ARTICLE

Control pollinated radiata pine seed – A comparison of seedling and cutting options for large-scale deployment

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ABSTRACT

Controlled pollination, CP, of radiata pine seed orchard clones is required to realise their full potential genetic gain. Vegetative multiplication of CP seedlots has been the usual practice till the present. However, this was found only to be economic for seed costs exceeding $1800 per kg or where seed quantities are limited. Recent developments in radiata pine seed orchard management will enable large-scale production of such seed at costs projected to be as low as $900 per kg. Isolated siting of future orchards could enable CP seed to be produced without a requirement for bag isolation of individual female cone whorls, decreasing costs even further. Given such costs, CP seed utilisation for seedling production can have significant advantages over its vegetative multiplication by cuttings from nursery seedling stools.

INTRODUCTION

Genetically improved radiata pine planting stock has, till very recent times, been produced as seedlings raised from OP (open pollinated) seed orchard seed. In New Zealand, this seed has been obtained from seed orchards composed of grafts and cuttings of different clones, planted in systematic layouts designed to minimise selfing (i.e. 'inbreeding').

In conventional OP radiata pine seed orchards, the clonal ramets develop into full-size trees. Wind dispersion of pollen effects the mating which is generally assumed and desired to be completely random.

OP seed orchard seed typically fails to provide the full genetic gain potentially available from the genotypes employed in seed production populations (Table 1). Gains from controlled pollination of seed orchard parents can be up to double those obtained with open pollination (Shelbourne *et al.* 1986, Shelbourne *et al.* 1989).

The potential genetic gains of the OP orchards are not achieved for a number of reasons, associated with inadequate control of pollen parentage. These include:

1) differences in the timing of anthesis; clones which produce pollen out of phase with the majority are of reduced effectiveness as paternal parents.
2) variability in pollen production between clones, which also reduces effectiveness of some as paternal parents.
3) lack of fully effective mechanisms to prevent inbreeding.
4) insurgence of contaminating pollens from external, genetically inferior sources.

The subsequent reality is that no single clone has equal probability of being pollinated by all other clones. (Sweet and Krugman 1977)

Full control over pollen parentage of orchard seed, an essential requisite for maximising genetic gains, is inhibited in conventional orchards by the relative inaccessibility of flower crops. Topping orchard trees, whilst commonly practised with some species, has proved of limited value in open pollinated radiata pine orchards due to the strong apical dominance shown by the species.

Recent development of a new technology for radiata pine seed orchards has made full control of seed parentage feasible on a commercial scale. Hedged clonal orchards specifically managed for CP (control pollinated) seed production is the means by which this is achieved (Shelbourne 1986).

PRODUCTION OF CP SEED

In CP seed orchards, highly selected and tested "female" clones, chosen for good cone production as well as high 'general combining ability' (GCA)[1] for different traits, are established in rows or blocks. These are then repeatedly hedged to maximise production of female cones at a level readily accessible from the ground (i.e. two metres or less). The receptive female cones are isolated with special cellulose bags and manually pollinated by highly-selected male parents when receptive (Shelbourne *et al.* 1989, FRI 1990).

Selection of orchard clones for cone production enables high seed productivity to be achieved. Clones of high breeding value which are unproductive in orchards due to poor cone production, can be used as pollen parents. For such purposes, they are not established in hedged orchards but are maintained in tree-form clonal archives or OP seed orchards.

Management practices for radiata pine CP orchards are currently in a dynamic state. Up until 1987, these seed orchards were established with 500 stems per hectare (5 x 4 metre espacement) managed on rotations of up to 15 years. The frequent hedging and trimming required in such orchards often compromises cone productivity. Today, new CP orchard regimes involving from 2000 to 10,000 trees per hectare are under dev-

TABLE 1. PERFORMANCE OF 3 NEW ZEALAND GROWTH AND FORM BREED RADIATA PINE SEEDLOTS COMPARED (Source: FRI 1987)

Seedlot	% Gain in Volume	% of Stems Acceptable
Bulk (i.e. unimproved)	0	45
Top 16 '268' Series Open Pollinated	19-23	70
Control Pollinated Top 16 '268' Series	27-32	80

