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EUCALYPTUS NITENS IN THE SOUTH ISLAND

PHIL CANNON AND RUTH McCONNOCHIE

REPORT NO. 4 JUNE 1992

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EXECUTIVE SUMMARY

From May 3 to May 9, the authors visited most of the hot spots for *Eucalyptus nitens* on the South Island. This report details observations and measurements made at dozens of plantations and 12 experiments visited during this trip. Generally, growing conditions for *E. nitens* forest plantations appear to be excellent in the Invercargill, West Coast and Golden Downs areas. Growth on the Canterbury Plains was relatively slow but there *E. nitens* has considerable potential as a windbreak species and in amenity plantings. Some climatic and soil factors influencing growth of *E. nitens* in each of these areas are considered. Attention is given to choosing optimal seed sources for the present and to breeding activities which will develop better sources for the future. Some of the more outstanding harvesting and marketing problems are also described for each area. This report does not discuss the situation of *E. nitens* in the Dunedin area; the other hot spot for *E. nitens* on the South Island.

This report also describes the provenance/progeny test of *Acacia melanoxylon* at Golden Downs, half of which was planted with *E. nitens* as a nurse crop.

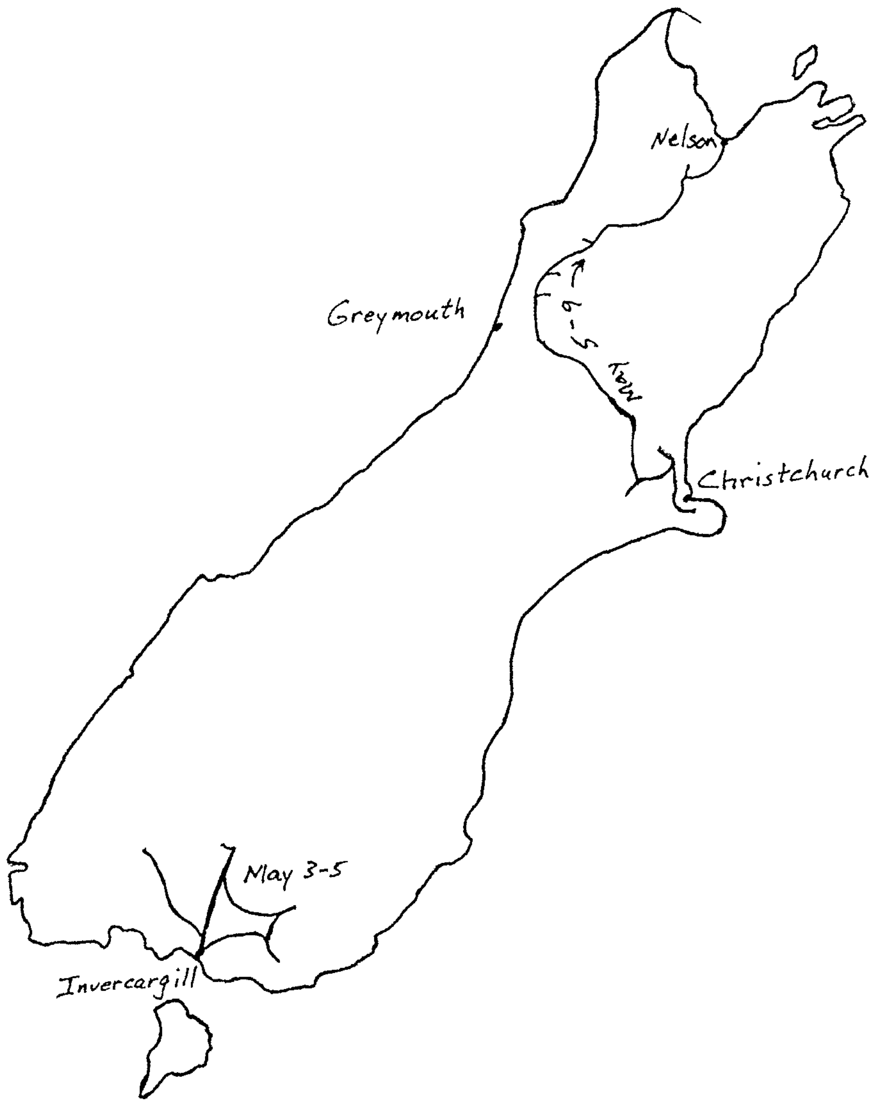
Many kind thanks are due to Graeme Manley and Dudley Franklin who proved to be most willing and knowledgeable hosts.

INTRODUCTION

From May 3 to May 9, a trip was made by the authors to the South Island to visit many of the areas which had been planted with *E. nitens* either in species, provenance of family tests or in trial plantations. The general route taken is shown in Figure 1. Larger scale maps of the southern South Island and northern South Island, Figures 2 and 3 respectively, show the areas visited more precisely.

The main purpose of this trip was to determine how well *E. nitens* was performing on a gamut of site types in much of the South Island and to determine which eucalyptus breeding activities would be most appropriate in the future. An ongoing, intensive plantation effort by South Wood Exports Ltd out of Invercargill, and a series of trials established by FRI over the past 25 years in Canterbury, West Coast and Nelson Conservancies provided very good opportunities for making such determinations. The remainder of this report details

FIGURE 1. Route taken by the authors during the May, 1992 visit to eucalypt hot spots on the South Island.



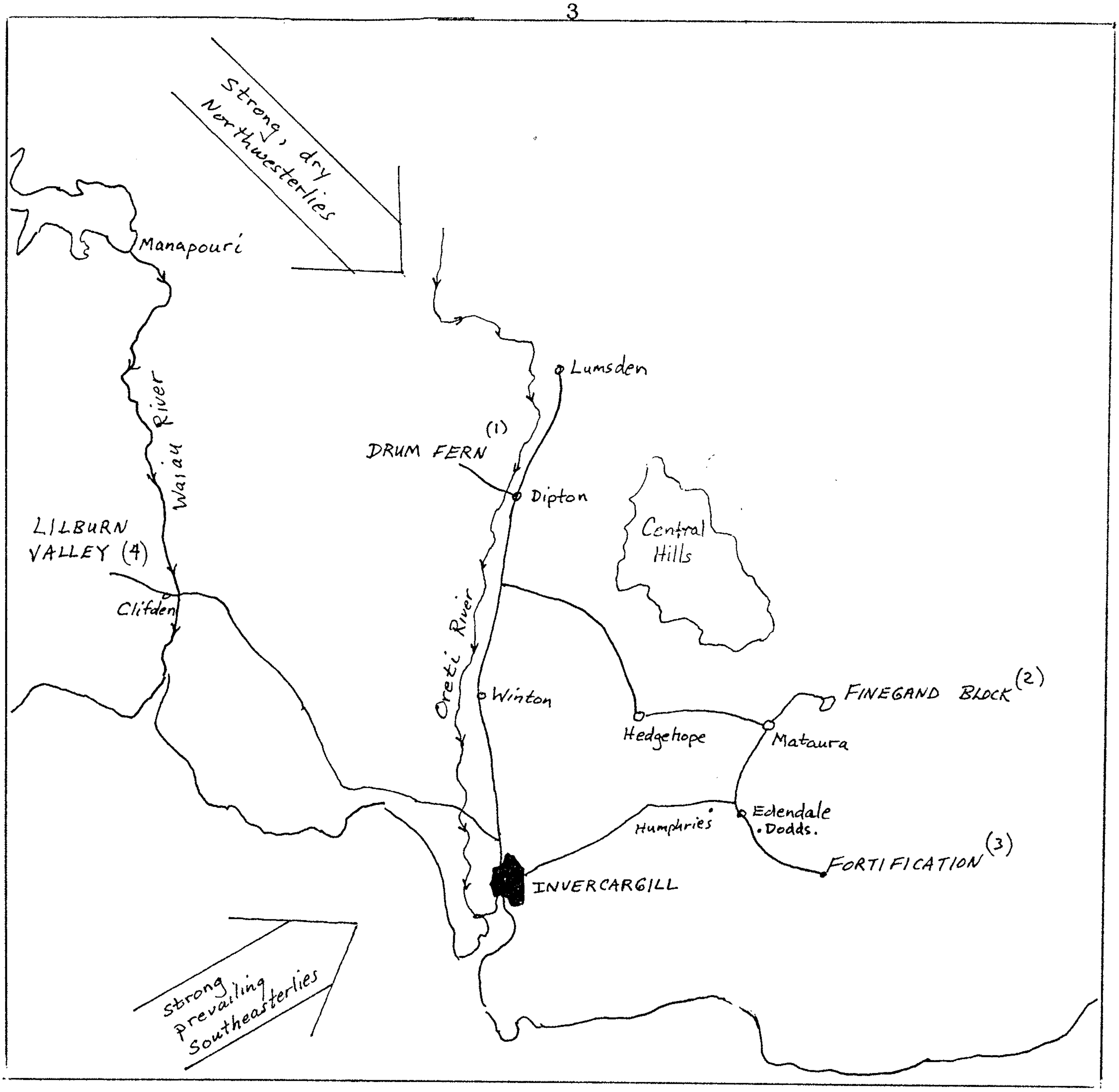
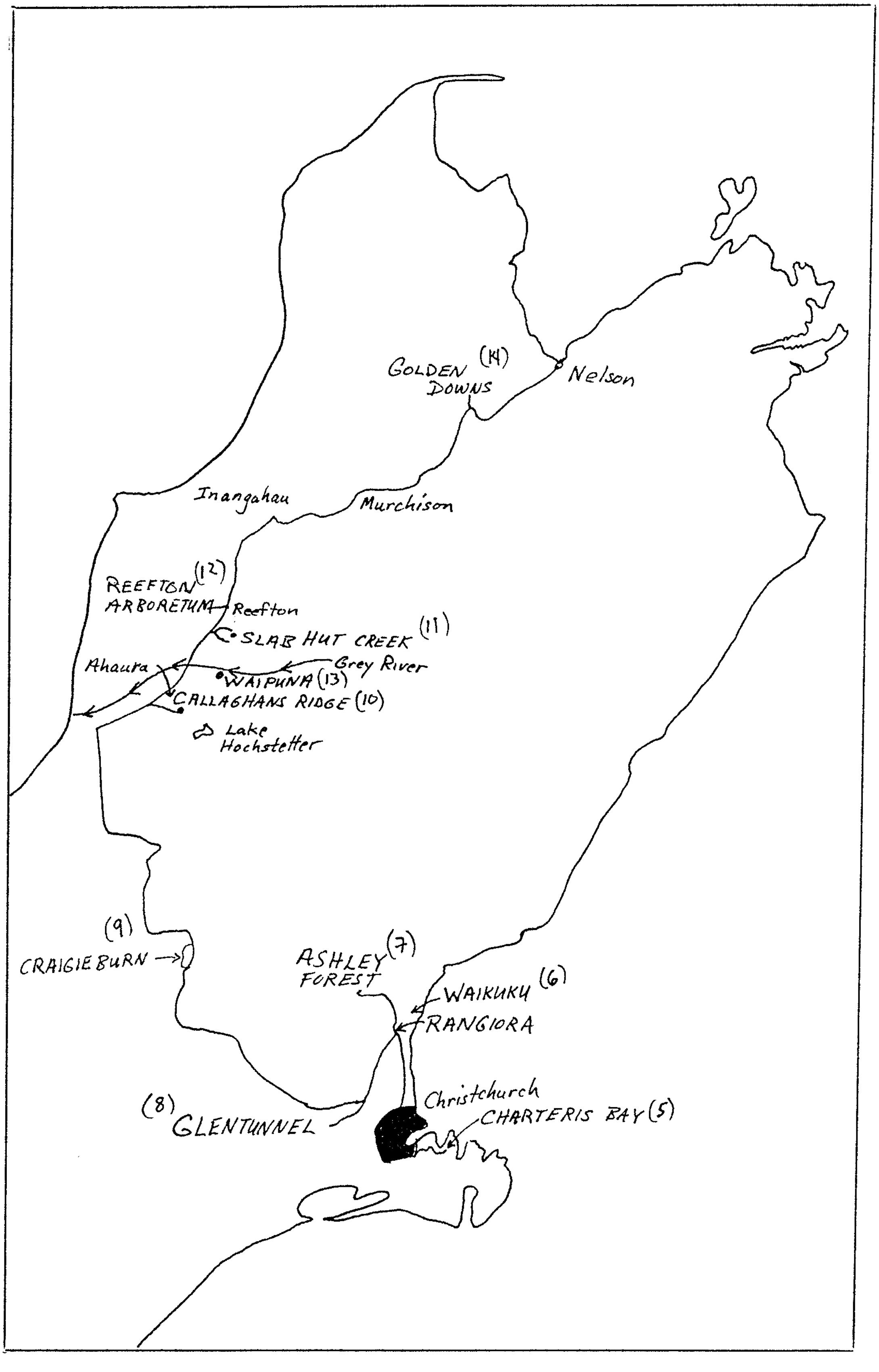


FIGURE 2. Areas visited in the Invercargill area; location names written entirely in upper case indicate places where observations were recorded. Prevailing winds are from the Southeast and Northwest. Near the coast salt bourne on the prevailing southeasterlies can be harmful to eucalypt leaders. Further inland the effects of these winds on the growth rate and form of trees is pronounced on exposed sites.

