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FORESTERS'
MANUAL

AFFORESTATION with PINES

FORESTS DEPARTMENT
PERTH
WESTERN AUSTRALIA

CONTENTS

AFFORESTATION WITH PINES

INTRODUCTION

1. Pine plantations are assuming an increasing role in forestry in Western Australia. With a rapidly increasing population, the requirement for timber products is expected to double during the 30 years 1971-2000.

Pine plantations needed to supplement future timber supplies

2. The native hardwood forests of the State are quite inadequate to provide for the requirements of more than one million people (*i.e.*, the present population). In order to supplement the State's future timber supplies the Forest Department aims to establish over 300,000 acres (121,400 ha) of pine plantations by the year 2000 A.D.

Policy

3. The plantation establishment programme is based on a policy designed to:

(a) Provide wood for the demands of a future increased population.

(b) Establish a better balance in the proportion of softwood and hardwood utilised within the State, *i.e.*, increase the proportion of softwood available.

(c) Prevent future dependence on wood imports to satisfy local demands.

4. Plantation establishment in W.A. faces a number of problems, both technical and financial. Many years of research and experience, however, have laid the foundations for a confident approach to large-scale planting.

Land suitable for plantations is limited

5. One of the major problems is a shortage of suitable land. This is being overcome by repurchase of farmland and by a major research effort to find ways of utilising poorer soils for plantations. One result of this shortage of land is that our plantations at present are scattered in relatively small units over a large area. Efforts are being made to consolidate the plantations into large blocks in selected centres.

Plantations confined to high rainfall areas in the South-West

6. The climate of W.A. is not generally suitable for pine plantations and the scope for establishment is limited to a small corner in the South-West of the State with a rainfall exceeding 30 inches (760 mm) per annum. Even here, plantations experience a long summer drought which presents a major fire control problem and necessitates particular sylvicultural techniques to ensure maximum production without drought losses.

7. Availability of finance is another major factor limiting the establishment of plantations at present.

Only two species suitable

8. Two species of pine are considered to be suitable for commercial plantations in the South-West of Western Australia. These are *Pinus radiata* and *Pinus pinaster*.

Pinus radiata requires fertile soil

9. The fast-growing *Pinus radiata* is very demanding in its site requirements in W.A. It can be grown successfully only on carefully selected fertile soil, and the availability of suitable soil limits the extent to which *P. radiata* can be planted. Nutrition research is continuing in an effort to expand the range of soils on which *P. radiata* can be grown.

Pinus pinaster tolerates poor sandy soil

10. *Pinus pinaster,* on the other hand, grows well on less fertile soils and is planted extensively on the coastal sand-plain close to Perth. Unfortunately its productivity is only one-third that of *P. radiata.*

Research aims to improve productivity and quality

11. Research into nutrition and tree improvement by breeding is continuing for both species, aiming at improving both the productivity and the timber quality.

12. Other species are being tested in arboreta and trial plots and will be considered further for plantation use depending on their performance.

20032—(2)

Planting programme aims at target of 300,000 acres (121,400 ha) by 2,000 A.D.

13. The current planting programme is 6,000 acres (2,430 ha) per annum carried out in nine centres (Divisions). At least half of the area is to be planted to *P. radiata*. It is hoped to increase the planting programme to at least 8,000 acres (3,240 ha) per annum in order to achieve the target of 300,000 acres (121,400 ha) by 2000 A.D. Future plantings will tend to be consolidated in two major centres—Wanneroo for *P. pinaster* and the Blackwood Valley for *P. radiata*.

14. The following sections of the Manual describe the methods and techniques to be employed in the various aspects of plantation management.

15. In each section, the objectives of each phase of the work are outlined, together with the policy adopted to achieve these objectives. The techniques described are based on the best information available at present. It must be realised that conditions are continually changing and that, in the course of time, both the objectives and the techniques may be altered to suit the changing situation. Instructions in this Manual will therefore be amended from time to time.

16. The term D.F.O. is used in these instructions to mean the officer-in-charge of the Division, regardless of rank.

SECTION 1 LAND FOR PINE PLANTING

Site Selection

101. Both *P. radiata* and *P. pinaster* have particular requirements as regards site. Study of existing plantations and pilot plots has shown a clear correlation between site and pine growth, and techniques have been developed whereby the soils and vegetation can be assessed in terms of suitability for pine growth. All areas proposed for planting are subject to careful soil and vegetation survey.

All areas proposed for pine planting are carefully assessed for suitability

102. In general, *Pinus radiata* requires a deep fertile soil and an annual rainfall exceeding 30 inches (760 mm). These soils are of very limited extent in the forest areas of the South-West of the State. They occur only in the valleys of major streams where the old laterite soils have been removed by erosion and new soils have developed. Soils suitable for *P. radiata* are the dark brown or red loams developed from basic rocks. Because of the shortage of such soils available to forestry the continued planting on this type of land will depend on repurchase of farmland.

Pinus radiata requires deep fertile soils

103. Trial plots have been established and research programmes are in hand to determine the extent to which *P. radiata* can be grown on less fertile soils. Results from nutrition trials on sands are promising and it is possible that *P. radiata* will be grown on poorer soils with fertilisers in the future.

104. *Pinus pinaster* is mainly grown, with the aid of fertilisers, on the sands of the coastal plain near Perth. Because of its tolerance to poorer soils and its resistance to *Phytophthora,* it is also used in reclamation planting in the jarrah forest. *P. pinaster* requires a good depth of soil with reasonable moisture relationships. On the coastal plain, the presence of organic matter or iron (yellow sands) is important for the retention of nutrients. Rapid techniques have been developed for delineating land suitable for *P. pinaster,* by assessment of the native vegetation.

Pinus pinaster grows well on deep sands with fertiliser

105. In planning future pine plantations it is important to realise that the financial return is heavily affected by haulage costs. This applies particularly to the low-value, small-sized material such as case logs and chipwood. Plantations should therefore be located in reasonable proximity to likely future markets. Indications are that these markets will be the major industrial centres of Perth and Bunbury.

Plantations should be close to future markets

Land Acquisition

106. The Forests Department has no authority to resume land for pine planting and land is therefore purchased by private treaty. Before any negotiations commence, the property must have been advertised for sale.

Land is purchased by private treaty

107. The value of properties to the Department depends upon:
- (a) suitable soils and topography;
- (b) location in relation to markets;
- (c) clearing on suitable soils (clearing on unsuitable soils cannot be regarded as an asset to the Department).

108. Valuations must be based on the value to the Department and not the cost value of the improvements. For example, orchards, fencing and buildings may in many cases have no value to a plantation scheme.

Valuations are based on value to the Department

109. In the case of areas of private property thought to be suitable for sale, the Divisional Forest Officer should—
- (a) Obtain a written offer from the owner indicating the price and giving permission for the Forests Department to carry out assessments and soil surveys on the property.
- (b) Forward the original copy of the offer for sale to head office with a brief report.
- (c) On instruction from head office, carry out a reconnaissance of the area and submit a sketch plan with notes as to timber, clearing and other improvement values, and whether improvements are of value to a plantation.

Written offer for sale of land to be obtained

Preliminary examination by local staff

110. A decision will then be made by head office as to whether a detailed soil survey is warranted. If it is decided to proceed further with the proposal, head office will arrange for a soil survey to be carried out.

SECTION 2 SURVEY AND SUBDIVISION

Subdivision Plans

Layout of plantations to be carefully planned

201. Plantation establishment involves considerable expenditure. Decisions made at this stage have long-term effects. It is therefore important that the layout of the plantation be carefully planned in advance.

Subdivision Plans describe initial planning

202. After the soil survey has been approved by the Superintendent of Plantations, the D.F.O. will prepare a subdivision proposal which will describe the initial planning for the plantation layout as regards:

(a) Area to be planted, by species and year of planting.
(b) Roads for extraction and access.
(c) Fire control. Firebreaks and burning proposals.

Subdivision proposals required five years ahead of planting

203. The proposal should be prepared at least five years ahead of planting. Utilisation of the area must not commence until the subdivision proposal has been approved by the Superintendent of Plantations, as a subdivision plan.

204. The subdivision plan will be on a scale of 1:12,500. Drafting branch will provide a base plan as a transparency on request. The plan should be of sufficient size beyond the limits of the plantation to show prescriptions for the fire control of the surrounding country. Some survey work may be required in new areas, but generally air photos will provide sufficient information.

Planning to consider fire hazards and access problems

205. The subdivision plan must be designed to meet the anticipated fire hazards and access problems for the particular area. Precise detail may not be practical and is not expected at this stage. All proposed firebreaks should be shown, but the definition of compartment boundaries and allocation of compartment numbers is not desirable at this stage. The plan should show:

(a) Area to be planted, by species, and the proposed year of planting.
(b) Alignment of all roads with a view to both extraction and access.
(c) Position and width of all firebreaks.
(d) Prescribed burning proposals.

206. **Plan Legend**

(a) Planting boundary (external) .... ////////////
(b) Species boundary (internal) ....
(c) Trafficable roads (all vehicles) .... ——— ——— ———
(d) Tracks .... – – – – – – – –
(e) Firebreaks (not trafficable) .... – – x – – x –
(f) Width of clearing shown in figures thus:

33′ (10 m)
——— ——— ———
66′(20 m)
– – x – – x –

Plantation Layout—Hills Plantations

Road System

First class roads restricted to main through access

207. Road building in hilly country is expensive and can easily become excessive if unnecessarily high intensities and standards are adopted. First-class roads of up to 22 ft. (7 m) formation width, *i.e.*, 18 ft. surface (6 m), must be restricted to the main through access for the plantation. For all other roads in the plantation a 16 ft. (5 m) formation width, *i.e.*, 12 ft. surface (4 m), is adequate provided that allowance is made for passing and turning at selected points. Adequate drainage is essential for all roads. Close attention to the standard required, both in the planning and construction stage, should obviate excessive expenditure on roads. All road specifications should be approved by the Inspector for the group before work commences.

