NOTES ON THE SILVICULTURE OF MAJOR N.S.W. FOREST TYPES

9. ALPINE ASH TYPES

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9. ALPINE ASH TYPES

1. INTRODUCTION

The Alpine Ash forest types are the most restricted and least extensive of all the major forest communities occurring naturally in N.S.W. The types, whose occurrence is identical with that of Alpine Ash[1], the tree, are limited in N.S.W. to parts of the Southern Highlands at elevations over about 900m, in an area where most of the stands are included within National Park; areas where the Forestry Commission has management responsibilities appear to total less than 20 000 ha.

At the same time the types are among the most productive of all native forest communities in N.S.W., they are highly amenable to management, they have been the object of considerable research, and they provide a valuable timber product, coming largely from one of the State's oldest continuously managed forest areas (which in turn shows a healthy surplus in its annual operations). Though restricted in N.S.W., the types are widely distributed in Victoria and Tasmania, and Alpine Ash itself is one of Australia's main commercial timbers. Together, these factors provide the justification for compiling a separate series of these Notes for the Alpine Ash types.

2. FOREST BOTANY AND ECOLOGY

2 .1 Taxonomy

Alpine Ash was originally known as *Eucalyptus gigantea*, a name bestowed by Sir Joseph Hooker in 1847, but referring to composite material including *E. obligua*. This name was in any case already preoccupied, having been used in 1832 to describe Tasmanian Blue Gum, which had previously (and validly) been named globulus in 1799. Because of this *E. gigantea* is an invalid name, and the much later name of *E. delegatensis*, given by R.T. Baker in 1900 and referring to a specimen collected near Delegate, close to the N.S.W.-Victorian border, is the correct name for Alpine Ash (Cameron, 1946; Boland, 1985).

Pryor and Johnson (1971) include *E. delegatensis* in the series Obliquae (MAK) of the subgenus Monocalyptus: the series Obliquae includes the Ash group of eucalypts, along with the Snow Gums and certain mallee eucalypts. *E. delegatensis* has been placed as the only species in the subseries Delegatensinae, and has been coded as MARBE.

Alpine Ash is a half-barked tree giving at times strong visual resemblance to Blackbutt. (In parts of Tasmania Alpine Ash is fully rough-barked). The leaves on young plants are distinctly bluish-coloured, while Boland et al. (1984) observes: *"over its whole range Alpine Ash produces characteristically striking red senescent leaves in the young canopy."*

Provenance trials in Alpine Ash (see section 2.4.1), and the concomitant botanical collections, have highlighted phenotypic differences between mainland and Tasmanian sources of the tree: in stem and leaf colour, in growth and in leaf sizes. These have led to the recent description of two subspecies of Alpine Ash, the mainland ssp. *delegatensis* (MAKBEA) and the Tasmanian ssp. *tasmaniensis* (MAKBEB) (Boland, 1985). Boland keys these subspecies apart on seedling characters:

1. Stems of seedlings glabrous; seedling leaves broad lanceolate: *ssp. delegatensis*

1X. Stems of seedlings prominently verrucose; seedling leaves orbicular with a prominent short drip-tip: *ssp. tasmaniensis*

[1] For botanical names of species mentioned in text, see Appendix 1. See also section 2.1.

2.2 Forest Types

The types being considered in these Notes are those making up the Alpine Ash league as described by the Forestry Commission of N.S.W. (1965):

> *"This is a small league confined to the Southern Tablelands on moist, favoured sites at altitudes between about 1 000 and 1 500m. The league is dominated by Alpine Ash, alone or in association with other species, forming a wet sclerophyll forest up to about 55m in height. The understorey usually consists of a low shrubby layer, but Narrowleaved Peppermint may often form a second tree storey. The league is valuable for the production of commercial timber.*
>
> *At higher altitudes this league gives way to the Snow Gum league, and at lower altitudes it passes into the Messmate-Brown Barrel league. It is most widely developed on the western parts of the Tablelands.*
>
> *Two types only are recognised in the league:*
>
> ***147. Alpine Ash.*** *The Ash forms a clear dominant, but may be associated with scattered stems of Manna, Mountain and Mountain Grey Gums, with Narrowleaved Peppermint frequently forming a subordinate tree layer. Usually occurs in sheltered sites, sometimes with an understorey of Tree Ferns, forming wet sclerophyll forest commonly over 45m in height.*
>
> ***148. Alpine Ash - Mountain/ Manna Gum.*** *The Ash is associated with Mountain Gum, or less commonly with Manna Gum, as dominants. Other associated species may include Narrowleaved Peppermint, Snow Gum and Mountain Grey Gum. Similar to the preceding type, though usually found on somewhat less favoured sites. However when Manna Gum is the associate the type may occupy the best gully sites in stands up to 55m in height. In some cases this type may be only a variant of previous one, reflecting chance regeneration patterns, probably usually as a result of different fire regimes."*

Stands of the Alpine Ash types are usually clearly defined, and ecotones with adjacent communities are normally narrow.

The Alpine Ash types in N.S.W. have the rare distinction of almost entirely lying within areas that have been the subjects of fairly intensive ecological study. Pryor (1938) dealt with stands lying within the A.C.T.: Costin (1954) covered the Monaro district, taking in the Snowy and Upper Murrumbidgee catchments; Newman (1955) studied the Tumut Catchment upstream from the site of Blowering Dam; and Morland (1958) reported on the Hume Catchment Area. Together these papers encompass the entire range of Alpine Ash communities within N.S.W., except for some stands lying west of the A.C.T. and outside the area of Newman's work: these excluded stands include those in Buccleuch S.F. and adjacent areas of Kosciuszko National Park, and have been partly covered by Forestry Commission resources surveys (Allen, l961a and b). Pryor (recording an Ash and Ash-Mountain Gum association), Newman (both pure Ash and Ash-Mountain Gum associations) and Morland (essentially pure Ash) all distinguished communities that relate directly to those used by the Forestry Commission; Costin recognised pure Ash, Ash-Mountain Gum, Ash-Manna Gum and Ash-Narrowleaved Peppermint associations (which again fit comfortably into the Commission's types), but also included stands excluding Alpine Ash, but dominated by Mountain Gum and sometimes by Snow Gum, in his Alpine Ash-Mountain Gum alliance: his map in consequence tends to exaggerate the area of Ash-dominated communities, though it still effectively portrays their general occurrence.

The stands typically contain the dominant tree storey, sometimes with a lower tree storey of Narrowleaved Peppermint or, at higher altitudes, Snow Gum, and then usually a relatively low, though sometimes moderately dense, shrub layer, often with Hop Bitter-Pea (Hop Bush) as a major component. Snow Grass is frequently present and may dominate the undergrowth in some sites. Wattles can be present, probably usually as a result of fire, and Blackwood may occur in the more sheltered valleys, with Teatrees forming dense thickets along some watercourses.

2.3 Environment

The most comprehensive discussion of the environment of the Alpine Ash types is given by Costin (1954), though as indicated above the communities recognised by Costin are rather broader in concept than the Ash types being considered here.

Climatic data for several stations in or close to Ash stands are presented in Appendix 2. Pilot Hill is located at the edge of productive stands on Bago S.F., and Laurel Hill is close to the westernmost occurrence of the Ash types. Major features of the climate include:

- Relatively high annual rainfall, probably in all cases exceeding 1 100mm a year.
- Rainfall distribution showing a maximum during the winter and early spring and a corresponding fall in the summer and early autumn, though without a pronounced summer drought.
- Several moderate to heavy snow falls each winter with the snow persisting for some weeks or even months at a time. Alpine Ash seed requires cold, moist conditions to remove its natural dormancy and to promote subsequent germination (see Section 6.3), and these winter climatic conditions may well be the factor determining the lower altitudinal limits of the tree.
- Frequent frosts which may occur at most times of the year except for mid-summer.
- Relatively cool temperatures, but with the mean monthly temperatures exceeding 0^0C for all months.

The consistently cold, wet winters create problems for timber harvesting, and bush logging operations typically cease in the Ash types during the winter months, with the mills operating on a stockpile of logs built up during the warmer and drier months.

The Ash types can occur on a range of soils and soil parent materials. Both Costin and Morland observe that soils from all local rocks appear suitable for the development of these types, and Costin records the types as occurring on transitional alpine humus soils (though probably rarely), brown podsolics, iron podsols, red loams and lithosols. The soils however are usually well drained and relatively deep: *"even in areas where there are large granite outcrops there is a good depth of soil close to the outcrops"* (Forestry Commission of NSW, 1980). Newman noted that on Bago S.F. *"a change from the light-textured granitic podsolised soils to the heavier basalt or basalt-influenced soils tends to favour a change"* to the Ash types, but that other influences such as aspect are of greater importance, while Lindsay (1939) commented that Ash occupies the most favourable sites as regards soil on Bago S.F.

Topographic effects appear of particular importance in the occurrence of Ash types, the most favourable situations being cool, moist, shady aspects on steep, well drained slopes (Costin, p. 402). Indeed the typical occurrence of Alpine Ash on the mainland appears to be in stands on the more sheltered sites in areas of steep topography, while it avoids the drier and more exposed sites (probably in major part due to the effects of fires) and also low lying sites that are very cold or poorly drained. Jacobs (1951) suggested that the upper altitude to which it will ascend depends mainly upon the height of the ridge above the trees.

In this general pattern of occurrence on steep slopes, the stands of Alpine Ash on Bago S.F. are decidely anomalous. Here the topography is that of a mostly gently undulating plateau. Referring to this area, Lindsay (1939) noted:

> *"Aspect is a controlling factor to the extent that better development is usually found on south and east aspects. There is the peculiar feature, however, that on north Bago which has a general north fall, there is a higher percentage of Ash, at p11 elevations, than on*

south Bago which has a general south fall. This may be partly due to the greater frequency of basalt outcrops in the northern section."

The Ash types occur within a fairly well defined altitudinal range, which presumably reflects the temperature requirements of Alpine Ash. In N.S.W. the types rarely if ever occur below 900m or above 1 500m the A.C.T., near the types northernmost limits, the lower altitude limit is about 1 100m. In the Bago-Maragle area optimum development of the types occurs between 1 100 and 1 300m altitude, with the Ash at lower altitudes usually restricted to the damper gully sites and sheltered southern and eastern aspects except, as noted above by Lindsay, on the north fall of Bago where it maintains a significant presence below 1 100m (Forestry Commission of N.S.W., 1980).

The distribution of the Alpine Ash types is directly related to the occurrence of Alpine Ash as a tree, introducing a major **biotic** factor. Discussing this, Costin (pp. 409 - 410) writes:

*"The present disjunct distribution of certain species of the alliance indicates an extension of a cooler, moister montane climate during the Kosciuszko glaciations of the Pleistocene period. The most critical of these indicator species is **E. delegatensis** itself, occurring with a continuous distribution on the western Monaro, but in more eastern areas only as disjunct relic communities as at Moonbar, near Mt. Tingiringi, Delegate Mt. (in Victoria), the Bobeyan Divide, Shannon's Flat, Robert's Mt., Mt. Clear, and possibly also in the hybrid condition with **E. pauciflora** on the Tinderry Mts.*

*In the eastern montane tract communities of the **E. delegatensis - E. dalrympleana** alliance frequently occupy the colder, more basal sites, but are excluded from adjoining favourable situations by competition from the **Eucalyptus fastigata - E. viminalis** alliance. This may indicate an earlier, more widespread distribution of the former alliance in the eastern montane tract and its partial replacement by more mesothermal wet sclerophyll forests during the increased temperatures which are thought to have occurred at the end of the Late Pleistocene.*

*Evidence for this warmer climatic period is also found on the western Monaro, both as relic communities of the **Eucalyptus fastigata - E. viminalis** alliance, as at Yaouk, near Eastbourne and Rocky Plains, and along the Lower Snowy River, and in the composition of the **E. delegatensis - E. dalrympleana** alliance itself. The rare **E. delegatensis - E. viminalis, E. delegatensis - E. radiata, E. pauciflora - E. viminalis and E. pauciflora - E. radiata** associations of the latter alliance represent unusual combinations of the relatively cold-loving species **E. delegatensis** and **E. pauciflora** with the more warmth-loving species **E. viminalis** and **E. radiata**. This may be attributed to the modification of pure communities of these mesothermal species by local invasions by **E. delegatensis** and E**. pauciflora,** such as would have been possible by the onset of cooler conditions in the Mid-Recent. The newly formed associations now seem to be stable and in equilibrium with the present climate."*

Fire is a major factor that has greatly influenced the nature and occurrence of Alpine Ash communities, and that would appear to have contributed significantly to the disjunct nature of the stands, as mentioned by Costin, above. Lindsay (1939) has commented percipiently on the effects of fire:

"……reproductive characteristics vary greatly from one eucalypt species to another. Alpine Ash is a prolific seeder but a very poor coppicer. Mountain Gum, Peppermint and Snow Gum are less prolific seeders but strong coppicers. Susceptibility to fire damage is another factor which affects the composition of the forest. Ash is susceptible to fire damage at all stages. Light fires kill seedling growth while fires of great severity may kill mature trees. Both Mountain Gum and Peppermint are much more resistant and it is rare to find mature trees of these species killed by fire. Seedlings may be destroyed but the species recover rapidly by coppicing.

The influence of fire on the composition of the forest is further complicated by the regeneration characteristics of the various species. Continuous light fires increase the amount of regeneration of Mountain Gum and Peppermint, since the Alpine Ash seedlings are totally destroyed by fire while the other species coppice from the roots, even if the parts above ground are destroyed. This may in time change the composition of the forest. The effect of very severe fires depends upon a number of factors, such as the number of Alpine Ash and seed trees, the amount of seed available, conditions for seedling growth and conditions during seasons following fire. Under some conditions pure stands of Ash, over extensive areas, may result. In other cases Ash survives as scattered trees only and the stand is predominantly composed of Mountain Gum and other species."

Lindsay also commented on the role of interspecific competition (another biotic effect) in determining the composition of the Ash types on Bago S.F.

2.4 Other Ecological Effects

2.4.1 Provenance

Alpine Ash has a latitudinal range of some 8º, and throughout its range numerous disjunct stands occur. This suggests that distinct provenance differences are likely to have developed within the species. To examine the extent and nature of such variation, a series of provenance trials of Alpine Ash, with associated botanical collections, have been established by the CSIRO Division of Forest Research within the species area of natural distribution. Trials were located at three sites in Tasmania and at one in N.S.W., with tests of some of the same seedlots also established in Victoria and New Zealand. The N.S.W. trial was planted on Bago S.F. in 1978 and included some 64 seedlots.

Assessed at age 3 years, mean heights for different seed sources at Bago S.F. ranged from 5.64m (mean DBH 4.68cm) down to 2.34m (mean DBH 2.33cm). The following general conclusions can be made from the results at this stage:

1. The local N.S.W. seed sources performed well, for height growth, and most of them suffered relatively little frost or snow damage.

2. Insect damage was least on the N.S.W. provenances.

3. Some Victorian provenances (notably Royston River, which is outstanding in several plantings) were better than the N.S.W. ones, but may possibly suffer more from frost, snow and insect attack.

4. The Tasmanian provenances showed poor ratings for all traits, including early survival.

Reviewing these results, Moran (in press) has suggested that the trials demonstrate that the genetic gain from correct initial provenance selection in a plantation breeding programme for Alpine Ash could be very great, and that several Victorian provenances would be a suitable seed source for plantations in the southeast region of the mainland.

Ohmart et al. (1984) used these same plantings to examine the extent of insect defoliation in selected provenances. Defoliation in the Tasmanian provenances at the Batlow trial was significantly greater than in the mainland provenances; in two other plantings, both in Tasmania, the level of defoliation in the Tasmanian seed sources was generally above that of the mainland sources, but not significantly so.

Detailed studies by Boland and Dunn (1985) on both the botanical collections and planted offspring clearly showed the existence of two major groupings, separating mainland and Tasmanian provenances. These have since been recognised as separate subspecies (Boland, 1985, see section 2.1). In addition Boland and Dunn also identified five sub-regional groupings of provenances, three

Tasmanian (essentially northwestern, southeastern and central), and two mainland. Of the mainland collections, most sources, including all from N.S.W., fell into one extensive and fairly homogenous grouping, with a separate and fairly distinct grouping taking in some Victorian sources, mostly north and west of the Great Divide.