FIGURE 3. Locations in the northern part of the South Island visited during the tour of eucalypt hot spots. Location names written entirely in upper case letters are the areas where observations were recorded.



observations and measurements made during stops in each of these conservancies. These stops are reported in chronological order (i.e., numbers 1-14 in Figures 2 and 3). The focus of almost all of this report centres on *Eucalyptus nitens* which was by far the fastest growing tree species (even compared with *Pinus radiata*). However, on the last stop, the performance of *Acacia melanoxylon* in a provenance/progeny test (half of which was planted with *E. nitens* as a nurse crop) was evaluated.

INVERCARGILL - SOUTH WOOD EXPORTS - HOST GRAEME MANLEY

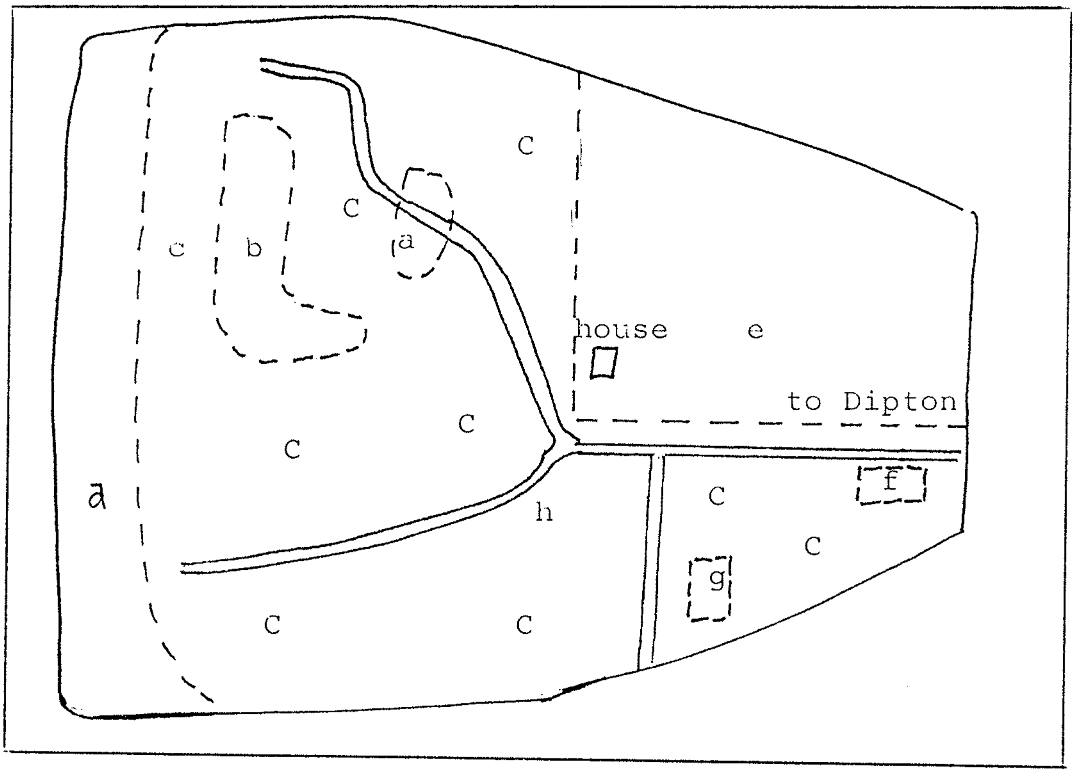
(i) Drum Fern

Drum Fern is located 72 km from the South Wood's mill at Bluff and about 10 km west of Dipton. The land of this ex-farm site runs from 150 masl in the flat (about 30 ha) up to 400 masl in the first set of hills rising out of the Invercargill plains. Most of this area was planted in 1991. By the end of the current year (1992), 400 ha will have been planted almost exclusively with *E. nitens*. Figure 4 shows the land use pattern. It is significant to note that not all of the Drum Fern land was used for eucalypt forestry. The farm house and some of the flat pasture land was sold to reduce capital assets; the highest elevation land was also sold for grazing as it is too high (read cold) and steep for planting; there are also some areas on bony (shallow soils over sandstone) and exposed ridges which will be planted with *Pinus radiata* as *E. nitens* is known to be unhappy on such sites.

Two months earlier Graeme Manley had visited Drum Fern and had been quite discouraged with the growth of the eucalypts. However, the past two months (March and April) have apparently been quite good for growth and the picture that we saw was not bad at all. Except for some of the bonier, more exposed areas (perhaps 10 ha) and one area, where tiny containerised planting stock had been used, most of this plantation appeared now to be well established and ready to take on winter. Seedlings on slopes at the higher elevations were in the 50-70 cm height range, seedling on slopes at the lower elevations were 70-100 cm in height and seedlings on the flat were 100 to 150 cm in height.

South Wood Export Ltd demonstrates that it is highly committed to mechanical site preparation. A D-9 cat is used to rip and slice the turf on all sites to be planted at a cost of about 130 NZ$ per ha However, due to tight financial constraints, South Woods generally feels that it can only afford one pass in site preparation (with a notable exception being the root raking which is practiced on brush-covered land prior to ripping) and this may be leaving the land in a condition which is somewhat shy of optimal for tree growth. The problem is that there are still many large clumps of sod covered soil which are more difficult to plant into and which present a slightly suboptimal environment for root expansion. The problem is that the additional tillage (with a rotary hoe for example),

FIGURE 4. Map showing (roughly) the land use pattern at Drum Fern.



(a) Land considered too high and bony for forestry, sold to a neighbour for grazing.
(b) Steep land, previously covered with brush; root raked and then ripped in preparation for planting.
(c) Pasture lands all ripped with a D-9 cat.
(d) Land prepared in the same way as (c), but exposed to the wind with sandstone outcroppings, G. Manley thinks it would be better in pine.
(e) Prime pasture land and house, sold to a neighbour to reduce capital assets.
(f) Location of <u>Eucalyptus nitens</u> genetic gain trial.
(g) Location of <u>Eucalyptus nitens</u> seedling seed orchard.

which would give an optimal physical environment for planting and root development, would require another pass and an additional 80 $NZ per ha.

On the flat area at the bottom of the plantation (see f in Figure 4) there were some adjacent areas on homogeneous land which had been prepared with and without this second pass. Eight months after planting the seedlings planted in areas which had been rotary-hoed in a second pass were markedly larger and more homogeneous in size than those planted in the area which had not been rotary hoed. Survival was also at nearly 100% in the intensively prepared area versus perhaps 85% in the less intensively site-prepared area. There are some slight genetic differences between the planting stock used in both cases but later we gathered evidence that indicated that genetic differences between the two stocks were not too great (see the Reefton section of this report) so it will definitely be well worth comparing the performance of *E. nitens* on these two differently prepared areas on into the future.

Of course, the best approach for resolving the economical justification for rotary hoeing is to lay out a proper site preparation experiment. Later, at Lilburn Valley, Graeme would show us a site which Ian Nicholas had identified for installing a "best practices" test which will thoroughly address this question (as well as several others). We would like to fully endorse the installation of this best practices test.

In September 1991, two *E. nitens* breeding trials were established at Drum Fern. These will be discussed next.

Seedling Seed Orchard

The seedling seed orchard of *Eucalyptus nitens* is comprised of 12 replications of four-tree row plots of each of the top 23 families from the Rotoaira provenance/progeny test. Each of these 4 tree row plots will be thinned to leave only the very best tree per row plot by age 6 and this will then provide a source of genetically outstanding *E. nitens* seed. In fact, from our calculations, this should provide the best *E. nitens* seed for New Zealand from about 1998 to about 2005 (at which time further improved parent trees will be producing seed). The layout of this seed orchard, minimises the chance of inbreeding (see Cannon, 1992 for details) and because of the orchards location near Dipton, extremely high seed yields are expected within 5 to 8 years.

Because this seed orchard has so much potential, it is especially nice to be able to report that it has been extremely well established (thanks to efforts by Graeme Manley's crew and Ruth McConnochie) and that, eight months after establishment, there is every indication that within family selection (the thinning of each 4-tree row plot to the best tree) will also be a very productive in terms of improving genetic gain.

Genetic Gain Test

A genetic gain test was also established on extremely homogeneous terrain to determine which seed source is best suited for areas such as this one at Drum Fern. However, *Eucalyptus nitens* families are somewhat famous for varying in growth rates; the rate of acceleration and deceleration also seems to vary from provenance to provenance (unpublished analyses of measurements of 1978 - established *E. nitens* progeny trials). For this reason, final decisions as to which are the very best sources of *E. nitens* should be deferred until this trial is approximately six years old.

Nevertheless, we measured this trial for height (it only takes 45 min. to measure the test) and obtained the results shown in Table 1.

TABLE 1: Performance of seven sources of *Eucalyptus nitens* in an eight-month-old genetic gain test at Drum Fern (near Dipton)

Source	Average Height	Duncans Multiple Range
Plus tree selections, Waiouru	81.2	|
Second generation selections, APM, Victoria	80.9	|
Top ranked families from 1978 Rotoaira Test	77.6	|
Southern NSW, second generation APPM, Tasmania	77.4	|
Bulked lower ranked families from Rotoaira	76.0	|
Northern NSW 2nd generation selections APPM, Tasmania	74.1	|
Commercial seedlot of "Toorongo" from CSIRO	69.7	|

$LSD_{0.05}$ = 15.19
$LSD_{0.10}$ = 12.06

From Table 1, it can be seen that there are no statistically valid declarations that can be made so far. More time will be required.

There were two aspects of this particular genetic gain trial which cause it to be somewhat less than perfect. One was that the Glentunnel source, which was used for most of the plantation stock at Drum Fern, was not included in the test. This is unfortunate and it might be stated here that another Genetic Gain test, which is planned for the Lilburn Valley (see ahead) will include the Glentunnel source.

What might be added here is that shortly after seeing Drum Fern, we visited the Reefton Aboretum where there has been a row by row 1989 planting of Glentunnel stock and diversified central Victoria stock. Knowing that the Glentunnel genetic value was of interest we measured this planting. The full results are given ahead in this report under "Reefton Arboretum"; it will just be briefly stated here that Glentunnel *E. nitens* is very homogeneous in its growth rate and that its growth rate is about the same as the average growth rate of (unimproved) commercial stock.

The other aspect of this genetic gain test which kept it from being somewhat short of perfect was that site preparation was not quite as thorough as it might have been. Because of bad weather and time constraints, the land had been ripped but had not yet been rotary-hoed. As a result, the survival and initial growth rate of seedlings in the genetic gain test is slightly lower and more irregular than in the surrounding areas which were planted after rotary hoeing had been completed. It is suggested that much of the observed variation in growth is mainly due to variations from the planting site of one tree to the planting site planting site of the next. A random sample of two row plots supports this observation; within one row plot (remember all trees are half-sibs) for example, seedlings measure 80, 110, 40, 90, 70 and 90 cm and average 78 cm in height. In another row plot they measure 90, 40, 40, 100, 110, 90 cm and average 78 cm in height.

Therefore, it is strongly suggested that for genetic gain and other breeding tests site preparation should also include rotary hoeing to make the planting environment as homogeneous as possible.

The need to test whether another pass (rotary hoeing) is economically smart for commercial plantings has already been mentioned in this report.