Road specifications to be approved

One mile of road per 100 acres (1 kilometre of road per 25 hecatres

208. Intensity of the road system will be a maximum of one mile per 100 acres (1 km per 25 ha). The basis will be a parallel road system generally along the contours and at 30 chains (600 m) centres with crosslinks at one to one and a half miles (1½ to 2½ km).

Road system planned in advance of hardwood logging

209. The road system should be planned well in advance and, wherever possible, the hardwood logging roads should be located to suit future plantation requirements.

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Trafficable alignment for boundary road

210. The top road will not religiously follow the planting boundary if easier alignments are available on more level ground within 3 chains (60 m) of the boundary. The top boundary road should cut across rather than follow around the edge of narrow intrusions of unplantable land. Gravelling will be limited in the early years, to the minimum required for gang truck access.

211. Drainage maintenance will be required annually on all existing roads but savings should be made on other road maintenance by strict control of programming and recording of the work.

Compartment Size

Compartments up to 250 acres (100 ha)

212. The size of compartments is not critical. Under the above roading prescription the plantation will be divided into compartments generally of the order of 250 acres (100 ha). Compartments may be as small as 100 acres (40 ha) if topography or other features necessitate more intensive roading.

External Firebreaks

External breaks 1 chain (20 m) wide

213. External breaks adjoining grassland (private property) are to be one chain (20 m) wide, maintained free of grass for the early years. When and where feasible this break will be reduced to a single swathe 10 ft. (3 m) wide kept free of grass and supplemented by a prescribed burning strip two chains (40 m) wide within the pines.

214. An external break adjoining hardwood (normally State Forest) will be cleared to one chain (20 m) beyond the planting boundary. Only the road surface will be maintained and the balance will be allowed to regrow. See Figure 1. Road edges will be maintained free of grass where possible.

Unfavourable slopes to be avoided on boundaries

215. Unfavourable slopes are to be avoided by selecting an alternative location for the break. All land inside the break will be treated as plantation whether planted or not.

Treatment Outside Perimeter

Surrounding forest to be control burnt

216. An outer perimeter enclosing approximately a 10 chain (200 m) wide buffer should be defined by tracks. This forest will be regularly burnt. Special treatment around the perimeter should be limited to the following:—

Stag felling up to 5 chains

217. Stag felling of dead-topped trees will be carried out up to five chains (100 m) from the boundary of the pines. All such merchantable trees to be removed as a trade operation.

Parkland clearing to be done at time of initial cleaning

218. Parkland clearing or the disposal of dead log wood on the ground outside the cleared break to facilitate future prescribed burning should be carried out at the time of initial clearing with contract machines. All heavy log material up to a distance from the pines equivalent to the height of the native forest should be pushed into windrows in the clearing.

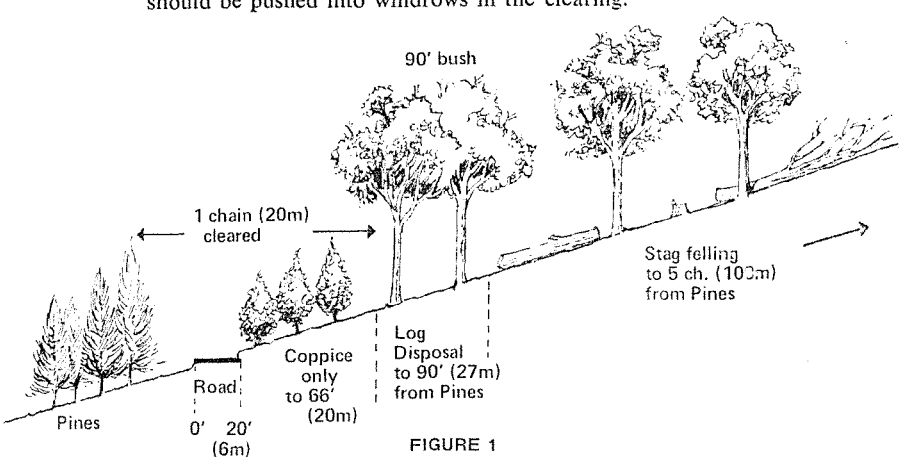

FIGURE 1

Figure 1.

Internal Firebreaks

Road verges to be kept free of grass in plantations

219. There will be no conventional cleared breaks within the plantation. Road verges should be maintained free of grass giving a basic subdivision of the area, but apart from this the age and condition of the plantation will determine the type of break system used.

Access tracks at 10 chain (200 m) centres kept clean

220. For the first five years (approximately) while grass fuel is a problem, 10 ft. (3 m) wide strips at approximately 10 chains (200 m) centres, selected to be free of stumps, will be established across the contours with weedicides. These breaks will be negotiable by tractor, and will coincide with a 12 ft. (4 m) access row.

221. From age 5 (approximately) to first thinning. The 10 ft. (4 m) wide strips will still form the basis of the control system, but will receive no treatment other than to keep them free of pruning debris.

Prescribed burning buffers to be established after first thinning

222. From first thinning onwards, internal breaks will be in the form of prescribed burning buffer strips at least 10 chains (200 m) wide separating cells of not more than 400 acres (160 ha). The buffers will be sited on the easiest burning country, generally along spurs of high ground running out across the main valley contours. The buffers will be burnt at 2 to 3 year intervals.

Water Points

223. Water supplies for fire fighting in plantations should be developed on the basis of a 20-minute turn-around, *i.e.,* from any point within the plantation a heavy duty unit should be able to travel to, fill and return from the water supply within 20 minutes.

Natural water supplies to be developed for fire control

224. Development of natural water supplies, such as dams, and soaks, is cheaper than the construction of tanks and they should, therefore, be used where possible. Only where the distribution of these natural supplies is insufficiently intense to fit the 20-minute turn-around specification will concrete tanks be used. This will usually be on the higher ground. Tanks of a minimum capacity of 10,000 gallons (45,000 litres) will be required.

Plantation Layout—Coastal Plantations

225. Topography is usually much easier on the coastal plain and the layout of plantations is therefore greatly simplified. However, the same forward planning is required as for the Hills plantations and the layout must be designed to meet the anticipated fire hazards and access problems for the particular area.

Forward planning required

Subdivision based on future haulage roads

226. The chief factor influencing design will still be topography and the location of suitable haulage roads. These roads must cater for heavy haulage vehicles eventually and so must be selected with a view to easy grades (1 in 10 to be the absolute maximum) and the most direct route to the nearest main road and market. Hauling roads should be at an intensity of 40 to 60 chain (800 to 1200 m) intervals.

227. The following guidelines should be followed for the subdivision of coastal plain plantations:—

(a) External boundary breaks to be one chain wide.

Compartments surrounded by one chain (20 m) breaks

(b) Internal firebreaks one chain (20 m) wide to surround "compartments" of 100 acres (40 ha) (minimum) to 250 acres (100 ha) (maximum).

Access tracks required

(c) Access tracks 22 feet (7 m) wide to be established so that no point within the planted area is more than 10 chains (200 m) from either a track or a break.

Extraction tracks at 1 chain (20 m) intervals

(d) Twelve foot (4 m) wide extraction tracks one chain (20 m) apart to be left at planting. (This of course does not apply where a 12 foot (4 m) planting spacing is employed.) Twelve foot (4 m) extraction tracks to be sited across the rows at 10 chain (200 m) intervals.

Prescribed burning buffers to be established

(e) Buffer burning strips to be incorporated in the design with 10 to 20 chains (200 to 400 m) wide strips surrounding blocks of 800 to 1200 acres (320 to 480 ha). There should be no necessity to burn strips under the pine along external boundaries where it is possible to keep the adjoining native bush burnt. Conversely, however, buffer strips will be needed where the boundaries adjoin swamps, main public roads, privately owned bush or other high-risk areas.

Use of Aerial Photographs

Accurate plantation plans prepared from air photos

228. Field survey work for mapping of plantations should be kept to a minimum. Base plans provided from head office will be used to record the early work of subdivision, clearing, roading and planting. These early plans will be approximate only. Accurate detailed plans are prepared from air photos after planting is completed.

Plantation Nomenclature

229. It is necessary to conform with rules for nomenclature which have been laid down by a State Committee. For efficient management, a standard system of naming plantation areas is essential. A standard system of Plantation Nomenclature has therefore been adopted as follows:—

(a) Plantations will bear the name of the *Division* in which they are located followed always by the designation "Coastal" or "Hills" as the case may be.

(b) Within both of these primary subdivisions they will next be broken into named "Groups". (Groups will be formed purely on the basis of wide geographic separation and will vary considerably in area planted.)

(c) Each group will be further subdivided into lettered Sections ("A", "B", "C", and so on). These will be subdivisions for convenience of reference, within the geographically delineated groups. Sections may also vary markedly in area but should not exceed 5,000 acres (2,000 ha) of planting.

(d) The further break-up of the Section shall be into *Year of Planting* and then to *Compartments*.

(e) Every plantation area of 20 acres (8 ha) or more in continuous area must have a name, letter and number allocated to it under the above system.

Whole areas allocated to Groups

230. The whole of the area of each division has been allocated to groups, that is, all the area within the Divisional boundary, including even private property and eucalypt forest. An exception to this is that areas demarcated for intensive management of eucalypt forest (I.M.U.'s) will not be included in plantation group areas.