2.4.2 Fauna

Although both Pryor (1938) and Costin (1954) include some discussion on the fauna of the areas where they worked, their contributions add little to the understanding of the wildlife of the Alpine Ash types, and indeed little study of this topic appears to have been undertaken. Excluding aquatic species, the Bago-Maragle management plan (Forestry Commission of N.S.W., 1980) lists about 90 birds recorded from the forest, virtually all from the Ash types. Rather unusual among these are the emus that occur on Bago and Maragle S.F.s. Wombats, or their traces, are prominent. Red-necked Wallabies may be common (in Tasmania wallabies and possums can be a major source of damage to Ash regeneration), but larger kangaroos are unusual. Old Ash and Mountain Gum trees would seem to provide favourable habitat for hollow-nesting species. Among the feral species, brumbies add an interesting and apparently fairly harmless presence to these types.

2.4.3 Ecological Relationships

The Alpine Ash types provide a distinct and distinctive plant community that has been recognised, very much in the forms understood here, in the various ecological studies undertaken in areas where it is present. The presence of Ash tends to define the types very clearly, but towards the margins species from adjoining communities are often associated with the Ash.

At the higher altitudinal limits the Ash types usually give way to stands dominated by Snow Gum or Alpine Snow Gum, while at the lower levels, or in less favourable sites within its altitudinal range, the Ash drops out leaving forest stands dominated by Mountain or Manna Gums and Narrowleaved Peppermint; the A.C.T. forests are unusual in having Brown Barrel types replace the Alpine Ash at lower altitudes. In poorly drained, frosty sites the Ash types are usually replaced by Snow Gum-Black Sallee woodlands, which in turn may give way to various swamp communities.

3. OCCURRENCE

In N.S.W. the Alpine Ash types are restricted to parts of the Southern Highlands at altitudes between 900 and 1 500m. The general occurrence in N.S.W. is exaggerated by the inclusion of stands dominated by Mountain Gum and other associated species, without an Ash component. (Costin also shows this alliance as occurring on the Tinderry Mountains, south of Queanbeyan, but Ash itself is absent from this elevated area except possibly as a genetic phantom in some of the Snow Gums.) The northwestern stands are backed by little fieldwork, and are diagrammatic rather than accurate.

The northernmost occurrence is probably that on Mt. Coree, on the N.S.W.-A.C.T. border, and the westernmost stand is an isolated occurrence west of the Batlow-Tumbarumba road, just south of Laurel Hill. The main occurrence extends along the eastern sides of the Brindabella and then of the Great Dividing Ranges into Victoria, with more isolated occurrences lying to both east and west.

Hoschke (1976) estimated the area of Alpine Ash types in N.S.W. as 67 000 ha, of which 21 000 ha were on State Forest, 40 000 ha on national park and 3 000 ha on leasehold lands. The estimate for State Forest is probably rather high, the area of the types in the main production forests (Bago = Maragle Management Area; Forestry Commission of N.S.W. 1980) being 13 200 ha, and with relatively small areas only (2 000 ha maximum?) in the Tumut management area east of the Tumut plantations. Small areas of leasehold, where the Forestry Commission has some statutory responsibilities, are in the Adaminaby and Badja M.A.s and are chiefly located immediately to the south of the A.C.T., while the recently dedicated Ingebirah S.F., in the Monaro South M.A., lies southwest of Jindabyne, adjoining Kosciuszko N.Y. The total area of the types subject to some Commission control would not appear to exceed 20 000 ha.

In Victoria, where it is sometimes known as Woollybutt, the Alpine Ash types are found along the Great Divide north and east of Melbourne, with its *"optimum altitudinal range ... from 1 000 – 1 400m, with extremes of 730 and 1 600m "* (Grose, 1961), and with widely disjunct stands occurring on Mt. Big Ben, Mt. Ellery and Mt. Macedon (Boland et al., 1984). It is also widespread in Tasmania (as Gum-topped Stringybark), with an altitudinal range of about 160-1 200m, again with some markedly disjunct occurrences (near Zeehan, Dazzler Range, Hartz Mtn., Mt. Dromedary and on Maria Is.). The Victorian stands are generally similar in composition and appearance to those in N.S.W., with Shining Gum also present as an occasional associate. On at least some of the relatively restricted occurrences of Alpine Ash on plateau topography in Victoria (e.g. Connors Plains), the undergrowth appears to be much denser than is the case on Bago S.F. In Tasmania, associates of Alpine Ash may include Messmate, Mountain Gum, Tasmanian Snow Gum, Urn Gum, Cider Gum and Alpine Yellow Gum, with a Myrtle Beech understorey present in the cooler, moister sites. A particularly interesting account of the interrelationships between Ash, Myrtle Beech rainforest and grassland in northeastern Tasmania is given by Ellis (1985). In both southern States pure stands of Alpine Ash are common. In Tasmanian trees the rough bark extends much further up the stem than on mainland trees, and as noted previously they are now recognised as a separate subspecies (see Section 2.1)

4. UTILISATION

The properties of the main **timbers** obtained from the Alpine Ash types are summarised in Appendix 3, using information obtained from Bootle (1983). Of the species occurring in the types, Ash itself is the one of prime importance as a timber-producer, and is described in the following terms in the Bago-Maragle Management Plan (Forestry Commission of N.S.W., 1980):

> *"Locally (Alpine Ash) is considered to be the mainstay of the hardwood joinery cut. It is light-weight for a eucalypt, flexible, and of low defect, suitable for a wide range of products including high quality structural building timber. Those products cut locally include internal use items such as door frames, staircases, feature floors and linings, mouldings and architraves from the higher-grade material. Specialist uses include the manufacture of handles and boat oars, for which Ash is favoured because of its light weight and ease of working. The optimum log size desired by industry to supply the above range of sawn products is about 4 to 5m long and 50 to 60cm c.d.u.b."*

Unfortunately, references to handle and oar manufacture should now be in the past tense. Local manufacture in N.S.W. tends to concentrate on the general timber market (e.g. air dried framing), but with some effort being made to sell into more specialist areas (e.g. furnishings).

In N.S.W. the volume of Ash cut is not great: less than 30 000 m^3 gross of sawlogs in 1984-85, ranking the species 14th in order of hardwood sawlog cut in the State. However it is a major species for wood production in Victoria and Tasmania, and is probably among the top half dozen native species in terms of volume cut annually in Australia. Southern timber, mixed with that of Mountain Ash and Messmate, is commonly marketed as Tasmanian or Victorian Oak. The wood is used for pulp in the southern States, with the wood being obtained from integrated sawlog/pulpwood operations, and there have been recent trials of its suitability for medium density fibreboard in N.S.W. Also in N.S.W. small thinnings have in the past been used to produce wood wool and, more recently, for pit props. The timber is noted for the presence of its distinct annual rings, and Boas (1947) comments that *"pores are numerous in the earlywood and occasionally absent from the latewood and this timber is consequently the eucalypt most nearly approaching ring porosity".*

The associated species, though capable of yielding useful general purpose hardwood, are generally much less well regarded than the Ash. Snow Gum, despite reaching utilisable size and form, is seldom cut because of its excessive collapse in seasoning.

Stands of Alpine Ash types on suitable topography are commonly used for grazing during the summer months. Stocking rates are usually low, and the effects appear to have been negligible unless, as has at times happened, the graziers endeavour to open out the undergrowth and promote grass growth by burning.

The Bago-Maragle management area is used extensively for bee sites, with apiarists following the flowering of Alpine Ash and Snow Gum (Forestry Commission of N.S.W. 1980). Clemson (1985) also lists Manna Gum and Narrowleaved Peppermint as among the better of the tableland nectar-producers.

Ash types in N.S.W. are almost without exception located within major **catchment** areas. Commenting on the role of these types in catchment protection, Morland (1958) wrote:

> *"The association forms a considerable area of very strong vegetation receiving a high rainfall. It has strong tree and undergrowth cover, heavy surface litter, and deep porous, loam soil, and therefore has a very high water absorption and storage capacity.*
>
> *Degradation by fire of forest cover and soil over very large areas has much impaired the catchment efficiency of the association. The Alpine Ash forest is thus of major importance for water storage, and located on steep mountain slopes, its stability is of prime concern."*

Morland noted that, although burnt sites normally revegetated speedily, *"repeated burning degenerates the soil and reduces its capacity to support growth".* Sheet erosion was widespread in the steep sites commonly occupied by the Ash types, and there was the prospect of mass movement of soil if the types were further degraded by repeated fire.

The types do not appear to have a particularly high **recreational** appeal, and their use for such purposes is largely associated with their proximity to other recreational sites - trout streams, waterfalls, scenic lookouts, alpine areas, and so on.

Unusually among the major forest types of N.S.W., Alpine Ash communities have been subject to little clearing for **alternative land uses**: Lindsay (1939) noted that *"only in the lowest fringe ... has land settlement taken place. In spite of the deep soil and high rainfall, the high clearing cost, severity of winter conditions and frequence of summer frosts are likely to prevent any immediate demand by settlers for land in this area"* (i.e. Bago). Outside the Bago area, the steep topography would be a further deterrent to land settlement. As a result, the area of Ash types present today is probably little less than that at the time of European settlement.

5. HISTORY OF USE AND MANAGEMENT

The rather remote and high altitude location of the Alpine Ash types resulted in delayed interest in the use of their timbers. Probably the earliest use was for the construction of stockyards and huts on some of the cattle runs, and for use in mining settlements (e.g. Kiandra: Quartzville on Bago S.F.) subsequent to the early 1860s.

The value of the Bago area for timber was speedily appreciated, and much of the area was gazetted as a Forest Reserve in 1878, with several other areas, carrying Ash stands (Jounama, Nattung), being reserved by the turn of the century. These, plus other areas supporting good stands of Ash, were dedicated as State Forests following the passage of the Forestry Act in 1916. By that time there was a long established sawmilling industry functioning on Bago S.F., while the surveyors reports on the other areas dedicated about that time noted that sawmilling operations were already under way on what became Thredbo and Yarrangobilly S.F.s, and that there had been unsuccessful efforts to start an operation on what became Yellow Bog S.F.

However Bago remained the main centre for timber harvesting in the Ash types, a fact reflecting the forests good resources and particularly its good access and topography. Early logging was highly selective with minimal control, leaving degraded stands, and treatment of 1 000 ha of such stands, involving heavy logging, ringbarking of non-merchantable trees and burning the debris, resulted in the fine 1917 Regeneration Area at the northern end of the Ash belt on Bago S.F. (Shepherd, 1957). Much of this regeneration was non-commercially thinned in 1933-34 to leave a stocking of about 650 stems per hectare.

Pine planting commenced on the northwestern edge of Bago S.F. in 1920. In general efforts were (and have been) made to exclude Alpine Ash stands from planting areas, though some of the earlier plantings included areas of Ash type. (A small area of Ash type included in the 1967 planting area on Buccleuch S.F. carries a mixed stand of *Pinus radiata* and regrowth Alpine Ash, the Ash slightly ahead of the pine in height growth after 18 years.)

A major advance in the management of Ash stands - and indeed of eucalypt stands generally - resulted from the establishment of investigations into the growth and yield of Alpine Ash on Bago S.F. about 1937. The investigations appear to have been inspired by the then Commissioner, E.H.F. Swain, and based upon his own earlier studies in the South Australian pine plantations. The work was carried out by A.D. Lindsay, under the general supervision of B.U. Byles, and in addition to acquiring information on the growth of Ash it served as a training ground for a large number of officers who subsequently occupied senior positions in the Commission. Much of the information obtained is repeated in these Notes.

Based on Lindsay's studies, the first management plan for Bago S.F. was prepared in 1939 and included a reduction in yield, the development of new marketing and roading policies, and the revision of grazing policy (in part aimed at avoiding having any grazier benefit from fire on his lease or permit area). In the plan, the Ash resources in the Maragle area, south of Bago and east of Tumbarumba, were regarded as part of the combined sustained yield resource for the local industry.

In 1944 the Government created the Kosciuszko State Park, withdrawing some 62 000 ha previously under Commission control, including much of the Maragle resource. Most of these revoked areas (57 000 ha of State Forest, 5 500 ha of Timber Reserve) had previously been set aside for their content of Alpine Ash stands. Following protracted negotiations, an exchange of land between the Commission and Kosciuszko National Park took place between 1967 and 1970. This saw a further 26 000 ha of State Forest (mostly towards the east of the park) revoked and added to the park, while some 32 000 ha were transferred from the park to State Forest: these additions to State Forest were along the west of the park and included the return of part of the Maragle resource. Since the establishment of the park, management of Alpine Ash for timber production has been confined primarily to the Bago-Maragle area, with smaller areas of interest remaining in the Buccleuch area and on leasehold lands and Ingebirah S.F. lying to the east of Kosciuszko N.P.

Apart from the 1917 Regeneration Area, most logging on Bago S.F. has been carried out under a group selection system, whereas on Maragle S.F., where logging commenced in 1968, harvesting was basically a clear-felling with seed trees, aimed at removing the existing overmature stand over a period of some 15 years. Culling of non-merchantable trees has occurred following logging, top disposal burning has been carried out, and there have been some efforts, by direct seeding or planting, to expand the area carrying Alpine Ash into adjacent stands. Management plans for the area (either Bago alone or with Maragle) have been prepared in 1954, 1969 and 1980, and Bago in particular is regarded as one of the most intensively and effectively managed hardwood forests in N.S.W.

6. Regeneration Requirements

6.1 Flowering Fruit Development

Fielding (1956) and Grose (1957b, 1960, 1961) have studied the flowering and seed development of Alpine Ash. In the A.C.T., Fielding found that the inflorescence buds appear in the leaf axils in September and October, and that their protective inflorescence bracts are shed about 14 months later (November and December of following year). The flower buds continue to develop for another 15 months, giving a period of nearly 2.5 years from the appearance of the inflorescence bud until flowering occurs. Seed matures towards the end of the year in which flowering occurs, about 3 years after the appearance of the inflorescence buds.

Grose's observations, from Victoria, largely coincide with those of Fielding, but with some minor differences in timing. The inflorescence buds appear from October to December and shed their bracts about 12 months later. The flower buds then develop for a further 14 to 16 months with flowering from January to March. Grose (l957b) notes that seed is viable, though difficult to extract, 2½ to 3 months after flowering, and he reports variously that the seed matures about 1 year after flowering (1960) or 20-24 months after flowering (1961), and adds (1961) that natural seed shed usually starts about 2 years after flowering, and that it may contribute to seed fall over a period of 4 years: Alpine Ash, in common with a number of other species in the series Obliquae, has a leisurely approach to flowering and seed production, but will normally carry an appreciable seed reserve, from several successive flowerings, in the crown.

Some flowering usually occurs each year in Ash, and moderate flowerings can follow each other in successive years. However a heavy flowering one year is invariably followed by a very light flower crop the next year (Grose, l957b). On trees carrying moderate to heavy crops of buds, flowering is preceded by the abscission of some or all leaves from many of the bud-bearing branchlets, and further leaf-shed occurs after flowering (Grose, 1960). The density of flowering can be materially affected by insect damage, with much of the loss of buds and immature capsules being caused by wasps, while psyllids can destroy nearly all the buds produced by a stand each year for a period of years (Grose, 1960).

Fielding made the observation that in dense, naturally regenerated stands of Alpine Ash, suppressed stems commonly flower at a very early age, but dominants do not flower until much later, and he recorded seed collection from a 7-years old suppressed tree only 2m high. In two other examples he recorded a tree 3.4m tall in a regrowth stand with dominants of 7.5m, carrying only 5 leaves but with 209 capsules, and a 3.7m stem in similar regrowth with 115 leaves, 1 172 flower buds and 7 capsules: the buds opened at the next flowering, and 80 per cent of them produced capsules. This attribute, of directing suppressed stems into early seed production while the young dominant stems concentrate on vegetative growth, has also been reported from the related Blue Mountains Ash (Glasby, 1981; see No. 3 in this series of Notes), and it has been noted in the field with Alpine Ash on Maragle S.F. It would appear to be a feature of considerable biological significance:

- It effectively reduces the flowering and fruiting age of the trees, providing an early seed source.
- It probably hastens the mortality of the suppressed trees, which put more of their growth resources into seeding.
- It allows a fire-sensitive species (such as both Ashes) to survive in sites where the fire frequency may be greater than the time for the dominant stems to reach reproductive maturity.