[1]*GCA or 'general combining ability' is the ability of a parent to transmit a trait to its offspring when crossed with a multiplicity of other individuals.*

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elopment. First commercial-scale establishment and development of these 'Meadow Orchards', originally proposed by Sweet and Krugman in 1977, was initiated by "PROSEED" in 1987 at Amberley near Christchurch. Management in this type of seed orchard aims for early prolific cone production from tightly spaced clonal ramets with minimal pruning and trimming. Controlled pollinations are then carried out on all flowering individuals for two to three years, whilst the female cones remain readily accessible from the ground. As soon as the last of the CP cones are mature, by about age six, the orchard will be cleared and re-established. Alternatively, cutting back to a basal branch whorl is a possibility which may save re-establishment costs. Viability of this later approach would be dependent on whether newer, genetically superior clones were available and on the growth and cone production response obtainable from the topped ramets.

Commercial scale radiata pine CP seed orchards have now been established on at least six separate sites within New Zealand. These include Te Teko, Onepu and Matakana Island in the North Island, and Amberley, Waikuku and Wairau Valley in the South Island. Experience from these has emphasised the impact of site and environment on seed orchard productivity, and on consequent seed cost. Sites conducive to prolific cone production in radiata pine may produce cone crops on mature trees of up to seven fold that of average sites, and up to 40 times that of poor sites. (Sweet 1975)

Environments with mild to warm climates, high rainfall and fertile soils favour rapid vegetative growth and are not suited to CP seed production. This has been borne out by experiences on fertile sites such as Tasman Forestry Limited's Te Teko orchard (1500 mm annual rainfall) in the Bay of Plenty, North Island. Excessive pruning and trimming with earlier management regimes is required in such environments to maintain desired form and health. This has proven both costly and detrimental to cone productivity. In comparison, drier sites in cooler climates, such as PROSEED's Amberley orchard (600 mm annual rainfall) on the South Island's central east coast, have proved close to ideal (Table 2).

TABLE 2. CONTROL POLLINATED SEED PRODUCTION COSTS; HIGH AND LOW PRODUCTIVITY SITES COMPARED

Item	Low Productivity Site – Te Teko S.O.	High Productivity Site – Amberley S.O.
No. of ramets per hectare	500	500
Average Productivity – kg seed/ha/year	5.1	12.5
Average Total Costs* – $/ha/yr	$12,200	$16,100
Average Total Seed Production Costs – $/kg	$2,392	$1,288

*Costs are inclusive of all establishment, orchard maintenance and seed production costs. Higher costs are incurred on higher productivity sites due to higher isolation, pollination and seed harvesting costs per hectare. This is in spite of the fact that orchard maintenance costs incurred are significantly cheaper; reduced vegetative growth minimises both hedge pruning and weed/pasture control costs.

The Amberley radiata pine CP orchard is now in commercial production. Current retail prices for CP seed of the best genetic qualities are around $2500 per kg (PROSEED 1989). However, up to 1989, quantities available have been extremely limited. Prices are expected to drop significantly as quantities produced increase, and actual production costs are further reduced by refinement of management techniques. Cost comparisons for the alternative radiata pine seed production options reveal some of the future potentials for decreases in price (Table 3).

TABLE 3. COMPARATIVE DIRECT PRODUCTION COSTS OF OP, CP, AND 'UN-ISOLATED' MANUALLY POLLINATED RADIATA PINE ORCHARD SEED

(Source: P. BOLTON, unpubl. data)

Seed Production Method	Direct Production Cost of Seed ($ per kg)
1. OP – open pollinated in conventional seed orchards	250
2. CP – control pollinated in conventional hedged CP seed orchards	1300
3. CP – control pollinated in meadow CP seed orchards	900
4. 'UN-ISOLATED' MANUALLY POLLINATED – produced in meadow orchards at 'isolated' locations	500

Artificial pollination by hand, without isolation, may be a feasible option in meadow orchards given suitable siting (i.e. adequate isolation of the site from external contaminating pollen sources). Seed produced would be of lower genetic quality than that from bag-isolated CP systems, due to some degree of pollen contamination. However, savings on labour and materials could make this a very cost-effective means of delivering optimum genetic gains to the forest grower.