Master plans held by Chief Draftsman

Amendments to be approved

231. Group boundaries and names are marked on 240 (1:200,000) scale plans, the master copies of which are held by the Chief Draftsman. Any subsequent amendments to group boundaries and/or names must be submitted to the Departmental Nomenclature Committee for approval before master plans or Divisional copies are altered.

Section boundaries to be shown on plan

232. Divisions will mark section boundaries on 80 scale (1:50,000) plans. Where possible, in groups where extensive plantings are in existence or planned, the whole of the group area should be allocated to sections. (This is not feasible in the opposite case where the group consists largely of private property and/or eucalypt forest within which no plantings or only small trial areas exist at the moment.)

233. The use of such terms of Central, North, South, East, West, etc., must be avoided in future, but, in so far as naming can be kept within the policy framework, such names as are already in existence and on plans will be approved.

234. Common names for sections can be used locally, but must not be used in reports or other written submissions unless qualified with the accepted nomenclature as in paragraph 228 above. Such common names should not be used as plan headings.

235. For some normal uses, such as in reports and as headings to plans, a condensed nomenclature giving only group name and section letter may be used (*i.e.*, omitting Division name and whether Hills or Coastal plantation). For other uses such as for Working Plans branch inventory records the whole nomenclature may need to be coded.

SECTION 3 SITE PREPARATION

Planning

Subdivision plan to be approved before development starts

301. Utilisation or clearing of native timber must not be commenced until subdivision plans are approved. On receipt of approved plans the D.F.O. must prepare a working plan programme for clearing and planting.

302. Areas of native forest occurring on soils to be planted often contain a large number of trees suitable for sale as poles and piles. The D.F.O. should advise his Inspector of the presence of any extensive area of poles and piles in order that orders are directed towards the plantation area as a first priority. All timber suitable for use in the round should be removed before sawmilling commences in the area. This may take a period of several years, and so detailed forward planning is essential.

Period between clearing and planting to be as brief as possible

303. In planning this work, the period between clearing and planting must be kept as brief as possible to minimise weed problems.

Clearing

304. Large savings can be made by accepting a clearing standard that aims at something less than a perfectly clean ground surface.

Initial Clearing

305. Except in light forest which can be chained down and raked up after a broadcast burn, initial clearing will be windrowed.

Windrowing normally let to contractors

306. The pushing down and windrowing should be done by contract and as far as possible should be on a "job basis", *i.e.*, a rate per acre (hectare). Realistic prices for this work depend on the contractor having a thorough understanding of what is involved and the Department can assist in this by supplying information gained from previous experience such as previous costs and performance of particular machines. In particular, adequate facilities for assessment of the job such as aerial photographs and soil and topographic data should be provided.

Stream flow not to be impeded by debris

307. To reduce the amount or final clearing required, windrowing across the contours may be practised on the easier slopes, *i.e.*, up to 1 in 8. To hold up silt along rivers and reservoirs, two windrows should be made along the contours on the lowest slopes. Logs and other debris must not be purposely pushed into creek beds to cause impediment to stream flow. Generally, the aim is for complete initial clearing within the plantation boundary. Particularly difficult areas, however, such as where a 'dozer cannot operate will be avoided and left uncleared and unplanted.

Final Clearing

Thorough burn to be aimed for

308. Considerable savings can be made by taking steps to ensure a thorough burn, and by accepting that some log debris will be left unburnt in the final clearing.

309. The minimum amount of re-stacking, preferably one operation only, should be carried out after the burn to give a minimum of two chains completely cleared out of every three chains of windrow.

Erosion Control

310. When necessary, grade drains should be established at a spacing of approximately 40 ft. (12 m) vertical height at a grade of 1 in 44. This is expensive work and is generally only required on steep country surrounding reservoirs.

Ground Preparation and Weed Control

The problem of coppice and scrub regrowth

311. In conversion from hardwood forest to plantation, the native species tend to persist in the form of coppice and root suckers of eulcalypts, and as subsequent regrowth and germination of scrub. The presence of this regrowth causes:

(a) Severe competition affecting survival and growth of the pines.
(b) Reduced access, making subsequent work difficult, dangerous and costly and, in extreme cases, rendering further tending work impossible.
(c) A serious fire hazard.

Grass competition

312. In areas previously cleared of native vegetation, competition for moisture by dense grass can have drastic effects on the survival and growth of young pines.

Mechanical Weed Control

Area to be ploughed where possible

313. Wherever possible the areas should be ploughed prior to planting. Ploughing will provide a suitable planting "bed", will encourage early growth and will eliminate most of the weeds likely to compete with the pines in the early years.

314. All coastal plain planting areas are to be ploughed, and in the hills areas ploughing will be carried out except on:

(a) Areas immediately adjacent to water reservoirs.
(b) Areas too steep or rocky to plough.
(c) Very high quality sites carrying pasture.

315. In these instances, herbicide sprays will be used for weed control, subject to conditions laid down in later sections of this instruction.

Ploughing to be deep

316. In sandy soils a ploughing depth of at least nine inches (230 mm) is required to eradicate scrub satisfactorily and to provide a good rooting medium for the young pine.

317. In heavier soils, often containing rock fragments or boulders, this depth can sometimes be difficult to attain. A minimum depth of six inches (150 mm) is therefore permitted, but the nine inch (230 mm) minimum must be attempted within limits imposed by correct machinery care.

Need for supervision of ploughing

318. Good ploughing requires experienced operators, and careful attention must be paid to this work to ensure:

(a) That the correct equipment is used and that it is in good working order.
(b) That the equipment is properly set up.

319. Neglect in these matters will certainly result in damage to the equipment and an unsatisfactory ploughing job.

Inter-row cultivation

320. Post-planting, inter-row cultivation is carried out as necessary where the terrain permits. As with ploughing, careful attention is required in setting up this equipment.

321. Where re-cultivation is not feasible because of frequent stumps or rough terrain, further control may be achieved with herbicides.

Chemical Weed Control

Herbicides to be used with caution

322. Herbicides provide a means of weed control when ploughing or re-cultivation is impracticable. However, they must be used with caution. Major hazards in the use of herbicides are:

(a) Damage to vegetation outside the target area.
(b) Damage to pines.
(c) Possible hazard to water supplies by the use of 2.4.5.T on water catchments. The use of 2.4.5.T will not be permitted where water contamination can occur.

323. All proposals for the use of herbicides must be carefully prescribed and planned with regard to possible damage and carefully carried out under adequate supervision.

324. One officer in each division who is well aware of the problems associated with herbicides should be responsible for the planning and control of these operations.

325. Estimates Works Programmes must show details of all proposals for spraying, in terms of location and proposed methods.

Special precautions on catchments

326. Special precautions must be taken in the use of 2.4.5.T on water catchments. The use of any herbicides on a catchment should be kept to a minimum and applied only with extreme care to avoid contamination of the water surface. Where herbicides are essential, uncleared buffers should be left half a chain wide on either side of running streams. **Aircraft will not be used at all on catchments, and misting machines are not to operate within two chains of the edge of reservoirs or feeder streams.** Such areas within two chains of the water surface to be treated by hand, by stem injection or basal spray.

327. Two different herbicides are used, each to cater for control of one of the two vegetation types encountered:
i.e.—

2.4.5.T butyl ester against native scrub and eucalypt coppice.
Vorox AA against grasses.

Use of 2.4.5.T on Eucalypt and Scrub Regrowth

328. Eucalypt coppice and scrub regrowth following the clearing of hardwood forest for conversion to plantation are controlled by the use of 2.4.5.T.

Use of 2.4.5.T for control of coppice and shrub

329. Complete elimination of all native species is difficult and costly to achieve. The aim in plantation establishment is to control the scrub regrowth at a satisfactory level, *i.e.*, the weeds must be kept down to a level where they do not interfere with the growth of the pine.

Complete elimination of scrub not essential

330. 2.4.5.T butyl ester is generally found to be the most effective herbicide for control of the native species. This is usually applied as a foliar spray at a specified rate per acre.

2.4.5.T as foliar spray

331. The aim is to achieve the desired scrub control prior to planting. In the event of the scrub not being controlled adequately before planting, techniques have been developed for post-planting scrub control, but this has many disadvantages compared with adequate pre-planting control.

Control scrub before planting

332. Weedicides are expensive and can be dangerous and damaging. Therefore they must be used with care. In the development of techniques for application, cost factors and safety factors must be considered, along with the effectiveness of the operations.

Need for care in using weedicides

333. The period between initial clearing and planting sees a strong development of scrub regrowth. Experience shows that, to minimise scrub problems, this period should be kept as brief as possible—no greater than 18 months, and preferably shorter.

Period between clearing and planting to be as brief as possible

334. Control of scrub prior to planting is usually achieved by two foliar applications of 2.4.5.T. The first treatment is applied when the eucalypt coppice is 2 feet (0.6 m) to 5 feet (1.5 m) in height, and the second in the autumn, prior to planting. In planning this work it is important to allow at least four months between spraying and subsequent burning of the regrowth.

Planning—two sprays

335. An effective kill can be obtained in any season provided that fine weather prevails during, and for an hour or so after, spraying.

336. **Temperatures in excess of 24°C cause rapid volatilisation and drift of the chemical.** Volatilisation and drift can occur several days after application, so spraying must not be attempted when there is any likelihood of warm weather (over 24°C) in the near future.

