and to a lesser extent from coastal Oregon, produced trees of superior growth to seed in current use, including the seed origin of the selected plus trees.

This assessment demonstrated the superiority in New Zealand of Douglas fir provenances from the coastal "fog-belt" of the western USA, so called because fog blankets the coast up to 16 km inland in summer, contributing summer moisture not normally available in a continental climate. There was also a trend for higher growth rate from seedlots originating in the southern end of the range in California, even at trial locations at the south of the South Island.

Interest in planting Douglas fir appeared to be waning at this time, partly due to uncertainty over the effect of the needlecast, and partly due to an awareness of the better cashflow generated by the shorter rotation length of radiata pine.

Extensive damage caused to radiata pine stands by cyclones such as BERNIE (1983) and BOLA (1987) caused a rethink of the role of Douglas fir. Stands of Douglas fir suffered broken branches, but weathered storms without blowdown or stem breakage. An equally important advantage of the species is its capacity to withstand heavy snowfalls, especially in the South Island at higher elevations, which usually cause blowdown and breakage of radiata pine.

In 1988 PROSEED (the NZ tree seed company) funded the selection of plus trees from the best coastal fog-belt provenances in the Douglas fir provenance tests. By this time the tests had been thinned (in 1976) to leave approximately 30 trees from the original 144 per plot. All trees in the best provenances were measured over six sites, then the best tree per plot was selected. Some mortality problems, and an earlier thinning trial complicated the measurements, summarised in the table.

The selected trees were grafted into a seed orchard in Canterbury over the next three years. PROSEED and the Forest Research Institute also funded a seed collection from southern coastal California, with the primary objective of widening the genetic base to include previously untried provenances.

South Island foresters became increasingly interested in the possibilities of Douglas fir, especially in the MacKenzie basin and increased their research efforts with the species. In 1992, a North American Douglas fir stand management cooperative became interested in gaining access to New Zealand data on Douglas fir plantation management. This became an opportunity to create a New Zealand Douglas fir cooperative, coordinating research on all possible areas of interest.

A Douglas fir cooperative was formed in February 1993, with strong support from industry for research projects covering a wide spectrum of research fields, and it is also linked to a North American stand management cooperative. The North American cooperative is funding a substantial amount of work in forest management which will result in the production of a Douglas fir version of STANDPAK.

A project of the New Zealand Douglas fir cooperative is the collection of seed from 200+ Douglas fir trees in the southern fog-belt zone. Cone collection is completed, and extraction of the seed is underway.

Other cooperative projects in progress are drying and machining clear timber, nutritional work, herbicide work, thinning and pruning trials, seed orchard research, and the formulation of a breeding strategy.

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Rangeland tree establishment – machine planting and direct seeding

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The South Island high country covers between one-quarter and one-third (depending on one's definition) of the island. It contains a high percentage of readily accessible land, flat with a light vegetation cover, much of which can be easily traversed in 4WD vehicles. When faced with the prospect of having to establish large quantities of trees on such a vast area of relatively flat land, thoughts often turn to easier and potentially cheaper establishment techniques than hand planting. Two possibilities are machine planting and direct seeding, both of which have been tested in the high country.

Machine planting

There are large areas of the high country ideally suited to machine planting and the method has many advantages. Costs are cheaper at around 15 cents/tree, compared to 25-45 cents/tree (depending on terrain) for hand planting (Belton, 1991). Planting rates are higher at around 600-1000 trees/hour for two people compared to 100-200/hour for two hand planters, and the quality can be consistent and generally good. The New Zealand Forest Research Institute Ltd (NZFRI) has investigated the comparative survival and growth of trees planted in the high country by machine and conventionally by hand in ripped and unripped ground. Differences were insignificant except on one site at Ribbonwood Station where machine-planted Douglas fir averaged 1.9 m in height at year four compared to 1.7 m for hand-planted in ripped ground and 1.6 m for hand-planted into unripped ground (Baker and Ledgard, 1991).