(2) Finegand Block

En Route

En route to the Finegand Block from Drum Fern (see Figure 2), Graeme deliberately took us through much of the rolling farm country at the base of the "central hill country". His company is earnestly considering the purchase of one large, and for dairying purposes unproductive, farms in this area. It is of some interest that South Wood's land purchasing scheme is to purchase blocks of land in diverse locations within a 100 km radius of Bluff ("logging trucks should be able to make at least two trips per day") rather than to concentrate all of the land holdings in one area. South Woods apparently feels that the inconvenience of having to shift planting and harvesting operations from place to place is far outweighed by the unfavourable political image that might result from the displacement of an entire farming community.

The land in the area from Drum Fern to Finegand Block all looked like it would be suitable to *E. nitens* with the exception of high ridge areas which are exposed to strong winds. More evidence for avoiding sites exposed to strong winds would come from the plantations at the Finegand Block itself.

The Plantations at Finegand Block

This farm, 20 km northeast of Mataura and 83 km from the Bluff mill, is situated between 250 and 500 masl with the highest land being on a bony knob of sandstone. To illustrate the punishment that *E. nitens* endures on such high, exposed sites, Graeme led us to the top of the largest knob to have been planted (see Figure 5). All of this 150 ha farm had been planted in *E. nitens* in 1989 and survival had been close to 90%; however, the *E. nitens* on the exposed knob had grown at most 20 to 30 cm since planting and their leaves had been shredded by the wind; the leaf margins had been particularly affected as shown in Figure 6. It is important to note that this symptom varies from the "salt spray" damage (see ahead) which can also affect *E. nitens* and from frost damage (see Cannon and McConnochie, 1992).

After visiting the knob, we hiked (Graeme drove around to meet us) along the path roughly shown in Figure 5. Growth became progressively better and evidence of wind damage progressively less as we went further and further into lower elevation and more protected (from wind) areas. However, it was amazing just how far down into the protected areas *E. nitens* trees continued to be leaning in the direction of the prevailing wind. *E. nitens* has a very stiff architecture and a large sail area and this has to be contributing to this leaning. The impact of this leaning may also have important affects on the type of wood being produced. Possible influences include more compression wood, more lignin or more variation in wood properties from one part of the tree to another (and hence less easy to pulp efficiently). Which of these influences actually exists to the extent that it effects the value of the wood produced remains to be determined, however, until such determinations (maybe a literature review would suffice) can be made, the possibility of having less valuable wood may be one more reason for choosing sites which are well sheltered from strong wind for the planting of *E. nitens*.

At the area labelled "Fertiliser Trial" in Figure 5 we stopped to look at an unreplicated fertiliser and herbicide trial which had been established in an attempt to find measures to try to correct "purple leaf-puny tree" symptoms which were affecting trees in this part of the plantation (and are still affecting trees outside the trial area). The treatments chosen to test ((1) fertilise with urea, (2) spray with gallant, (3) fertilise with urea and spray with gallant and (4) control (do nothing)) were spot on in terms of what we might have suggested as being worth comparing. Furthermore, the trees in the areas treated with either the fertiliser

FIGURE 5. The route taken at Finegand Block.

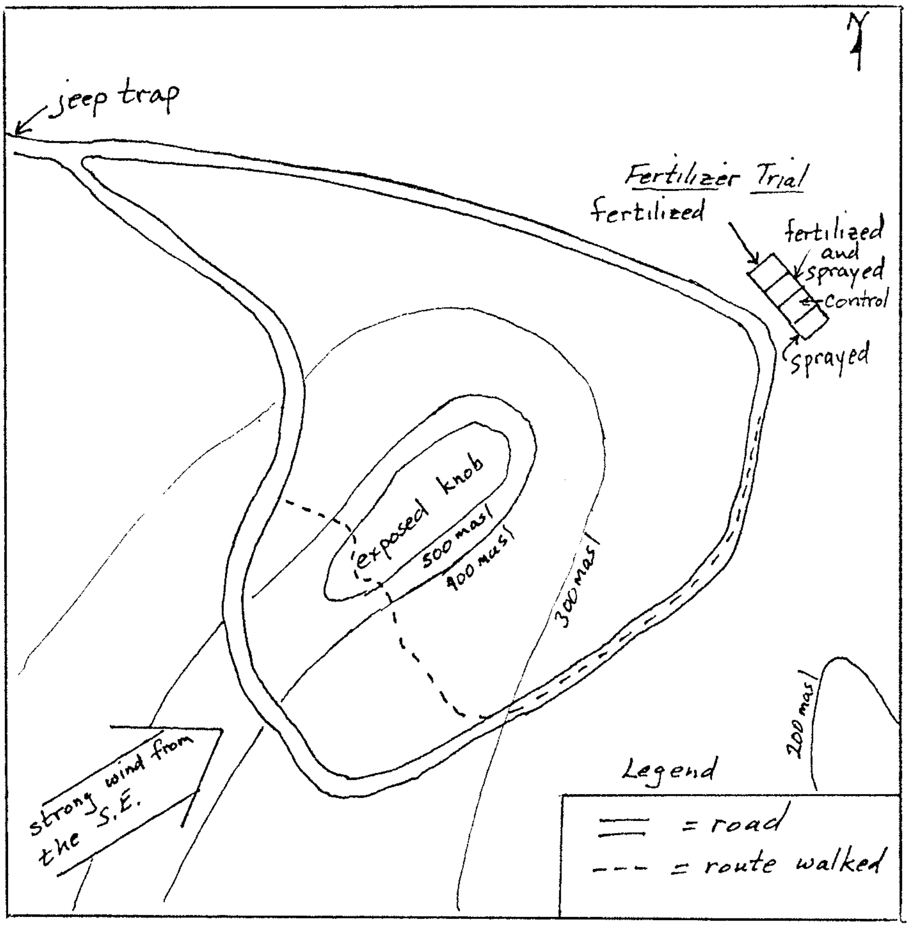
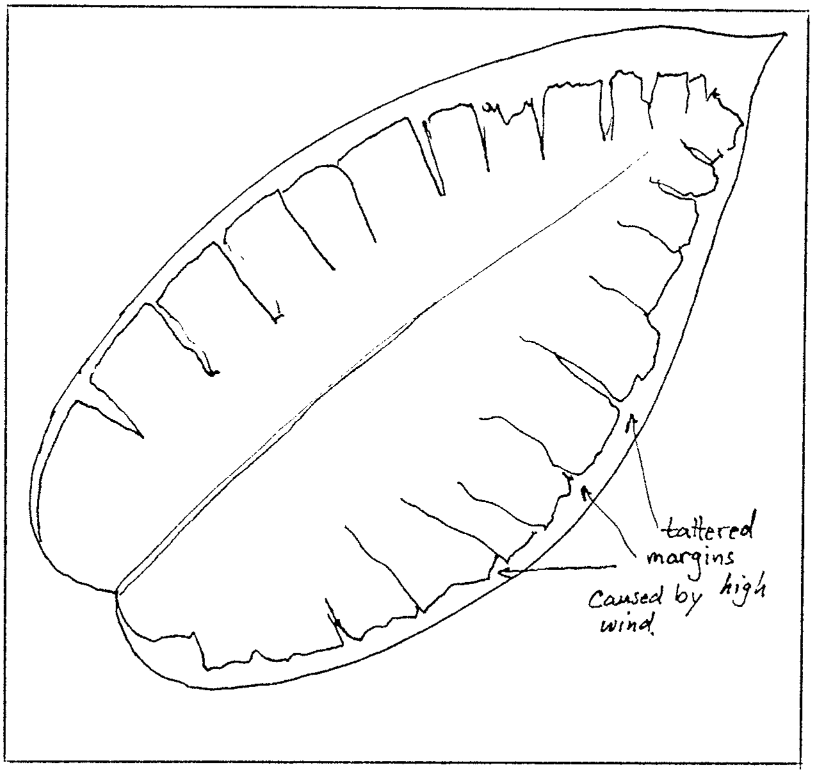


FIGURE 6. The effect of exposure to high winds on the morphology of juvenile *Eucalyptus nitens* leaves. Leaf margins are shredded on the inner wind-affected leaf. The outside line depicts the shape of a leaf which has not been affected by wind.



and/or the urea certainly seemed much greener and larger than trees outside of these treatment areas. However, it is impossible to accurately access the actual impact of these practices, because this experiment contains no replications, and because there were no measurements of the trees at the start of this experiment.

The initiative of perceiving the need and setting up this kind of trial is vigorously applauded. In the future, however, a randomised block experimental design is recommended to avoid the aforementioned pitfalls.

Feral goats were also found in this plantation despite continued efforts to eradicate them.

The general conclusion that South Wood Exports reached as a result of the Finegand experience was that they would not buy land (with intent to plant eucalypts) if it was above 350 masl;particularly if it was exposed to the wind. It seems worth stressing the point that it is more the wind factor than the cold factor that limits the performance of *E. nitens* in the Invercargill area.

In terms of strong winds, lands exposed to the northwesterlies and southwesterlies appear to be in particular jeopardy (this point is illustrated briefly in Figure 2).

One other item which Graeme brought up at this site was the difficulty that caterpillar drivers working for South Woods seemed to be having in ripping the sites to a full 120 cm, furthermore he wondered whether the "shatter zone" (zone of soil and rock that is disturbed during ripping) was optimal.

It was mentioned that Peter Gardiner, of South Africa, had done considerable research on optimising the ripping of soils derived from sandstone and conglomerates in Natal. A diagram of the optimal ripping configuration which he developed is shown in Figure 7. A report of his on this subject is given in Appendix I.

(3) Fortification

This ex-farm site is located 30 km southeast of Edendale and 62 km from the Bluff mill. Most of the 200 ha is between 100 and 250 masl. It was planted in 1989. Since we arrived in twilight we didn't have a chance to explore the higher reaches of this land holding so all of the comments made here will apply to the plantings on low (between 100 and 120 masl) flat to slightly rolling areas. Our 20 minute visit to this site took us along the path shown in Figure 8. In general most of these trees had grown quite well and formed a homogeneous plantation. It is significant, however, that *E. nitens* exposed to the southeasterly winds had their branches blown away from the windward side and that all trees were gently inclined

FIGURE 7. Details on the subsoiler used by Peter Gardiner for eucalypt site preparation in South Africa. The side view shows that the side tines should be slightly advanced from the middle and deeper tine. The front view shows the additional wings which are welded on to the subsoiler to give a better shattering efect.

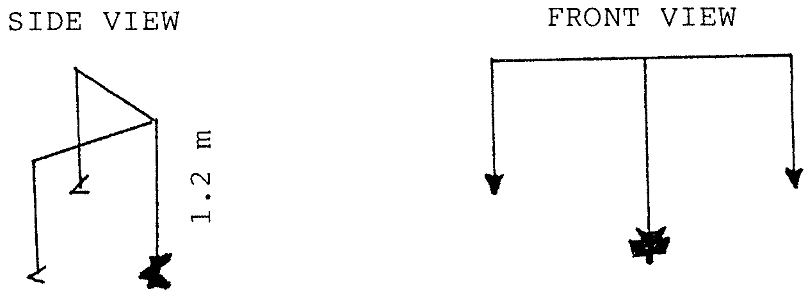
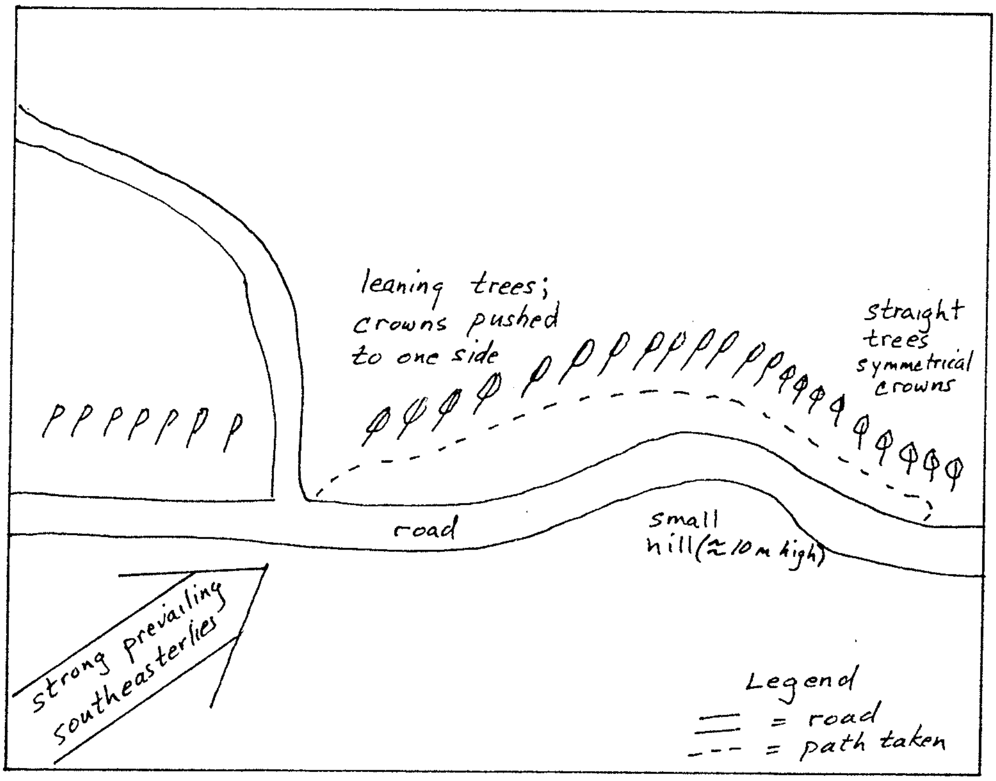


FIGURE 8. The effect of exposure to the wind on the growth and form of E. nitens at Fortification.