Avoid spraying in hot weather

337. The rate of application is specified in terms of pounds of "active ingredient" per acre. **It is most important that the chemical be applied at the correct rate.**

Need for accuracy in rates of application

338. 2.4.5.T is applied as a solution in water with wetting agent added. The amount of solution used varies depending on the type of spray equipment and method of application and with the density of the weed population. With misting machines, 5 to 10 gallons per acre (60 to 110 litres per ha) are required to achieve a reliable coverage.

Strength of solution varies according to amount of spray to be used per acre

339. 2.4.5.T is purchased as an 80 per cent. formulation. This means that 80 per cent. of the material is "active ingredient". Since one gallon weighs approximately 10 pounds, a gallon contains 8 pounds of "active ingredient". Thus one pint of 80 per cent. 2.4.5.T is equivalent to one pound of "active ingredient".

One pint of 80% 2.4.5.T contains one pound of "active ingredient"

340. For an application rate of three pounds per acre and applying five gallons of solution per acre, three pints of 2.4.5.T are added to five gallons of water. If the amount of spray is to be 10 gallons per acre, the solution is made by mixing three pints of 2.4.5.T in 10 gallons of water.

341. Table 1 shows the quantities of 2.4.5.T required to make up 100 gallons (1,000 litres) of solution for various rates of application.

TABLE 1: To make up 100 gallons of Solution

Rate of Application (pounds per acre)	Gallons per acre to be sprayed	
	5 gallons	10 gallons
	Amount of 2.4.5.T to be added	
1 pound	20 pints	10 pints
2 pounds	40 pints	20 pints
3 pounds	60 pints	30 pints
4 pounds	80 pints	40 pints

TABLE 1: To Make up 1,000 litres of Solution

Rate of Application (kg–ha)	Litres per hectare to be sprayed	
	50 litres	100 litres
	Amount of 2.4.5.T to be added	
1 kg	25 litres	12·5 litres
2 kg	50 litres	25 litres
3 kg	75 litres	37·5 litres
4 kg	100 litres	50 litres

Wetting agent to be used

342. A wetting agent ("Plus 50") is always added to the solution at a constant rate of 0.25 per cent., or 2 pints per 100 gallons (1 litre per 400 litres).

Need for care in making up solution

343. The quantity of chemical required for one tankful should be calculated and checked by the officer in charge of the job. To obviate mistakes in the field, it is preferable that the chemical be made up into containers in the store at headquarters so that the job in the field involves only adding a container of chemical to the tank and filling up with water.

Rates of application to be specified

344. For pre-planting scrub control the 2.4.5.T is applied as a low-volume foliar spray at the rate of 3 pounds active ingredient per acre (3 kg a.i. per ha). This can be reduced to 2 pounds a.i. per acre (2 kg a.i. per ha) under very favourable conditions.

i.e.,—

(a) When spraying is carried out in early summer (November to February).

(b) Where there is a high proportion of marri coppice.

345. The rate should be increased to 4 pounds a.i. per acre (4 kg a.i. per ha) when there is a high proportion of blackbutt coppice.

Use of aircraft strictly limited

346. The use of aircraft is precluded for most of this work, because of the impossibility of guaranteering against drift outside the target area. Aircraft will not be used:

(a) On water supply catchments.

(b) Within a minimum of one mile of private property or a scenic reserve.

(c) During summer months when temperatures in excess of 75°F (24°C) may be expected.

(d) In winds in excess of 5 m.p.h. (8 km.p.h.).

In effect, this practically eliminates the use of aircraft for 2.4.5.T spraying.

Misting machines.

347. Foliar spraying of 2.4.5.T is usually carried out by means of tractor-mounted misting machines (Conomist) at the rate of 10 gallons per acre (100 litres per ha).

Entire area to be covered

348. The use of the Conomist is limited to reasonable terrain. Much of the poor results achieved with the Conomist can be attributed to inadequate coverage in the application. It is essential that the **entire area be treated.** This

requires careful attention to the swath width and spray pattern and to the selection of suitable weather (*i.e.*, fine weather with temperature below 75°F (24°C) and little or no wind). Operators must be thoroughly instructed and trained in the work and careful supervision is necessary.

349. Safety precautions in using this material must be observed to avoid excessive skin contact or inhalation of 2.4.5.T. The operators must be suitably protected by means of an effective canopy, long-sleeved shirt and long trousers, use of mask, goggles and barrier cream. Soap and water must be available on the job for use before eating or smoking. These precautions must be strictly enforced.

Safety precautions, private property

350. The utmost precautions must also be taken to ensure against drift on to private property. Grapevines, fruit trees and many vegetable crops are susceptible.

Avoid drift on to

351. There will be areas where misting machines cannot be used. The advisability of clearing such areas in future needs to be carefully considered in view of the difficulties and extra cost of all subsequent operations in this type of country.

Consider advisability of clearing very difficult areas

352. Where it is not possible to use machinery, coppice control is achieved by means of basal spraying. This involves hand spraying of the coppice stem to the height of 15 inches (380 mm) with a 4 per cent. solution of 2.4.5.T in dieseline. The entire circumference of the stem over this length **must be saturated** to ensure success of the treatment.

Basal spraying

353. Where the terrain permits, basal spraying is best done with hoses from a tractor-mounted tank. Where tractors cannot be used, the material must be carried in pack sprays. The problem of spillage with the knapsack-type sprays necessitates great care in their use. Other types such as the 2-gallon (9 litres) Rega Pneumatic Sprayer carried on a shoulder strap are available and should reduce the discomfort caused by spillage.

Basal spraying with hoses

Pack sprays

354. Best results are achieved from basal spraying during spring and summer. This operation should only be carried out during the period August to February.

355. Basal spraying is a very expensive and unpleasant operations and should be carried out only as a last resort—*i.e.*, where coppice is still persisting after "pre" and "post" planting treatments, basal spraying may be used at the time of early cleaning.

Basal spraying a last resort

356. Pre-planting scrub control can be fully effective under ideal conditions. It is much easier to carry out this type of work before the pines are planted and therefore the aim must be to achieve control of the scrub prior to planting.

Main points to consider

357. The main points necessary to achieve success are:

(a) Minimum period between clearing and planting.
(b) Careful attention to timing of the operations to treat the scrub before it becomes strongly established.
(c) Supervision and training of operators to ensure full coverage with the correct amount of weedicide.

358. The problem of scrub regrowth after planting can occur due either to inadequate pre-planting scrub control or to subsequent germination of ground species such as wattles or netic. This is to be controlled by mechanical methods, *i.e.*, cultivation, where possible.

Use re-cultivation where possible, for post-planting scrub control

359. Where cultivation is not possible, herbicide techniques which will control the scrub with minimum damage to the pines have been developed. The precision required in this operation is **much more critical because of the risk of damage to the pines.**

Risk of damage to pines in post-planting spraying

360. For post-planting foliar spray, the rate of application is to be one pound a.i. per acre (1 kg a.i. per ha).

Rate of application one pound 2.4.5.T per acre

361. The timing of this operation is critical and it is essential that this spraying be restricted to the first 12 months after planting, *i.e.*, not later than May in the year following planting.

Timing of post-planting spray is critical

362. Foliar spraying of pines older than 12 months causes severe, permanent malformation of the pines and is not to be undertaken.

No foliar spray on pines over one year old

363. Conditions governing the use of misting machines and basal spraying are as for pre-planting treatment except that in basal spraying direct application to the pines must be avoided.

Constant observation and prompt action essential

364. The overriding principle in all weed control work is to **spray at the correct time.** A constant watch must be kept on weed development and prompt action taken when necessary. Any delay in treatment can lead to greatly increased costs of control or, ultimately, to failure to control the problem.

Use of Vorox for Control of Grass

Use of Vorox.

365. The competition for moisture by dense grass in old pasture can have drastic effects on the survival and growth of young pines. Vorox AA has been found to be very effective in reducing this competition.

For control of grass competition

366. Vorox is normally used to reduce grass competition on unploughed pasture. It may also be required in some cases as a follow-up treatment in ploughed areas.

Vorox applied in late winter after planting

367. Vorox is applied during the winter or early spring of the year of planting. There is no detrimental effect on the pines at this time of the year. Vorox should be applied when grass germination is complete but before the grass matures. August generally meets these requirements.

Application rates for Vorox

368. Vorox is a wettable powder and is applied in water as a low-volume spray. The rate of application varies depending on the density of the grass and the method of application. With aircraft, 3 pounds of Vorox per acre (3 kg/ha) in 5 gallons of water per acre (50 litres/ha) is recommended. With ground application where control is more precise, 2 pounds per acre (2 kg/ha) of Vorox is usually adequate.

Marker dye to be used.

369. It is important to achieve full coverage with the spray and careful supervision is essential. To ensure that no areas are missed, a Red Herbicide Marking Compound is recommended. This is used at the rate of 2 pounds per 100 gallons of solution (1 kg per 500 litres).

Making up Vorox mixture

370. A wetting agent ("Plus 50") at 0.25 per cent. is used in the mixture. A 100-gallon mixture for Vorox spraying at 3 pounds in 5 gallons per acre is made up as follows:—

60 pounds Vorox AA
2 pints "Plus 50"
2 pounds Red Marking Compound.

(A 500-litre mixture for Vorox spraying at 3 kilograms in 50 litres per rectare is made up as follows:—

30 kg Vorox AA
1.25 litres Plus 50
1.0 kg Red Marking Compound.)

The components should be placed in the tank and water added.

Precautions against drift

371. Careful precautions must be taken to avoid accidental drift of the weedicide on to private property. Most grasses, including many crops, are susceptible to Vorox.