Table 1

SEED PRODUCTION BY CROWN TYPES - ALPINE ASH
(from Jacobs, 1955)

Crown Class	**DBH** (cm)	**Weight of Seed** (g)	Effectiveness (c.f. with suppressed)
Dominant, Open grown	99	2 012	624
Co-dominant	75	255	79
Epicormic Crown	60	32	10
Suppressed	48	3.2	1

By contrast, in the more mature trees it is the dominant stems that are the major flowerers and seed producers, and Jacobs (1955, para. 192) has provided an example of this from Alpine Ash in the A.C.T.: see Table 1.

An outline of the flowering and seeding habits of some species present in the Alpine Ash types is given in Table 2, taken from Boland et al. (1980).

Table 2
FLOWERING AND SEED COLLECTION TIMES: ALPINE ASH TYPES
(from Boland et al., 1980)

Species	Flowering	Seed	Duration	No. Crops	Notes
Ash, Alpine	Dec-Mar	Jan-Feb	* * *	**+**	
Gum, Manna	Jan-May	July-Jan	* *		Good every 2-3 years
Gum, Mountain	Mar-May	Dec-May	* *		
Gum, Mountain Grey	Dec-Feb	Jan-June	* *		
Gum, Snow	Oct-Jan	Dec-Feb	* * *	**+**	
Peppermint, Narrowleaved	Oct-Jan	Dec-Feb	* * *	**+**	

Notes: **Seed collection**: most convenient months for collection.
Duration: indication of period in which particular seed crop is present on tree:
* * * Long duration - some seed available most months;
*** *** Medium duration - major seed collection should be confined to months shown.
No. Crops: **+** indicates species often carries more than 1 seed crop on tree.

Similar information with respect to flowering time is given by Clemson (1985) for those species dealt with by him: Manna Gum, Snow Gum and Peppermint. Fielding (1956) noted that the period of bud development for Snow Gum *"was found to exactly parallel"* that of Alpine Ash, though Clemson suggests that Snow Gum flowers only 6 to 9 months after bud formation: he in fact is probably referring to the appearance of the individual flower buds from within the protection of the inflorescence bracts.

Clemson indicates a period of 15 months between bud formation and flowering for Manna Gum.

6.2 Seeding

Table 3
SEED FEATURES: ALPINE ASH TYPES

Species	Number of Viable Seeds/kg		Germination		
	Mean	Highest	Temp (1)	1st Count (2)	Final Count (2)
Ash, Alpine	101 000	231 000	20	5	14 (3)
Gum, Manna	353 000	1 220 000	(25)	7	14
Gum, Mountain	201 000	630 000	20;25	5	14
Gum, Mountain Grey	157 000	304 500	20;25	7	14
Gum, Snow	59 000	112 000	15	7	21 (4)
Peppermint, Narrowleaved	97 000	154 000	15;20	10	21

Notes: (1) Temperatures recommended for germination tests. Where figure is bracketed, e.g. (25), this temperature is satisfactory, but others have not been tested; where two or more figures are given, e.g. 20;25, all have been found satisfactory.

(2) "Count" figures relate to laboratory tests, but give a relative measure of the speed of germination (days from start of test).

(3) Requires stratification for 6-10 weeks

(4) Alternatively stratify for 3 weeks, and then use temperature of 20ºC.

Features of the seeds of major species occurring in the Alpine Ash types are given in Table 3, again taken from Boland et al. (1980).

The seed production of Alpine Ash itself was studied by Grose (1957b; with some amplification, 1961) in the Delatite area of northeastern Victoria, in stands with a complete canopy of Ash. The main findings by Grose can be summarised as follows:

1. In confirmation of Jacobs' findings, little seed was produced from suppressed or intermediate trees in stands slightly over 100 years in age. From a heavy capsule crop, co-dominant trees shed about 100 000 viable seeds in a year - slightly over 1 kg of seed plus chaff per tree.

2. Stands on a northwest aspect produced about twice as much seed, in two successive years, as those on a southeast aspect: an average of 5.8 million seeds per hectare per year from the northwest aspect, 2.6 million/ha/year from the southeast aspect.

3. Stands aged 55-60 years produced only about one sixth the amount of seed of stands aged 105-110 years.

4. 15-20 per cent of the potentially viable seed in the capsules was destroyed prior to seed shed by the activities of small wasps.

5. Seed fall normally starts about 2 years after flowering, though the seed is ripe much earlier and some is cast earlier in capsules on leafy branches or umbels which blow off during strong winds or are nipped off by such birds as Black or Gang-Gang Cockatoos.

6. About a third to a half of the total seed production is cast in capsules, usually during periods of strong winds or snow. While seed can be shed from these capsules on the ground, they make relatively little contribution to regeneration as much of the seed is infertile or eaten by insects.

7. The peak seed shed from capsules on the trees occurs in the late summer and early autumn: in two successive seasons, 60 per cent and 43 per cent of the total annual seed shed from capsules occurred between the ends of January and April. However some seed shed occurs in virtually all months.

8. Seed shed is partly related to warm, dry weather conditions, but appears to be no less related to a physiological process of die-back of the capsule-bearing branchlets in the second year after flowering.

9. Most seed is shed in the third year after flowering.

10. Alpine Ash seed in free fall has a terminal velocity of about 5m/second, meaning that seed shed from a typical mature tree is airborne for about 10 seconds. This infers that seed could travel over 100m during windstorms, with seed in capsules on detached branchlets travelling further. However the effective distance of seed dissemination from seed trees appears to be in the order of 40-50m.

11. Rapid seed cast can be induced by sap-ringing: in a plot sap - rung in December, most seed had been shed within 2 months. By contrast, with ringbarking the seed shed continued for a further 12 months.

12. Much of the seed that is shed may not be available for subsequent establishment. Significant quantities can be held in grass tussocks, where the seeds may germinate but will not establish. Large quantities are harvested by insects, including a lygaeid bug and ants: in one test, insecticide- treated seeds were not removed, whereas similar batches of untreated seeds were completely robbed of all full seeds in 5 days. Ants and lygaeid bugs are often common under the heads of recently felled trees, and the *"generally observed lack of seedlings around and under heads of felled trees is partially attributed to the activity of insects."* In the later paper (1961), Grose indicates that insects harvest 50 to 75 per cent of the seed falling to the ground, and that only about 15 to 34 per cent of the total fall is available for spring germination.

Over a period of 5 years, the average annual seed cast under a full canopy of 105-110 years old trees was about 3 million seeds per hectare. By comparison, in a logged Ash stand in the A.C.T., carrying about 22 seed trees per hectare, Fielding (1956) recorded production of 3.2 million seeds per hectare in one year and 1.1 million in another year, and noted that these figures were underestimates.

Boland and Martensz (1981) have examined the insect-caused loss of seeds within capsules on the trees, looking at capsules from 18 stands throughout the range of Alpine Ash in N.S.W. and the A.C.T. Seed loss was as high as 81 per cent in the case of one tree, but over all sites it averaged about 20 per cent - close to the value reported by Grose in Victoria (see point 4, above). Wasps were the major cause of loss.

Grose's findings relating to the removal of seeds on the ground by insects (point 12, about) prompted a study by O'Dowd and Gill (1984) in the A.C.T. concerning seed fall and seed predation following severe fire. Two comparable stands of Alpine Ash were used, one being burnt in a high- intensity experimental February fire, which killed over 90 per cent of the Ash trees present and prompted a massive synchronised release of seeds, averaging over 4 million viable seeds per hectare, in the 3 weeks following the fire. The fire precipitated an immediate drop in weekly removal of seeds, from an average of 65 per cent before the fire to 14 per cent after the fire. Ants were found to be the only important removal agents. Although the abundance and species richness of ants trapped on the seedbed increased after the fire, the number of ants trapped per available seed significantly declined due to the massive input of seed, enhancing the likelihood of adequate subsequent germination and establishment.

One further observation concerning the dispersal of Alpine Ash seed is of interest. Ellis (1985) working in a plateau area carrying several more or less treeless plains dominated by Snow Grass in northeastern Tasmania, records the presence of isolated and small (under 1 ha) groups of Alpine Ash trees within the plains. The groups are remarkably similar in structure:

> *"They consist of one or two veteran trees that are all of similar size, and thus probably of similar age, surrounded by young trees that diminish in age with distance from the veteran. The veteran trees have short boles and wide candelabra crowns commonly found in isolated open grown trees. The younger trees are tall and straight, a form typical of trees that have grown amongst close neighbours."*

Ellis observes that the groups have originated later than the fire-caused destruction of rainforest that at one time occupied these grassland sites, and that they originated with the establishment of the veteran trees, which occur well beyond the normal range of distribution of seed from preexisting eucalypt stands. He notes historic records of the Tasmania Aborigines carrying green branches, probably for use as "mosquito fans", and he postulates that seed from such boughs might well have successfully established eucalypt seedlings on the favourable microsites left by the Aborigines' campfires.

To summarise the information relevant to seed production in Alpine Ash stands:

- Stands typically carry a substantial amount of seed, from several successive seasons' flowering, in the crowns of the trees.

- Most of the seed is carried by dominant and co-dominant stems, with older stands carrying more seed than immature stands, and with stands in the warmer and drier sites carrying more than those in more mesic sites.
- Severe fire or sap-ringing will induce the rapid shedding of all or most of the seed held in the crowns.
- Under normal conditions most seed fall occurs in late summer and early autumn, though some seed fall may occur at any season of the year.
- Effective seed fall is limited to a distance of about 40-50m (roughly 1-1.5 times the height) from seed trees.
- Up to half the seed crop may be shed within capsules: relatively little of this usually contributes to subsequent regeneration establishment.
- A significant proportion (average about 20 per cent in several studies) of seed is destroyed in capsules by wasps and other insects.
- Even larger quantities of seed are lost after seed shed through predation by ants. Fire-caused saturation seed shed reduces the effects of this predation.

6.3 Germination

Pryor (1954) pointed out that the germination of some high altitude eucalypts, including Alpine Ash, was greatly improved by a period of moist, cold storage (stratification) prior to sowing, and this phenomenon was subsequently studied in considerable detail with respect to Alpine Ash by Grose (l957a, 1957b, 1961, 1963; also other publications not quoted here).

Grose’s major findings can be summarised as follows:

1. Freshly collected seed, or seed taken from dry cold storage, germinates very poorly if sown without any pretreatment. Over one protracted series of tests, an average of about 21 per cent of the viable seeds germinated when incubated at 17ºC with a range for different batches of from 0 to 67 per cent; germination at higher or lower temperatures (some germination occurred at temperatures between 10 and 25ºC), or at alternating temperatures, was even less.

2. Germination is enhanced when the seeds are incubated in an oxygen- enriched atmosphere. This and other evidence suggests that the dormancy in the seeds is caused by poor permeability of the seed coat for gaseous exchange, limiting the supply of oxygen to the embryo.

3. As pointed out by Pryor, the dormancy in the seeds can be broken by stratification.

4. The breaking of the dormancy, or after-ripening, is most effective when the seeds are given moist storage at 5ºC, but storage at 7ºC is little less effective. After-ripening occurs very slowly at 1ºC, and at 10ºC is even less effective.

5. Four weeks stratification at 5^0C promotes relatively fast and high capacity germination at the near-optimal temperatures of 17ºC and 21ºC, and promotes some germination at 27ºC. Stratification for periods longer than 4 weeks increases the speed of germination, extends the range of temperatures at which high capacity germination is achieved, and extends the range of temperatures within which the seeds will germinate: see Table 4. (Note in Table 4 that at 5ºC the temperature used for incubation is identical with that used for stratification, and the conditions (moist, cold) are also identical. Only one batch of “unstratified” seed

was carried through in Grose's test, with germination commencing after 9 weeks and continuing for a further 7 weeks until germination was complete.) Germination of stratified seeds was retarded when the seeds were subjected to alternating incubation temperatures.

Table 4

MEAN GERMINATION AND GERMINATIVE ENERGY OF ALPINE ASH SEEDS, STRATIFIED AT 5ºC FOR 0, 2, 4, 6 AND 8 WEEKS AND THEN INCUBATED AT VARIOUS CONSTANT TEMPERATURES
(from Grose, 1961)

Stratification weeks	0	2	4	6	8
Germination Temp. ºC	**Germination per cent**				
5	96.3	96.3	96.3	96.3	96.3
10	3.7	9.2	68.2	94.1	97.6
17	29.3	65.8	93.6	91.8	98.7
21	17.0	58.7	92.1	94.2	98.2
27	0	0	40.9	69.3	85.6
32	0	0	0	11.4	69.2
35	0	0	0	0	17.8
	Germinative Energy Index *				
5	.245	.290	.321	.375	.474
10	.215	.281	.413	.416	.613
17	.381	.562	.617	.716	.805
21	.549	.683	.603	.846	.915
27		-	.194	.856	.955
32		-	-	.933	.961
35		-	-	-	.981

* Germinative Energy Index is a measure of the speed with which germination occurs: the greater the value, the faster the germination.

7. Following stratification, secondary dormancy can be induced if seeds are then subjected to conditions unfavourable to germination. In particular, at low moisture availability, secondary dormancy can be induced by storage at temperatures of 5ºC and above; alternatively high temperature, unfavourable for germination, will induce secondary dormancy. The conditions producing secondary dormancy are also dependent on the degree of after-ripening that the seeds have received: less severe temperatures will induce secondary dormancy to a greater extent in seeds stratified for a short period than in those stratified for long periods.

8. Longevity of Alpine Ash seeds in air-dry storage appear to be greatly shortened by after-ripening. Whereas air-dry non-stratified seeds retain their viability during storage for at least 7 years, most stratified seeds become non-viable in air-dry storage within a few months.

The dormancy shown by Alpine Ash seeds is a feature of seeds of a number of species of the eucalypt subgenus Monocalyptus growing at high altitude (e.g. Alpine Snow Gum). It is less common, or less well developed, in the associated subgenus Symphyomyrtus.

The dormancy of Alpine Ash seed has considerable implications in the regeneration of this species:

- Although the peak seed fall is in the late summer and early autumn, dormancy ensures that little seed will germinate before the spring thaw, with the main period of field germination being October-November, a few weeks after snow thaw, in Grose's studies (1960). Grose (1957b, 1961) observes that a small percentage of free seeds germinates in the autumn, but the resultant plants die before spring.

- The chance of autumn-germination is reduced further by the strengthening of primary dormancy in seed that is shed in the summer-autumn period.

- Winter field conditions of ample moisture, frequent snow, and low temperatures favour the after-ripening of the seed.

- Seeds that have overwintered at or near the exposed surface of the seed bed are likely to experience wide and rapid fluctuations in moisture content and temperature in the spring, and these conditions induce secondary dormancy and subsequent non-viability: no store of seed accumulates in the seed bed beyond each winter. (This statement may not be completely correct. Nurseries in Victoria have reported the appearance of occasional Ash germinates in the year following the use of a nursery bed for an Ash seedling crop, indicating that a small number of seeds have failed to germinate in the season they were sown, but have survived in the soil and then germinated 12 months later. However the numbers involved scarcely represent a 'Store', and the phenomenon would seem to have little, if any, practical significance.)

- Seeds protected from these fluctuations by mulch or shade will usually germinate in the spring. These seedlings are the basis for natural regeneration in Ash stands.

- Presumably because of low moisture conditions, seeds overwintering in capsules do not receive after-ripening during the winter, and thus do not contribute to the regeneration.

- Where seed is to be sown in a nursery, stratification should be carried out. The seed will then rapidly and fully germinate after sowing in the moist seedbed.

