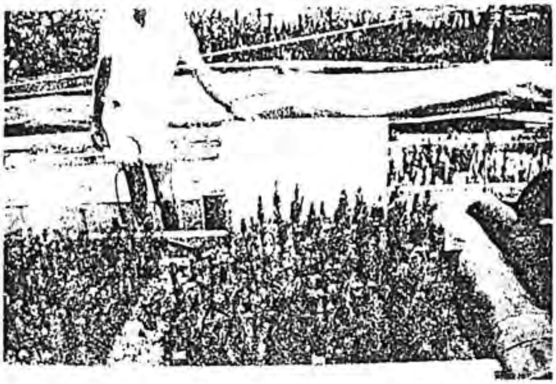

Figure 4. A propagation bed with cuttings taken 12 months previously and now suitable for field establishment.

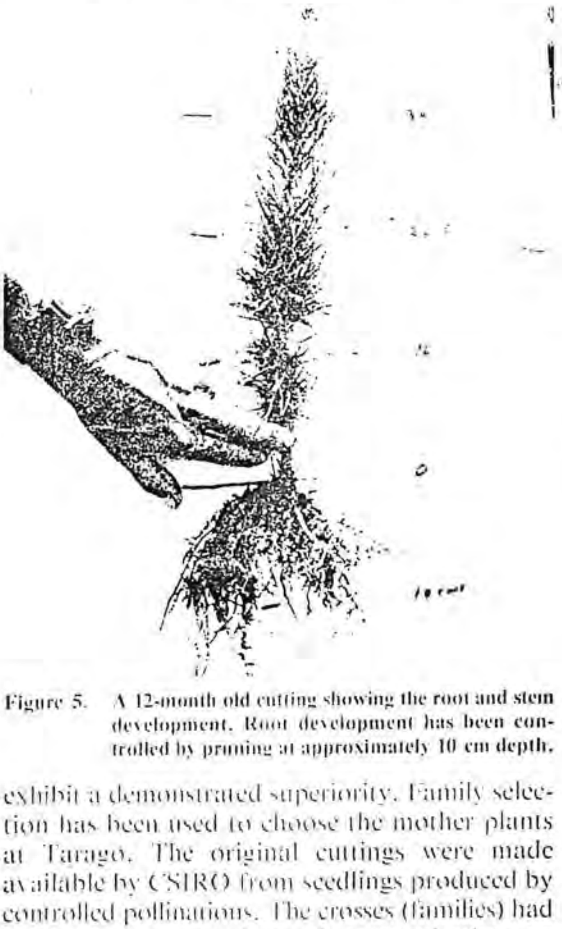

Figure 5. A 12-month old cutting showing the root and stem development. Root development has been controlled by pruning at approximately 10 cm depth.

exhibit a demonstrated superiority. Family selection has been used to choose the mother plants at Tarago. The original cuttings were made available by CSIRO from seedlings produced by controlled pollinations. The crosses (families) had been tested previously by that organisation, or other research workers, and proven to exhibit high vigour and desirable form characteristics. However, although each family is known to be of good quality, there will still be variation between individuals within the family. Consequently each individual clone is separately identified and records kept of its performance. As trials indicate which are the inferior and superior clones within each family the clone garden will be rogued and upgraded. Thus an important requirement for defining development of the Tarago programme is a knowledge of the degree of variation within each family. This basic information will determine how many clones within each family should be propagated.

There are other questions which require attention. What crossing programmes are needed to produce new families? What is the extent of clone/site interaction and how much clonal variation is there on different sites? Is somaclonal variation important? Do we need to be as worried about inbreeding as much as previously? These and similar questions require major research attention so clonal forestry can become fully integrated with tree breeding programmes.

Foresters have always been wary of large areas of genetically narrow material because of the long term nature of plantations and the danger of widespread losses if there is no inherent resistance to repel a catastrophe. Consequently, whenever clonal forestry is practised attention must be given to the number of clones to be included and the planting designs to be used. These must provide the advantages of the clonal forest yet retain adequate genetic diversity. For example, a random mix of a large number of different clones would lose the silvicultural advantages of uniformity. Libby (1983) has suggested planting individual clones in a mosaic of small to medium sized areas. He suggested each area could be up to 5 ha in size and there may need to be be between 7 and 30 clones in any one planting. As an alternative, or additional, safeguard Libby suggested the clonal material could be interplanted with seedlings. These would generally be removed later during thinning operations after a forest crop was established. There seems no reason why satisfactory planting designs for the implementation of clonal forestry cannot be devised.