Safety precautions

372. Vorox is non-toxic to animals, but normal precautions against swallowing or inhaling the chemical should be observed.

Vorox for firebreak maintenance

373. Vorox is also used in hilly country for firebreak maintenance. This is usually carried out with tractor-mounted boom sprays. In areas treated annually, the rate per acre (hectare) can be reduced considerably after the first application. Local experience should be used to determine minimum rates of application.

Special Preparation for Particular Sites

374. Some sites require special additional preparation. Specialised implements and techniques have been developed for some of this work.

Furrow Lining

Furrow lining essential on dry sandy sites

375. This operation greatly improves the site for planting in dry, sandy soils. These sands resist wetting and, in normally ploughed ground, dry patches of soil persist until well into winter. To ensure that the pines are planted into moist soil, which is essential for their survival, the technique of furrow lining has been developed.

376. Furrow lining consists of marking out the planting lines prior to planting, but after ploughing, with a special tractor-drawn implement (a "furrow-liner"). This creates a broad, shallow "vee" furrow three feet (1 m) wide and

six inches (150 mm) deep and has the effect of channelling rain water into the planting line and ensuring thorough wetting of the soil.

Numerous benefits from furrow lining

377. Furrow-lining improves the site for planting in several other ways as well:

(a) Reduces competition by removing newly germinated weeds close to the ploughing line.
(b) Removes obstacles such as sticks and roots which may obstruct the planting machines.
(c) Compacts the loose ploughed surface and reduces drying.
(d) Provides a more sheltered situation for the newly planted pines.

378. Furrow-lining should be carried out in all dry, sandy planting sites.

Mounding

Mounding improves wet sandy sites

379. The reverse of furrow-lining, mounding of the planting line, is carried out prior to planting in wet situations. This is done with a special mounding plough. This treatment provides better drainage and aeration of the soil and is essential where free water is likely to lie on the surface in winter.

Drainage

Drainage essential in wet areas

380. Most areas which require mounding also require additional drainage work. It is essential that all surface water be enabled to drain from the site. Too often a great deal of work and money is spent in preparing and planting an area, only to result in failure because of inadequate drainage.

381. Generally, a system of shallow drains is all that is required but they must be carefully selected to ensure that they do in fact function as drains. In flat situations where the drainage lines are not obvious, a Dumpy Level or similar equipment should be used to determine the location and direction of the drains.

382. In sandy country, drains can be established quite cheaply by graders after the ploughing and mounding operations are completed.

Rabbit Control

383. In most areas, rabbit damage can be a major cause of loss in young pines.

Rabbits must be eradicated from planting site

384. Measures must be taken to eradicate all rabbits from the site prior to planting. This often requires continuous effort over a period of some months. The advice and assistance of the Vermin Control Officer of the Agriculture Protection Board should be sought in this work.

SECTION 4 PLANTING

General

Planting one year old seedlings

401. All plantation establishment in W.A. is by planting one-year-old seedlings. On most easy terrain, planting machines are used, but hand planting continues to play an important part, especially in hilly areas.

402. Extreme care is needed to ensure that the trees are properly planted as there are many factors which influence the survival and development of the transplanted seedling.

Planting Season

Planting season limited to June and July

403. The planting season in W.A. is limited to the months of June and July. The start of the planting season depends on the amount of rain received in early winter, as the soil *must* be thoroughly wet before planting can commence. Experience has shown that, generally, planting should not commence before the 1st June in areas south of Bunbury or before the 15th June in areas north of Bunbury. Permission to commence before these dates must be obtained from the Superintendent, Plantations.

Planting suspended in dry weather

404. On no account may planting be continued beyond the end of July.

405. Planting must be suspended if prolonged dry spells occur during the planting season.

Layout of Planting Site

Planting areas to be marked in advance

406. Where the terrain permits, compartment boundaries should be marked by a furrow or some other means so that the limits of the planting area are clearly defined.

407. In the hills plantations, planting lines are run across the contour (*i.e.*, up and down slope). The rows must be kept reasonably straight to facilitate the future use of machinery. Alignment is achieved by the use of sighting waddies.

408. On the coast, with machine planting, the direction of the rows is determined largely by the shape of the planting area. Long runs are preferred to reduce time lost in turning.

Spacing

Aim to plant sufficient for final crop selection

409. Spacing varies according to species, seed source and site. The aim is to plant only sufficient plants to provide for selection of high quality trees in the final crop.

410. The current spacings of rows and of plants along rows which are to be used for various situations are as follows:—

(a) *P. radiata*		
Hills Plantations	9 ft. x 7 ft.	(690 s.p.a.)
	(2·74 m x 2·13 m)	(1704 s.p.ha)
Coastal Plantations	9 ft x 9 ft	(540 s.p.a)
	(2·74 m x 2·74 m)	(1334 s.p.ha)
(b) *P. pinaster*		
All areas (routine seed)	9 ft. x 6 ft.	(805 s.p.a.)
	(2·74 m x 1·83 m)	(1988 s.p.ha)
Seedlings from Orchard seed	12 ft. x 8 ft.	(455 s.p.a.)
	(3·66 m x 2·44 m)	(1124 s.p.ha)
(c) *Other Species*		
All areas	9 ft. x 6 ft.	(805 s.p.a.)
	(2·74 m x 1·83 m)	(1988 s.p.ha)
(d) *Trial Plots*		
All species	9 ft. x 6 ft.	(805 s.p.a.)
	(2·74 m x 1·83 m)	(1988 s.p.ha)

Check on spacing.

411. Officers supervising planting operations must pay particular attention to the actual spacings being obtained in the field. In recent years, with the introduction of piecework and contract planting, the spacing between plants along the rows has tended to shorten. This is not to be permitted.

Delivery and Care of Plants

Avoid holding plants too long

412. Delivery of plants to the planting site must be arranged with care to avoid unnecessary delay between lifting and planting. The placing of dumps must be arranged each day by the officer in charge of planting so that the planters or machines can conveniently refill their plant carriers without unnecessary walking.

Keep plants wet and shaded and avoid root exposure

413. The plants must be kept wet and shaded at all stages of transport or waiting time. Vehicles transporting the plants must be provided with canopies. Root exposure must be kept to a minimum at all stages from the nursery to the planting hole.

414. In the event of plants arriving from the nursery in an unsatisfactory condition, this should be brought immediately to the attention of the officer in charge of the nursery.

Planting

Planting must be done properly

415. Planting is a most important and exacting operation. It must be done properly and the quality of this work must not be sacrificed for speed.

Pre-planting briefing

416. At the beginning of the season, before planting starts, all personnel must be fully briefed as to what is expected. The method of planting and the required result must be demonstrated and practised by all concerned.

Constant supervision to maintain standards

417. Constant supervision is necessary throughout the planting to ensure that the required standards are maintained.

Short list of faults

418. Common faults in both machine and hand planting are:

(a) Seedling planted too shallow. The plants must be set 2 to 3 inches (50 mm to 75 mm) deeper than they were in the nursery.

(b) Soil not compacted around the roots. Air pockets must be eliminated and the plant must be held firmly in the ground.

(c) Seedling not planted vertically upright. Crooked planting leads to crooked butt logs.

(d) Fertiliser inaccurately placed. It must be placed within 12 inches (300 mm) of the plant.

Hand Planting

419. The hand-planting method to be employed is called notch planting using a special planting spear. The method is described as follows:—

(a) The spear is driven into the ground so as to open a notch approximately 4 inches (100 mm) by 2 inches (50 mm) by 12 inches (300 mm) deep.

Avoid bending roots.

(b The seedling is inserted into the notch, taking care that the roots are disposed downwards and not bent over. The seedling must be set 2 to 3 inches (50 to 75 mm) below the nursery level.

(c) The notch is closed by a heavy stamp of the heel. Care must be taken to eliminate air pockets around the roots and in heavy soils; this necessitates double spearing, *i.e.*, the spear is placed into the soil a second time, alongside the plant, and moved so as to pack the soil tight around the roots.

Plant to be vertical

(d) The plant must finish in a vertical position.

420. The planting lines should be maintained as straight as possible but variation in spacing along the line is permitted to avoid planting in unsuitable situations. Trees must not be planted against stumps or other large plants. Patches of dry soil must also be avoided.

421. Hand planting is mainly carried out by piecework with payment being based on either the number of plants planted or on the *area* planted. Wherever possible the area basis for calculation is preferable as this obviates the need for counting the pines when bundling in the nursery.

422. Various working arrangements have been developed for different situations. One satisfactory arrangement of the gang is a three-man unit—one of whom is a plant carrier who hands trees to the two planters. A fair day's work planting in this manner is 2,500 trees per three-man gang. Output obviously depends to a large extent on the terrain.

423. Various types of plant carriers have been developed locally for hand planting. The two main ones are the "wheatsack" type and the "kerosene tin" type. Both are satisfactory. The main point is that the plants must be carried in such a way that they are not exposed.

Planting With Machines

424. Where the terrain permits, planting is carried out by means of tractor-drawn planting machines. Two types of planting machine are employed:

(a) Gnangara type universal mounted planting machine. These machines are suitable for the easy terrain of the sand plain and are usually drawn in pairs. Each machine carries two operators, one planting and the other operating the fertiliser applicator.

(b) Three-point linkage planting machine. These machines can be used on moderate slopes in hilly country. They normally carry one operator.

Machines to be properly set up and operators well trained

425. As with most mechanised operations, machine planting can greatly improve the efficiency of the work, but careful attention is essential to ensure that the machines are properly set up and that operators are well trained in the planting method.