- However for direct seeding, where there is no control over subsequent moisture and where in consequence then must be considerable doubt over the ability of the seeds to remain imbibed, seed should not be stratified as secondary dormancy and loss of viability is likely to result. Bowing of unstratified seed prior to the winter, for after-ripening in the field, is the preferred course.

6.4 Seedling Establishment

Alpine Ash does not develop lignotubers, and whilst young stems may coppice when cut back the tree is not a vigorous or reliable coppicer. By contrast its main associates in mixed stands, Narrowleaved Peppermint, Mountain Gum and Manna Gum, all possess lignotubers and will coppice more freely. Natural regeneration of Alpine Ash depends upon the establishment of seedlings that will survive and continue to grow.

It has been previously noted that Ash normally carries a good reserve of seed in the crown, that dissemination up to about 50m from the seed tree can be expected, and that the seeds require an over-wintering period of cold, moist conditions for after-ripening so that they can germinate in the spring.

Predictably, field establishment of Alpine Ash was studied by Grose (1957b, 1960, 1961), who examined the effectiveness of establishment on different seedbeds:

> *"Ash beds provided by broadcast slash fires and loosely cultivated seed beds, on each of which many seeds may become covered with a protective layer by the actions of rain-slash, surface runoff and frost, are most favourable for germinations. Compacted bare soil is relatively unfavourable, and grass- and litter-covered seedbeds are even less*

favourable for germination. Percentage germination of seeds on receptive seedbed on sites protected by aspect or shade is often at least twice that of seeds on similar seedbed on exposed sites. This difference in germination between aspects may usually overcome the problems imposed by differential seed production between exposed and sheltered aspects." (Grose, 1961)

Longer term survival and early growth tend to parallel this pattern of the suitability of different seed beds for germination, with ash beds giving the best results, mechanically disturbed sites intermediate survival, and grass-covered or heavily compacted bare sites virtually no establishment. Heavy litter cover or dense logging slash may prevent establishment, while O'Dowd and Gill (1984) recorded substantial mortality in dense regeneration establishment under a fire-killed stand a as result of the subsequent drop of the scorched leaves which covered many young seedlings.

Heavy grass provides a particularly adverse seed bed: it prevents much of the seed making contact with the mineral soil; it provides strong competition for water and nutrients; and in openings a grass sward enhances the severity of radiation frost, often resulting in temperatures below the minima that can be tolerated by the eucalypt seedlings (Ellis, 1985). Establishment of Alpine Ash in grass cover is a significant problem in parts of Tasmania (e.g. Needham, 1960; Kennan and Candy, 1983; Ellis, 1985; RJ Keenan, pers. comm.). The development of a grass sward seems usually to be associated with sites that were unburnt or that would support only a very mild fire after logging, and even where seedlings become established before the sward develops they suffer early growth check and high subsequent mortality (Ellis et al., 1985). The grass problem appears to be much less significant on the mainland than it is in Tasmania, though examples are known from both Victoria and N.S.W.

At Connors Plains, in the Heyfield area of Victoria, a very heavily stocked stand of Alpine Ash was logged in the 1950s, leaving seed trees which were subsequently removed. The site was not burnt, very little regeneration appeared, and a dense grass sward developed. Thirty years later the few regrowth stems are widely scattered, stunted and of poor form, but small patches of regeneration are starting to appear under the shelter of their crowns, and it might be assumed that future development will tend to resemble that discussed by Ellis (1985) in Tasmania (see Section 6.2). On another Victorian site (Macalister River) a steep, south-facing, unburnt slope failed to regenerate after logging and rapidly was colonised by grass and weeds: establishment of Ash seedlings will now be expensive to achieve, but is required on this site under a contractual agreement.

In N.S.W. there is a site on Maragle S.F. where following logging but no burning, the coupe converted to a dense sward of grass and dandelions, with very little Ash regeneration established. The site would have carried heavy grass cover prior to logging in 1980-81. Where such sites can be identified in advance, limited logging openings (so as to minimise the creation of frost hollows) and top disposal burning in autumn (to produce patches of favourable seed bed and to reduce grass competition on the same patches) would appear desirable measures. Correction of the problem once it develops is likely to be slow, or costly, or in some cases both.

Grose (1957b) observed germination of Ash in several successive years under a dense Hop Bitter-Pea canopy, but none of the seedlings survived the following autumn. Similarly in Tasmania Needham (1960) reported the inability of Ash to become established within a dense Peppertree understorey: pushing and smashing down the Peppertree by dozer, with resultant soil disturbance, prior to logging the Ash enabled good establishment to take place. Grose (1960) gives further examples to show that, *"irrespective of seed supply, seedlings establish only on sites where bare soil has been exposed",* whether by mechanical disturbance, fire or other cause. As an interesting aside on this, two of the eight seedlings recorded by O'Dowd and Gill (1984) within an unburnt site appeared in a small wombat digging.

Increasingly, Victorian research and field experience came to favour a burnt seedbed for Ash establishment (Forests Commission, Victoria 1963). Reasons included:

(a) A high proportion of the seedbed will be made receptive, a much higher proportion than that of bare soil, during normal extraction.

(b) It is loose and not compacted, contrasting with much of the soil bared during extraction of logs by tractor.

(c) It provides great stimulus to early seedling growth - i.e. “ash bed effect”.

(d) It is a suitable seedbed in all circumstances, whereas a bare soil seedbed is poorly receptive on “sheltered” sites.

Loose, unburnt seed beds were considered suitable for regeneration in other than sheltered sites, but were often difficult or impracticable to provide over significant proportions of the area to be regenerated. Autumn burns to produce the seed bed were (and are) strongly favoured: heat penetrates deeper into the soil, enhancing the ash bed effect; many rhizomes and similar underground parts of potential competitors to the young seedlings are killed; and the fire weeds and perennials that can occupy much of the seed bed in the season following a spring burn are absent when regeneration occurs in the spring following autumn burning (with a spring burn, regeneration is delayed for 12 months)

Grose (1961) points out that seedling losses prior to the two-leaf stage are high on all seedbeds:

- On bare soil and ash bed, the two main forms of receptive seedbed, usually 50-60 per cent of the observed germination dies before winter. Most of these deaths are caused through exposure of roots by water-wash and frost heave, decapitation by ice action, and by lethal high temperatures at the boundary layer between soil and air. Although some seeds germinate in grass, particularly when spring is wet, most are killed by spring frosts. Any that survive are usually killed by soil drought in summer.

- There are 150-200 frosts annually in the Alpine Ash zone, and frosts may occur each month of the year. The critical temperature for natural seedlings growing in the open on bare soil, and hardened under field conditions, appears to be about $-14^{0}C$. Temperatures as low as this occur infrequently over bare soil, but are cannon over grass and freshly fallen snow. Foliar damage through frosting of seedlings on bare soil or ash bed is usually slight, except in the special circumstances where leaves are wet when frozen, or where freezing temperatures occur under a shallow layer of snow. When snow is absent, the only action of frosts that has any significance in establishment of natural regeneration on bare seedbeds appears to be frost-heave. Approximately 25 per cent of seedlings on these seed beds are killed by frost heave in spring when in the cotyledon stage. In autumn frost-heave may also kill 30-60 per cent of seedlings aged 6 months growing on snig tracks on sheltered wet sites, but few seedlings growing on exposed and drier sites are killed by frost-heave when of this age.

- Worthwhile numbers of seedlings develop and survive until winter on two types of seedbed, namely, bare soil and ash bed. Of these, seedlings on ash bed survive winter snow much better than those on bare soil.

Considerable germination occurs under the canopy of an untouched mature stand, but few seedlings will survive for more than one season. Competition for light, moisture or nutrients, or quite probably all three, prevents their establishment. (For some Tasmanian studies on this topic, see Bowman and Kirkpatrick, 1986 a, b, c). Alpine Ash is a light- demanding species, and Bowman and Kirkpatrick (1986b) have shown how sapling growth is retarded for up to about 15m or even more from the north side of gaps (shaded side), but extends close to the southern edge of the gap with little retardation. Although some regeneration will certainly appear and develop in smaller gaps, gaps in the order of 40m diameter appear desirable for effective regeneration establishment.

The review of factors influencing regeneration establishment in Alpine Ash may give the impression that the odds are stacked against it and that successful establishment is the exception, not the rule. Certainly in the N.S.W. Alpine Ash types this is not so, and the optimistic, but realistic, words of Jacobs (1951) summarise the position as it is in the A.C.T. and N.S.W. Ash forests:

> *"Alpine Ash seeds well and reproduces vigorously. In earlier years it was considered that fire was necessary to obtain good regeneration. Dense regeneration does follow a fire in a forest of Alpine Ash, but observations made in the A.C.T. since the 1939 fires indicate that the species will regenerate satisfactorily, even if not so spectacularly, without fire. The young trees may take a year or two longer to get away, but they will capture a suitable vacant site even if it is grass covered. The Alpine Ash belt is essentially a forest locality, and Ash is the most vigorous native species there."*

6.5 Artificial Regeneration Establishment

Whilst natural regeneration can normally be relied upon for the restocking of logged Alpine Ash stands in N.S.W., in other parts of its range in Australia artificial establishment is widely used; it has received limited use in N.S.W.; and planting is used for the establishment of Ash overseas.

Outside Australia Alpine Ash has been successfully established in a number of countries (it is one of the species that will survive and grow in parts of Britain; Martin, 1948; Evans at al., 1983), but it is used significantly for commercial plantations only in Mew Zealand, where its frost hardiness, relative unpalatability to possums, and ability to grow on poor sites have resulted in its widespread use (Turnbull and Pryor, 1976; F.A.O., 1979). New Zealand practice utilises both plants raised in containers and open-root stock, which is raised by a system similar to that used for *Pinus radiata*: stratified seed sown in late spring, speedy germination, frequent root pruning (typically by a tractor-drawn root- pruning machine), sometimes a top pruning, and planting, either by hand or machine, in the winter. A similar technique was independently developed at Batlow and is used to raise limited stock for planting in the Bago-Maragle Management Area. Seed is sown and germinated under the shelter of a shade cloth, which is removed when the seedlings are about 15-20cm tall to expose them to full sunlight.

In N.S.W. artificial regeneration has been used to introduce Ash into apparently suitable sites from which it is currently lacking within the general area of occurrence of the species: such sites typically carry Mountain Gum and Narrowleaved Peppermint of high site quality and are beyond the distance for natural seed dissemination from existing Ash Seed trees. Such sites are completely logged and the logging slash burnt in a hot fire, with the open-root Ash seedlings being planted at a spacing of about 5m x 5m during the period July to September. The areas involved are small and the results appear satisfactory.

Some direct seeding has also been used on similar sites, with the seed being broadcast by hand in the late autumn: one such site on Maragle S.F., sown in 1973, carried Ash regrowth up to about 15m in height after 21 years, with the natural Mountain Gum regeneration slightly smaller.

Planting has been used in northwestern Tasmania, where in 1976 there were 270 ha of Alpine Ash plantation, established by sowing stratified seed into seed trays where it germinates, the young seedlings then being pricked into paper pots for planting in the spring, and into early summer at elevations above 550m (Turnbull and Pryor, 1978). Planting trials on the Toorongo Plateau in Central Victoria *"on denuded sites in the harsh, frost prone environment"* showed Alpine Ash to be a suitable species for the less exposed sites, though Shining Gum generally gave the best results. Site preparation by ploughing, ripping or furrowing and the use of N fertiliser were required for the best results (McKimm and Flinn, 1979), while studies in Tasmania have confirmed the benefits obtained by eliminating competing vegetation and applying N fertiliser (Ellis et al., 1985). Planting of Ash seedlings may be used in Victoria to establish an adequate stocking of regeneration on local sites where other establishment techniques have failed.

The major approach to artificial establishment of Alpine Ash in Australia has however been that of direct seeding on to clearfelled and burnt sites, usually using aerial sowing but sometimes by manual methods. The technique used in Tasmania has been outlined by Gilbert and Cunningham (1972) and by Keenan and Candy (1983): the understorey remaining after logging is felled, and the debris burnt in late summer or autumn, followed by the sowing of the Ash seed, collected from a similar altitude in the same locality, in the autumn. The seed then stratifies on the ground during the winter and germinates in the following spring. The development of the technique in Victoria, including the change from natural regeneration approaches to artificial regeneration, is outlined in a series of research reports (Forests Commission, Victoria, 1963, 1964b, 1964c). Initially untreated seed was used, but soon pelletting or coating was introduced to give better distribution and less wastage. Coating also allows the inclusion of additives such as fungicides, pesticides and fertiliser. Current Victorian pelletting practice (Forests Commission, Victoria, 1981) involves:

- Coating carried out immediately prior to the sowing operations. Treatment increases the size of the seeds by coating them with kaolin, held on by an adhesive (tablet mucilage) that normally has added to it an insecticide (2 per cent chlordane) and sometimes also a fungicide.

- Coating may increase the weight of the seed by up to 400 per cent.

- Pellets are dyed yellow, for ease of assessment and monitoring.

- The standard sowing rate (aerial) is 4.5 g coated particles per hectare (this is the minimum rate needed to get an even flow through the hopper). A calculated weight of untreated seed is coated so that 4.5 kg of coated particles will contain the specified number of viable seeds required for the area that is being regenerated.

The areas treated by direct seeding are considerable: Turnbull and Pryor (1978) record 1 200 ha treated in Victoria and over 3 000 ha in Tasmania, using Alpine Ash, in 1976. Victorian field practice, as observed in the Heyfield district, involved coupes that were normally about 30-40 ha in area; coupes over 50 ha were considered large, though there was one plateau coupe of 200 ha prepared for sowing in 1986. Five hectares were regarded as about the minimum size that could be handled for burning. There was a requirement to retain 5 trees per 15 ha for wildlife purposes, and these could be clumped. Despite integrated logging for sawlogs and pulp some useless trees remained scattered through the coupes: these are mostly killed by the burn or die from subsequent exposure. The district's regeneration programme for the year involved 7 dispersed coupes totalling 350 ha. Results from the technique seemed generally very good, though Victorian foresters present expressed some concern at the striping pattern of regeneration evident in some earlier coupes, resulting from poor control of seed dispersal from the plane. (The N.S.W. observer, perhaps with lower standards of success, marvelled that any pilot would fly in some the steep, gorge-side coupes seen, let alone manage an even seeding pattern over them.) An assessment of regeneration resulting from the treatment is regarded as most important, and can allow for failures or deficiencies to be recognised at an early stage, and to be rectified if warranted.

6.6 Natural Regeneration Establishment

Under natural conditions in the virgin forest it would seem that Alpine Ash almost invariably regenerated following fire, which would kill some or all of the standing trees, produce a suitable seed bed, and precipitate heavy seed fall. Despite insect predation, the massive fall of seed ensured that a large reserve survived till the winter when it was stratified on the ground and germinated after the spring thaw. Where stand opening was adequate - sometimes over large areas, sometimes from the death of only one or two trees - the seedlings would develop, often in dense regrowth stands where, from an early stage (perhaps as little as 5 years), suppressed stems, but not the active growers, would be flowering and producing seed. The transfer of seeding from suppressed to dominant stems probably occurred at about age 20. Subsequent lighter fires might promote scattered regeneration within these even-aged stands, and whilst most new seedlings would die, some stems might survive and contribute a further suppressed component. As Lindsay (1939) stated with respect to Bago:

"Probably the position, over a greater part of the area, can best be described as a mixture of even-aged overlapping groups. Most stands can be classified as belonging to a certain age group on the basis of the age of the dominant stems."

Lindsay noted that windstorms may occasionally bring in even-aged Ash stands, but he did not consider these to be a major cause of regeneration. Nonetheless, at least in the Bago context, it would seem that patches of regeneration could establish in the absence of fire following the death of scattered older trees, while Bowman and Kirkpatrick (1986a) have commented on the presence of a "distinctive sapling layer" in the drier Ash forests of central. Tasmania. In the probably more typical, moister Ash stands in Tasmania, where there is often invasion by a dense scrub understorey and ultimately by rainforest, such regeneration in the absence of fire would seem most unlikely. Some spasmodic regeneration would undoubtedly also have occurred in the absence of fire in Victoria, though at least some of the plateau stands, where it might have been most readily expected, tend to support a denser understorey than is usual at Bago, and this would hinder regeneration without fire. However even at Bago fire would have been the main cause of regeneration: as stressed by O'Dowd and Gill (1984), "*fire is a potent agent of natural selection and has shaped many of the individual and population characteristics of Eucalyptus delegatensis*".