SEED DEPLOYMENT STRATEGIES

Seedling Production

One option for deployment of CP seedlots is directly as seedling planting stock. This is the most technically efficient option, due to the following advantages:

I Rapid deployment: seedlings can be propagated ready to establish in plantations in less than 12 months from harvest of the seed (the seed production itself though takes two years from pollination).

II Ease of production: high-quality 1/0 bare-root radiata pine seedlings can be readily grown in a wide range of nursery environments.

III. Technical expertise: fewer skills and less experience is required for seedling propagation than for juvenile cutting production of radiata pine.

IV. Scale of production: the scale of seedling production can be rapidly and drastically changed from one year to the next to service abrupt fluctuations in establishment programmes, given adequate seed supplies. Other deployment options are rigidly constrained by their inherent time lags.

Advantages alluded to for seedling options, however, may be outweighed by the high cost of CP seed. Seedling production costs are very sensitive to the cost of seed; Table 4. Every $100/kg increase in seed cost increases the cost of producing seedlings by $6.67 per 1000. Retail prices of the highest genetic quality CP seedlots are currently a function of scarcity rather than one of actual production costs. Development of CP orchards on more productive sites will both alleviate scarcity and significantly reduce seed costs.

Where only very limited quantities of the best genetic quality radiata pine seedlots are available, multiplication through vegetative propagation is intuitively sensible. Such multiplication will maximise the economic returns from their high genetic gains.

TABLE 4. PRODUCTION COSTS FOR 1/0 BARE ROOT RADIATA PINE SEEDLINGS AT TFL'S* TE TEKO NURSERY

Seed Seed Cost	OP; GF Rating** = 16 $400/kg		CP; GF Rating* = 25 $2500/kg	
Production Component	Cost $/100	% of Total	Cost $/100	% of Total
SEED***	$26.67	34.2%	$166.70	76.4%
NURSERY LAND RENT	$1.40	1.8%	$1.40	0.6%
PROPAGATION – including lifting, packaging, and dispatch	$50.00	64.0%	$50.00	22.9%
TOTALS	$78.07	100.0%	$218.10	100.0%

* Tasman Forestry Limited

** 'GF Rating' provides a quantitative rating of genetic quality; the higher the number the higher the genetic quality (Vincent 1987).

*** Costs specified assume 15,000 quality, plantable seedlings obtained per kg.

Juvenile Cutting Production

Juvenile cutting propagation from nursery stools of radiata pine provides an effective means for the vegetative amplification of scarce seed of superior genetic quality. Techniques for such propagation are well developed, and are now widely applied in the commercial production of trees for plantation establishment in New Zealand (FRI 1986, Dibley and Faulds 1989, FRI 1989). Multiplication rates achieved, which depend on stool treatment, can vary between four and 50 fold, two years from seed.

Costs of propagating juvenile cuttings are sensitive to the rooting success rate. Seed costs and subsequent multiplication rates impact less sensitively on total propagation cost (Table 5, & Dibley and Faulds 1989).

Automation of juvenile cutting collection and setting is a future possibility which might significantly reduce costs of cutting production. However, development of the technology would require significant capital input; it would not alleviate stool bed costs or other disadvantages discussed. Availability of such technology currently appears very remote.

In addition to cost, time becomes a significant consideration with the juvenile cutting option. It can take stool plants 18 months or more from sowing to reach reasonable productivities.

From the time of harvesting shoots as cuttings, up to an additional 12 months is required for nursery propagation off bare-rooted cuttings (Figure 1). Total lead time from harvest of CP seed through to juvenile cutting establishment in the forest is approximately 20 months at a minimum. For substantial amplification, the lead time increases to 32 months at a minimum.