(5-20°) whereas trees which were in topographic positions just barely blocked from this wind showed no branch migration or bole inclination whatsoever.

In the low-lying swampy areas of this ex-farm, *E. nitens* had not survived. Such areas were very limited in extent (we saw less than 0.5 ha).

Other Edendale Attractions

There are three other places which would have been interesting to visit in the vicinity of Edendale:

(1) The Edendale nursery where most of South Wood's *E. nitens* planting stock is raised ... unfortunately it was closed for the night when we arrived;

(2) The line planting of NSW nitens at G.R. Dodds place, which we could only look at in passing because of time constraints ... it looked good; and

(3) Humphries' Wool Shed where Peter Davey has a *E. nitens* seed extraction facility.

(4) Lilburn Valley

An ex-farm in the Lilburn Valley is where South Wood Exports intends to do most of its 1992 planting of *E. nitens.* This farm lays between 150 to 200 masl, 100 km northwest of Invercargill. Ninety percent of its 1000 hectares can (and most of it has) been ripped with a cat or a skidder. As at Drum Fern, many capital assets have been sold off, brushy areas have been root raked prior to ripping and the debate as to whether or not to do rotary hoeing in addition to ripping remains open.

We went to the top of two hills (see Figure 9) and drove along a road in the valley bottom to get a better feel for the lay of the land and to select some potential areas for trials.

Generally this farm site appears to be fabulous for *E. nitens* and expectations of an excellent plantation appear quite reasonable based on what we have seen earlier in the Invercargill area. However, Figure 10 shows one aspect of the lay of the land which may be both a problem and an opportunity on a small portion of this farm. Cold air off the Southern Alps will be trapped in the valley bottoms making low-lying portions of this farm much colder sites than their elevation would suggest. Because of this potential for having frost in these hollows this may be a good area to conduct some frosting trials. Accordingly the trials shown schematically in Figure 11 have been proposed by us and generally accepted by Graeme.

FIGURE 9. General outlay of the 1000 ha farm in Lilburn Valley. Most of the land had been ripped at the time of our visit.

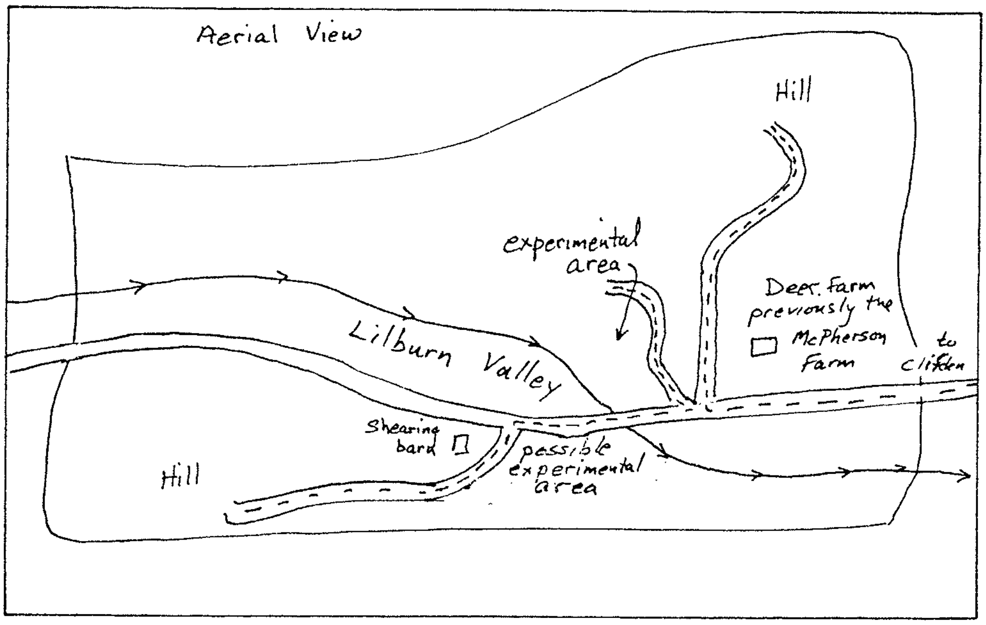


FIGURE 10. A lateral view of the farm at Lilburn Valley. Since much of the farm (labelled as x in this diagram) is in a frost hollow, some frost problems might be anticipated.

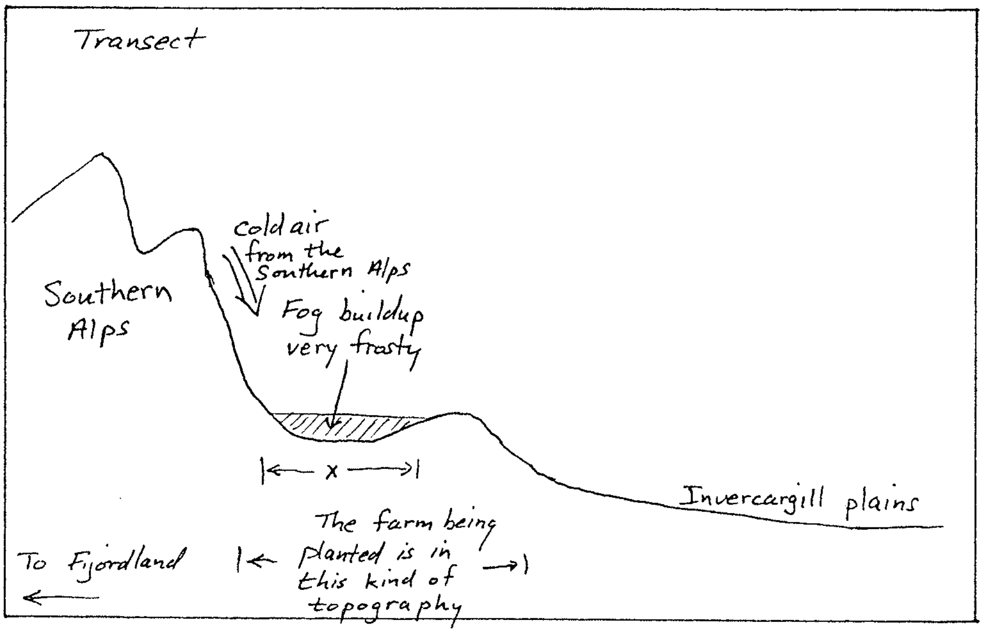
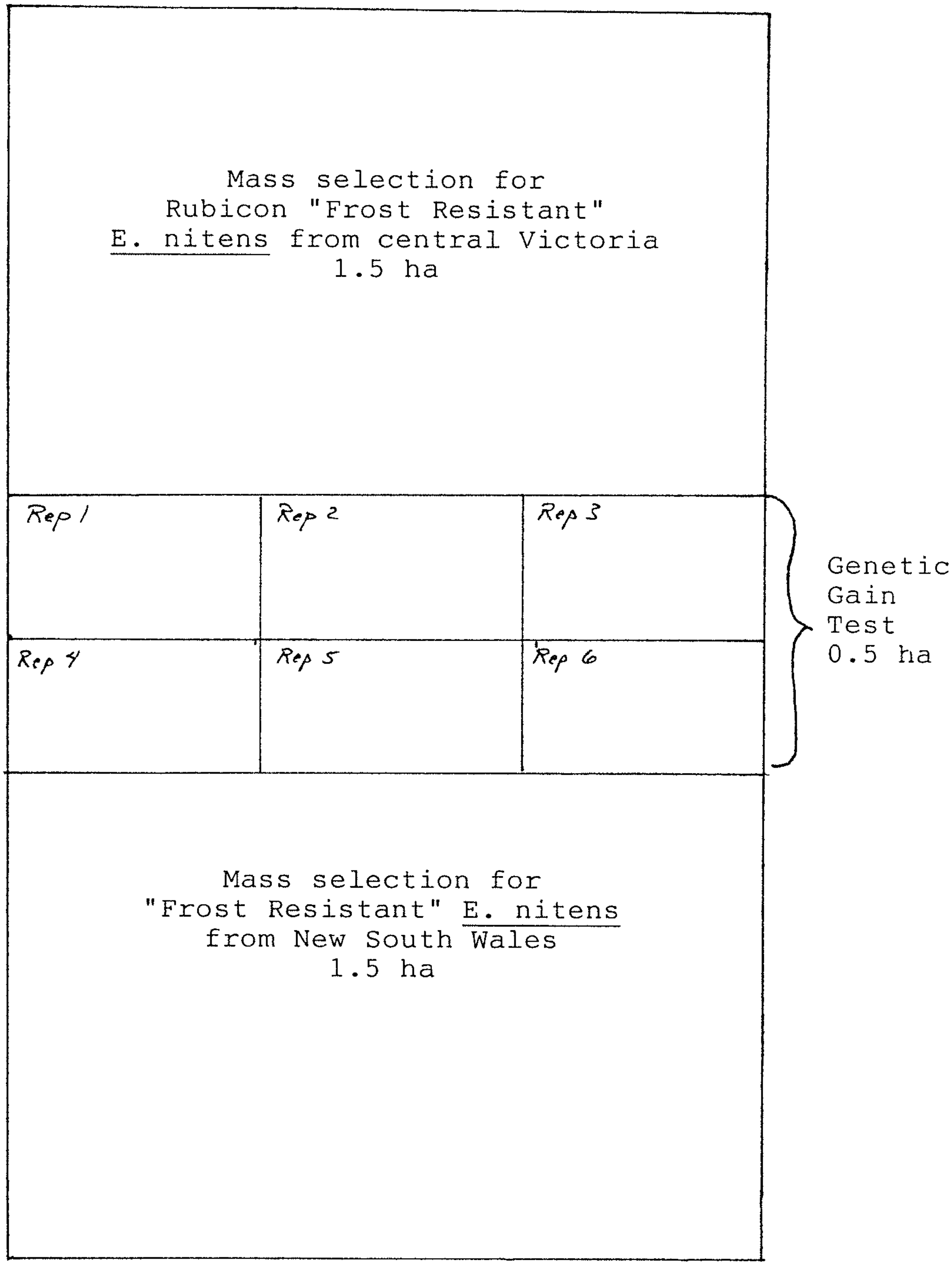


FIGURE 11. General layout of *Eucalyptus nitens* breeding activities proposed for the Lilburn Valley. Test results will be optimal if established in a very hard frost flat on near level ground near the river.



We were also pleased to see the site than Ian Nicholas and Graeme had chosen for the "best practices" test ... good results should be easily forthcoming on such homogeneous land.

Other Items of Business

One of Graeme's big concerns is that South Wood Exports uses the best seed sources of *E. nitens* currently available and he is actively soliciting advice. The genetic gain trials already established at Drum Fern and proposed above for Lilburn Valley will eventually shed an enormous amount of light on this question. Already there are several indications that the seedling seed orchard at Drum Fern and one or more of the mass selections trials at Lilburn Valley will provide superior seed for use in the Invercargill area in the future.

In the meantime however, Graeme must purchase *E. nitens* seed elsewhere, so we will review his options.