Lindsay noted that, on Bago, regeneration of Alpine Ash following milling frequently occurred in small groups, reflecting the selective nature of the early operations; the groups often also included culls and suppressed trees from the old crop. The presence of these groups - effectively small even-aged stands - has shaped the subsequent development of silviculture in the area, and has led to an effective demonstration of group selection, with logging disturbance providing the seed bed and adjacent unlogged areas the seed source. Regeneration establishment has rarely been a problem, though some years may elapse before openings are fully stocked, reflecting the point made by Jacobs (1951) in relation to the not-far-distant Ash stands of the A.C.T. (see section 6.4; concluding quotation)

By contrast, on Maragle S.F. where virgin stands, virtually all in mature or overmature age-classes, were present and the topography was more rugged (and thus resembling most Ash stands in N.S.W. and Victoria), clear felling with seed trees has been utilised, followed by top disposal burning. Early operations involved more general hot burns, but these often resulted in dense and competitive wattle with the Ash regrowth, and the loss of the seed trees. Regeneration establishment from natural seed sources is normally spectacular following the logging and burn, though the retained seed trees tend subsequently to lose much of their primary crown and to develop an epicormic crown up the trunk.

Thus in N.S.W. natural regeneration is almost exclusively used in Alpine Ash stands, with both group selection and clear felling with seed trees proving highly effective in promoting regeneration. The choice has largely been dictated by the history of the stands and the nature of the topography [2]

In Victoria Grose (1957b) stated that *"fellings have usually been in the form of clear - cutting with the retention of single trees, or groups or strips of trees variously distributed, as seed sources."* Because regeneration was unsatisfactory on some logged areas, Grose undertook the extensive research that has already been quoted, and in subsequent more senior positions oversaw its continued development.

In the light of the concentrated research effort, attitudes towards Ash silviculture changed rapidly in Victoria. Grose (1960) recommended clear felling with seed trees and believed that *"with careful application fire may be the answer to preparing a receptive seed bed."* He drew attention to the deterioration often experienced with isolated scattered seed trees, and added some interesting observations on the type of seed tree to favour in selection:

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[2] It is worth noting that history and topography are related in these cases. The ready access and easy topography of Bago resulted in the development of selective logging from the 1880's, whereas the poorer access of Maragle and its more rugged topography kept it free of logging for nearly a century more.

> *"When selecting single seed-trees good form is one of the first features desired because of the danger of poor form being inherent. Whenever possible, trees of good form and apparently wind-firm but non-merchantable or doubtfully merchantable because of a high "dry-side" are preferred. A healthy crown but not necessarily a vigorous crown is a further requirement. Vigour of a crown is often judged by its leafiness. Observations have shown that a leafy crown commonly indicates a poor producer of seed. This is probably related to the leaf shed which precedes flowering and which occurs during the maturing of the capsule-bearing branchlets."*

He also referred to a partial-cut technique that was being tried: in this 60 per cent of the volume was removed in the first cut, with the remaining 40 per cent to be recovered 3-4 years later.

Three years later (Forests Commission, Victoria, 1963) seed bed preparation by fire was definitely recommended; 15 trees per hectare were to be retained for seed, and these were to be sap-rung or poisoned immediately after burning to promote seedfall and then logged out immediately after seed fall. A year later again (ibid, 1964c) the Commission would state: *"With the recognition of difficulties in applying the two-stage felling system to regenerate Ash-type eucalypts, emphasis has been directed to systems involving clear-felling and direct seeding",* thus leading in to the aerial seeding widely used in later years. Selection systems do not appear to have been tried in Victoria until recently, probably primarily for the same reasons that prompted clear felling at Maragle - past stand history and topography. At the same time it also appears that, in some sites at least, natural regeneration may not be so readily obtained in the absence of burning in Victoria as it is in the more northerly N.S.W. and A.C.T. stands.

6.7 Regeneration Damage

Agencies affecting the establishment of Alpine Ash have already mostly been mentioned: psyllids destroying buds on the trees; wasps destroying much seed in the capsules; ants and beetles removing seed that has fallen to the ground. In the discussion accompanying the presentation of the APPITA paper of Grose (1960) it was noted that cockatoos at times destroy large quantities of Ash capsules: Grose considered that the attack was largely confined to ridge and spur tops, and was not of major significance, a conclusion disputed by one of his colleagues.

Newly germinated seedlings are subject to mortality from a range of causes. Grose (l957b) lists soil desiccation (with which should probably be linked competition from other plants), water-wash of soil in heavy rain, autumn frosts causing frost heave and some burn, fungi (damping off), grazing by cattle, the decapitation of some small germinates by shield bugs, and the loss of usually weaker or etiolated seedlings under the winter snow cover. O'Dowd and Gill (1984) list much the same agencies, but include browse by other vertebrates and covering by the fall of fire-scorched leaves. One potentially worrying problem in parts of Bago is blackberry, which can respond to the canopy opening following logging and produce aggressive clumps that prevent regeneration establishment.

Seedlings of Alpine Ash raised under artificial conditions of high humidity (e.g. in glass-house or sheltered nursery bed) may develop blister-like galls on the leaves: the condition, sometimes called **oedemia**, can occur in many eucalypts, but is particularly common with Ash, where all leaves may be affected. It is apparently a reaction to the high humidity, and it has not been seen to kill seedlings (Warrington, 1980; Evans et al., 1983).

More advanced regeneration faces a different array of damage agencies. Young Alpine Ash is particularly susceptible to fire damage, which kills the young plants, while its main associates tend to survive from lignotubers or ground level coppice. Frequent light fires will thus tend to favour these other species at the expense of the Ash.

Grass competition can have a severe retarding effect on the growth of Ash seedlings. Where a dense grass sward develops, growth may virtually cease and the seedlings develop a bushy habit with small, thick discoloured leaves and many necrotic naked buds. In Tasmania this condition may occur on poorly burnt sites at age 2-3 years, when the plants are from 30cm to 2m in height. Relatively rapid growth may resume after an interval of 5-15 years, but mortality in the meantime is high, leaving a poorly or unevenly stocked stand, with many trees of poor form (Ellis et al., 1985).

Browsing by marsupials (particularly wallabies and possums) is widespread, and in Tasmania may significantly reduce regeneration survival and growth, necessitating control measures, usually poisoning (Needham, 1960; McIlroy, 1978; Turnbull and Pryor, 1978).

Insects can damage the young plants and both Turnbull and Pryor (1978) and Carne and Taylor (1978) list a number of species recorded as damaging Ash regeneration, though most of the information refers to Tasmanian experience - possibly a reflection of more study having been carried out there, rather than of a more serious insect problem in the South. Among the pests mentioned are scarab and chrysomelid beetles, the Gum-leaf Skeletoniser *(Uraba lugens),* Gum-tree Scale *(Eriococcus coriaceus)* and various sap-sucking bugs. In general, however, these do not appear to be a major cause of mortality or poor growth in young Alpine Ash stands. Phasmatids can defoliate Ash saplings, and this pest will be examined further in Section 8.

6.8 Early Development

As with most plants, early development of Alpine Ash is strongly influenced by the conditions of the seedbed. On a favourable ash bed site seedlings may exceed a metre in height at 12 months, whilst on compacted soil or amid heavy grass a 2.5 years old plant may be less than 25cm in height: such slow starters are likely to die without ever achieving active growth. With planted stock, site preparation and sometimes fertiliser use will greatly improve growth rates.

As the young plants develop, other local site factors increasingly influence growth. In a study in northeastern Tasmania, Keenan and Candy (1983) found that height growth was significantly correlated with altitude, slope, soil parent material, soil pH, drainage and exposure. The best correlation occurred with the presence or absence of various associated plants, poor growth being correlated with the presence of Snow Grass and Teatree, and good growth with the presence of Bracken, Tree Fern and Silver Wattle.

Early growth is obviously also influenced by proximity to established trees, though Alpine Ash is possibly less affected in this way than some other species: at Maragle, good regeneration occurs close to retained seed trees, and the zone of obvious regeneration suppression appears to be as little as 5m from the base of such trees. At Bago, Shepherd (1957a) found that retained seed trees in the 1917 regeneration area had developed into huge veterans 40 years later, with an average DBH of 120cm. These were found to be suppressing regrowth over a surrounding area of about 192 m^2, equivalent to a radius of 7.8m: a zone of influence closely corresponding to the crown area of such trees from the data obtained by Lindsay (1939). Shepherd recommended that such trees should now be ringbarked. In Tasmania, Bowman and Kirkpatrick (l986b) also noted that the suppressive effect of adult Ash trees on saplings extends to about the edge of the adult tree canopy, a rather lesser zone of influence than has been reported for some other eucalypts.

In the massive seed falls triggered by fire, regeneration stockings can be very dense. Lindsay (1939) noted that counts made in 3 years old stands showed stockings of 100 000 to 150 000 plants per hectare, 2 to 4.5m in height. Natural reduction in the stocking of such stands takes place very rapidly, and it is stands of this nature that, within a few years, are starting to produce seed on the suppressed stems present.

Table 5 summarises some of the information available on the early growth of Alpine Ash.

Table 5
Regeneration Growth - Alpine Ash

Age (yrs)	Locality	Height (m)	DBH (cm)	Notes	Source
0.5	Victoria	0.10		In grass	Grose, 1957b
0.5	Victoria	0.18		Bare soil	Grose, 1957b
0.5	Victoria	0.40		Ashbed	Grose, 1957b
0.5	Victoria	0.11		Bare soil	Grose, 1961
0.5	Victoria	0.32		Ashbed	Grose, 1961
1	Victoria	0.18		Grass	Grose, 1957b
1	Victoria	0.30		Bare soil	Grose, 1957b
1	Victoria	I.20		Ashbed	Grose, 1957b
2	Tasmania	3.0		Seeded after burn	Lockett and Candy, 1984
2.5	Victoria	0.25		Grass	Grose, 1957b
2.5	Victoria	0.40		Bare soil	Grose, 1957b
2.5	Victoria	2.4		Ashbed	Grose, 1957b
2.5	Bago	0.1-0.6		Logging opening	Field observation, Dec. 1984
3	Tasmania	3.3		Seeded after burn	Lockett and Candy, 1984
4	Victoria	2.3		No fertiliser, planted	McKimm and Flinn, 1979
4	Victoria	5.7		Fertiliser, planted	McKimm and Flinn, 1979
5	Victoria	3.8	6.5	Planted, no preparation	McKimm and Flinn, 1979
5	Victoria	7.1	9.1	Ploughed	McKimm and Flinn, 1979
5	Tasmania	4.5		Seeded after burn	Lockett and Candy, 1984
5	Maragle	7.5		Dom's.: clear felling	Field observation, Dec. 1984
5	Bago	6.0		Actual plot	Lindsay, 1939
5	Bago	5.5	2.5	Yield Table: S1 100	Lindsay, 1939
5	Bago	8.8	3.8	Yield Table: S1 160	Lindsay, 1939
6	Tasmania	1.0-5.6		Range of sites	Keenan and Candy, 1983
6	Victoria	12.0	9.3	Doms, in thinning trial	Forests Commission, Vic., l964(a)
7	Tasmania	5.8		Seeded after burn	Lockett and Candy, 1984
10	Bago	9-11		Actual plots	Lindsay, 1939
10	Bago	11	5.7	Yield Table: S1 100	Lindsay, 1939
10	Bago	17	8.4	Yield Table: S1 160	Lindsay, 1939
11	Maragle	15		Off-site sowing: Dom's	Field observation, Dec. 1984
15	Bago	15		Yield Table: S1 100	Lindsay, 1939
15	Bago		24	Yield Table: S1 160	Lindsay, 1939

7. GROWTH AND YIELD

7.1 Growth in the Natural Forest

What must be almost the definitive study on growth of Alpine Ash was carried out by Lindsay (1939)[3] on Bago S.F. It remains one of the most intensive studies of eucalypt growth ever made, but beyond this it was a major pioneering exercise in Australian forest mensuration, and directly or indirectly has influenced much later work in this field.

Lindsay was aided by two features:

(1) Alpine Ash is among the few species of eucalypts (and essentially the only major commercial species in N.S.W.) to produce distinct and reliable annual rings, thus enabling tree age to be simply determined.

[3] This report by Lindsay was unfortunately never formally published and exists only as a small number of type-written copies with very limited distribution, though parts of it have subsequently received wider exposure, e.g. as an appendix to Jacobs (1951) and in Borough et al (1978).

(2) The forest consisted of recognisable stands, where the dominants, if not in all, cases some of the smaller stems, were essentially even-aged.

Over 100 plots were established, each confined to an even-aged stand. Plots varied from 0.04 to about 0.4 ha in area, depending on tree size. In each plot all stems over 2.5cm DBH were measured for a large number of parameters, the plot itself was described for a range of characters, including soil and undergrowth, and sample trees were felled for age determination and more detailed measurement. (One discovery from the sample trees was that it was virtually impossible to measure from the ground the height of trees over 30m to an order of accuracy greater than + 2-3m.)

From the data collected, Lindsay developed a series of yield tables for unthinned stands of Alpine Ash, covering seven different site indices, from Site 100 ft. (31m - the average height of dominant stems at age 50 years) to Site 160 ft. (49m). The yield table for Site 130, which Lindsay regarded as average for Bago S.F., is reproduced (in metric) in Table 6, and four other tables covering the range of site indices at 20 ft. (6m) intervals are given in Appendix 4.

Table 6
YIELD TABLE - ALPINE ASH, BAGO S.F.
Site Index 40m (130 ft.) (After Lindsay, 1939)

Age (yrs)	**Dom.Ht** (m)	**Mean DBH** (cm)	**Stocking** (/ha)	**B.A.** (m^2/ha)	**Tot. Vol.** (m^3/ha)	**Merch. Vol. Gross** (m^3/ha)
10	14	7.1	5 600	22.3	92	
20	24	15.5	1 870	35.1	252	
30	31	24.9	919	44.5	430	
40	36	34.5	544	57.2	574	
50	40	42.9	381	55.3	682	
60	42	50.8	292	58.3	763	67
70	44	57.9	230	60.2	822	174
80	45	64.5	185	61.3	861	256
90	45	70.6	158	62.5	892	308
100	46	76.5	138	62.9	915	340
110	46	81.5	121	63.4	934	366
120	47	86.1	111	63.8	949	380
130	47	89.9	101	64.1	960	395

In these tables, Total Volume was the volume of stemwood to the top of the tree, whilst Merchantable Volume was based on the actual gross measure of logs recovered from sample trees felled, using the then current standard local practice: 1m stump; 15cm trimming allowance per log; minimum centre diameter underbark of 44cm (centre girth of 4ft 6 in), equivalent to a top diameter of about 40cm.

As Lindsay comments, Alpine Ash *"is shown to be a species of high increment in height, diameter, basal area and total volume."* Indeed it is remarkable that the species that forms the altitudinal limit of commercial forest production in southeastern Australia, under conditions of a limited growing season and soils that are far from being the country's most fertile, is among our most productive eucalypts.

The tables show several notable features:

1. Stocking, which tends to be higher at any age on the poorer sites, shows a rapid decline, particularly during the first 3 or 4 decades of growth.

2. Height growth is rapid, with half the mature height being reached by about age 20 years, and three quarters by age 40 years.

3. Mature height of dominants varies with site index, and ranges from slightly less than 40m to about 60m under the conditions at Bago.

4. Diameter growth is extremely high, and is well maintained on trees of average DBH for about 80 years. (Some 40-47 per cent of the trees in any stand were of, or above, the mean DBH for the stand.) The larger trees, of course, grow more rapidly, and Lindsay, by pooling his data from all plots, showed that by age 80 years the most rapidly growing trees had a DBH of about 90cm when growing in well stocked stands.