Conclusion

The propagation methods described in this paper and in use at Tarago indicate that clonal forestry with radiata pine is a practical possibility. Provided logistical problems can be overcome very large quantities of rooted cuttings can be produced. The substantial advantages of clonal forestry over traditional methods suggest this form of forestry should be most seriously considered. However, adequate safeguards against excessive genetic uniformity will be necessary.

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ATTACHMENT 3

1. IMMEDIATE PRODUCTION OF CUTTINGS.

1a) Seedling stool multiplication systems
(gain component = moderate genetic)

Genetic source:

Seedlot D655, collected from 10 outstanding radiata clones in the Manjimup orchard in 1984.

Action:

August 1985 - sow 15kg seed each at Nannup and Gnangara nurseries at a seedling density of 20/meter of drill; grow with optimum treatment.

June 1986 - retain 2 outside drills (of 6) in nursery bed and lift seedlings within retained row to leave the most vigorous 10 seedlings/meter of drill. At each nursery retain 25,000 seedlings as mother ortets (A). operations planting of approx. 300,000 seedlings at normal spacing in production plantations. Give these areas optimum establishment and tending treatments as these will be used, at age 3-4 years, with low intensity selection (1:5) and set as woody cuttings (see 2 b).

October 1986 - decapitate mother ortets (A) when they are about 60cm tall and set 10cm tops in propagation beds (40,000 cuttings for P1987). Tie down or mesh seedlings to provide the multiplication stools; each seedling stool can provide 25-30 cuttings, and can be used for two years production.

June 1987 - lift and plant 50,000 x 25 + 40,000 = 900,000 cuttings possible.

August 1987 - prepare seedling stools.

June 1988 - lift and plant 50,000 x 25 = 900,000 cuttings possible.

Research:

October 1985 - develop seedling stools at Nannup and Gnagara nurseries.

November 1985 - commence setting of fascicle shoots in heated trays and transplants rootedcuttings (after 4 weeks) into open nursery beds.

January 1986 - investigate setting of woody shootsin misted open nursery beds.

May 1986 - recommend propagation technique.

1b) Woody trees, multiplication system
(gain component = selection + ageing)

Genetic source:

Seedlots originating from Manjimup seed orchard, age 3-4 years.

Action:

May 1986 - moderate intensity selection (1:10) and collection of woody cuttings from selected trees in the field. Set cuttings at Manjimup (heavy soils) and Gnangara (sand).

June 1987 - lift xxx, xxx cuttings and plant.

2. INTERMEDIATE PRODUCTION OF CUTTINGS

2a) Fascicle shoot, multiplication systems
(gain component = high genetic)

Genetic source:

50-80 selected pedigree families, 10-30 seed of each family.

Action:

August 1985 - sow and germinate seed in jiffy pots, and then pot on into plastic pots (50x20 = 1,000 (A) ortets).

February 1986 - decapitate and set seedling tops in Wanneroo propagation beds (50x20 = 1,000 (B) ramets).

April 1986 - remove fascicle shoots from (A) ortets set in Wanneroo heated propagation beds (50x20x5 = 5,000 (C) ramets).

June 1986 - plant into clonal gardens (5,000 (C)).

July 1986 - remove fascicle shoots from (A) ortets, set in Wanneroo heated propagation beds (50x20x5 = 5,000 (D) ramets - decapitate (B) ramets and set in propagation beds at Wanneroo (50x20 = 1,000 (E) ramets) - plant ortets (A) and ramets (B) and age to form future cutting donor hedges (1,000 + 1,000 = 2,000)

September 1986 - plant into clonal gardens (5,000 (D) + 1,000 (E)), grow clonal gardens.

** at this stage, have 5,000 (C) + 5,000 (D) + 1,000 (E) ramets in the clone garden. Area required for the clone garden is 2,000m². In the second year, multiplication rates of x 100 are possible ... production is expected

June 1988 - ~~lift and plant~~ 100,000 cuttings, maintain clonal gardens.

June 1989 - ~~lift and plant~~ 500,000 cuttings, maintain clonal gardens.

June 1990 - lift and plant 500,000 cuttings, maintain clonal gardens.

June 1991 - lift and plant 500,000 cuttings, maintain clonal gardens.

continue.

Research:

September 1985 - investigate setting of various size fascicle shoots in heated propagation beds at Wanneroo; root and line out in open nursery.

2b) Woody trees, multiplication system
(gain component = moderate genetic + selection + ageing)

Genetic source:

Seedlot D655 field planted in 1986.