TABLE 5. PRODUCTION COSTS FOR 1/0 BARE ROOT RADIATA PINE JUVENILE CUTTINGS AT TFL'S TE TEKO NURSERY

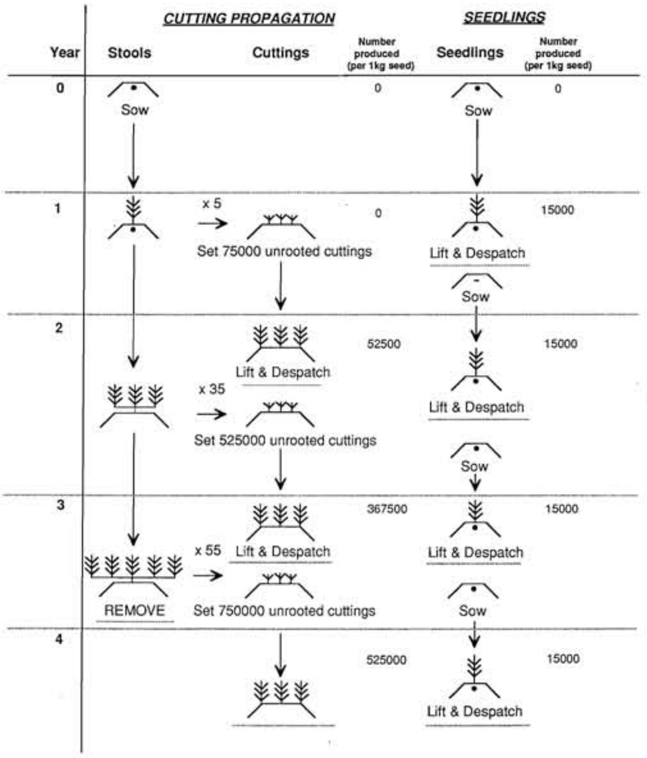
Component	Year 1	Year 2	Year 3
MULTIPLICATION RATE – cuttings/seedling stool	5	35	50
AREA PRODUCTIVITY – cuttings/ha of stool plants	175,000	1,225,000	1,750,000
INITIAL SEED COST*** – $/seedling stool	$0.125	$0.00	$0.00
CUTTING PRODUCTION COST* – $/1000 cuttings	$156.56	$13.71	$9.60
CUTTING HARVEST & SETTING COST – $/1000 cuttings	$37.00	$37.00	$37.00
PROPAGATION COST** – $/1000 cuttings (70% yield from cuttings set)	$146.43	$146.43	$146.43
TOTAL PRODUCTION COST 1/0 BARE ROOT JUVENILE CUTTINGS – $/1000	$302.99	$160.15	$156.03
WEIGHTED MEAN PRODUCTION COST OVER THE 3 YEAR SEEDLING STOOL ROTATION –			**$165.80 $/1000**

* Production costs include initial seeds, establishment, all maintenance and land rent.

** Propagation costs include all tending; irrigation; root conditioning; weed and pest control; lifting, packing and dispatch; and land rent costs.

*** Seed cost is based on a price of $2500 per kg, and a seedling stool yield of 20,000kg.

Figure 1



Clonal Option

Radiata pine seed from the very best CP families can be utilised to initiate clones for field testing and subsequent replication 'en masse' by some vegetative propagation technique. Two of these currently being pursued in New Zealand are micropropagation and juvenile cuttings from nursery stools.

The juvenile cutting approach, whilst appearing to be the simplest approach, currently faces significant challenges. Foremost is the maintenance of juvenility in nursery stools for the duration of a clonal field testing phase. Time lags combined with inescapable maturation incurred in the 'cascade' development of nursery stools pose additional barriers (Clarke and Slee 1989).

Micropropagation provides potential for maintenance of juvenility during the clonal testing phase through cold-storage of cultured shoots. The subsequent rapid multiplication required for selected clones, is also readily achievable with micropropagation. Cryogenic storage of cultured tissue, though unproven as yet for radiata pine, is a future possibility for embryonic cells but not for shoots (Davis and Aitken-Christie 1989). Such storage may circumvent problems of maturation in clonal forestry programmes.

EVALUATING ALTERNATIVE STRATEGIES

Identification of the optimum alternative for deployment of the highest genetic quality CP seed requires comprehensive development evaluation of the following factors:

I Time required.
II Quantity of seed available.
III Cost of seed.
IV Differences between the potential genetic gains of CP seed versus the 'next best' seedlot available in relative abundance.