5. Total volume production is high, and can exceed 1 000 m^3/ha in mature stands on the better sites. Oddly, regardless of site the total volume MAI peaks at about age 35 years, with values ranging from 9.3 m^3/ha/year on SI 100 ft. to nearly 20 m^3 on SI 160 ft.

6. Gross merchantable volume production inevitably reflects the utilisation standards of the time: in comparison with the 44cm c.d.u.b. used by Lindsay, quota logs in 1960 were those exceeding 30cm c.d.u.b. (Forestry Commission of N.S.W., 1960). On Lindsay's standards, total merchantable volume reached about 400 m^3/ha in untreated mature stands of average site (SI 130 ft), with MAI peaking at about age 90 years at 3.4 m^3/ha/year. Better sites showed a higher MAI at a slightly earlier age (5.6 m^3/ha/year at age 80 for SI 160 ft.), and poorer sites a lower MAI, peaking later (1.7 m^3/ha/year at age 120 for SI 100 ft.).

Although by using his plot data Lindsay was able to distinguish a range of site qualities, in his fieldwork only two qualities were recognised, using a combination of two factors - mature stand height and the presence of an indicator species. Veronica, an easily recognised shrub whose presence (unlike Hop Bitter-Pea and Wattle) was not dependent on fire, was found to have a fair correlation with the better than average sites. However the correlation was not complete, and a compromise basis of site quality determination was used:

- Veronica present: SQI, unless mature stand height under 43m.
- Veronica absent: SQII, unless mature stand height over 49m.

Lindsay noted that though the use of a height division (say 46m) might have seemed simpler, the easy recognition of Veronica made it simple for field parties to take it as the basis, and then check height, while it could also be used where mature trees were absent.

The Bago study came up with much other information about the growth of Alpine Ash stands. Among the more pertinent items were:

1. Although Ash frequently occurred in association with other eucalypts, this often appeared to reflect chance events related to fire, and Lindsay believed that there was *"no reason why, under managed conditions, the greater part of the Ash type should not carry continuous pure stands of Alpine Ash."*

2. Stem form in Ash was not particularly good, though the effects of bends could often be minimised when trees were cut into logs.

3. Damage by termites, fungi and fire considerably decreased the merchantable volume available in unthinned stands.

4. It was found that the ratio of dominant height/stand BA gave a value that varied little for any site index, rising slightly with age and with increasing site index.

5. The average height of the rough bark on dominant stems proved to have, for certain ages, as good a correlation with total volume as did the average height of

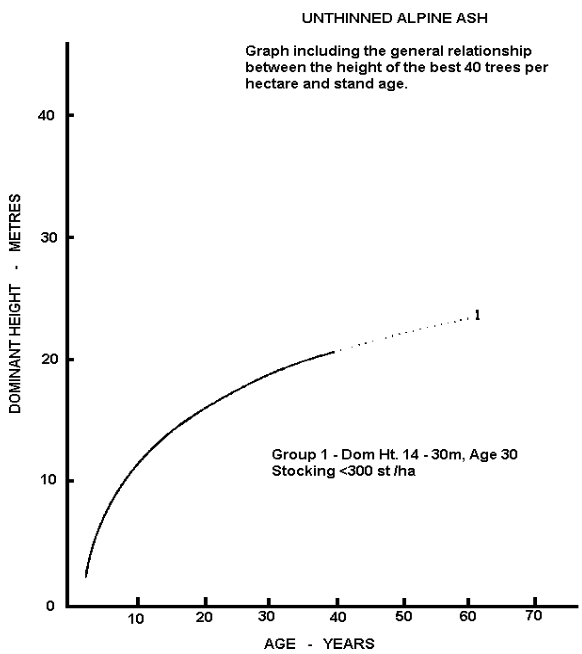
the dominants, and it appeared to be independent of stocking. However above about age 50 years it behaved irregularly, and indeed tended to diminish in the case of trees over 60 years of age. On average the rough bark made up about 36 per cent of the total height at 15 years, rising to about 47 per cent at 40 years and then diminishing to about 34 per cent at 130 years.

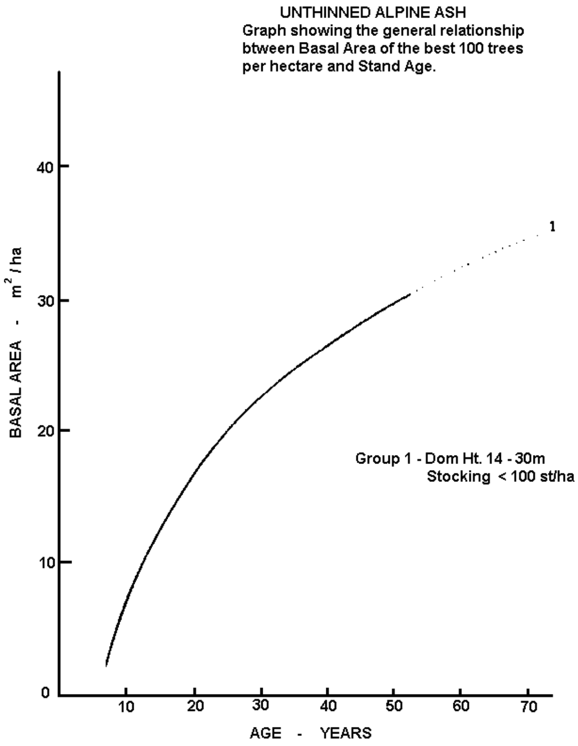
6. Three crown classes were recorded in the study - dominant, dominated and suppressed - along with the presence of dead trees. To age 10, dominated and suppressed made up most of the stems, but by age 30 dominants formed the largest class and thereafter the percentage of dominants constantly increased and by age 100-120 years exceeded 50 per cent. The percentage of dead trees was at its maximum at about age 30 and thereafter decreased.

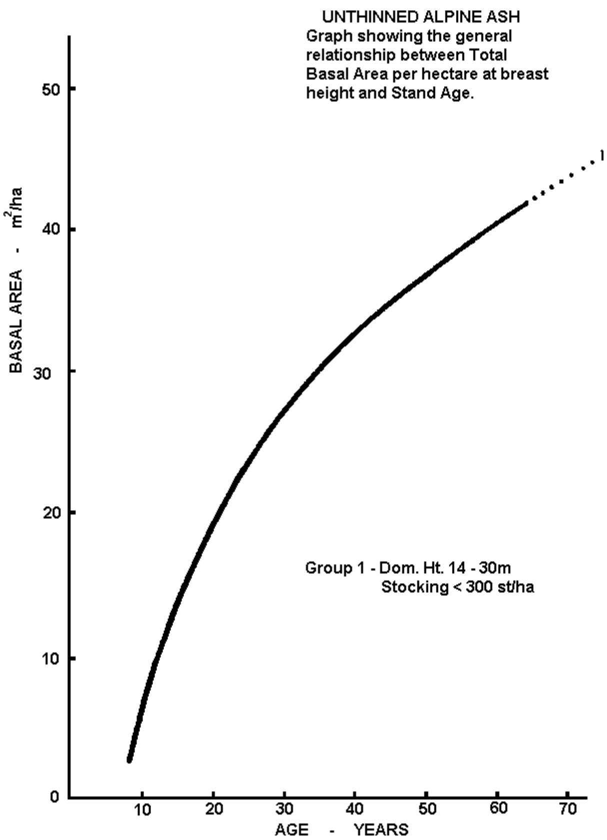
Whilst Lindsay's study was specific to Bago S.F., closely similar growth-age relationships were found in untreated, even-aged stands in the Marysville district of Victoria, suggesting that the Bago findings could be applied fairly directly to these more southern stands (Forests Commission, Victoria, 1967).

More recent growth-age relationships from Bago S.F., developed from unthinned experimental plots, are portrayed in Figure 2. These represent lower quality sites than most of Lindsay's plots.

FIGURE 2 GROWTH AGE RELATIONSHIPS, BAGO S.F.
(provided by Mr R.R. Horne, W.T.F.R.D.)




UNTHINNED ALPINE ASH
Graph showing the general relationship btween Basal Area of the best 100 trees per hectare and Stand Age.
BASAL AREA - m² / ha
0
10
20
30
40
10
20
30
40
50
60
70
AGE - YEARS
1
Group 1 - Dom Ht. 14 - 30m
Stocking < 100 st/ha


UNTHINNED ALPINE ASH
Graph showing the general relationship between Total Basal Area per hectare at breast height and Stand Age.
BASAL AREA - m²/ha
0
10
20
30
40
50
10
20
30
40
50
60
70
AGE - YEARS
1
Group 1 - Dom. Ht. 14 - 30m
Stocking < 300 st/ha

7.2 Growth in Managed Stands

Lindsay's study was confined to unmanaged, unthinned stands, mostly originating from fire but in some of the younger stands resulting from logging openings. Lindsay, in his report, discusses the significance of his findings to managed stands, but the discussion is of a distinctly theoretical nature.

Since Lindsay's time the Alpine Ash stands on Bago S.F. have developed into some of the State's most intensively managed native forest areas. Utilisation standards are good, and regeneration is obtained essentially by group selection, thus perpetuating the mosaic of even-aged stands noted by Lindsay. Current management seeks to treat *"all Ash areas equally, and the objective is to universally thin all the forest from below, thus retaining all vigorous stems in all logging areas regardless of size"* (Clements, 1985). Under these conditions the dense stands studied by Lindsay are replaced by stands where individual stems tend to be more widely spaced and freely growing.

Growth in these stands has been followed in a series of continuous inventory plots established in 1958 and remeasured in 1971 and 1982. The results have been used in management investigations, but the plot data have unfortunately not been subject to the type of comprehensive analysis given to the Yarratt S.F. C.F.I. plots by R.A. Curtin. However earlier diameter growth in these plots has been summarised by diameter and crown classes, and the results are shown in Table 7. The data for Alpine Ash have been used to allow the graph4cal estimation of mean DBH for all stems and for dominants at various ages, and these results are shown in Table 8, with the heights from Mountain Gum dominants and SI 130 ft. yield table (Table 6) included for comparison. (In the graphical transformation it was assumed that 20 years were required for the average "All stems" Ash to reach 20cm DBH, 15 years for the average dominant Ash, and 30 years for the average dominant Gum.)

It can be seen that little difference exists between Lindsay's yield table and the C.F.I.-based estimates of diameter at different ages for all stems. This is somewhat surprising, but in part at least reflects Lindsay's table representing rather idealised conditions whereas the C.F.I. plots sample the distinctly varied stand conditions of the field. Dominants, as expected, show appreciably more rapid growth than the stand as a whole, and Mountain Gum shows much slower growth than Alpine Ash.

Table 7

INCREMENT IN DIAMETER CLASSES ON STATE FOREST
(from C.F.I. plots, 1958-71)

Diameter Class:	20-30 (cms)	30-40 (cms)	40-50 (cms)	50-60 (cms)	60-70 (cms)	70-80 (cms)	80-90 (cms)	90-100 (cms)	100+ (cms)
Alpine Ash									
Dominant	1.11	1.06	1.04	.98	.97	.96	.75	.69	.58
Codominant	.84	.79	.74	.86	.79	.74	.72	.32	.75
Subdominant	.71	.66	.66	.74	.75	.65	-	-	-
Suppressed	.55	.51	.44	.38	.48	-	-	-	-
All Stems	.77	.77	.75	.87	.83	.86	.74	.59	.62
Mountain Gum									
Dominant	.69	.66	.55	.60	.51	.63	-	-	.68
Codominant	.52	.59	.50	.52	.55	.85	-	-	-
Subdominant	.43	.37	.42	.43	.55	-	.40	-	-
Suppressed	.31	.18	.26	.15	-	-	-	-	-
All Stems	.48	.47	.46	.48	.54	.74	.40	-	.68

Table 8

DIAMETER/AGE RELATIONSHIPS - BAGO S.F.

Age	Alpine Ash			Mountain Gum
	Yield Table (SI 130ft)	**All Stems** (CFI)	**Dominants** (CFI)	**Dominants** (CFI)
20	16	20	26	13
30	25	28	37	20
40	35	36	47	26
50	43	44	57	32
60	51	51	67	39
70	58	59	76	45
80	65	67	85	51
90	71	76	92	56
100	77	83	99	62

Lindsay stressed the point that Alpine Ash is a species that shows *"rapid and sustained diameter growth in dense stands",* that sorts itself out most effectively into dominance classes, and that markedly reduces stocking through natural thinning with developing age. Nonetheless he found evidence that early wide spacing would produce still faster growth in retained dominants, but pointed out that at young age (under age 10), light thinning produces little response, whilst heavier thinning leaves the stands open to snow damage and to the development of epicormics on the upper, smooth part of the stem (at age 20 years the rough bark only extends to a height of about 10m). He recommended a first thinning to about 370 good form dominant 60 stems per hectare at age 30 years, though he considered that a new crop of seedlings would almost certainly develop beneath the stands at this spacing and that ideally these (and any Mountain Gum regrowth) should be removed. No markets were envisaged for any of the stems removed in these operations. In the event, periodic small timber markets (e.g. mining timber, wood wool and, most recently, medium density fibreboard) have been used to give many of the regrowth stands on Bago an early commercial thinning.

Growth responses in a series of thinning trials established on Bago S.F. have been followed over a period of 30 years (from age 30 to age 60 years). In a 1986 review of the results, carried out by a trainee (G. Sonter) under the oversight of R. Horne, a number of trends were identified:

1. Unthinned Ash stands showed a high level of mortality - from 900 trees per ha at age 30 to 500/ha at age 40. These values correspond closely with those obtained by Lindsay in his yield table for Site 140 ft. (see Table 6)

2. The larger stems in the stands (50 largest DBH trees per hectare) always showed a greater response to thinning from below than did the smaller stems. This is in contrast with the responses shown by Blackbutt and, more particularly, Flooded Gum.

3. The diameter response from thinning the stand to 250-350 stems per ha at age 30 years was an average increase of 6-9cm per tree over comparable trees in the unthinned plot for the largest 50 trees per ha, and of 0.5-2cm per tree for the next largest 100 trees per ha, by age 60 years.

4. The diameter response growth indicated that the optimum time for a second thinning is about 15 years after the first thinning at age 30 years.

5. Ash responded well to thinning from above. Some plots inadvertently thinned from above at age 42 showed a mean diameter response of 6cm per tree more than the control over the subsequent 18 years.

Thinning response in young Alpine Ash stands has also been studied in Victoria. One trial involved the thinning, at about age 25 years, of regrowth from the 1939 fires. The regrowth occurred on three site qualities (roughly equivalent to Lindsay's SI 120, 140 and 160 ft), and was thinned to three intensities with residual BA's of 16, 23 and 30 m^2/ha. After 4 years BA increment showed the typical plateau relationship with residual BA, increment being lost where the thinning intensity left less than half the original BA. The greatest response was obtained on the best sites, with BA increments up to 1.95 m^2/ha. Diameter growth on the 75 largest trees per hectare showed a consistent increase related to the intensity of thinning, again with response greatest on the highest site quality, where mean diameter increments of 2.2 cm/year were obtained, compared with 1.1 cm/year on the unthinned plots. Highest volume increments were attained where about half the initial BA was retained, and reached 26 m^3/ha/year (Incoll and Webb, 1970).

Earlier thinning, in 6 and 7 years old regrowth, has also been examined (Forests Commission, Victoria, 1964a; Incoll, 1972). Growth response at age 15 years, metricated by Borough et al. (1978), is shown in Table 9.

According to Incoll (1977), thinning of this nature has the potential to reduce sawlog rotations to between 30 and 40 years - a similar period to that suggested by Lindsay in the extrapolation of his findings to some managed stands. However recent work in Victoria suggests that the wood quality of Ash is much lower in logs obtained from widely spaced stands (R. Squire, pers. comm.), suggesting that heavy and early thinning treatments should be approached very cautiously.

Table 9

THINNING RESPONSE IN ALPINE ASH

(Thinned at age 7 years; growth to age 15 years - after Incoll, 1972; Borough et al, 1978)

Treatment	**Mean DBH of largest trees** (cm) (a)	**Standing merchantable volume** (m^3/ha) (b)
Unthinned (4200 stems per hectare)	21	155
200 stems per hectare retained	25	192
100 stems per hectare retained	26	135

(a) The 74 largest DBH trees per hectare
(b) Underbark volume to 10cm small-end diameter

Volume production in managed Ash stands shows the usual disparity between the results obtained from research and study plots and those applying to the broad area forest.