Action:

May 1988 - low intensity selection (1:5), collect 30 woody cuttings from selected trees and set in open nursery beds with mist irrigation.

May 1989 - return to the same field trees (now age 3) and collect 30-50 woody cuttings; set in open nursery beds with mist irrigation.

June 1989 - lift and plant xxx, xxx cuttings.

May 1990 - return to the same field trees (now age 4) and collect 30-50 woody cuttings; set in open nursery beds with mist irrigation.

June 1990 - lift and plant xxx, xxx cuttings.

June 1991 - lift and plant xxx, xxx cuttings.

August 1991 - form prune the field donor trees and grow on as a normal plantation.

3. LONG TERM PRODUCTION OF CUTTINGS

3a) Woody trees, cyclic multiplication system of superior genetic material
(gain component = genetic + selection + ageing)

Genetic source:

Control pollinated families of outstanding clones.

Action:

July 1985 - Series I, isolation and collection of pollen.

July 1986 - Series I, control pollination.

July 1988 - Series II, isolation and collection of pollen.

August 1988 - Series I, collect control pollinated cones and extract seed; sow seedlots in Gnangara nursery maintaining family pedigrees.

June 1989 - Series I, field planting maintaining pedigrees; grow seedlings and trees with optimum treatments.

July 1989 - Series II, control pollination.

May 1991 - Series I, low intensity (1:5) field selection, collect 30 woody cuttings from selected trees in each family and set in misted open nursery beds.

July 1991 - Series III, isolation and collection of pollen.

August 1991 - Series II, collect control pollenated cones and extract seed; sow family seedlots at Gnangara nursery.

May 1992 - Series I, return to the field donor trees (now age 3) and collect 30-50 woody cuttings; set in misted open nursery beds.

June 1992 - Series I, lift and plant xxx, xxx cuttings.

- Series II, field planting of families; grow with optimum treatment.

July 1992 - Series III, control pollination.

May 1993 - Series I, return to the field donor trees (now age 4) and collect 30-50 woody cuttings; set in misted open nursery beds.

June 1993 - Series I, lift and plant xxx, xxx cuttings.

August 1993 - Series I, form prune the field donor trees and grow on as a normal plantation.

May 1994 - Series II, low intensity (1:5) field selection, collect 30 woody cuttings from selected trees in each family and set in misted open nursery beds.

June 1994 - Series I, lift and plant xxx, xxx cuttings.

July 1994 - Series IV, isolation and collection of pollen.

Continue - annual production of xxx, xxx cuttings.

3b Fascicle shoots, multiplication system
(gain component = high genetic)

Genetic source:

Outstanding clones with particular characteristics can be crossed and then multiplied by the fascicle shoot method. For example, clones with high basic density, disease resistance, rapid growth, fine branching character etc. New material from the breeding programme can be immediately included in operations by this method.

4. SUMMARY OF POTENTIAL CUTTINGS PRODUCTION

P 1986 - 30,000 type 1b.

P 1987 - 900,000 type 1a possible + 100,000 type 1b.

P 1988 - 900,000 type 1a possible + 100,000 type 2a.

P 1989 - 500,000 type 2a + 500,000 type 2b.

P 1990 - 500,000 type 2a + 500,000 type 2b.

P 1991 - 500,000 type 2a + 500,000 type 2b.

P 1992 - 750,000 type 3a + 500,000 type 2a.

P 1993 - 750,000 type 3a + 500,000 type 2a & 3b.

P 1994 - 750,000 type 3a + 500,000 type 2a & 3b.

Continue

ATTACHMENT 4

TIMETABLE FOR HAPSO DEVELOPMENT

July 1985	:	250 grafts planted in "Phytophthora cinnamomi" tolerant colonal rows and 250 grafts planted in "general" clonal rows. Spacing 6x3m.
August 1985	:	2,000 grafts of superior first and second generation selections from the Western Australian,Victorian and South Australian breeding programmes. Victorian and South Australian imports will be quarantined for six months to guard against pest or disease introduction, for example Dothistroma.
June 1986	:	complete the Block I planting. initial planting of male orchard.
August 1986	:	3,000 grafts of superior first and second generation selections from the Western Australian, Victorian, South Australian and APM breeding programmes. APM selection will be quarantined for six months before release.
June 1987	:	plant Block II, 1.5ha "P. c." clonal rows and 2.5ha "general" clonal rows.
	:	complete the planting of the male orchard.
August 1987	:	3,000 grafts of superior first and second generation selections from the Western Australian, Victorian, South Australian and APM breeding programmes.
June 1988	:	plant Block III, 1.5ha "P. c." clonal rows and 2.5ha "general" clonal rows.