APPM, Tasmania

Wayne Tibbits, acting research director of APPM's forestry section, has sold Graeme Manley 0.1 kg of seed from Mt Erica families from the APPM seedling seed orchard and 0.5 kg of seed from NSW families which had been growing in the same orchard.

Eventually the APPM seedling seed orchard (at The Huntsman) will be producing some excellent seed (whether or not this will be available commercially to other companies is uncertain) however, we are of the opinion that nothing especially marvellous should be expected from this present purchase. The price of the seed strongly suggests that the 0.1 kg of seed from Mt Erica families may well have come off of the poorer trees (the ones that got thinned out a few years ago) and/or off the lower ranked families, and that the 0.5 kg of NSW nitens seed comes from trees which APPM is unlikely to favour themselves and comes with only the identification of NSW as to source. If Graeme wishes we can easily include both of these sources in the genetic gain test planned for Lilburn Valley (just send us about 2.0 grams of each seed source, Graeme); in the meantime a letter from Graeme to Wayne requesting information on the original origin (where in NSW?) of the NSW sources could prove useful.

PROSEED

At the airport, a list of all PROSEED seed collections was given to Graeme. Three of these were earmarked as being especially promising for the Invercargill area. It was pleasing to note that Graeme has purchased 8.0 kilos of seed from PROSEED seed although we are not sure his purchases were exactly the ones that were suggested.

In the near future (2 to 4 years) seed will probably be available from PROSEED's clonal orchard at Waikuku. This may well prove to the be the very best source of seed for South Wood Exports until South Wood's own seedling seed orchard comes into production. It is strongly suggested that seed from the ortets of these Waikuku clones be included in the Lilburn genetic gain test.

It will be important to try some southern NSW seed collected by PROSEED in plantations, some of the trees that this seed comes from have phenomenal biomass on the North Island (Kaingaroa). Obviously, these "better" sources of NSW nitens also need to be tried in the genetic gain test as well.

Peter Davey, Daveyseeds

Additional sources well worth trying both in commercial plantings and in the genetic gain test include some of those collected by Peter Davey (see list in Appendix V). The big advantage of these collections is that they come from local land races and from trees among these which "have grown well" (Peter Davey pers. comm.) and that their original source of origin in Australia is still known.

Graham Milligan

Graeme Manley is in a much better position to assess the appropriateness of this source since G. Milligan is located in Dipton.

Glentunnel - via Dudley Franklin

The plantation of "Glentunnel" nitens which Graeme showed us down in the flat area at Drum Fern certainly looked very well established, very very homogeneous and off to a good start. As such it seems to be quite an adequate source for the Invercargill area. However, in a test which Dudley Franklin would show me later, the Glentunnel source was performing better than some other *E. nitens* but poorer than other unidentified families (see Reefton Arboretum). Therefore, the Glentunnel source should probably be used (and depended on as tried and true) only until a better source can clearly be identified (in the next 5 to 6 years). It is recommended that Glentunnel seed be used in about 15 to 30% of current plantations and that it be included in the genetic gain test.

Graeme Manley's House

Graeme Manley has planted about 20 *E. nitens* around his house near the Invercargill airport. These trees grew very well until their tops passed a mechanical windbreak (about 4 m high); after this their tops have been repeatedly singed showing symptoms which we have associated with salt burn. Salt in the offshore winds would appear to be a problem near the coast. It is not known how wide an area would be affected or what the gradients in potential damage might be. Top singing (caused by salty winds) probably should not be confused with damage caused by wind alone which tends to shred leaves rather than singe tops.

CANTERBURY

(5) Charteris Bay

Dudley Franklin met us at the airport on the afternoon of the 15th and we visited the "Orton Bradley Estate" at Charteris Bay first off. The bay is actually the result of a caldera blowing out a huge hole of land, the base of which happens to be below sea level. The trials visited are on the steeply sloping land about 200 masl on the inside of this caldera. There is a lot of basalt rock in the soils, and soils overlying any parts of the topography which are convex are particularly thin.

In the first trial, *Eucalyptus nitens, E. obliqua, E. regnans, E. fastigata, E. delegatensis* and *E. oreades* were planted in amongst widely spaced *Pinus radiata*. Of the eucalypt species, *E. nitens* was the only one which had grown at all well, but its form was pyrimidal (chunky) perhaps as a result of restricted rooting, although a long history of severe *Paropsis* damage (now under reasonable check) may also have had an impact. There were a couple of small groves of poplars as well in this trial. However, all of these trees had been severely ravaged by possums so that after 11 years of growth they were only 2 to 3 metres tall and quite bushy.

The second trial visited involved using *E. nitens* as a nurse crop for *Cupressus macrocarpa* and *Cupressus lawsoniana.* We have no basis for judging whether the nurse crop had any affect on the performance of either of these cypresses, but both the eucalypts and cypresses seemed to be growing fine.

(6) Waikuku Clonal Orchard

Three years ago scion was collected from the top ortets of the top 27 families in the provenance/progeny test of *E. nitens* at Rotoaira and grafted. Most of these grafts were outplanted in the Waikuku clonal orchard (although 2 grafts of each clone were also planted in the Longmile seed orchard). This season, for the first time, most of these clones are beginning to flower - in the order of several hundreds flowers per graft (generally much more so than the clones at the Longmile) which gives an indication that within two to three years time commercially significant amounts of seed should start to be available from this orchard. It is expected that the amounts of seed available will continue to increase in subsequent years. Nonetheless, it is still questionable that Waikuku is the best location for this seed orchard. Probably even higher levels of seeding would be forthcoming if the orchard was located in harsher Southland sites.

(7) Ashley Forest

On a flattish terrace of soil derived from glacial till (about 100 masl), several known sources of *E. nitens*, *E. delegatensis* and *E. regnans* were planted in alternative spacing with *Pinus radiata* which had been planted 5 years earlier at a wide spacing. On one site, after 3 years of growth, *E. nitens* from central Victoria were averaging greater annual growth rates than *P. radiata* which were 17 years old and *E. delegatensis* which were 13 years old. On a second site *E. nitens* from Nimmitabel was averaging 2.70 cm in diameter per year whereas *P. radiata* was averaging 2.08 cm per year. The heights of both species of trees was 18 m at this time, which means that on average NSW *E. nitens* grew 56% faster in volume than *P. radiata* and central Victorian *E. nitens* grew 27% faster in volume. See Table 2.

TABLE 2: Growth of *Pinus radiata, Eucalyptus nitens* from central Victoria, *E. nitens* from Nimmitabel (NSW) and *E. delegatensis* on two sites at Ashley

Species	Age	Average dbh (cm)	Diameter growth/yr (cm)	Average height	Ratio of *nitens* volume growth rate to *P. radiata* volume growth rate
Site 1					
E. nitens central Victoria	13	30.0	2.30	16	1.27
Pinus radiata	17	33.9	1.99	16	
E. delegatensis	13	22.0	1.69	9	
Site 2					
E. nitens Nimmitabel (NSW)	14	37.8	2.70	18	1.56
Pinus radiata	17	35.3	2.08	18	

In spite of the relatively rapid growth rates of the *E. nitens* from both central Victoria and NSW compared with *Pinus radiata*, it is hard to get too enthused about their growth on this site. Their form was a bit chunky and rough and their diameters really are not even close to what *E. nitens* can attain on better sites. Probably the chunky form is due in part to the shallow soils which tend to be poorly drained in the rainy periods and to dry out quickly during dry periods. Ripping was done prior to planting, but soil physical properties still may be subadequate.

Canterbury Plains

All across the Canterbury Plains there are windbreaks; certainly hundreds of kilometres of them and probably thousands. FRI in Rangiora has done considerable research on the best ways of establishing these windbreaks. Dudley explained some of the more salient results of this research and these will be passed on briefly here. In all cases windbreaks should be oriented at right angles to the prevailing winds. There are two types of prevailing winds in Canterbury, a cold moist southwesterly and a dry northwesterly. To block the southwester, a solid low hedge (pruned *Cupressus* to a height of 4 metres for example) is desirable and these should be planted in bands about every 100 m. To diffuse the northwesterly, a taller and less compact windbreak is needed. For such windbreaks, a single row of *E. nitens* every 200 m should suffice. As the nitens grow taller they can be interplanted with cypress. Eventually the *E. nitens* can be pruned to a height of about 6 m and the cypress can be fan pruned.

Besides windbreaks, there was plenty of evidence that *E. nitens* is one of the most favoured species for planting in amenity plantings and fuelwood plantings across the Canterbury plains. A medium density fibreboard plant located at the base of the Ashley forest has not tried *E. nitens* as a raw material, however, it has tried *Eucalyptus deglupta* (on a contract) and found its performance to be adequate but the board too dark (Jack McLaughlan, pers. comm.). This plant should be encouraged to try *E. nitens* because its heartwood is very light compared with that of *E. deglupta* and because there will be plenty of this resource in the Canterbury area.

(8) Glentunnel

The famous "Glentunnel" stand is located on Colin Brown's farm near Whitecliffs in one of the first sets of hills after leaving the Canterbury Plains. Actually, there are two stands of *E. nitens* at Glentunnel. The first to be established was planted by Colin's father 32 years ago with seed that is thought to have come from Mt Erica. The original stand has been thinned heavily and today about 35 trees are left. The largest of these trees is 83 cm dbh and approximately 35 metres tall, but there are several other trees which are about 70 cm in diameter and 30 m tall.

Some time ago, seed was collected off three trees in the first stand and this was bulked and used to plant the second stand in 1978. The trees in this second stand have also grown extremely well. In fact they are certainly amongst the finest looking eucalypts I have seen in New Zealand; nice clean straight stems, a long cylindrical bole and small branches. They resemble *E. nitens* as grown in South Africa or *E. grandis* as grown at Aracruz.

It is easy to rave on about these excellent trees, but a word of caution might be in store when considering the use of seed obtained from this second Glentunnel stand. Since the trees for this entire stand were obtained from only three parent trees, there is a very large chance for related matings to occur. The consequences of these related matings were unknown at the time that we are talking with the Browns (Colin and his father), however, the next day, at the Reefton Arboretum we would have an excellent opportunity to measure the effects of this restricted breeding.

Seed production in this second stand is quite good (one edge tree, for example, yielded 25 kg of seed on felling) so it is important to know how well this copious supply of seed can be expected to perform.

(9) Craigieburns

At the bottom of the Craigieburn park, easily visible from the Arthurs Pass Highway, there are two square 1978 planted eucalypt trials sitting on a north facing slope at 900 masl. In the eucalypt species trial, *E. nitens* has done the best. The largest trees are 25 cm in diameter, but have stunted top growth. *E. johnstonii* was the second best species in the trial. Several other high altitude eucalypts, such as *E. pauciflora*, survived well, but their growth has been very slow.

In the adjacent *E. delegatensis* provenance test, 12 sources of this species were represented. None of these did particularly well, but the Tasmanian sources were the best of the lot. All of the sources developed glaucous leaves at this site except for a Canberra source and a New Zealand source.

Siting of *E. nitens* in Canterbury

Largely it is the exposure to prevailing winds year round and exposure to sunshine in winter which exerts the greatest influence on the suitability of sites for *E. nitens* on the eastern side of New Zealand's South Island.

Basically, there are two prevailing winds, a moist, cold southwesterly and a dry (and sometimes hot) northwesterly. Due to a orographic influences as the northwesterlies pass over the Alps, these particular winds tend to much drier at the low elevations than the high.

Because of the prevailing northwesterlies and southwesterlies, it has been found that *E. nitens* (and indeed most plants in general) are happiest when they are planted on south and southwest facing topographic positions when planted at the lower elevations (below 250 masl) because at such elevations, moisture is a major concern and temperature is not. At the higher elevations (400 to 900 masl), however, it is the north and northwesterly facing slopes which generally are best. The northwesterly winds still have not become too dry at these higher elevations and the warmth from the sun (which is most intense when received at angles close to perpendicular) becomes the critical factor. At the middle elevations (250 to 400 masl), aspect is less important, however much of the land at this middle elevation on the South Island tends to be very steep.

THE WEST COAST

Generalities

In the gold and coal mining days of the West Coast, which began in the 1800's and continued up until quite recently, timber provided from native stands was counted on for a myriad of uses and vast tracks of land on the West Coast were clearfelled (some of this timber also went to Nelson and Christchurch). Most of the early trials with eucalypts were established on such cutover lands and particularly in loose soil on the sides of skid roads leading up to landings (most logging was by cable). The two first trials reported on here were established on such cutover "native bush".