Lindsay's average (SI 130 ft) unthinned stand showed a maximum MAI for total volume of 14.3 m^3/ha at age 40 years, whereas the maximum merchantable MAI was only 3.4 m^3/ha, reached at age 90. Increments shown cm/year by Incoll's thinning plots (Table 9) range at age 15 years from 9 to 12.8 m^3/ha/year, measurements being effectively the same basis as Lindsay's total volume but probably on a better quality site. By comparison the current quota yield from Bago S.F. is about 1.1 m^3/ha/year, though recent cutting cycle analysis suggests that the yield could ultimately be sustained at nearly 3 times this level - a similar level to the gross merchantable MAI calculated by Lindsay, though to much improved utilisation standards and from treated stands.

The Bago-Maragle management plan (Forestry Commission of N.S.W., 1980) contains rules for the marking of Ash stands, aimed at fostering the retention and growth of the most vigorous stems and at the creation of regeneration openings. These rules are given in Appendix 5 and represent the essence of experience in the management of these stands over nearly half a century.

7.3 Size and Longevity

Boland et al. (1984) state that Alpine Ash can occasionally reach heights of 90m with stem diameters of 2-3m. These larger sizes are considerably greater than any known in N.S.W., and appear to relate to stands in Tasmania. From Victoria, Grose (1961) describes how, on the better sites, it grows to heights of 75m and over, with diameters up to 3m and merchantable log lengths to 43m. *"Gigantea"* indeed!

Lindsay's detailed survey on Bago S.F., which is probably the best growing site for Alpine Ash in N.S.W., revealed one tree 62m tall in a stand aged about 90 years, whilst the largest diameter was 142cm in a stand aged about 130 years. These dimensions closely approximate those of current largest known Ash on Bago S.F. In 1975 this tree (near Reids Road, in the Granites Section) had a height of 59m, a DBH of 140cm, and a height to crown of 40m.

O'Dowd and Gill (1984) misquote Jacobs (1955) as suggesting that Alpine Ash has a longevity of 200-400 years. In fact in N.S.W. (and probably also Victoria, but possibly not Tasmania) the oldest stems are substantially younger than this, and Lindsay notes that the oldest material encountered in his survey at Bago was the stump of a felled tree showing about 160 rings; otherwise few if any trees exceeded about 130-140 years. In Tasmania, Ellis (1985) notes that in an area of rainforest burnt 130 years previously and regenerated with Ash and rainforest species, very few eucalypts now survive: the pattern was for decline to commence after about 50-60 years, with most Ash trees dying over the next 20-25 years. By contrast some trees that regenerated in grassland plains and subsequently served as the parents of slowly expanding clumps of Ash are in the age range 170-190 years. From the same general area, Ellis (1980) notes a study area where the *"age of the mature trees was estimated to range from 200 to 350 years."* Nonetheless, in comparison with most of the commercially important eucalypts, Alpine Ash is very much a sprinter - particularly in N.S.W.

8. DAMAGE TO OLDER STANDS

The Alpine Ash types, like other forest types, are subject to damage from a wide array of agencies, though in N.S.W. only three of these - fire, phasmatid and termite - appear to be of major significance.

The Ash types are well attuned to their environment, and little in the way of damage to established stands by **climatic agencies** normally occurs. Isolated patches of dead trees occurred following drought conditions near Laurel Hill, at the westernmost limit of Ash occurrence in N.S.W. Turnbull and Pryor (1978) note that E.W. Pock reported similar drought damage to Alpine Ash in the A.C.T. during the 1965 drought.

Ash is one of the best eucalypts for resistance to snow damage, but can suffer damage during severe storms. Cremer (1983) examined extensive areas of highland forest in southeastern Australia following a heavy snow storm in June, 1981, and recorded widespread damage in the subalpine stands, primarily of Alpine Ash and Snow Gum types, including particularly the uprooting of older trees and branch breakage, which usually occurred at a small distance from the point of branching, rarely at the crotch itself. Cremer suggests that the ecological effects of the storm were probably less than those of a low intensity fire, but with relatively more disturbance to the trees, and less to the undergrowth, than would occur from fire.

As noted in earlier sections, fire is a major ecological factor in the occurrence of Alpine Ash, and to a large extent in Nature controls the establishment of its regeneration. It is also a major factor in the production of gum veins, which can mar and reduce the value of timber in Alpine Ash. Bowman and Kirkpatrick (1986a), working in Tasmania, found Ash trees to be fairly fire-hardy:

> *"In ... severely burnt forest no crown escaped undamaged, although 77% of the trees subsequently recovered fully and only 6% were killed. Most of the larger trees which died succumbed to stem failure as a result of damage to their butts during this and previous*

fires, whereas the smaller trees which died did so standing. Butt damage is common in the forest and is related to the presence of large fuel accumulations near the base of the tree."

By contrast, on the mainland Alpine Ash is regarded as a relatively fire-sensitive species: the difference may in part reflect the greater amount of rough bark found on the Tasmanian trees. N.S.W. experience is that light fires will kill young regeneration, while a severe fire will kill mature stems. O'Dowd and Gill (1984) observe that 91 per cent of Ash trees in the area in the A.C.T. burnt by a high intensity experimental burn were killed outright, and no trees with complete leaf scorch showed any signs of recovery; in comparison, only 11 per cent of other eucalypts in the burnt area (Mountain Gum, Manna Gum and Narrowleaved Peppermint) failed to resprout. Fires of lesser intensity will cause damage to the older stems, usually showing up as butt damage, associated with gum vein formation in the wood. The fire damage can expose the trees to later windblow and to insect and fungal attack.

Fire itself may be fairly common in the Ash types: Clements (1985) reports some 40 fires resui$_4$ting from lightning strikes in the space of two days during the 1984-85 summer, but with little damage due to the mild conditions and prompt, if hectic, suppression. However blow-up conditions appear fortunately rare. To minimise the risks from fire, top disposal burning is normally carried out after logging in the Bago-Maragle area, and areas outside the Ash types are spasmodically burnt to reduce fuel levels; under safe conditions, light hazard reduction burning may also be countenanced under the older Ash stands.

The most spectacular damage to Alpine Ash and associated forest types in N.S.W. in recent decades has been caused by a **phasmatid**, *Didymuria violescens*. Plague outbreaks were first reported from Bago in the summer of 1952-53, recurring at 2-yearly intervals over increasing areas until 1960-61, and then contracting (Shepherd, 1957; Readshaw and Mazanec, 1969); the plagues also spread south into Victoria. The pest was intensively studied during the 1950's and '60's (above papers; Mazanec 1966, 1968; also other references quoted by Carne and Taylor, 1978).

Briefly, the life cycle is as follows. The eggs hatch in the spring and early summer (October-December) and the young nymphs climb and settle on the nearest eucalypts. There are five nymphal instars, each lasting from one to three weeks, depending on temperature conditions. First and second instar nymphs eat only the youngest leaves, causing apical defoliation ("brooming") of the host trees when numbers of *D. violescens* are high. Later instar nymphs eat older leaves and may completely defoliate their host trees. Adults appear between January and March; each female lays about 200 eggs that drop one at a time to the forest floor. A few of the eggs hatch during the following spring and early summer (one-year eggs), but most of the insects have a two-year life cycle and hatching occurs about 18 months after oviposition. The outbreaks of *D. violescens* are largely confined to areas where the two-year life cycle predominates. The hatching of eggs in very high and very low numbers in alternate years, results in marked defoliation every second year and little defoliation in the intervening year. (Mazanec, 1966).

All local eucalypts in plague areas were attacked, with Mountain Gum and Peppermint preferred. After the first outbreak it was found that defoliated Mountain Gum produced vigorous epicormic growth the following spring, whereas Alpine Ash showed no signs of recovery: salvage logging of the Ash then occurred. Subsequently it was found that much of this salvage was premature, as the recovery of defoliated Alpine Ash cannot be assessed until about February. Nonetheless mortality in severely affected areas was high, and Shepherd (1957b) records about 66 per cent death in badly damaged parts of the 1917 regeneration area on Bago. Readshaw and Mazanec (1969) concluded that damage from phasmatids at Bago produced an average loss of 20 per cent of the expected diameter growth over the period of 16 years that serious outbreaks occurred, with a reduction of 56 per cent occurring in 1962.

There was disagreement over the cause of the outbreaks, though changed fire incidence appeared to be implicated, and there is some evidence that plague proportions are more likely to build up under the dense canopy of unthinned stands than under more open stands. Parasitism to eggs was largely responsible for the end of the plagues. During the height of the outbreak there was doubt about the ability to continue to manage Ash stands for sustained timber production, and some spraying was carried out as a control measure.

Less spectacular, but more chronic, is the damage caused by the alpine **termite**, *Porotermes adamsoni*. This has been studied by Greaves (1959) and Greaves et al. (1965). Attack is initiated through bark injury, usually as a result of fire damage, and can occur from ground level to the crown of the tree. The development of the colony is assisted by the presence of rot (Lenz et al., 1982), and attack is limited to the one tree: it does not spread to neighboring trees from the one colony. There is no central nursery, and the colony will develop slowly over many years, with attack being most serious in the older trees. In a study at Bago, Greaves et al. (1965) found that defect, attributable primarily to termites, resulted in a royalty loss of $189/ha, equivalent to over half the royalty actually obtained from the logging of a virgin stand. In comparison, in logging in the 1917 regeneration area defect caused a royalty loss of only $32/ha, about a fifth of the royalty value obtained from the operation in this younger stand. Most of the defect in the younger stand came from veteran seed trees that had been retained. Greaves and his colleagues suggested that in regrowth stands, protected from fire, losses from termite and decay should be relatively small.

This study by Greaves et al. apportioned volume losses due to defect to fire, termite and **fungal decay**. Termites produced the greatest loss - 56 to 81 per cent of total volume loss. Decay losses ranged from 13 to 36 per cent in different compartments, and fire losses were a relatively minor 0.5 to 4.6 per cent. (Other losses came from poor form and breakages in felling.) Although direct fire losses were small, fire was indirectly responsible for allowing most ingress by termites and decay agencies: minimise fire damage and termite attack becomes of minor importance.

Carne and Taylor (1978) mention a number of other **insects** that have caused damage in Alpine Ash types, but none of these appear to be of more than local and temporary significance in N.S.W.

Native Cherry occurs in the understorey of some Ash stands, and probably has some effect on the growth and health of nearby trees. It is reported as adversely affecting Mountain Gum in the A.C.T. (Jehne, 1972).

In parts of Tasmania extensive dieback and death of Alpine Ash have occurred in both mature and immature stands, and have become known as **altitude dieback** (Ellis, 1964, 1980, 1981). The condition appears to be associated with an absence of periodic burning and the development of a dense understorey of rainforest species. Felling and burning the understorey has been found to produce recovery in the eucalypts.

9. PRESERVATION

As noted in section 3, Alpine Ash types have an unusually high level of preservation in N.S.W., with possibly three quarters of the total area lying within the Kosciuszko National Park. Because of this, only limited preservation of the types has been undertaken on State Forests, with one Flora Reserve notified:

> **Bago Flora Reserve No. 79980 Bago S.F.** 27 ha. Alpine Ash to 45m with some Mountain Gum, and with Snow Gum at higher levels. Blackwood in gullies. Part of stand approaching age limit and showing signs of tree deterioration.

The large tree of Ash, mentioned in section 7.3, has been reserved for the remainder of its life.

10. MANAGEMENT ASPECTS

10.1 Objectives

The indigenous forest policy for N.S.W. (Forestry Commission of N.S.W. 1976) exempts the Alpine Ash types from the low activity guidelines laid out for tableland forests generally:

> *"The exception to these provisions is the Alpine Ash forest that should continue to be managed for production of hardwood sawlogs. This management should encourage the extension of the Alpine Ash type onto suitable sites."*

This policy was designed around long standing management practice in the Ash types, and offers no conflict with it.

10.2 Management Practices and Problems

In N.S.W., Alpine Ash types have proved extremely amenable to management. They regenerate readily following logging under both group selection and clear cutting systems; they show rapid growth; they respond to thinning; although relatively fire sensitive, fire protection is rarely a major problem in the main commercial stands; the timber of Ash itself has a wide range of uses, is much sought after, and produces one of the highest nett returns of any N.S.W. hardwood; management accounts for Bago S.F. show a healthy surplus, which more than covers the losses from Maragle S.F. stands.

Problems and uncertainties tend to be minor compared with most of the State's major forest types. The most important of these appear to be:

- Refining yield calculations.
- Improving utilisation of small stems.

Other problems, mostly indicated by elements (1985), include:

- Development of thinning regimes for even-aged stands. Effects of cattle grazing on swamp areas within the forests.
- Feasibility of further extension of Ash into current non-Ash areas.
- Role of fire in management practices - for regeneration, phasmatid control, etc.
- Improved data on fauna and flora, and particularly on the effects of management on wildlife.
- Significance of blackberry on regeneration.
- Desirability of re-establishing Alpine Ash in some of the higher altitude "other species" conifer plantations, at the northern end of Bago S.F., at the end of the conifer rotation.

Some of these would be fitting topics for further research if or as the opportunities arise.

10.3 Guidance Points

These excessively voluminous Notes outline many of the matters known to influence the silviculture of the Alpine Ash stands. In this section, what are considered to be the most significant of these in relation to the management of Alpine Ash in N.S.W. are highlighted.

1. Alpine Ash has a limited occurrence at high altitude in N.S.W. Its lower level may well be determined by the availability of winter conditions for seed stratification, and its upper limit often appears to be determined by exposure. It is almost certainly absent from some suitable areas because of past fire regimes, and with adequate protection efforts to extend its range into such suitable sites are justified.

2. In Nature, regeneration is almost entirely dependent upon fire that will kill young regrowth and, under conditions of high intensity, even stands of mature trees.

3. Ash is non-lignotuberous and coppices poorly.

4. Flower buds develop for up to 2½ years prior to flowering in late summer, and capsules may be present for a further 2 years before seed shed commences, though the seed may be ripe much earlier.

5. In dense stands of regeneration, suppressed stems can be found carrying capsules with viable seeds by age 7 years.

6. In more mature stands seed is mostly borne on dominant and co- dominant trees.

7. Substantial reserves of seed are usually present in the crowns of mature stands. This may contribute to low-level seed fall for up to 4 years from any one seed crop, mostly occurring in late summer and autumn, or it may be shed in a single massive event following fire or sap-ringing.

8. Much seed is shed in falling capsules, but this makes only a minor contribution to subsequent regeneration.

9. Much of the seed on the ground is removed by ants: one effect of fire-induced seed fall is to swamp the capacity of ants to remove the seed.

10. Effective seed shed tends to be limited to a distance of about 40-50m from the source: in clear cutting, seed trees should be retained at a spacing of about 80m.

11. The seed requires stratification for effective germination, and this is provided by winter snowfalls. The few autumn germinates do not usually survive the winter. Under controlled conditions, moist storage at 5-7ºC for 4-8 weeks gives the best results.

12. The dormancy of unstratified seed can be strengthened by adverse conditions (e.g. high temperature or high moisture conditions), and after stratification secondary dormancy can be induced if unfavourable conditions for germination occur (notably low moisture content). In practice, unstratified seed sown in autumn should be used for direct seeding with Alpine Ash, but stratified seed sown in late spring should be used in nursery sowings.

13. Following field stratification, germination occurs in the late spring. Best results are obtained on burnt or mechanically disturbed seedbeds; heavy grass cover is most unfavourable.

14. Where heavy grass is likely to be a problem, burning should be attempted and a heavier than usual overwood canopy retained in an effort to limit severe frosting and to weaken grass growth.

15. Seedlings show considerable tolerance of frost.

16. Seedlings are intolerant with respect to light and competition, and successful regeneration establishment is usually confined to openings of 40m or more diameter, although satisfactory growth can be obtained to within 5-6m of the base of retained seed trees.