Note: This completes the first HAPSO series. Annual successive production of about 100kg seed is forecast, to produce about 1.5million seedlings.

A second HAPSO series will be commenced almost immediately and will include the very best of the available Australian material. Further testing of the South African population, which has high Phytophthora cinnamomi tolerance, should provide new genetic material. By this stage, we hope to be able to import these South African selections by tissue culturing to facilitate quarantine.

i.e. continuing annual production based on 750,000 woody cuttings and 500,000 fascicle shoot cuttings. With time, it is possible that the more intensive fascicle shoot programe should be phased out.

D. Sykes

ATTACHMENT 5 42.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

COMO RESEARCH
H.O. 343/69

232 . 31

DR CHRISTENSEN
COMO RESEARCH

PINUS RADIATA SEED ORCHARDS (HAPSO)

Pederick and Eldridge (1983) recently reported on the considerable gains that have already been made through the breeding of radiata pine, and of the substantial benefits still to be achieved by developing these programmes. Investment in tree breeding will lead to greater productivity and efficiency of land use; Zobel (1978) quotes it as "perhaps even the best of all forestry investments".

There appears to be a greater interest and awareness currently of the benefits of tree breeding with Governments and Companies in Australia and New Zealand keen to expand these activities. New Zealand has a particularly active genetics group doing outstanding basic and applied research on genetic improvement of radiata pine; a noteworthy aspect of their programme is the primary concern to quickly transfer improved genetic material into operations through the use of cuttings and intensively managed seed orchards.

In Australia, though of a national concern radiata breeding is somewhat fragmentary with CSIRO directing research into principles and reducing its effort on applications. State Governments and large Companies concerned with radiata pine each have their own breeding programmes. This is inefficient but repeated requests from the Research Working Group 1 for a co-ordinated Australian breeding of radiata pine have been unsuccessful; coordination and cooperation has been left between individuals. It is for this reason that New Zealand is "leaving Australia for dead" in the breeding of radiata pine.

Currently, substantial resources in Australia are being invested to putting breeding results into practice. Increasing amounts of cuttings of superior material is being used for afforestation, for example 500,000 cuttings in South Australia, 200,000 cuttings in Victoria (APM) and the hybrid cutting programme in Queensland. However, all programmes still rely on seed orchards as the major means of getting improved material into practice.

The concept of intensive management with artificial pollination, seed orchards was first promoted by Sweet and Krugman (1977). They listed the major problems of conventional seed orchards as:

1 Insufficient and variable initiation of reproductive structures.

2 Problems of incomplete pollination and subsequent seed development.

3 Management problems concerned with tree size.

The efficiency of seed orchards could be increased by having artificial pollination to achieve more genetic control of seeds, by having intensive management during all phases of flower and seed development and by hedging to bring flowers closer to the ground. Volume production can be increased by the order of 10% by having better genetic control of the seed.

Hedged artificial pollination seed orchards (HAPSO) are ideal for producing seed for special purposes or for special sites.Brown & Eldridge (1983) suggested this type of orchard for Western Australia where Phytophthora cinnamomi was a particular concern.

In Western Australia, the recent interest shown in the radiata programme is remarkable with the stimulus coming from Don Spriggins and Don Keene. Gains have already been reported in the breeding document and can be summarised as:

* increase in volume production of the order of 10% and to increase to 15-20% with new conventional seed orchards.

* dramatic improvement both in stem form and branching quality; increase in double the number of trees with acceptable form and branch size.

* development of a Phytophthora cinnamomi tolerant population of radiata pine.

It was opportune that the breeding programme come under review in July 1985, at the time when the old West Manjimup seed orchard was being replaced. This meeting was of significance and no doubt will be regarded as a watershed for future radiata pine afforestation in Western Australia. The important recommendations were:

1 To develop a programme to produce 1.5 million cuttings/ annum (Appendix 1).

2 Adopt the concept of intensive management seed orchards to produce the balance(one half) of afforestation requirements.

I was instructed to proceed with the planning of the HAPSO (will be planted in July 1985). However, I feel that it is necessary to reiterate that this concept is radical and that there are no other orchards of this type in the world. New Zealand, however have gone one step further and intend to control pollinate (HCPSO). No other Australian programme is using the HAPSO concept, because of the intensive management commitment. Management in the main will involve hedging and trellising the clonal rows, continual removal of competing shoots above the developing cones, pollen collection, storage and handling, artificial pollination when flowers are receptive, castration or removal of any pollen that appears in the HAPSO, weed control through grazing, fertilisation and irrigation. Compensating this will be the safe and relatively cheap cone collection.