However, probably the greatest advantage as far as a high-country farmer is concerned is the ease with which machine planting can be slotted into a busy spring schedule. The operation takes considerably less time and effort than hand planting and there is no need to organise large labour gangs and the accommodation and food that goes with them. All that is needed is a tractor (which most farmers have) plus driver, a planting machine and an operator. With such a set-up 5-10 ha can be planted daily. Machine planting is

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not difficult but it does require some experience to be properly carried out. Machines are consistent in their planting quality but if the operators are inexperienced then the quality is likely to be consistently bad and poor tree survival and growth will result.

The best known machine in the high country was developed by John and Colin Mackay of Montana and Ribbonwood Stations respectively. This machine has operated in the upper Waitaki for the last 15 years and would have been responsible for planting well over one million trees. In 1993 NZFRI used the Mackay machine over four days to successfully plant over 40,000 trees in dryland trials on Balmoral Station near Lake Tekapo. The Waikato Catchment Commission operated another machine in the 1980s before selling it to a Marlborough buyer. A third machine, a modified Lotus tree planter belonging to the Selwyn Plantation Board, has been used very successfully in the upper Rakaia River.

Machine planting Corsican pine with the Mackay tree planter in dryland MacKenzie Basin. Using a machine on such sites, three people can comfortably plant 8000 trees in one day.

Direct seeding

When there are large areas to plant with considerable costs involved, the option of bypassing the expensive seedling nursery stage and sowing the seed directly on the planting site is often considered. The main attraction is the reduction in establishment costs. These will depend to a large extent on the price of seed, but with high-country species, costs are typically between 20% and 50% of comparable planting costs (Belton, 1991).

Historically, those who have tried to establish plantation forests by seeding techniques have not persisted for more than a few years. The main reason is wide variability in establishment success. Results have varied from very poor, with virtually no trees resulting, to so good that intensive thinning would be required to produce a commercial crop. Variability is mainly due to browsing by animals, birds and insects, lack of infecting mycorrhizal fungi, competition from other vegetation, drought and frost heave. It is precisely these factors that nurserymen strive to control within their nurseries in order to achieve consistent production of quality seedlings.

Direct seeding could be the cheapest tree establishment technique in the high country, but has yet to achieve consistently good results. This experimental rig was used in the 1993 seeding trials on Balmoral Station in the MacKenzie basin.

NZFRI has looked at seeding (Ledgard, 1978) and direct drilling (Davis 1989) of tree seed for a number of years. Davis had good success using a conventional agricultural triple disc direct drill to establish pine species in unimproved short tussock grassland, but in improved grassland, competition from the resident vegetation inhibited establishment unless a herbicide was applied. In later trials germination was again reasonable, but many seedlings never progressed beyond a small, yellow chlorotic stage and eventually died. This is thought to be because of lack of mycorrhizal infection. The earlier trials were probably more successful because they were adjacent to established trees from which accidental mycorrhizal infection would have occurred.

New drilling technology which is capable of cultivating the seeding spot, removing competitive vegetation and precisely placing seed and possibly fertilisers, could enhance the chances of better seed strike in the field. When this is combined with improved means of reducing losses to birds and insects and a better understanding of mycorrhizal inoculation, it should be possible to minimise the variability currently found in direct seeding operations. NZFRI has trials underway exploring these options.

Conclusion

Although small areas of the high country are suited to intensive management (e.g., irrigation), low population and large property size favour extensive rather than intensive land-use systems. Forestry lends itself to such a system, particularly if 'plant and leave' regimes are employed. Establishment could become the major

cost and hence the main determinant of financial viability. Machine planting and direct seeding are two obvious means of reducing establishment costs. At the moment machine planting looks more attractive, due to its greater reliability, but if research can reduce the inconsistency usually experienced in seeding operations then the lower costs of direct seeding could well make this the most attractive forest establishment technique.