The Factor of Time

The importance of time in production of improved planting stocks has already been emphasised. Seedlings are the most rapid means of deploying seed with superior genetic quality. High-quality radiata pine seedlings can be propagated in less than 12 months from seed harvest, compared to the minimum of around 20 months for planting stock of juvenile cuttings.

Seed Availability

Though a scarce commodity up till now, CP seed will be produced in substantial quantities in the near future. Early abundant seed production is now a prime objective in CP seed orchards. Vegetative amplification of such seed may therefore become unnecessary. Consequently, stool bed development and their yields of cutting material must be carefully evaluated alongside the sequential availability of much larger CP seedlots of equivalent genetic quality.

It may be expected that CP seed from recently selected

FIGURE 2:
EFFECTS OF SEED COST ON PROPAGATION COSTS OF 1/0 SEEDLINGS AND JUVENILE CUTTINGS OF RADIATA PINE.

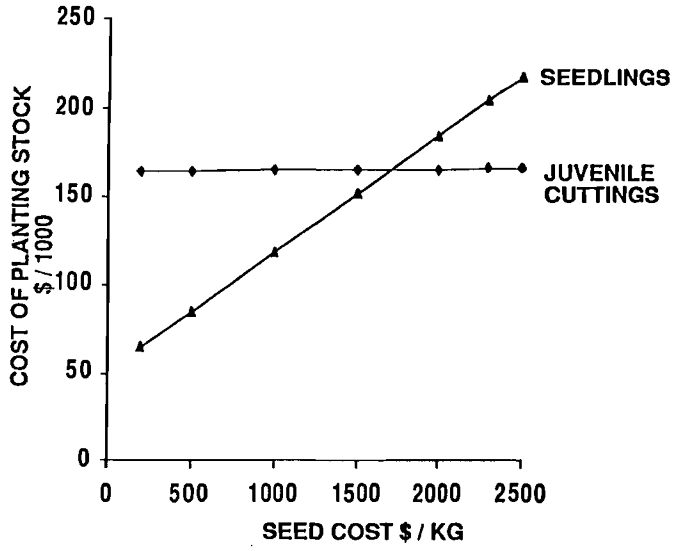


TABLE 6. A COMPARISON OF CP SEED DEPLOYMENT STRATEGIES, GIVEN AN ANNUAL PLANTING STOCK REQUIREMENT FOR 3.75 MILLION TREES

SEED AVAILABILITY	Yr 1	Yr 2	Yr 3	Yr 4
CP Seed Supply * (kg)) GF Rating** = 25	2	60	250	250
OP Seed Supply * (kg); GF Rating = 19	300***	300	300	300
CP SEED DEPLOYMENT OPTION				
I. 100% SEEDLINGS				
a) No. of CP Seedlings Produced (millions)	0.03	1.50	3.75	3.75
b) No. of OP Seedlings Produced (millions)	3.72	2.25	0.00	0.00
c) Mean GF Rating	18.1	20.8	25.0	25.0
d) Mean Costs of Stock ($/1000)				
– High Seed Cost****	$95.98	$144.20	$218.00	$218.00
– Low Seed Cost***	$95.40	$114.89	$144.73	$144.73
II. UP TO 100% JUVENILE CUTTINGS				
a) No. of CP Seedlings Produced (millions)	0.00	1.46	2.87	1.53
b) No. of Juvenile Cuttings Produced (millions)	0.00	0.11	0.88	2.22
c) No. of OP Seedlings Produced (millions)	3.75	2.19	0.00	0.00
d) Mean GF Rating	18.0	20.9	25.0	25.0
e) Mean Costs of Stock ($/1000)				
– High Seed Cost	$95.00	$148.74	$210.05	$188.27
– Low Seed Cost	$95.00	$119.91	$153.53	$157.85

* Seed supply incorporates a one year lag; e.g. 2 kg CP seed in year I is available in year 0 for sowing and subsequent production of seedlings in year 1 or cuttings from year 2.

** 'GF Rating' provides a quantitative rating of genetic quality; the higher the number the higher the genetic quality (Vincent 1987).