The HAPSO has the obvious advantages listed by Sweet and Krugman (1977) but they are of special significance to Western Australia:

1 "Specialty Phytophthora cinnamomi tolerance" and "general' seed populations of radiata pine required for afforestation. With conventional designs, two distinct orchards are required. This is not necessary for the HAPSO; different pollen mixes can be used for each purpose.

2 Serious seed development problems have been encountered in the WMSO. Flower initiation is excellent but embryo development is adversely affected in certain years by competition for limited moisture. The HAPSO is designed for efficient applications of any cultural treatment. Irrigation needs to be applied when the seed is developing. High seed abortion and potential fluctuations of more than one half of the number of viable seed can be removed.

3 The radiata breeding programme in W.A. has been secondary to the pinaster programme; as a consequence our full pedigree breeding population is rather limited. We have made many outstanding second generation selections within progeny trials that could be used in new seed orchards. However there is the problem that the pollen parent of these selections is unknown and possibly related to other clones being reselected. Placing these clones in a conventional seed orchard could lead to an unacceptable degree of inbreeding depression through related matings; this would result in a loss of potential volume production. In the HAPSO, selfing and related matings can be completely eliminated or controlled at a particular level. Second generation selections in the WA programme can be used in HAPSO.

4 The versatility of the HAPSO suits a rapidly expanding and improving genetic quality programme. Clonal rows of new genetic material can be added to the HAPSO and almost immediately included in general afforestation. In conventional orchards, this may be delayed by 12-15 years.

5 Additional or improved characters can be added to the genetic makeup of the HAPSO product, for example if greater wood density, or less spiral grain, or Dothistroma resistance is required, a pollen mix can be so constituted.

I am convinced that the HAPSO is the seed orchard required for Western Australia. However, because of the clonal rows they are a one way track and once we start, then we are stuck with them. Intensive management is a must and a continued commitment from operations is obligatory. I believe that the advantages of the HAPSO far outweigh the additional intensive management. If we are really serious about increasing the productivity of our pine plantations, then these radical steps are necessary. The HAPSO concept is untried and will require major inputs from research branch to develop the most efficient techniques. With this impetus to the radiata production programme, not withstanding the necessary rapid development of the breeding population programme or the pinaster programme, additional staff is necessary to achieve these important forest production goals. How many?

T B BUTCHER
SDFO

26 July 1985

I believe we are zealous
of benefits of "HAPSO"

TBB:sl

DISTRIBUTION: MR HAVEL
MR KEENE
MR SPRIGGINS

Noted

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D.S. - for your action

To note: Mr J. Gilchrist.

APPENDIX I

OPTIONS FOR DEVELOPMENT OF SELECT PINUS RADIATA CUTTINGS FOR LARGE SCALE OPERATIONS USE

1 IMMEDIATE

: seedling stool, multiplication systems.

* Sow SN8406 seed at Nannup and Gnangara nurseries in 1985.

* June 1986, lift 300,000 seedlings for planting in 1986. retain about 50,000 of the most vigorous seedlings in thinned rows; grow on to a height of 50-60cm, remove top and set as woody cuttings; tie or mesh down these 50,000 topped seedlings; remove 25 fascicle shoots or woody cuttings and set; raise 1,000,000 cuttings for planting in 1987? and repeat again in 1988.

2 INTERMEDIATE

: fascicle shoot, multiplication system.

* sow family seed lots in August 1985.

* develop hedge rows and/or clonal gardens leading to the operations planting of 50,000 cuttings in 1988? increasing to 100,000 cuttings in 1989.

3 LONG TERM

: woody trees, cyclic multiplication system of super genetic material.

* identify outstanding unrelated clones, collect pollen in August 1985.

* controlled pollination to create large number of seed, in August 1986.

* sow seed and plant seedlings in family blocks in the field at normal spacing.

* age trees to 2 or 3 years, select 1 in 3 and collect 30 woody cuttings, set in May and harvest xxx xxx cuttings for planting in the following year.

* repeat in the next year collecting 30-40 cuttings from the same trees to strike and plant in the following year. Form prune donor trees to grow on as plantation.

* continue, with the use of better developing mother trees.

ATTACHMENT 6

options for

RAISING PINE CUTTINGS - WEST MANJIMUP NURSERY

1. Raising Methods

1.1 Stem Cuttings: Stem cuttings can be directly placed into field beds under suitable conditions. Approx 50 000 have been set (autumn 1985) for 1986 planting.