17. In contrast to Alpine Ash, its main associates are lignotuberous, coppice strongly, and are more tolerant, but tend to be less fast growing.

18. Small scale open-root plantings and direct seedings have been successfully used in N.S.W. to extend Ash into sites from which it has been absent. Aerial seeding, using pelletted seed on burnt sites, is the main regeneration technique used for Alpine Ash in Victoria and Tasmania.

19. In N.S.W. regeneration is usually obtained following logging on sites where, if practicable, top disposal burning has been carried out. Logging may be either in the form of group selection or clear cutting.

20. Although subject to a number of damage agencies, reasonable survival can usually be expected from regeneration established in favourable sites, and very dense stands may occur.

21. Growth can be rapid, with dominants exceeding a metre in height a year from the first few years.

22. A rapid segregation into crown classes occurs in developing clumps of regeneration, and the rate of mortality among the weaker plants is high. This rapid decline in stocking may continue for 3 or 4 decades.

23. Mature stand height in the N.S.W. Ash types ranges from about 40m on the poorer sites to 60 m on the best. About half this height is attained by age 20 years; and three quarters by age 40 years.

24. Even in unmanaged stands dominant stems retain a fast rate of diameter growth for up to 80 years, with the fastest stems averaging over 1cm diameter growth a year over this period on average sites.

25. The longevity of Alpine Ash in the N.S.W. forests appears to be about 160 years, with the largest trees attaining heights of about 60m and DBH of about 140cm: it is a relatively short-lived, though fast-growing, tree that attains large, but not massive, dimensions in N.S.W. In Tasmania it reaches both larger size and greater age.

26. Veronica can be used as an indicator of the better quality Ash sites in the N.S.W. commercial stands.

27. The growth of Ash stems can be speeded up through thinning, though thinning at an early age (under 15 years) can result in snow damage, and wide spacings may cause much epicormic growth on retained stems, promote a fresh regeneration establishment and result in lower quality timber.

28. Present indications are that the Bago stands can sustain a gross sawlog yield of about 3 m^3/ha/year.

29. Apart from fire, the major damage agencies of Alpine Ash stands in N.S.W. have been termites and phasmatids. Termite damage appears to be a feature of old stands, and it can be kept to a low level in regrowth areas receiving adequate fire protection. Phasmatids appeared in epidemic proportions in the 1950's and 1960's, since when populations have been kept at a low level by natural parasitism

of the eggs. Causes of the outbreak still do not appear to be well understood.

Management of the Alpine Ash stands in N.S.W. needs to take place within the constraints offered by these silvicultural characteristics of the stands.

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H. Drielsma
R.Horne
R. Riddell

together with a number of other unidentified officers from W.T. & F.R.D.

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Appendix 1

BOTANICAL NAMES OF SPECIES MENTIONED IN TEXT

(Eucalypt coding after Pryor and Johnson, 1971)

Common Name	Botanical Name	
Ash, Alpine	Eucalyptus delegatensis	MAKBE
Blue Mountains	E. oreades	MAKDA
Mountain	E. regnans	MAKCA
Barrel, Brown	E. fastigata	MAKCB
Beech, Myrtle	Nothofagus cunninghamii	
Bitter-Pea, Hop	Daviesia latifolia	
Blackwood	Acacia melanoxylon	
Bracken	Pteridium esculentum	
Cherry, Native	Exocarpos cupressiforrnis	
Fern, Tree	Dicksonia antarctica	
Grass, Snow	Poa spp.	
Gum, Cider	Eucalyptus gunnii	SPINI
Manna	E. viminalis	SPIKK
Mountain	E. dalrympleana	SPINC
Mountain Grey	E. cypellocarpa	SPIFE
Shining	E. nitens	SPIFG
Snow	E. pauciflora	MAKHA
Alpine	E. pauciflora ssp. niphophila	MAKHAC
Tasmanian	E. coccifera	MATES
Urn	E. urnigera	SPINL
Yellow, Alpine	E. vernicosa ssp. subcrenulata	SPIJAB
Hop Bush (see Bitter-Pea, hop)		
Messmate	E. obliqua	MAKMA
Peppermint, Narrowleaved	E. radiata (and especially ssp. robertsonii MATELC)	MATEL
Pepper tree	Tasmannia aromatica	
Sallee, Black	Eucalyptus stellulata	MAKMA
Teatree	Leptospermum spp.	
Veronica	Parahebe (syn. Veronica) derwentii	
Wattle	Acacia app.	
Silver	A. dealbata	

Appendix 2

CLIMATIC DETAILS - ALPINE ASH TYPES

JOUNAMA: **Latitude** 35°39'S **Longitude** 148°28'E **Altitude** 1 020m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
77	68	86	97	113	135	134	153	117	142	102	81	1304

Lowest Annual: 751 mm Highest Annual: 1962 mm

Temperature

Hottest Month: Mean Min : 5.3°C (Jan) Mean Max: 26.2°C
Coldest Month: Mean Min: -3.7°C (Jul) Mean Max: 7.2°C
Highest recorded: 38.3°C Lowest recorded: -12.8°C
No. over 32°C: 3 days Over 38°C: less than 1 day
Av. No. Frosts/Year: 184 Av. Frost-free period: 19 days /year

PILOT HILL: **Latitude** 35°37'S **Longitude** 148°9'E **Altitude** 1 150m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
74	75	101	102	124	161	171	158	129	140	98	80	1419

Lowest Annual: 749 mm Highest Annual: 2062 mm

Temperature

Hottest Month: Mean Min : 10.3°C (Feb) Mean Max: 23.2°C
Coldest Month: Mean Min: -1.5°C (Jul) Mean Max: 6.6°C
Highest recorded: 38.1°C Lowest recorded: -8.9°C
Av. No. Frosts/Year: 100 Av. Frost-free period: 58 days /year

CABRAMURRA: **Latitude** 35°56'S **Longitude** 148°23'E **Altitude** 1463m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
92	63	90	111	178	145	205	208	149	169	128	99	1637

Temperature

Hottest Month: Mean Min : 9.3°C (Jan) Mean Max: 19.2°C
Coldest Month: Mean Min: -1.4°C (Jul) Mean Max: 3.5°C

ISLAND BEND: **Latitude** 36°19'S **Longitude** 148°29'E **Altitude** 1 250m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
62	53	81	87	105	141	138	134	134	149	132	113	1329

Temperature

Hottest Month: Mean Min : 6.5°C (Feb) Mean Max: 22.3°C
Coldest Month: Mean Min: -3.1°C (Jul) Mean Max: 5.8°C

LAUREL HILL: **Latitude** 35°39'S **Longitude** 148°4'E **Altitude** 1 006m

Rainfall (mm)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
134	66	67	140	118	108	115	169	132	106	122	83	1360

Temperature

Hottest Month: Mean Min 12.3°C (Jan) Mean Max: 23.5°C
Coldest Month: Mean Min: 1.5°C (Jul) Mean Max: 7.7°C

Appendix 3

PROPERTIES OF MAJOR TIMBER SPECIES: ALPINE ASH TYPE
(Derived from K. R. Bootle: 'Wood in Australia')

Abbreviations: L-S, Lyctid susceptible; G, green; A, air-dried (re density) density)

Common Name	Ash, Alpine	Gum, Manna	Gum, Mountain
Botanical Name	Eucalyptus delegatensis	Eucalyptus viminalis	Eucalyptus dalrympleana
General Properties	Pale pink or pale yellowish, sapwood wide, not clearly, distinguishable. Texture moderately coarse; grain usually straight, occasionally wavy. Gum veins common prominent annual growth rings.	Pale pink or pinkish brown; sapwood wide, not distinct. Texture medium and even; grain variable; prominent growth rings.	Similar to Manna Gum, grain usually straight.
Density kg/m³	G: 1050 A: 620	G: 1100 A: 750	G: 1100 A: 700
Durability	4 Sapwood rarely attacked by Lyctids .	L-S Heartwood not sufficiently durable for exposed use.	L-S Heartwood not sufficiently durable for exposed use.
Strength	S4 SD4	S4 SD4	S4 SD5
Sawlog Group	B	C	C
Uses	Very useful and versatile furniture, plywood, joinery, panelling, flooring, oars, skis, handles, cooperage, general construction. An important pulping species in Victoria and Tasmania. Easy to work; satisfactory for steam bending; glues well.	Internal joinery, furniture, panelling, flooring, handles plywood. Not difficult to work; glues well; may need pre-drilling when nailed near ends of boards	General construction, joinery, flooring, handles.
Other Notes	Care needed in drying – collapse, internal checking, surface checking on tangential surface.	Difficult to work without degrade - internal honeycombing, surface checking, collapse.	Some collapse. Not suitable in drying.

PROPERTIES OF MAJOR TIMBER SPECIES: ALPINE ASH TYPE
(Derived from K. R. Bootle: 'Wood in Australia')

Abbreviations: L-S, Lyctid susceptible; G, green; A, air-dried (re density)

Common Name	Gum, Mountain Grey	Peppermint Narrowleaved
Botanical Name	Eucalyptus cypellocarpa	Eucalyptus radiata
General Properties	Pinkish brown, sapwood usually paler to red. Moderately coarse texture, even; grain sometimes interlocked. Often numerous gum veins.	Pale pinkish brown; sapwood slightly paler but not sharply differentiated. Texture medium, even; grain sometimes interlocked; gum veins common.
Density kg/m^3	G: 1100 A: 880	G: 1100 A: 800
Durability	3 L-S	3 L-S
Strength	S3 SD2	S4 SD4
Sawlog Group	C	D
Uses	General construction. Appearance suggests use in veneer, furniture, panelling, joinery and flooring	General construction.
Other Notes	Some collapse in drying.	Difficult to dry without degrade - much collapse.

Appendix 4

YIELD TABLES FOR ALPINE ASH
BAGO S.F.

(after Lindsay, 1939)

Age (years)	Dom. Ht. (m)	Mean DBH(cm)	Stocking (/ha)	BA (m^2/ha)	Total Vol. (m^3/ha)	Merch. Vol. (m^3/ha)
Site Index 31 (100 ft.)						
10	11	5.8	7220	19.1	59	
20	18	12.4	2410	29.8	162	
30	24	20.1	1190	37.9	216	
40	28	21.9	107	43.4	311	
50	31	34.8	494	41.1	439	
60	32	41.1	376	49.6	493	
10	34	47.0	291	51.2	530	15
80	34	52.3	242	52.1	556	63
90	35	57.2	205	53.0	575	115
100	35	61.7	118	53.5	591	156
110	36	66.0	158	54.0	603	186
120	36	69.9	141	54.2	612	208
130	36	12.9	131	54.4	619	223
Site Index 37 (120 ft)						
10	13	6.6	6030	21.4	82	
20	22	14.5	2020	33.5	223	
30	29	23.4	988	42.5	379	
40	33	32.3	590	48.9	508	
50	31	40.4	413	52.8	604	
60	39	41.5	311	55.8	675	26
70	40	54.4	245	51.4	728	111
80	41	60.4	203	58.5	762	189
90	42	66.3	173	59.7	190	245
100	42	11.6	148	60.2	810	286
110	43	76.5	131	60.6	821	316
120	43	80.8	119	60.8	840	334
130	43	84.3	109	61.1	849	349
Site Index 43 (140 ft)						
10	15	7.6	5220	23.4	104	
20	26	16.5	1140	36.7	282	
30	34	26.4	860	46.6	482	
40	39	36.6	511	53.2	643	
50	43	45.S	356	57.7	764	7
60	45	53.6	212	61.2	854	119
70	47	61.5	213	62.4	921	241
80	48	68.3	173	64.3	965	316
90	49	74.9	148	65.2	999	375
100	49	81.0	128	65.9	1024	408
110	50	86.4	114	66.4	1046	434
120	50	91.2	101	66.8	1063	449
130	50	95.3	94	67.0	1075	460

Age (years)	Dom. Ht. (m)	Mean DBH(cm)	Stocking (/ha)	BA (m^2/ha)	Total Vol. (m^3/ha)	Merch. Vol. (m^3/ha)
Site Index 49 (160 ft.)						
10	17	8.4	4520	25.0	126	
20	30	18.3	1511	39.3	342	
30	38	29.5	744	49.8	585	
40	45	40.6	445	57.4	781	
50	49	50.5	309	62.0	927	78
60	52	59.7	235	65.4	1038	249
‘70	53	68.3	183	61.5	1117	361
80	55	76.2	148	68.9	1171	445
90	56	83.3	128	70.0	1213	494
100	56	89.9	111	70.5	1245	523
110	57	96.0	96	71.2	1270	546
120	57	101.3	86	71.4	1290	553
130	57	105.9	79	71.9	1306	561

Appendix 5

A GUIDE TO MARKING ALPINE ASH

Tree selection for logging of a high quality, fast growing eucalypt species such as Alpine Ash must be based on the concept of improvement of the stand as timber producer both in regard to (a) volume and (b) quality.

Consistent with this is the primary object of management to conserve growing stock to sustain or increase the yield. Thus, the silvicultural needs of the forest are paramount and these determine the range of products available to industry.

Tree selection for logging should be aimed at the following:

1. Conserving vigour
2. Eliminating potential mortality
3. Reducing defect
4. Providing for regeneration

1. Conserving Vigour and Eliminating Potential Mortality

The fundamental idea is that vigorously growing trees are healthy trees and are good producers.

Trees selected for retention after logging should be the most vigorous growing stock that will make the best use of the interval between loggings in terms of quality-volume production.

This means that in any one group all, none or a few trees may remain after logging.

Partially suppressed and unhealthy ash trees may occasionally respond to release but it is better to rely for future increment on trees that are obviously vigorous at present than on those which will probably continue to decline regardless of their release. It is important to retain all vigorous trees.

The vigour of standing ash trees can be assessed visually by observing:

(a) The crown characteristics of the trees. It is important to recognise the signs that mean that death or senility are approaching, and trees exhibiting these signs should be the first to be marked, since they may die or contribute negligible increment before the next logging. These signs are:

  (1) Crown showing dead branches and branch endings. Old phasmatid attacks may confuse the picture.

  (2) A general thinning of foliage.

  (3) Browning and thinning of foliage due to repeated phasmatid attack.

  (4) Lightning damage.

(b) Comparison of diameters of trees in the same group. Adjacent trees of many different diameters may in fact be about the same age. The stand has sorted itself in to dominant, sub-dominant and suppressed members and the suppressed ones have a much smaller diameter than the dominants and co-dominants and also generally exhibit crown deterioration. As a check the observation of the stumps of felled trees in a given group will show, by the count of growth rings, that the small diameter trees of a group are usually severely suppressed trees of the same age as the dominants. Those suppressed trees should all be removed.

2. Reducing Defect

Trees exhibiting some form of defect are frequently encountered at the time of marking for logging.

Few trees will be completely defect free. Hence, it is only those defects that reduce vigour or merchantability that should be selected against.

These defects include:

(1) Damaged Butt. Allows termite attack; often the result of felling or snigging damage, or fire.

(2) Excessively gumrny appearance. Usually means extensive gum rings in the log with consequent downgrading in value.

(3) Termite Presence. Can often be detected by sounding with an axe. Termites are sometimes abundantly present in what appears to be visually a very healthy tree.

(4) Irregular Bole. Often disguises grown-over butt damage or termite infestation.

(5) Very Limby Tree Type. Often associated with very low stocking. Inferior merchantable quality and therefore should be selected against whenever encountered.

3. Providing for Regeneration

When marking, regard must be paid to the question of regeneration. If there is adequate regeneration already visible no special action is required. When it is deficient, however, allowance should be made when marking. In general, this will mean the retention of suitable trees for the provision of seed and the opening of gaps around them to provide soil disturbance and adequate light penetration.

In a mature to overmature stand, such as parts of Maragle State Forest, the stocking remaining after logging may have to be reduced to the minimum number of seed trees required. In this case the most vigorous large-crown trees available should be retained at a maximum spacing of 80 metres, but no limitations on minimum spacing are specified.

4. Marking for Smallwood Timber

Marking for smallwood timber in even aged stands should aim at the retention of vigorous members of the stand at an average of 6m x 6m spacing.