However, over the past decade the scope of forest plantations on the West Coast has changed markedly with the almost complete withdrawal of the native forests from the harvesting scene. Fortunately, there are also some splendid examples of *E. nitens* forestry in non-native bush lands as well.

(10) Callaghans Ridge

Callaghans Ridge is not far off the main Greymouth-Reefton road, just 5 km south of Ahaura. After a quick rise off the valley plain, one is quickly on a finger of land that runs to the northeast. The road follows the top of this finger eventually leading to a large plateau and Lake Hochstetter. About 15 km along this road, a 1976 planted *E. nitens* provenance trial is found situated on steep land running from the ridge top well down the slope to the beginnings of a water catchment area. Two families of NSW, two families of Errinundra and three families of central Victorian *E. nitens* were included in this trial. Two families of *E. regnans* and *E. delegatensis* are also included. The design is the same as other eucalypt species tests established by Dudley, each family is represented by one randomly assigned tree in each row. After 5 years, all of the most poorly performing eucalypt trees were thinned from the planting. This left only the *E. nitens* with an occasional *E. delegatensis*. Today it is easy to distinguish between the 3 "races" of *E. nitens* (actually the Errinundra source has been reclassified as *E. denticulata*). They are as follows:

Errinundra	-	thin, cylindrical solid bright green boles with tiny horizontal self-pruning branches.
NSW sources	-	grey bark, squat big-based pyramidal shaped bole with thick persistent branches.
Central Victorian sources	-	grey bark, more or less cylindrical bole with intermediate branching habits.

At 5 years, the Errinundra source was considered to have done extremely well on this site relative to the other *E. nitens* sources. Dudley thought that this may have been due to the extremely low nutrient status of these soils (there was about 2 cm of duff and 2 cm of mineral soil covering glacial till in two profiles we examined ... site preparation involved burning of slash following the logging of the native forest). However, by 1992 (age 16) the Errinundra sources would have dropped to the bottom of the rankings; they are still quite tall, but they are very small in diameter, most of them between 20 and 25 cm dbh. Central Victorian and Nimmitabel *E. nitens* have now become the dominant trees.

The largest trees at this site, however, are not any of the *E. nitens* in the trial, but rather a row of NSW *E. nitens* that had been planted in the loose soil (and rock) that was pushed aside when the road was built. One of these (chosen at random) measured 44 cm dbh.

(11) Slab Hut

This trial is a replicate of the Callaghan's Ridge trial in terms of design and species provenances and families included in the test. This test is also planted on steep ground and again the soil is derived from glacial till. But here there is a distinct gradation in soil fertility. At the top of the trial (near the top of a ridge) trees are relatively short and have small (25 cm dbh) diameters. Near the bottom of the trial (nearer the base of the slope) trees get much larger, many of them with diameters of 45-50 cm.

Again, as a result of the 5 year thinning (in which all of the runtier trees were removed) it was mainly only *E. nitens* sources which were left. Dudley's group intends to measure all of the remaining trees again, which will be good because then it can be decided which *E. nitens* source has the best growth potential for this site. There were also one or two *E. regnans* and *E. delegatensis* trees which had passed the 5 year test. These have not been doing exceptionally well, however, they were outstanding for one feature at this trial; their foliage was dark green and healthy whereas the foliage of the *E. nitens* trees has been hammered by *Paropsis*. Indeed this was by far the heaviest impact *Paropsis* has had on an *E. nitens* stand in years. One could speculate several things including the following:

(1) The Enoggera wasp may not have made it to this area;

(2) The *E. nitens* are losing a significant amount of their potential growth;

(12) Reefton Arboretum

The Reefton Arboretum contains quite a treasurehold of *ad hoc* forestry experiments including two marvellous trials with *E. nitens*.

The first is a trial in which *E. nitens* is a nurse crop for an *Acacia melanoxylon* underplanting. Both species are doing fine with many of the *E. nitens* in the 35 cm diameter range after 8 years of growth.

It was noticed, however, that pinhole borers had attacked the butt log of about 5% of the trees and that in some cases there was quite copious kino bleeding. In many cases (maybe 3 trees out of 50 trees looked at) there were large clusters of wasps (10 to 15 wasps per cluster) milling about in the vicinity of these holes apparently feeding on the kino leakages. I have speculated on previous occasions that such insect activity might keep the kino from hardening and thus prolong its flow. It has been documented that excessive kino formation can lead to severe degrade of the wood for either solid timber or pulp; solutions to this problem (silvicultural or genetic) could therefore be important.

The second *E. nitens* trial at Reefton is perhaps the most fascinating. Here, there are alternative rows of Glentunnel *E. nitens* and *E. nitens* from seed collected off thinned-out *E. nitens* trees from the aforementioned Slab Hut experiment.

We measured the dbh of 20 trees of each of these sources where they had been grown on flat land (trees in drainage ways, forked trees and trees which were on the edge of this planted area were avoided). The results are shown in Table 3.

TABLE 3: The dbh of Glentunnel *E. nitens* and mixed central Victorian *E. nitens*

	Glentunnel *E. nitens*	Mixed central Victorian
	13.0	13.9
	15.5	6.5
	11.3	15.8
	14.0	14.3
	12.5	13.8
	9.9	13.0
	12.5	9.1
	11.9	15.1
	11.6	15.6
	10.6	12.6
	9.3	11.4
	12.1	11.9
	15.7	14.3
	10.1	13.3
	12.9	6.9
	12.9	14.9
	13.1	11.4
	12.1	12.5
	15.9	17.1
	13.1	15.7
	12.5	
Total	262.5	259.1
Average	12.50	12.955
Average DBH of Top 10 trees	13.86	15.05
Average Volume of Average Top 10 trees	0.050	0.073

From the averages of the dbh's of these two sources of seed, one might be tempted to conclude that it did not make much difference which seed source was used.

However, the standard deviations of those data would show that the Glentunnel source has a fairly constant dbh whereas the central Victorian source has a much more varied dbh. Both sources are growing well; however, the central Victorian source should be preferred by the forester because it can be improved further either through thinning of the present plantation (removing the lower half of all trees in both row plots would leave the Glentunnel source with a dbh of 13.86 (with a height of 8 m) whereas the average dbh of the better half of the trees from the mixed central Victorian sources would be 15.05 (with a height of 10 m) or about 46% more in terms of woody biomass) or through genetic improvement.

The homogeneity of the Glentunnel source was also marked by another phenomena: the foliage. Essentially every tree had one to two metres of branches with juvenile foliage on them at the base of the crown and the remainder was mature foliage. The Glentunnel trees were all in the 7 to 8 metre height range as well. By comparison, the central Victorian families had much more varied proportions of juvenile/mature foliage and heights which ranged from 6 to 10 metres.

That the best trees of the Glentunnel source has grown more poorly than the best trees of the central Victorian may not be due to an inferior genetic makeup of the original Glentunnel trees, but rather to the result of inbreeding. The seed from this planting came from the second planting at Glentunnel which in turn came off of two to three trees from the first Glentunnel planting which probably (it is not certain) came off of a limited number of trees (maybe only one) somewhere in Australia (suspected to be Mt Erica). The exact degree of related matings is somewhat hard to pin down, but the striking morphological features (foliage dbh and height) of all of the trees from this Glentunnel source confirms that indeed they are closely related. The slightly lower diameter growth rates may be the result of a measure of inbreeding. It would be useful to have an experiment which could resolve this point. One possibility for doing this might be to compare Glentunnel *E. nitens* from the first and second plantations. Dudley has volunteered the seed for this trial. These two sources should be included in the genetic gain trial to be established at Lilburn since South Wood Exports is actively planting nitens from Glentunnel.

Before leaving the Reefton Arboretum, it will be mentioned that one *E. nitens* border tree was 12.0 m tall and 19.3 cm in dbh. Not bad growth for a 30-month-old tree.

(13) Waipuna

Waipuna is a large sheep farm on a tongue of flattish glacial-fluvial terraces that extends up the base of a valley which follows the Big Grey River. Two plantings of *E. nitens* are worth reporting.

The first is a trial that is modelled after the Tikitere Agroforestry trial (with 75, 100, 150, 200 stems per ha) in every aspect except that it also includes a eucalyptus component as well. Initially, the eucalypt area had been planted with a typical Dudley species trial design (i.e. several rows which contained a few families of several species planted at a 3 x 3 spacing) and again this trial had been thinned out to leave the best 150 stems per hectare. It was almost exclusively the *E. nitens* from NSW (Tallaganda) which had survived this early test.

Since the same level of thinning had been applied to some of the *Pinus radiata* plots as well, it was felt that measurements of trees in the 150 stems/ha plots of these two species would provide a fair comparison of their relative growth potentials. The results are shown in Table 4.

TABLE 4: Diameter of *Eucalyptus nitens* and *Pinus radiata* at Waipuna

	E. nitens Est. vol.	*Pinus radiata* Est. vol.
	43.3	44.6
	56.5	43.5
	61.1	48.5
	55.2	38.5
	62.7	43.7
	54.4	47.1
	68.1	45.5
	44.4	47.6
	52.2	47.2
	61.8	40.8
	61.0	48.0
	52.5	47.9
	63.4	52.1
Average	56.7	45.8

Additionally, it was estimated that the heights of the eucalypts were 28 m tall and the heights of the pines were 23 m tall. The average *E. nitens* and *P. radiata* therefore have volumes of 2.45 and 1.75 m^3, respectively. In other words, the *E. nitens* have 40% more biomass than *P. radiata* after 24 years of growth.

There was one particularly large *E. nitens* which was measured at 78.8 cm dbh with a height of 34 m. This is a border tree, however. These eighteen-year-old *E. nitens* trees were often found to have enormous branches indicating that it may be wise to prune butt logs if sawtimber is an objective.

Five kilometres of windbreaks have also been planted on this farm using central Victorian *E. nitens*. At 7 years of age, these trees have grown extremely well. In many of these windbreaks every other tree planted was a cypress. Just a few months before our visit, a few kilometres of *E. nitens* had been butt pruned to a height of 5 m (at Dudley's suggestion) and the cypress had been fan pruned to help slow the wind.

We talked with an especially articulate farm shepherd who went on at great lengths to describe how much more productive the harder (exposed to wind) sites had become subsequent to the development of the windbreaks (particularly during the lambing season).

GOLDEN DOWNS (14)

Most of our efforts this day were concentrated on measuring two trials. We did however peek over a fence a few times to look at a trial which tested a large number of eucalypt species. *Eucalyptus nitens*, again, was clearly the winner (for anyone interested, there are fairly copious file notes from a much earlier visit to this trial by Mike Wilcox). There is also a planting of "frost hardy" *E. regnans* families which is seeding heavily. These trees are from seed of the most frost resistant regnans from the Wiltsdown test.

PSP Measurements

In 1978, a provenance/progeny test of *Eucalyptus nitens* was planted at Golden Downs. This test included all of the same families as the provenance/progeny tests at Murupara, Rotoaira and Longwoods. Unfortunately site preparation was minimal and, as a result, such a large number of trees failed to become established that this particular trial was written off two years after planting. Survival was not all that poor, however, and several years later permanent sample plots were established. At the time of our visit, these sample plots had not been measured in three years so we volunteered for the task, hoping this would save someone else a long trip.

A full analysis of the growth in these plots should be forthcoming from the Eucalypt Management Coop. shortly. Here it will just be stated briefly that most diameter gains seemed to be in the range of 6 to 11 cm over the past three years or 2.0 to 3.6 cm per year (just slightly below average annual diameter increase over the previous 11 years). Diameter growth was slightly greater in the less dense plots. Plots 1, 2 and 4 had markedly more *Paropsis* damage than Plot 3 which was located 150 metres upslope from these three plots. Still, *Paropsis* damage may not have been heavy enough to detract from growth.

Acacia melanoxylon provenance/progeny test

This test was laid out on the ground as depicted in Figure 12; *E. nitens* is a nurse crop for one half of the test. A lateral view of the trial (Figure 13) may also help conceptualise its layout. Again each row functions as a replication in which all families being tested are represented once (at least) and their location within that row is decided at random.