1.2 Fascicle shoots - open beds: Fascicle shoots are rooted in glass house conditions (approx 3 weeks) and subsequently transplanted into field beds and raised similar to open rooted seedlings.

1.3 Fascicle shoots - container stock: Fascicle shoots are set directly into suitable containers (eg jiffy pots) in a glass house and transferred to a maintenance area when rooted.

2. Choice of Method

The merits of stem cuttings vs fasicle shoots for genetic improvement are discussed elsewhere. The choice of methods used to raise the cuttings is dependent on cost. Whilst there is an initial higher capital cutting (container, soil mix) for container growing stock this may be offset by reduced handling, better control of environment, higher percentage strike, less area required, less water.

The relative costs and success rates are to be determined at operational runs at West Manjimup (mainly containers with some open-rooted) and Gnangara.

3. Suitability of West Manjimup

3.1 Climate: West Manjimup was initially considered for stem cuttings in part for its moist climate. In the case of fascicle shoot cuttings this is less important as the critical phase is carried out in a glass house, were conditions may be controlled.

3.2 Soils: Soils at West Manjimup are highly variable and not ideal for new rooted production. Work is being undertaken to maintain/restore soil structure.

Available beds are committed to the current Nursery programme and traditional areas would need to be developed for a large scale open-rooted cutting programme.

3.3 Water: Water quality is good but current supplies are committed. Production in access of approx. 100,000 cuttings would require construction of additonal water supplies. A site for a new storage is available sufficient for both an expand cutting programme and trickle irrigation of the new seed orchard.

3.4 Infastructure: The West Manjimup Nursery is higly mechanized for soil mixing, container filling and sterilization. A large cuttings programme could make use of this existing set up, with only minor expansion required

Glass house and storage areas need to be developed. There is some flexibility to use existing storage area whilst hardwood requirements are below the 1984 record 1.5 million container stock level.

Additional areas can be developed to handle up to 1.5 million cuttings as well as 1.5 million hardwood seedlings (container stock).

3.5 Nursery Staff: There is competant staff at the West Manjimup Nursery to overseer/carry out much of this programme. Unfortunately current practise would be in conflict with a "busy" period in the nursery and some additonal staff would be required.

3.6 Proximity to Market: West Manjimup is well located in respect to both existing and developing pine areas particularly is pine leasing and/or agroforestry developed in the Manjimup region.

The cost of transport must be considered as part of the overall cost. The plants should be raised for the lowest unit cost (including transport). Transport costs are unlikely to be overriding.

4. Proposed Developments

4.1 1985-1986: It is aimed to produce 100,000 cuttings from fascicle shoots for 1986 plantings at West Manjimup. The source of material will be:

A. Tips of stem cuttings (from selected stock) currently being raised at West Manjimup.

B. Vegetated shoots from stem laying trials at Nannup.

This pilot operation will develop and test operational techniques and provide rapidly much more genetically superior planting stock. It will provide the basic information for implementing a much larger programme.

4.2 Future Developments: Expansion beyond a 100,000 cuttings is dependant on a new water supply. This can not be established before 1986-1987. The output of pine cuttings before 1988 planting year from West Manjimup can only be expanded if there is a commensurate production in the hardwood seedling production.

4.3 Staffing: Additional (casual) employees will be required to assist with the peak periods, and one additional permanent employee.

Currently the Nursery is supervised on a part-time basis by an officer. If the programme is expanded to include 1.5 cuttings a full-time nursery officer is warranted. This will be essential if any sales are to be made direct to the public.

5. Development Programme/Projected Costs

August to October 1985

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Glass House        )
Maintenance Area   )
Watering System    )  Estimated capital costs $20 000.
Misting System     )
Heated Beds        )
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October to June 1985

1985/86

Development Costs

Greenhouse (approx 150m² to take 30,000 cuttings)	$ 7 500
Greenhouse equipment (mesh, beds, misting)	$ 7 500
Bed Heating	$ 2 000
Maintenance Area/capacity 100,000	
Mesh, stands	$ 3 000
Reticulation/irrigation	$ 1 000
Transfer System	$ 1 000
Development Costs	$22 000

Production Costs

Incl. Purchase of trays, pots, soil mix, harvesting shoots etc.

Pots/soil/trays	$0.04
Harvest and setting	$0.10
Maintenance/transfer) Pack/despatch)	$0.04
	1.18

Production 100 000 @ 0.18 =	$18 000
Total	$40 000

1986/1987

1. Water Supply

Storage	$25 000
Pump and Motor and switching gear	$ 9 000
Reticulation	$ 6 000
	$40 000

2. Establishment of additonal greenhouses, maintenance and associated equipment (based on three periods of setting cuttings in the greenhouse per season) Establishment costs $250/1000 capacity.