Constant supervision to detect and correct faults

426. Machines increase the rate of planting and it is therefore doubly important that any faults in planting be detected early and corrected swiftly. Constant supervision is essential.

Pine Counts

Pine count to show percentage of deaths and cause of death

427. In October and again in March (or after the first autumn rains) a count must be made of a sample of the current season's planting.

428. Sample rows are to be pegged. All trees along the row are to be counted and the dead trees recorded by booking their consecutive numbers along the row; *i.e.*, in a row of 120 trees, five trees, numbers 11, 17, 96, 102 and 103, may have died.

429. A pine count report is to be forwarded to Head Office giving the percentage of deaths by rows and by compartments, together with notes on causes of deaths.

430. To ensure that the same rows are counted each time they should be marked by distinctive pegs at the time of the first count.

Refilling

431. Experience has shown that re-filling or "beating up", *i.e.*, the replacement of scattered failed trees one year after the general planting, is not warranted.

The refills are invariably inferior to the original plantings and rarely develop into usable trees. Refilling is only to be undertaken when definite areas have failed, *i.e.*, less than 50 per cent. survival, and only when thorough scrub and grass control can be assured.

SECTION 5 NUTRITION

Use of Fertilisers in Plantations

Use of fertilisers increasing

501. Research has led to an increasing use of fertilisers in forestry work. In pine plantations, fertilisers are used to establish trees on poor sites, to maintain and improve production, and to extend the range of soils which can be used for effective pine planting.

502. In W.A. it is now standard practice to apply superphosphate to all plantings in the coastal plain plantations. Minor elements have been found to be necessary on certain sites and there are indications that nitrogen in conjunction with superphosphate can boost production.

Fertiliser at Time of Planting

Superphosphate at time of planting

503. Superphosphate is applied at the rate of 2 ounces (57 grammes) per tree at time of planting to *P. pinaster* on the coastal plain. In mechanised operations with planting machines, the fertiliser is usually applied from the machine by means of a special hopper and a manually operated mechanism. In other cases, the fertiliser is applied by hand as a separate operation.

Supervision to ensure accuracy

504. Officers supervising this work must ensure that the fertiliser is accurately applied within 12 inches (300 mm) of the tree.

Minor elements needed on some sites

505. Zinc, copper and manganese in mixture with the superphosphate are necessary in certain areas.

Radiata has high Fertiliser requirements

506. *P. radiata* has a greater fertiliser requirement for healthy growth than *P. pinaster,* but by the same token it has the ability to provide greater returns, by way of greater production in response to fertiliser. The use of fertilisers is enabling *P. radiata* to be grown on much poorer soils (such as the yellow sands on the coastal plain) than was previously considered possible.

507. Research is continuing into the use of superphosphate and other fertilisers, including nitrogen, to improve the establishment and early growth of plantations on all sites.

508. Fertiliser requirements vary for different situations. Specific instructions for particular situations are set down in the Divisional Pine Working Plans.

Subsequent Applications of Fertiliser

Additional fertiliser needed on certain sites

509. Further applications of fertiliser are required on certain sites to maintain the growth of the pines. In general, the greatest benefit is obtained if refertilising is carried out to coincide with a thinning.

Gnangara

510. In *P. pinaster* plantations at Gnangara it has become routine practice to re-super at approximately 5 to 6 years of age, at the rate of four hundredweight per acre (500 kg per ha). The fertiliser is applied by aircraft.

Supervision to ensure accuracy

511. Officers supervising these operations must ensure that the correct quantity of fertiliser is applied and that the coverage is reasonably even.

Research continuing

512. The frequency and rate of subsequent fertiliser dressings required will depend on various soil and other factors and will be decided individually for particular areas. Research into the wider use of fertilisers for maintaining and improving production is continuing.

Proposals to be approved

513. Proposals for fertiliser applications other than routine must be approved by the Superintendent, Plantations.

SECTION 6 PINE NURSERIES

General

601. Pine planting stock for the plantation establishment programme is raised as one-year-old, open rooted seedlings in three large centralised nurseries. These large nurseries allow the economies of large-scale operations and reduce production costs. Specialised equipment is available in a large nursery and, most important, skilled specialists can develop the expertise necessary for this vital part of the forest programme.

Pine Seed Supplies

Seed supplies

Local collection

602. Until very recently, all pine seed used in W.A. was imported. Apart from quarantine problems, this was unsatisfactory from the viewpoint of seed quality. The Forests Department has been working towards self-sufficiency in seed supplies by local collection of seed.

Tree improvement programme

603. A programme to improve the form and vigour of future plantations by selective breeding has resulted in the establishment of seed orchards of both the major species. These orchards are providing part of the seed requirements for the planting programme, and in the future all seed will come from seed orchards.

Special seed production areas

604. The balance of seed requirements is provided by local collection from specially developed seed production areas. These are stands which have been heavily thinned to leave only the very best trees for seed production.

Collection of cones

605. Collection of cones must be carefully supervised as only mature cones from selected trees are used. Cones are collected during the winter months—May to September—but they must be stored in a cool situation (usually under pine litter) until spring. The seed is not mature until spring and premature extraction from the cones results in infertile seed.

Full details of seed origin required

606. Full details of the origin of any seed collected must be recorded and forwarded to Seed Store.

Extraction

607. Seed may be extracted locally in special drying areas, or the cones forwarded for extraction by the Seed Store at Como. With local extraction, care must be taken to avoid contamination of the seed by dirt or other seed material.

608. After extraction the seed is cleaned and stored in cool storage facilities at Seed Store.

609. Prior to despatch to nurseries, the seed is stratified, dusted with fungicide and tested for germination.

Seed serial number

610. Each seed lot is allocated a serial number to provide a reference as to seed source. A label identifying the serial number and the germination result will accompany the seed on delivery. Care must be taken to maintain a record of the serial number in the nursery.

Nursery Practice

Nursery Layout

Nursery layout for mechanisation

611. All operations in the nursery are mechanised as far as possible so the nursery layout must be designed to provide long runs for economical use of machinery. The beds are therefore long and narrow, of a width that can be straddled by the tractor wheels.

New Nursery Soils

Inoculation of new nursery soil

612. New nursery soils must be inoculated with mycorrhizal fungi which are essential to the growth of pine. This is done by collecting soil and litter from under a healthy, mature pine stand and applying it liberally as a top dressing to the new soil.

Seed Bed Preparation

Preparation of nursery beds

613. All roots and stones must be picked up and removed from the new nursery site.

614. Techniques for the preparation of nursery beds for sowing vary somewhat with different soil types. The aim is to provide a level surface of good, fine tilth and avoid soil compaction. This is achieved by a sequence of ploughing, cultivation and raking.

615. Suitable weather conditions are essential in the final stages of preparation, *i.e.*, the soil must be in a moist condition but the operation must be timed to allow the final preparation and seeding to be carried out in continuous fine weather.

Soil sterilisation

616. Sterilisation of the soil can be beneficial in circumstances where fungal problems occur. It is an expensive operation and will only be undertaken where the need is demonstrated. Large-scale soil sterilisation must be approved by the Superintendent of Plantations.

Sowing the Seed

Fine weather needed for sowing

617. Sowing is carried out in August to September. Fine weather is essential and the operation must therefore be well organised so that the operation can be carried out quickly when conditions are favourable.

Stanhay Seeder

618. The seed is sown with a tractor mounted machine consisting of six Stanhay Seeders each nine inches (230 mm) apart, *i.e.*, a 6-row bed is sown at the one time.

Check operation of seeder

619. These machines allow precise control of the sowing rate and depth of sowing, but they must be carefully adjusted by trial before sowing proceeds. It is most important that the actual seed flow also be carefully watched during sowing to ensure against blockages and that the covering mechanism is functioning properly.

Sowing rate 6-8 plants per foot

620. The sowing rate should be such as to produce six to eight plants per foot (20 to 26 plants per metre) of row. This fairly open spacing is desirable to raise sturdy, uniform plants. The number of seeds to be sown per foot is calculated from the germination percentage provided by Seed Store.

Depth of sowing

621. A common cause of failure in nurseries is due to sowing too deep. The seeds should be covered by no more than one-quarter of one inch (6 mm) of soil.

Maintenance of Soil Fertility

Depletion of humus

622. Continuous cropping of a nursery soil leads to depletion of the humus fraction and often to a deterioration of the soil structure. These problems are overcome in various ways for different soils.

Green crops

623. Rotational cropping, with green crops alternated with the pine crop, is practical in some nurseries. Oats and various legumes are grown and ploughed in while green, to build up the organic matter.

Addition of organic matter

624. This method is being replaced to some extent by the practice of adding other forms of organic matter such as peat or sawdust to the soil. This second method gives greater precision for control, once the desirable levels of organic matter are known. The method is also more economical of space and reduces the risk of introduction and build-up of weeds and insects. Various combinations of these methods are used at different nurseries depending on soil type and the availability of additives.

Nutrition

625. Fertiliser requirements vary with the type of soil. Fertiliser regimes are developed for each nursery. The addition of raw organic matter needs to be balanced by applications of nitrogen, at the rate of one hundredweight of Urea per acre (125 kg/ha) for each inch (25 mm) of peat. Subsequent light applications of Urea, at one-half a hundredweight per acre (60 kg/ha) can be made if seedlings show signs of nitrogen deficiency, *i.e.,* yellow colour and stunted growth.

Maintenance of Crop

626. Young seedlings are delicate and easily damaged by any one of a number of agencies. The most critical period is during the first few weeks following germination when weeds, disease and even bad weather can cause serious losses. An almost constant watch must be kept on the young plants at this stage and prompt action taken to guard against the various hazards.