Prior to analysis, one trait, "form", was considered to be a bit tricky. According to instructions from Tony Firth, via Ruth McConnochie, form could be graded on a 1 to 9 basis. Top scores would be reserved for trees with a spire top, with a score of 6 to be assigned to the worst formed of these and a score of 9 to be assigned to the best formed of these. Lower scores would be for trees with a "bushy" top, with a score of 1 for the very worst formed of

FIGURE 12. General layout of the <u>Acacia melanoxylon</u> provenance-progeny test. Individual acacia trees are represented by the small circles. The acacia trees on the right side of the test had <u>Eucalyptus nitens</u> (represented by the larger circles) as a nurse crop.

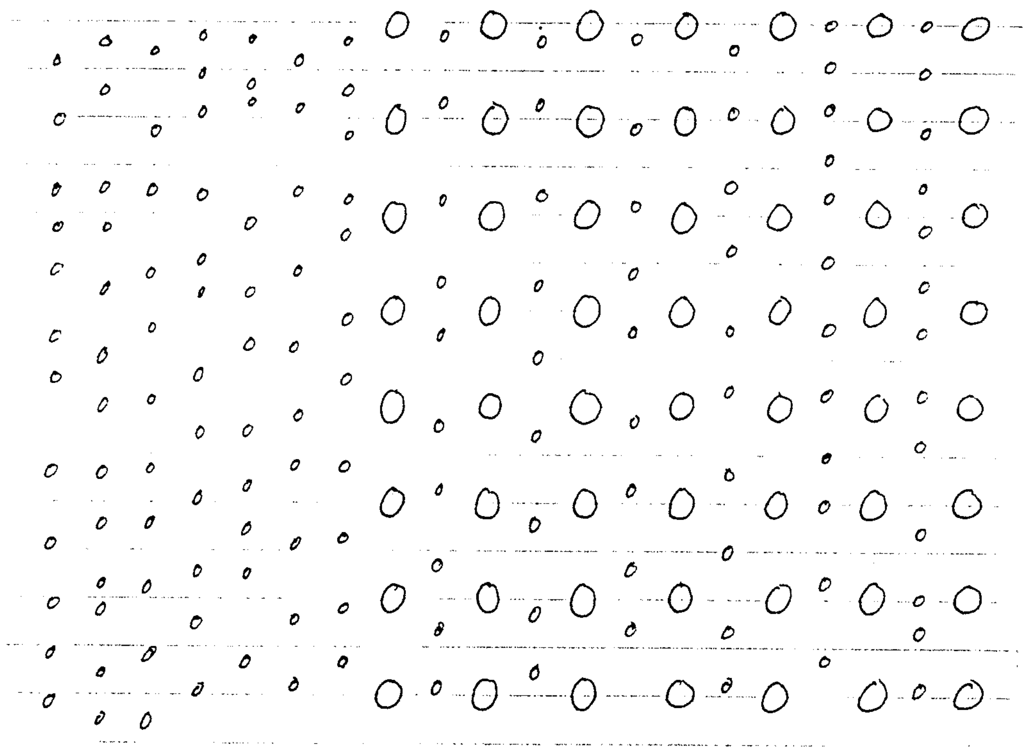
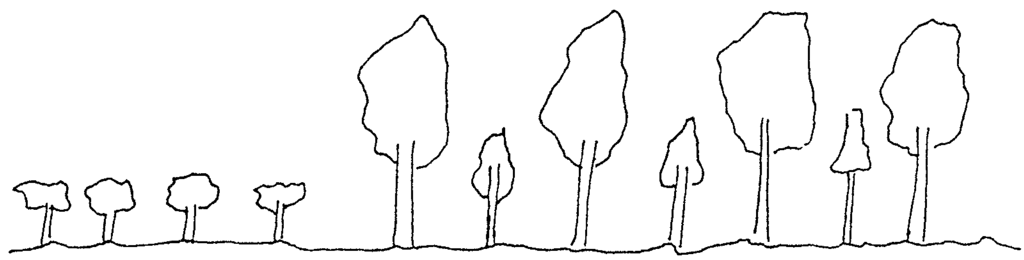


FIGURE 13. Lateral view of the <u>Acacia melanoxylon</u> provenance-progeny test. The larger trees on the right depict the <u>Eucalyptus nitens</u> nurse crop. The <u>A. melanoxylon</u> in the understorey of this eucalypt generally had developed a longer butt log and had better form than the <u>A. melanoxylon</u> grown in the open.



these and a score of 4 for the best formed of these. The score of 5 was to be avoided if at all possible and was actually only resorted to on two or three obviously intermediate trees.

GTI will eventually make a thorough analysis of this experiment. In the meantime a few general comments will be made.

The most time consuming trait to measure was height of the butt log (about 5 seconds on average per tree).

Form, score and height of the butt log were highly related to the presence or absence of an *E. nitens* nurse crop. The estimated impact of the nurse crop on these parameters is shown in Table 5.

TABLE 5: Estimated impact of nurse (*E. nitens* trees) on the form, straightness and butt log length of *Acacia melanoxylon* (Note: More precise estimates of these effects will be available following full analysis of the data)

	In the open	In the understorey of *E. nitens*
Average form	3	7
Average straightness	6	7
Average butt log length (m)	3.5	5

The fact that *E. nitens* as a nurse crop has a marked favourable impact on form and butt log length of *Acacia melanoxylon* seems quite clear. Reasons for this impact are unclear. One possibility may be related to the fact that the tips of exposed acacia branches and leaves seemed to be heavily singed, much more so than branches and leaves of these acacias growing under the *E. nitens*. Perhaps this is caused by their greater exposure to wind, sunshine or cold, as would be encountered in open-grown conditions. It might also be due to a higher incidence of feeding by psyllids. Here it should be noted that no adult psyllids were observed, perhaps because of the season, but their small dark egg masses (collectively about the size of a pinhead), were found abundantly on the leaves of many families of acacia (but not all) growing out in the open.

It may turn out that there are genetic differences that have an influence on form and butt log length, but at present there is nothing intuitive to run on (a computer will have to crunch the numbers) and certainly the impact of genetic-caused variation in growth and form pales beside the impact that the *E. nitens* nurse crop has had at this site.

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Early Response of *Eucalyptus grandis* to Intensive Silviculture on Marginal Land at Ifafa

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ABSTRACT

Plantation forestry in Spain and Portugal makes use of deep-contour tillage techniques to improve the marginal sites allocated to plantations. Contour tillage, including bench terracing and deep ripping, has resulted in the successful establishment of large commercial plantations of *Eucalyptus globulus* on sites with steep slopes, shallow soils and rainfall as low as 600 mm per annum.

The first commercial application of deep-contour tillage for forestry on steep slopes in South Africa was implemented in July 1988 by N.T.E. at Ifafa along the Natal South Coast.

These tillage techniques, including important local adaptations, have resulted in rapid early growth and even stands of *Eucalyptus grandis* on the marginal sites at Ifafa.

KEYWORDS: Site-specific silviculture, bench-terracing, deep ripping, buffer, actual evapotranspiration, growth rate, conservation

THE IFAFA SITE

Location and Site Details

Location:	Latitude 30°26', longitude 30°36' (Natal Coast, RSA)
Plantation area:	1100 ha
Altitude:	120 m
Climate:	Warm and humid. Summers are hot and winters mild and frost free.
Rainfall:	950 mm (high intensity storms—predominantly summer rainfall)
Temperature:	Mean maximum 25.0 °C, mean minimum 14.1 °C
Soils:	Shallow, 0.45–0.55 m effective rooting depth. Dominant soil form Glenrosa—sandy loam, 15–30% clay in the A Horizon over lithocutanic B.
Topography:	Rolling topography, 30–40% slopes common.

Although the climate would seem well suited to *E. grandis*, the shallow soils and steep slopes reduce the effectiveness of the rainfall and explain why commercial forestry had not previously been successful in this area which is only 35 km from a major pulp mill (Table 1).

TABLE 1 – Some important comparisons of Ifafa (RSA) and Abrantes (Portugal)

	Ifafa	Abrantes
Mean monthly temperature	19.6°C	15.7°C
Mean annual precipitation (MAP)	942 mm	669 mm
	Summer	Winter
Actual evapotranspiration (AET)	940*/760**	451*
Wind run	172 km/day	(unavailable)

* Actual evapotranspiration according to C.W. Thorthwrite and J.R. Mather, 1957 (calculations by A.P. Schonau, 1988).

** Actual evapotranspiration according to Agricultural Catchment Research Unit (ACRU) model.

Daily rainfall records over a 51 year period were used in the Agricultural Catchment Research Unit (ACRU) model (Schulze, 1988) to simulate the actual evapotranspiration (AET) and to predict the changes in AET as a result of using deep-contour tillage rather than conventional tillage.

Actual evapotranspiration may be taken as a good index of growth as it reflects the plant's water "consumption", mainly through the transpiration process.

For conventional tillage it was assumed ploughing and ripping would be done to a depth of 0.5 m. The deep-contour tillage was assumed to be ripping to a depth of

From: M.I. Menzies, G.E. Parrott and L.J. Whitehouse (Eds). Efficiency of Stand Establishment Operations. Proceedings of a IUFRO Symposium held at the Forest Research Institute, Rotorua, New Zealand, 11-15 Sept. 1989.

1.2 m, using a three-tyne ripper with tynes spaced 1 metre apart (Table 2).

TABLE 2 – Comparison of actual evapotranspiration (AET) using the ACRU model

	Deep contour rip 1.2 m x 3 tyne	Conventional till 0.5 m
Actual evapotranspiration Clay soil	766 mm	699 mm
Actual evapotranspiration Sandy soil	758 mm	685 mm

The ACRU model indicated that 10–11% gains in AET were possible if deep tillage replaced conventional tillage. The ACRU model also showed that there were frequent 4–5 month periods when the soil moisture content of both the A and B soil horizons were at permanent wilting point.

The increase in AET as a result of deep ripping was viewed not only as increased growth potential but as an important buffer against the periodic droughts.

The ACRU model did not cater for the effect of bench terracing in addition to deep contour ripping and it was assumed that if deep- contour ripping could result in a 10-11% increase in AET then the vast water- holding potential of bench terraces would enhance the AET by at least a further 10%. Therefore, the combination of bench terraces and deep ripping was expected to result in a 20% increase of AET when compared with conventional tillage. The figures predicted are set out in Table 3 and will be re-examined after the discussion on growth.

TABLE 3 – Comparison of AET for various tillage techniques at Ifafa

	ACRU model prediction		Assumption
	Conventional tillage to 0.5 m depth	Deep contour ripping 1.2 m	Bench terrace rip to 1.2 m depth
AET (growth potential)	699 mm Base value	766 mm 10% AET increase	840 mm 20% AET increase

Site Specific Silviculture: Techniques and Procedures

With the exception of a few riverine forest strips, the entire 1100 hectare farm was planted in sugar cane at the time of purchase.

(i) Soil survey

A complete soil survey was carried out, using a 150-m grid. In addition to being described by soil profiles, the soils were grouped into site- capability classes which closely resemble pedogenetically similar soils. The dominant soil form was Glenrosa* as described in the book "Soil Classification, a Binomial System for South Africa" (MacVicar *et al.*, 1977). Mispah and Mayo forms were also evident.

(ii) Selection of species

The company policy was to retain 20% of the area under sugar cane and convert the remaining area to *E. grandis*. All natural forests were to be protected and riparian zones cleared of cane and returned to natural vegetation.

It was decided to retain cane on the sandier more permeable grey soils where the effects of the periodic droughts are most serious.

The choice of *E. grandis* as a forest crop was based on the climatic requirements for the species as described by Schonau and Schulze (1984), i.e., a minimum mean annual precipitation of 900 mm, mean annual temperature greater than 16 °C, with a mean July temperature greater than11 °C. These requirements were adequately met at Ifafa.

Eucalyptus grandis requires a minimum soil depth of 0.6 m, and acheives optimum growth only on deeper well-drained dystrophic soils. Soils at Ifafa met neither of these requirements and required correction through tillage.

(iii) Land preparation

Initially, where slopes allowed, it was decided to contour rip, using a three-tyne ripper, with each tyne 1.2 m in depth, and spaced at 1-m intervals (as in Spain and Portugal). Bench terraces were expected to be used only on the steeper slopes where machines could not pull a ripper on contour unless a terrace platform had been constructed.

The large Caterpillar D8 and D9 machines used in Spain and Portugal proved unsuitable for Ifafa owing to their excessive weight (>42 tons) and lack of manoeuvrability on the highly rolling terrain.