   The establishment of the maintenance area can be deferred to year of production (1987/88) but water supply and greenhouses must be established 1986/87
   ie water supply $40 000
   greenhouse and equipment $170/1000

1987/88

Establish maintenance area $80/1000
Production costs $180/1000

NOTES

1. Establishment costs are "1 off" costs and should be amortized.

2. Estimates are based on best current knowledge. Considerable better cost information will be available following the 1985/86 operation.

3. The above costs are based on production in jiffy pots.

ATTACH 7

REPORT ON THE COLLECTION OF P. RADIATA TIP CUTTINGS BUSSELTON SUNKLANDS - MAY/JUNE 1985

INTRODUCTION:

The use of P. radiata cuttings for agroforestry tree breeding improvement has been recognised as an essential development. Clonal methods using cuttings is one way of achieving an improved agroforestry tree and shows exciting potential. The objective of the P. radiata cuttings project is to produce 30,000 cuttings for planting in agroforestry projects in 1986. This report covers the initial collection phase; the methods and costs involved.

METHOD:

1. Location

   Areas were selected with known genetic seed quality. Four year old cuttings were collected from Baudin Plantation, compartment 12 which was planted in 1981 (serial number ?). See map 1. Three year old cuttings were collected from Vasse Plantation compartment 5, planted in 1982 (serial number 8003). See map 2.

2. Tree Selection

   All trees were selected and marked which showed desirable agroforestry characteristics. These are straight, vigorous and healthy trees; small diameter or flat angled branches; and narrow crowns. Selection of trees were roughly in the order of 1:20 (as recommended by G. Chester) but this varied between sites or soil types and could have been up to 1:50 trees. Marking of all trees on this project was done by an officer, but a trained overseer could have undertaken this. Four rows of pines were covered at one time, as trees were often wide apart. There were no problems selecting four year old trees as their tree characteristics (branch type, habit etc) were obvious. However, making judgement on three year old trees was difficult because tree habit and branch form etc were not as developed.

3. Collection of Cuttings

   Two, two-man teams were involved in the collection of cuttings. This proved to be most efficient, as carrying of the large containers became heavy after a while. Also, cuttings were

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collected much faster and boredom was eased.

Cuttings were collected by the teams covering four rows at a time. Tips were taken from side branches of selected trees using small secateurs and were approximately 150mm long and ≈ 3mm in diameter. Only tips that were fairly woody were selected. Tips that were fleshy, had 'shot' or started to elongate were not sampled. Where a cuttings tip had 'shot' these were not to exceed 60mm. Tips were then placed into plastic bag lined containers in a vertical position with the cut end in about 30mm of water. The containers with plastic liners are the same as thosed used for transporting karri seedlings and hold about 450 pine cuttings. When containers were filled, the liners were folded over to maintain humidity. Containers were stored under shade and had branches placed on top them to avoid the sun. From past experience, cuttings have been burnt which were left for a few minutes in covered containers.

Using the technique described above an average of 3,800 cuttings were collected from four year old trees and 4,170 from three year old trees.

Overall a total of 56,100 cuttings were collected over a period of 12 days. These were sampled from a total of 78ha and involved 57 man days (not including the driver or nursery workers who 'set' the cuttings. See G. Gardners report). See table 1 for summary:

TABLE 1: Summary of collection of pine cuttings programme May/June 1985

PLANTATION	AGE	CUTTINGS COLLECTED	$\bar{x}$ COLLECTED PER DAY	HECTARE COLLECTED FROM	NUMBER OF DAYS INVOLVED	NUMBER OF MANDAYS TO COLLECT*
Baudin 12 (P.81)	4	39,420	3,800	63	8	38
Vasse 5 (P.82)	3	16,680	4,170	15	4	19
TOTAL		56,100		78	12	57

* Includes tree marker (5 man team mostly)

4. Transportation of Cuttings

Each day, a driver from Manjimup picked up containers and returned them and liners from the previous day.