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Management of Eucalypts Cooperative

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In 1986 the formation of the Management of Eucalypts Cooperative brought together the main eucalypt growers of New Zealand, the NZ Forest Research Institute (NZFRI) and one overseas member, the Forestry Commission of Tasmania. The original objectives of the cooperative were to investigate the growth and yield of selected eucalypt species over as wide a geographical range and as wide a range of silvicultural regimes as practicable, and to develop eucalypt growth and yield models. In 1990 the objectives were modified to include "eucalypt growth and yield response to site, establishment and silvicultural practices".

The cooperative research programme has, over the last seven years, made a significant contribution to the research database for analysing eucalypt silviculture. The database is derived from the measurement of existing NZFRI trials and permanent sample plots from members' stands throughout the country. In 1986 NZFRI researchers were measuring approximately 100 eucalypt growth plots, mostly from regime trials and elder spacing trials in the central North Island, established in the late 1970s. Now the cooperative has approximately 550 plots spread throughout the country. Figure 1 provides a breakdown of these by species.

Although the trials were initially based around traditional "ash" group eucalypts (*Eucalyptus regnans, E. fastigata* and *E. delegatensis*) and *E. saligna*, recent emphasis has been on *E. nitens*. Until recently this species was not widely planted in New Zealand because of severe Tortoise Beetle (*Paropsis charybdis*) defoliation, particularly in the North Island. Since the successful biological control of this insect by *Enoggera nassaui, E. nitens* has been established in plantations for fibre. The establishment of seven *E. nitens* regime trials from Whangarei to Invercargill from 1990 to 1992 will be a valuable source of data for future analysis of growth and yield.

The main thrust of the research programme has been in data gathering to develop a broader data base than previously existed. More than half of the total plots in the programme are measured annually to give a consistent and detailed data series for growth model construction. The remaining plots are usually measured on a cyclic programme every second, third or fourth year. Once gathered, all measurements are processed through the NZFRI Permanent Sample Plot system where the data are checked against previous measurements for any discrepancies or errors and then, after any necessary corrections, plots are summarised into a form suitable for analysis in growth modelling and other research uses. In addition to plot measurement, detailed sectional measurements of trees have been undertaken for the development of yield and taper equations for individual species. Volume tables and compatible taper equations have been developed for *E. nitens,* and *E. saligna* by the Cooperative; *E. fastigata* and *E. regnans* also have volume tables available.

Currently cooperative members have the use of two growth models, one a central North Island *E. regnans* model, and recently a national *E. saligna* model. While neither of these has the sophistication of recent radiata pine models, they represent a major advance, enabling forest managers to better predict future yields for plantations of these species.

Although the research project on siting commenced only in 1992, it has already provided exciting results. Preliminary analysis of site data collected near Toko-

MANAGEMENT OF EUCALYPTS COOPERATIVE PLOT DISTRIBUTION BY SPECIES

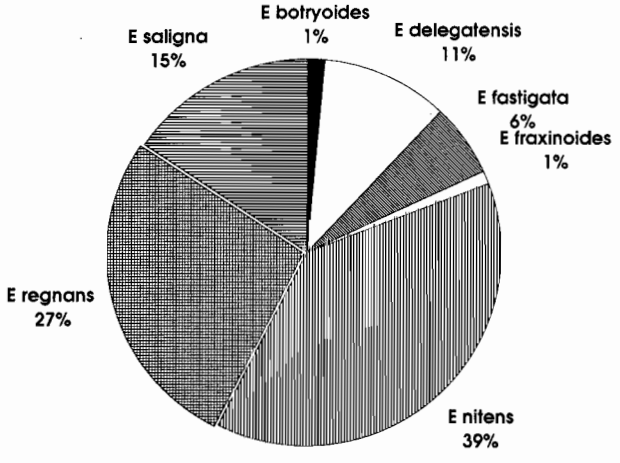

Figure 1

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