The Caterpillar D7H was the smallest machine (26 tons) which could accommodate a 1.2 m ripper shank. However, pulling three ripper shanks to a depth of 1.2 m required all the machine power on the level area, and was inadequate for the slopes. Through trial and error, a successful shank combination was devised which provided adequate tilth while maintaining the critical depth of 1.2 m.

The three-shank frame on the D7H was utilised, with the two outer shanks remaining at the standard 0.9-m depth.

* Glenrosa (F.O.A. correlation Lithosol. USDA correlation Inseptisols).

The middle shank was fitted with a 1.2-m shank and the standard ripping tip was replaced with a 0.3- m wide "ducks foot" tip made up by welding three standard tips together. The tilth and shattering effect of the modified ripper far exceeded the disturbance of a standard ripper and provided not only adequate rooting depth to 1.2 m but an adequate planting tilth. Profile pits showed that the standard ripper tended to leave three grooves, whereas the modified ripper shattered soil virtually throughout the 1.2- m depth.

Ripping only on contour was rapidly replaced by the full treatment of bench terracing and contour ripping because:

- The level terrace showed great resilience against storms and an impressive water holding capacity. On properly constructed terraces which had been ripped after terracing, there was no visual evidence of surface runoff after a 100-mm storm.
- Ripping on the terrace platform with a three-shank ripper, as described above, was well within the machine capability whereas the D7H struggled to pull a three-tyne ripper on slopes greater than 20%.
- Planting and weed control operations were infinitely easier on a flat platform.
- The quality of local management, coupled with the skill of the D7 operator, resulted in high productivity levels compared with Spain and Portugal and therefore a relatively low-cost operation.

Each terrace was surveyed and marked on the level contour at an approximate 4.5 metre espacement. Conducting a survey of each terrace was of paramount importance and prevented the bulldozer from taking a wrong line and compounding the error down the slope.

The terraces were constructed in such a manner than the terrace platforms were wide enough to accommodate the bulldozer (2.5-3.0 metres wide) and all terrace platforms sloped into the hill. This inward slope gave a minimum of 300 mm freeboard and 0.5 m^2 of surface storage space.

Trials conducted with the aid of the Department of Agriculture to compare terraces constructed on the level contour with terraces constructed with a 1:200 fall, proved that gradients allowed rain water to accumulate and run, causing erosion and over topping where this passage or water was blocked by minor soil slips or silt. Continued maintenance would be required to ensure the free flow of water along graded terraces.

The level terraces allowed water to accumulate in the freeboard storage area and to seep through the profile.

The number of machine passes required to construct and rip a terrace depended on the slope. This varied from one pass to cut and one pass to rip on gentle slopes, to five passes of the machine to cut a terrace platform on a 40% slope. The performance table (Table 4) was drawn up by the N.T.E. Workstudy Department.

The terracing and ripping produced an adequate planting tilth and no further land preparation was required. The average site-preparation time for the 250 ha completed at Ifafa was 6.5 hours per hectare. This commercial average included machine time for closing in existing roads and machine time for the removal of the old cane crop. The cost of this operation exceeded the cost of conventional tillage by only R350–R400/ha.

TABLE 4 – Output levels for D7H terracing and ripping

Method		Slope
No terracing required		0–12%
Single pass with blade per terrace		12–26%
Up to 5 passes with blade per terrace		26–40%
Per contour		
Terrace 1 pass 12–26% slope	Terrace 5 pass 27–40% slope	Output hectares/9- hour shift
Nil	Nil	7.03 (ripping only)
100%	–	3.83
80%	20%	3.25
60%	40%	2.83
40%	60%	2.50
20%	80%	2.24
–	100%	2.03

NTE Work Study Dept.

Note: On a site where 60% of the time only one pass with the blade is required to construct a terrace and 40% of the time up to 5 passes with the blade are required, an output of 2.8 ha per 9-hour shift will be achieved. Considering that terracing is a once-off operation, this additional cost to permanently shape land into a markedly more productive form in terms of water management is very worthwhile.

(iv) Establishment

The average distance between terraces worked out at 4.2-4.5 metres and the seedlings were planted at 1.5- m intervals along the terrace, just inside the outer rip lane. The population of 1480–1580 stems/ha was close enough to the ideal population of 1600 stems/ha.

The trees were fertilised at planting with 100 g of 3-1-4 (40) + 0.5% Zn placed in a circle 25 cm from the base of the seedling. Selective additional applications to counter leaching were applied to trees less than 0.5 m in height after storms exceeding 140 mm.

The soils had a low phosphorus fixation capacity with a Phosphorus Desorption Index (PDI) in excess of 0.4. The low phosphorus fixation and the continuous use of fertiliser blends, such as 5-1-5, on the sugar cane over the past decades, resulted in reasonably high levels of available P in the soil. Nitrogen and potassium levels are inherently low on these soils. The 3-1-4 was therefore a better plant mixture than the ammoniated supers in standard use.

(v) Pest control

Termites were a problem at Ifafa and the application of chlordane at planting was essential.

(vi) Weed control

It is company policy to ensure that *Eucalyptus* plantings are kept free of weeds for the first year.

At Ifafa, the terrace platform was kept free of weeds through a combination of hand-hoeing the tree line and spraying the remainder with glyphosate or paraquat, depending on the weed spectrum.

Initially, the slopes of the terrace were slashed to clear weeds as a conservation measure, but the preferred treatment now is to allow the weeds to reach calf height and then to spray the area with glyphosate at 3 *l*/ha before planting. Strips of sugar cane, predominantly on the terrace slopes, were sprayed twice to ensure that the minimum of 6 *l*/ha required to kill sugar cane was applied.

Use of cones to protect the seedlings during spraying operations plus using enclosed inter-row sprayers, such as wrickshas and windboxes, is now common practice.

(vii) Maintenance

Properly constructed terraces require little maintenance. However, during commercial operations, the levels and inward slopes are not always perfectly formed. Cross- berms to maximise freeboard must be constructed at 10-m intervals along the terrace platforms whenever runoff tends to move along the terrace line due to construction errors or topographic changes.

The use of mules drawing mouldboard ploughs has proved very successful in maintaining adequate freeboard where levels and slopes were not sufficiently accurate.

(viii) Conservation

The visual impact of terracing attracted concerned conservationists from all over the country and the company operation at Ifafa was monitored closely by the conservation committee. Many conservationists predicted a disaster and large-scale wash-aways in this storm-prone area.

The conservation pressures encouraged the local management to perform their task with an even greater degree of excellence and some important features were introduced as a result. Whereas previously terracing and ripping continued through natural depressions or waterways, the conservationists ensured that the natural depressions (4-7 metres in width) were left undisturbed. These natural depressions carried off excess storm water and reduced erosion considerably.

The conservationists also ensured that water discharged from roads was properly catered for and, where minor erosion occurred on a terrace, that these eroded sites were repaired to ensure adequate freeboard at all times (0.5 m^2).

The company policy of preserving all natural forests and the refurbishing of sensitive riparian zones was appreciated by the conservation committees.

In spite of two exceptionally heavy storms of 145 mm in 36 hours and 197 mm in 18 hours accompanied by gale force winds (wind run of 524 km), the conservation pressures were such that the terraces were subjected to simulated rainstorms under the supervision of the Deparment of Agriculture.

Four tests were carried out, varying from 175 mm and 285 mm of water applied over two consecutive days, to 270 mm applied over 6 hours. The trials were designed to apply as much water as the heaviest storms on record. These were in the region of 250–300 mm over a 24 hour period. The result was that no overtopping of any bench terrace occurred and no terraces were damaged in the trials.

TABLE 5 – Particulars of water applied to each site

Site no.	Averaged wetted area (m^2)	Depth of application (mm)	Intensity of application (mm/ha)
1	180	550	58
2	140	280	57
3	180	260	48
4	200	370	41

Details extracted from Department of Agriculture Report dated September 1989.

It is expected that, with continuing growth of the eucalypts, the surface storage will increase, because of increased canopy interception and associated reduction of rainfall kinetic energy. Furthermore, plantation litter will improve ground cover, and root colonisation of the benches will strengthen and stabilise the cut/fill slopes.

(ix) Growth

Measurements of the first commercial plantings showed a height growth of 6.2 m at 12 months of age. Rainfall during this period was 920 mm (Table 6). The growth rate equates at this stage to that under the best growing conditions in the RSA, namely the coastal Zululand area, where very deep soils, 1200 mm of rainfall, and an ideal climate result in *E. grandis* measuring 160 m^3 at 3 years, and mean annual increments of 45–50 m^3 are common.

The growth rate at Ifafa will largely depend on the effectiveness of rainfall retention, as each storm fully recharges the profile. Normally, under South African conditions, *E. grandis* will fully utilise the site at 4 years of age and make maximum demands on the available water thereafter. Provided the 950-mm average rainfall at Ifafa is maintained, the growth is likely to be good and certainly a lot better than the target set for the purchase of Ifafa, i.e., 114 tons at 8 years (160 m^3/ha or MAI of 20 m^3/ha/annum).

The very rapid early growth at Ifafa is likely to level off after 4 years, when maximum demands will be made on available water, and during drought periods the felling age could be as low as 6 years. The actual yields at Ifafa will be keenly awaited.

The remarkable initial early growth rate at Ifafa tends to support the AET of 940 mm predicted by the Thorthwrite and Mather model rather than the AET of 760 mm predicted by ACRU. When the ACRU model is calibrated to include the massive water-holding capacity of bench terraces we believe that the AET prediction for Ifafa will increase substantially from 760 mm to somewhere around the 850 mm mark. This, however, is a mere assumption at this stage and cannot be verified until growth measurements are taken at 4 years.

DISCUSSION

The introduction of bench terracing, deep ripping, and site specific silviculture to the humid summer rainfall area of the Natal South Coast has resulted in remarkable initial growth of *E. grandis* on these marginal tree sites.

The permanent improvement to the site as a result of bench terracing and deep ripping is expected to increase actual evapotranspiration by at least 20%, with most of this change resulting from increased growth.

A model used to predict changes in AET as a result of tillage operations served as a practical management tool.

Water management is of paramount importance at Ifafa where high temperature, shallow soils, periodic droughts and high-intensity storms are the norm. The vastly improved water retention of the site has markedly increased the effectiveness of the rainfall and established a buffer against the periodic droughts.

The marked climatic differences between Portugal and Ifafa were of major concern to local conservationists, who expected the bench terraces to collapse under the high intensity storms in the area. The stability of the terraces on a wide range of soils containing a lithocutanic B horizon, at Ifafa, was however confirmed during two severe storms and simulated rainfall tests. The technique is site specific and the careful matching of soils and geology is essential to avoid material such as mudstone where the possibility of rotational slip and mass movement is very high.

The benefits of the intensive silviculture at Ifafa are obvious, but it must be emphasised that the success of Ifafa is largely due to the skill and competence of the local manager and his operators.

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TABLE 6 – Rainfall records for period July 1988 to June 1989

Total rainfall for season = 920 mm											
Month	J	A	S	O	N	D	J	F	M	A	MJ
Rainfall (mm)	17	88	41	49	52	129	36	290	8	199	110
Storm element								145		197	

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DISCUSSION

Wilcox – You have achieved a yield of 160 m^3 in 3 years. Have you done a financial cost benefit analysis?

Gardiner– A yield of 140 tonnes at 10 years was required to cover costs; therefore as growth rates are abovepredictions it will be profitable. The pulp mill is only 35 km away.

Young – How do you intend to harvest?

Gardiner – With a sky line hauler.

Young – Have you roaded?

Gardiner –Yes, minimal roads are required for a skyline system— at the ridge top and bottom of valleys.

Page – You used three-tine ripping with two outboard tines trailing. We found that if the outboard tines preceded the ripper then less horse power was required.

Gardiner – We used a Portuguese design in which the outboard tines were in a straight line, which didn't work on the slope. Our consultant has recommended that preceding outboard tines be tried.

Nelson– You didn't use wings on the ripper?

Gardiner – With the ducks foot design it was not required on that site.

Sheik Ali Abod – In Malaysia high growth rates are achieved with *Acacia mangium.* We are concerned about low wood density—are you concerned about this factor?

Gardiner– *Eucalyptus grandis* produces lower-density timber which is required for pulp and mining timber. The furniture manufacturers like it because they buy by weight and sell by volume. If fuel wood was being grown, it could be a problem. We wouldn't harvest at less than 6 years in any case.