Watering

Water supply essential

627. An efficient irrigation system and a good supply of fresh water are essential for a nursery. The size of the plants and the form of the root system can be controlled by watering and fertiliser regimes. Adequate summer watering promotes the development of a desirable fibrous root system close to the surface, while inadequate watering leads to the development of a deep tap root.

Regular watering

628. Watering should not be regarded as an emergency life saver to be used only in times of drought, but should be used regularly to maintain healthy growth.

Weed Control

Weed control mainly by chemical weedicides

629. Control of weeds in nurseries is now achieved mainly by the use of chemical weedicides. Problems and control measures vary under different conditions of soil, species and climate, necessitating variations in technique in different nurseries. Good techniques have been developed. The essence of control is in timing, i.e., by dealing with the problem as soon as, or even before, it becomes apparent.

630. Weedicides used in nurseries fall into two main groups, *i.e.,* pre-emergent and post-emergent weedicides.

"Dacthal" for sandy soils

631. "Dacthal" is a very efficient pre-emergent weedicide in sandy soils. It is most effective against couch and crab grass and is harmless to pines. "Dacthal" is applied immediately after sowing, at the rate of 12 pounds in 100 gallons of water per acre (13.4 kg in 1124 litres per hectare). "Dacthal" has not been found to be very effective in heavier soils.

"Simazine" for heavy soils

"Simazine" toxic to pines at heavier rates

632. "Simazine" is effective as a pre-emergent weedicide in the heavier soils. It is applied at the rate of 1½ pounds per acre in 40 gallons (1.6 kg per ha in 450 litres) of water, immediately after sowing. It is most important to note that "Simazine" is toxic to pines at heavier rates of application, so great care must be taken to ensure that the correct quantity is applied.

Barrier to weeds

Fine tilth necessary

633. Pre-emergent weedicides form a film or barrier on the surface of the soil which inhibits the germination of the weeds. It is therefore important that a fine tilth be established prior to treatment since large clods impede the effectiveness of the weedicide barrier. The barrier will be broken by disturbance of the surface after treatment so care must be taken to avoid subsequent working on the beds for as long as possible.

Mineral oil

Aromatic content 25-28%

634. Mineral oil is an effective, selective weedicide against crab grass and some other soft weeds. It is usually prepared as a 60:40 mixture of power kerosene and lighting kerosene. The aromatic content is the critical factor, and for safe use with pines it must be between 25 per cent. and 28 per cent. The higher the aromatic content, the more severe the effect. Pure power kerosene is normally 38 to 40 per cent. aromatic while lighting kerosene is much lower at about 7 per cent. These percentages vary from time to time and it is preferable to order a blended mixture of a specified aromatic content, *i.e.,* 25 per cent. to 28 per cent.

Do not exceed 70 gal/ac. (785 litres/ha.)

635. Mineral oil is applied as a spray in fine, still weather at the rate of 70 gallons per acre (785 litres per hectare). Careful calibration of equipment is needed to ensure that rates of application are not exceeded. Excessive rates of mineral oil will damage the pines.

Spray while grass is very young

636. Mineral oil at this concentration is only effective on very young weeds. Crab grass should be sprayed while still in the cotyledonary stage.

Paraquat-Diquat mixture

637. Paraquat-Diquat mixture is a powerful contact weedicide. It is toxic to pines and can only be applied with shielded sprays to prevent contact with the pines.

Safety precautions

638. Personal safety precautions to avoid skin contact and inhalation of vapours must be observed when handling these chemicals.

Hand weeding

Action not to be delayed

639. Hand weeding may become necessary at times, despite the use of weedicides. On such occasions it should be realised that the longer action is delayed the more difficult the problem becomes. If hand weeding is necessary it is usually best to attack it with as many men as possible and clean it up as quickly as possible.

Fungal Diseases

640. The major fungal problem in nurseries is "Damping Off". This disease is caused by a number of soil fungi such as Pythium, Rhizoctania and Phytophthora, which are common inhabitants of garden soils. Under favourable (*i.e.*, warm and moist) conditions the fungus attacks the germinating seed or young seedling causing it to rot.

641. Pre-emergence Damping-off kills the seedling before it emerges.

642. Post-emergence Damping-off usually occurs within the first few weeks after germination. The symptoms are the collapse of the stem at ground level followed by wilt and death of the seedling.

Control measures
Seed dusting

Careful watch for damping-off

643. The seed is always dusted with a fungicide (Ceresan or Captan) prior to delivery as a precautionary measure. This does not provide complete protection and a very careful watch must be maintained during the first few weeks after initial germination for any signs of damping-off. Any affected area should be treated promptly by the application of a fungicidal drench.

644. There are various organic fungicides available for this purpose, including "Thiram", "Captan" or "Zineb". The fungicide should be mixed in accordance with instructions and applied liberally at the rate of half to one gallon per square yard (2 to 3 litres per square metre) to affected areas. Stocks of fungicide must be kept on hand at nurseries, available for immediate use.

Stocks of fungicide kept on hand

Insects and Birds

645. A variety of insects may cause damage to nurseries.

Cut worms

646. Cut worms are larvae of the cut-worm moths of which the genus "Agrotis" has worldwide distribution. The caterpillars in the metropolitan district are dull grey to greenish naked grubs of uniform thickness, about one inch (25 mm) long when fully grown and having eight pairs of legs. They are first seen when somewhat less than one-quarter of one inch (6 mm) in length. They feed nearly always at night, concealing themselves in the ground by day. Water soluble D.D.T. has been found to give a very effective control over this pest.

Safety precautions when handling chemicals

647. As with weedicides, safety precautions must be observed when handling fungicides and insecticides.

Black Beetles

648. Black Beetle (*Heteronychus sanctae-helenae*) has caused considerable damage to both *P. pinaster* and *P. radiata* seedlings at Hamel and has been observed in other nurseries. Eggs are laid in the soil and the beetle breeds in uncultivated or neglected land. The beetles migrate by flying, so infestation can be from adjoining areas. Treatment is by spraying with Dieldrin as a solution of one gallon "Dieldrin 15" to 160 gallons (10 litres to 1800 litres) of water at the rate of 160 gallons per acre (1800 litres per hectare).

Some parrots steal seed

649. Some species of parrots occasionally steal newly sown seed. A watch should be kept for this and appropriate action taken.

Lifting, Bagging and Distribution

Machines undercut roots and loosen soil

650. Machines have been developed for undercutting and loosening of the soil around the roots to facilitate lifting. Seedlings are pulled from the ground (lifted) by hand. The plants are packed immediately in jute bags.

Prevent roots drying out

651. This is a critical operation, and it is vital that every precaution be taken to prevent drying out of the roots by exposure to wind and sun. The plants must be placed as quickly as possible into the bags.

652. The bags are made from wheat sacks cut down one side. Prior to use, the bags must be thoroughly soaked and kept wet throughout the operation.

653. Various methods have been developed for packing the plants into the bags. The following illustration indicates the general technique for filling and fastening.

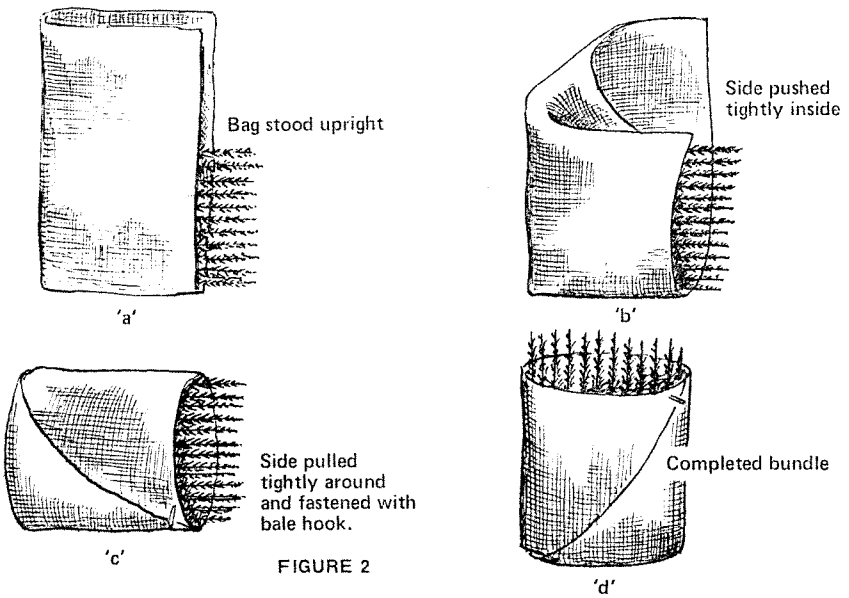

FIGURE 2

654. The number of plants per bag varies according to plant size. Generally, a bag holds about 500 plants.

655. Counting of plants is practised in some nurseries to assist in tallying piecework planting operations. This practice takes time, at a stage when minimal exposure of the roots is vital. It also slows up the procedure drastically unless special equipment for counting and packing is provided. The practice of counting plants in the nursery should be avoided as far as possible. Sample counts to determine an average number of plants per bag will normally suffice.

Determine average per bag

Protection of plants in transport

656. Plants are often transported long distances from the central nursery. It is most important that the vehicles used for transport of plants be suitably equipped with canvas covers to prevent exposure and drying out of the bags of plants during transport to the planting site.

657. A large nursery is a very busy place during the planting season, and there is a limit to the number of plants that can be lifted each day. A programme setting out a timetable of deliveries to the various planting centres must be prepared by the officer in charge of each nursery, in advance, and circulated to all concerned. This co-ordination is essential if the operation is to proceed smoothly.