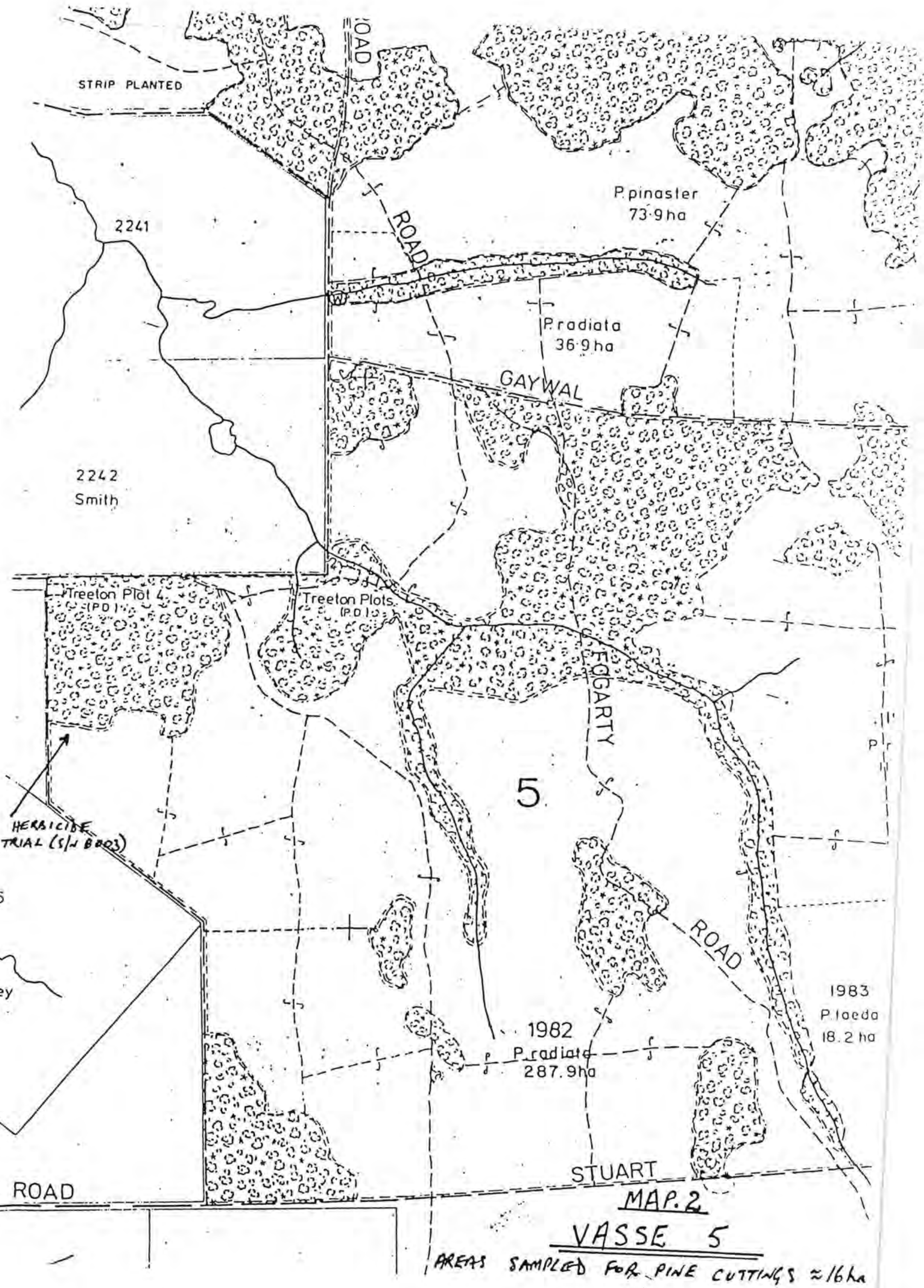
COSTS:

The costing of the cuttings collection phase involves a five man team, one tree marking and four collectors. Costing is based on an overseer and four Grade III forest workmen. Vehicle running costs is calculated using a Toyota Dyna for gang transport.

Wages	- Overseer	$843.60
	Grade III	$2685.60
Plant	-	$327.32
Total Cost		$3856.52
Cost per cutting		7c/cutting (COLLECTION ONLY)

RHingston.

R. Hingston
A/F Tech.


STRIP PLANTED
ROAD
ROAD
2241
P. pinaster
73·9 ha
P. radiata
36·9 ha
GAYWAL
2242
Smith
Treeton Plot 4.
(PD)
Treeton Plots.
(PD)
FOGARTY
5
HERBICIDE TRIAL (S/N 8003)
ROAD
1983
P. taeda
18.2 ha
1982
P. radiata
287.9 ha
STUART
ROAD
MAP. 2
VASSE 5
AREAS SAMPLED FOR PINE CUTTINGS ≈ 16 ha

BAUDIN 12

AREAS SAMPLED FOR PINE CUTTINGS ≈ 63 ha