*** There is a surplus of OP seed over requirements in all cases.

**** Seed Costs HIGH: CP $2500/kg
OP $650/kg
LOW: CP $1400/kg
OP $650/kg

clones of the most genetically advanced generation would be limited. Significant time lags can be encountered in mass production of ramets of recent selections. Supplies of scion material, for production of the required clone by grafting, are usually scarce in the early years of a clone's deployment as a seed orchard parent. However, genetic superiority of recent selections is rapidly realised in CP seed production through their utilisation as pollen parents, prior to their establishment in orchards.

Costs of Alternatives

Production costs of seedlings are much more sensitive to seed costs than are juvenile cuttings (Figure 2). Only at seed costs greater than or equal to $1800 per kg is the production of juvenile cuttings economic in comparison to the seedling alternative. Other factors though, could add some differential weighting or opportunity costs to affect this.

Future retail values of CP seed are projected to fall to less than half the current values within five years (Shelbourne *et al* 1989). This will be due to increased supplies combined with decreased costs of production if the CP meadow orchards perform up to expectations. Production of seed with genetic gains and improvements close to CP seed by manual pollination of un-isolated female cones in meadow orchards would provide further large seed cost reductions as earlier indicated. With such price decreases CP seedlings, or ones of equivalent genetic quality, will become substantially cheaper than juvenile cuttings.

Potential Genetic Gains

Forest growers will commonly try to maximise genetic quality of planting stock in any one year. However, this could prove to be misguided if substantial marginal costs of increased genetic quality provide only a minor or trivial increase in genetic gain. Actual increases in gain to be achieved through alternate strategies must be considered.

Numerous analyses have previously shown the added costs of genetically superior radiata pine stock to be generally well justified. (Smith 1984, Arnold and Gleed 1985, Gleed 1983, Talbert *et al* 1985). In 1985 for example, it was projected that each 1% increase in final-crop volume would have justified up to an extra $48 per 1000 in the cost of tree stocks, given a discount rate of 6% (Aitken-Christie and Gleed 1985). It is important to emphasise however that higher levels of genetic improvement are only one factor contributing to greater volume and value production in forests. Improvement is only fully realised on the best sites under optimum management.

Evaluation of Alternative Strategies for CP Seed Use

Evaluations of options for CP seed use must incorporate seed availability, costs of planting stock and time for different steps within the plan. One example, pertaining to current circumstances within New Zealand, is presented in Table 6. The two costs of CP seed evaluated, 'low' at $1400 per kg and high at $2500 per kg, equate approximately to the production costs from two orchards evaluated earlier (Table 2). Parameters and costs employed in the analyses for both seedling and juvenile cutting propagation are also based on information presented earlier.

The seed supply situation presented in Table 6 is realistic, reflecting the projected ability of present CP seed orchard technology to provide for early seed production in substantial quantity. Time lags between seed availability and planting stock production have been incorporated on all counts.

Planting stock numbers, costs and genetic qualities projected in this analysis are instructive. Vegetative multiplication of limited seed lots of superior genetic quality seed lots has been seen to enable greater areas to be planted with trees of superior genetic quality. However, the reality for radiata pine at present, as indicated by this evaluation, is that this widely advocated "advantage" may not always exist; i.e. no real increase may be obtained in the average genetic quality of the planting stock to be deployed. This clearly results from rapid increase in seed supply through successive years coupled with planting stock production lags for cuttings arising from the period required for stool bed development. By the time substantial quantities of shoots can be harvested off seedling stool beds for setting in open beds as cuttings, rapid increases in production projected for developing CP seed orchards should supply plentiful seed of the same genetic quality.

Cost of planting stock could be the decisive factor in choosing the best strategy. Though genetic quality of the OP seedlings differs from the CP seedlings and juvenile cuttings, no significant differences in the average genetic quality resulted. At the higher seed cost, juvenile cuttings will provide the cheaper planting stock by year three, whilst at the lower CP seed cost the CP seedling option will be most cost effective.

Technical efficiency and flexibility are two factors not enumerated in this analysis. Consideration of both these would favour seedling strategies. Planting stock production by seedlings requires the minimum lead time to service rapid or massive fluctuations in establishment programmes, given adequate seed stocks. Such flexibility is particularly valuable when the fluctuations are frequent and often unforeseen.

Physiological Age; An Advantage for Juvenile Cuttings?

Physiological age of radiata cuttings is known to affect their form, branching, malformation, and vigour (Gleed 1983), Arnold and Gleed 1985, Menzies and Klomp 1988, Eldridge and Spencer 1986). Ageing, which in general reduces the rate of diameter growth, imparts significant branching and form improvement. These quality improvements are over and above genetic quality and can be particularly valuable on fertile ex-farm sites. It has been well established that rooted juvenile cuttings from "seedling-based stool beds" are at a slightly more advanced physiological age than seedlings (Klomp and Menzies 1988, Menzies *et al.* 1989).

Cost differentials between seedlings and juvenile cuttings of equal genetic quality are sensitively controlled by seed costs, as shown earlier. However, degrees of physiological age obtainable in juvenile cuttings may confer additional gains in tree form and elevate their effective improvement rating given satisfactory growth rates. This could become an additional consideration in comparisons of costs and deployment options.

CONCLUSIONS

CP seed orchard technology and the new meadow orchards, even though at present in a dynamically evolving phase, will soon enable large-scale production of CP seed. Siting of such production orchards, and their management, has a critical influence on productivity and overall seed cost.

A range of factors must be considered in choosing the best strategy for using CP seed.

These include:

I Time required for production of improved stock; this tends to diminish advantages of vegetative multiplication. This situation arises from the early abundant production achievable in today's CP orchards. Time influences returns from total tree improvement investment.

II Cost per 1000 plants; another major factor which favours use of CP seedlings if seed prices below $1800 are obtained with orchards which are sited in better environments.

III Genetic quality of planting stock; evaluations must consider the average quality of all stock to be established in any given year, and not just the qualities of the specific types of propagules.

IV Technical efficiency; high-quality radiata pine seedlings can be more readily propagated than cuttings, and they can be grown in a far wider range of environments.

V Form and growth differences between juvenile cuttings and seedlings arising from the slightly advanced physiological maturity of the former.

Overall, these factors favour use of seedlings from CP seed as opposed to its vegetative multiplication by way of juvenile cuttings, provided sufficient CP seed is or will be available. Foreseen future developments in seed production technology may increase cost advantages of CP seedling strategies.

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No waste timber cutting

Mike Wolseley, London Press Service

Thousands fewer trees will be needed by the timber industry in future as a result of the use of a new type of machine that can cut wood without producing waste or sawdust.

The machine, developed from basic German Linck machinery by two Northern Ireland firms, William Lees Sawmills and the Pallet Centre, is said to be capable of producing thin boards and fencing slats at over three times the speed of the fastest saw.

Traditional Waste

Traditional timber saws create a substantial amount of sawdust and require oversized timber to allow for the waste involved in cutting. In a bid to cut this waste, the two Ulster firms have produced a cutting system that uses differing cutting knife angles and high-pressure feeding.

Mr Ashley Stewart of William Lees explained: "This saw is the first of its type in the world. The wood is fed by rollers at very high speed through the blade, which remains static as opposed to the traditional circular blades or bandsaws which always removed their own thickness as sawdust.

Problem Overcome

"The main problem in slicing timber along the grain, as anyone chopping firewood with an axe would know, is that the blade tends to follow the grain of the timber. This has been overcome totally by a combination of cutting knife angles, high-pressure feeding, and by careful timing and speed this pressure is released."

As each piece of timber passes through the machine, an electronic sensor which is able to measure the exact size and internal stress allows the cutting to be adjusted to produce thin boards ranging in thickness from 16mm to five millimetres.

Merry-go-round

The machine itself takes up a large floor area and the process is described by Mr Stewart as "a conveyor belt merry-go-round" with the wood being passed through the blade several times.

Traditional methods of cutting timber are noisy and involve a waste of 10 per cent in sawdust. Mr Stewart says his firm has produced 15,000 tonnes of sawdust in its traditional cutting operations, which is the equivalent of 60,000 mature spruce trees.