Co-ordination of distribution to be planned

Annual Nursery Report

658. At the end of the planting season, a report is required on the operation of the nursery for the past year.

This report is set out in a standard form and provides an analysis of expenditure, the number of plants raised and details of the distribution of plants.

SECTION 7 PRUNING AND THINNING

Sylvicultural Objectives

High quality timber from high pruned crop trees
Heavy early thinning allows short rotation

701. Plantation sylviculture in W.A. aims at producing high quality timber on a short rotation by heavy, early thinning, and high pruning of crop trees. Production thinnings are heavy and infrequent, the stand being reduced to final crop stocking early in the rotation.

702. Prescriptions for pruning and thinning based on this objective are described in the following paragraphs. All young stands will be managed according to this regime which has been named "Prescription 70". Treatment for older stands is described separately.

"Prescription '70"

Early pruning and cleaning

Early reduction to final crop stocking

703. Under this regime, 300 selected trees per acre (750 stems per hectare) are low pruned, and the balance of the stand cut down at any early age. Final crop trees are selected early and high pruned in two lifts to a height of 20 feet (6 m). The stand is reduced to final crop stocking by production thinning early in the rotation.

704. The following schedules set out the type of treatments and the approximate timing which is planned. These schedules may be modified in the future as further information on stand development under this regime is obtained.

P. radiata schedule

705.

Schedule for "P. radiata"

Age (approx.)	Treatment
5 years	300 s.p.a. (750 s.p.ha) selected for retention and pruned to 7 ft. (2 m). Other trees removed.
7 years	80 s.p.a. (200 s.p.ha) selected for final crop and pruned 7 to 15 ft. (2 m to 4.5 m).
9 years	80 s.p.a. (200 s.p.ha) final crop, pruned 15 to 20 ft. (4.5 to 6 m).
11 years	Production thinning—remove all trees except 80 final crop trees per acre (200 final crop trees per ha).
30 years	Clear fell.

P. pinaster schedule

706.

Schedule for "P. pinaster"

Age (approx.)	Treatment
6 years	300 s.p.a. (750 s.p.ha) selected for retention and pruned to 7 ft. (2 m). Other trees removed.
9 years	50 s.p.a. (125 s.p.ha) selected and high pruned 7 ft. to 15 ft. (2 m to 4.5 m).
11 years	50 s.p.a. (125 s.p.ha) high pruned 15 to 20 ft. 4.5 to 6 m).
14 years	First production thinning to 100 s.p.a. (250 s.p.ha).
25 years	Select and mark 40 s.p.a. (100 s.p.ha) for final crop.
25 years	Second production thinning to 40 s.p.a. (100 s.p.ha) (final crop).
40 years	Clear fell.

Early Pruning and Cleaning

Low pruning and cleaning

707. Three hundred stems per acre (750 stems per hectare) are to be selected and pruned to seven feet (2 m) and all other trees cut down.

Age of stands

708. The age at which this operation is carried out will depend on the site quality (or rate of growth achieved). Stands are considered ready for treatment when dominant height reaches 16 to 20 feet (5 to 6 m). In *P. radiata* this is normally at age 4 to 6 years and in *P. pinaster* at age 5 to 7 years.

Assessment

709. Programming this work requires an assessment of the stands and some mapping to delineate areas ready for the treatment.

710. In this operation the aim is to retain the 300 most vigorous, straight trees per acre (750 per hectare). The problem of selection is simplified by considering a small number of trees at a time and selecting a suitable proportion of them, *i.e.,* two out of every four, one out of three, etc., depending on the initial stocking.

711. Another method is to assume that at 300 s.p.a. (750 s.p.ha) each tree occupies 16 sq. yards (13.5 m^2) and then, using two rows at a time calculate the number of yards (metres) along the rows which must contain one selected tree, thus with—

Eight foot (2.4 m) rows, two rows occupy 16 feet or 5.3 yards (5 m). Sixteen square yards (13.5 m^2) divided by 5.3 yards (5 m) equals 3 yards (2.7 m). So one tree in two rows should be retained every three yards (2.7 m) along the row.

Selection by pruner

712. Selection of trees to be pruned and retained is to be done by the pruners. The men must be fully trained in this aspect before commencing this work.

Crop trees

713. All trees retained in this operation are considered potential crop trees. Crop trees must have a straight 20 ft. (6 m) butt log and straightness is therefore a primary criterion for selection. The selected trees should also be as vigorous as possible. No attempt is to be made to retain sub-standard trees, merely to reach the full number of 300 per acre (750 per hectare). So, less than 300 per acre (750 per hectare) may be retained if there are not sufficient suitable trees.

Tools for low pruning

714. Low pruning is to be carried out by means of long-handled shears as far as possible. Particularly heavy branches may have to be removed by other means, such as axe or power saw. Care must be taken to avoid damage to the tree, by scarring of the stem or breaking off the tops.

Felling

715. Removal of the unpruned trees is usually carried out as a separate subsequent operation by means of chain saws.

Stumps to be cut low

716. Stumps are to be cut low to avoid, as far as possible, leaving green branches on the stumps. These branches tend to persist and develop as small trees, reducing the effectiveness of the thinning.

Payment

717. Various methods of incentive payment have been developed for this work. Rates are based on timed trials.

Quality control

718. Quality control checks must be carried out to ensure maintenance of standards. This is done by assessment of specific sample areas on which the quality of the work is measured and recorded.

High Pruning

719. Final crop trees are selected early and high pruned in two lifts to 15 feet (4.5 m) and to 20 feet (6 m).

Priority given to young stands

720. Priority in this work will be given to stands which are being managed under "Prescription '70", or which are young enough for conversion to the new regime.

Age for high pruning

721. High pruning is carried out as soon as the diameter over bark exceeds four inches (100 mm) at the base of the zone to be pruned. The age will vary with site quality. In *P. radiata* the age is normally 7 to 8 years for first lift (15 ft.) (4.5 m) and 9 to 10 years for second lift (20 ft) (6 m). In *P. pinaster* first lift high pruning is normally due at 8 to 9 years and second lift at 11 to 12 years.

Selection for high pruning

722. Selection of final crop trees for high pruning must only be carried out by men specially trained in this work.

Final crop trees to be straight

723. Final crop trees must be straight in the first 20 feet (6 m). The most vigorous straight trees are to be selected. In *P. radiata,* 80 stems per acre (200 s.p.h.a.) are high pruned and 50 per acre (125 s.p.ha.) in *P. pinaster.*

Trees for high pruning

724. High pruning is carried out by means of pole saws. These are special saw blades fixed to long aluminimum handles. Normally a 12 ft. (3.6 m) handle is used for first lift and a 16 ft. (4.9 m) handle for the second lift. Other methods of high pruning are being examined.

725. It is most important that high pruning schedules be kept up to date. Delay in pruning means an increase in the size of the knotty core and reduces the value of the pruning.

High pruning to be kept up to date

Production Thinning

726. Thinning, or the removal of some of the trees before the end of the rotation, is necessary if anything other than low-value pulp material is to be produced. To grow trees to an economical millable size, it is necessary to thin, to open up the stand and provide room for the development of the crop trees. Delay in thinning leads to suppression of growth on the crop trees and, in some cases, to death of part of the stand due to drought.

Thinning to permit development of crop trees

727. Thinnings can provide a useful intermediate yield and help towards defraying some of the expenses of establishment and maintenance of the plantation, but it is important to recognise that the major monetary return comes from the sale of the final crop trees. The value of log timber increases steeply with increase in diameter, and so the value of the thinnings varies with the size and type of product and with the distance from market. Some centres close to market are ideally situated to take advantage of thinnings, while in others, more remote, thinning is a necessary evil, producing a low-value product at a high cost.

Major return is from clear felling

728. Production thinning depends on markets and at present in W.A. the volume of thinnings available generally exceeds the demand. It is important therefore to determine priorities, to ensure that thinning is carried out in stands which will benefit most from thinning, *i.e.*, within the limits imposed by the market requirements, stands which will best respond to thinning by the growth of high-value material on the remaining trees should receive priority in thinning programmes.

Thinning depends on markets

729. Stands which have been managed under "Prescription 70" and high pruned must receive priority in planning thinning programmes.

Priority in thinning to "Prescription 70" stands

730. Under "Prescription 70", the trees to be retained in the first production thinning have already been selected and high pruned. In most areas, *i.e.*, where a full complement of trees have been high pruned, no further tree-marking will be necessary for this thinning.

Crop trees selected by high pruning

731. Felling and logging must be carried out in such a way as to avoid damage to the remaining trees. This requires strict supervision. Common causes of damage are: careless felling, breaking other trees and de-barking of butts of crop trees by ropes or logs in snigging operations. These remaining trees are the crop trees and are of far more value potentially than the thinnings. Every care must be taken to avoid damage to the crop trees.

Avoid damage to remaining trees

Application of "Prescription 70"

732. All stands younger than six years of age will be managed under the "Prescription 70" schedules, *i.e.*, with an early cleaning and high pruning of crop trees to 20 feet (6 m).

"Prescription 70" for young stands

Conversion of stands

733. Stands which are too old for the non-merchantable cleaning but which are still small enough for high pruning will be converted to this regime by means of high pruning and production thinning as opportunities for disposal of thinnings permit. Stands will be considered to be too old for conversion if the crop trees exceed 6 inches (152 mm) D.O.B. at the base of the unpruned zone.

734. When there are arrears of high pruning in stands awaiting conversion, work is to be programmed to complete arrears of high pruning 15 feet (4.5 m) only, commencing with the younger high-quality stands and working back through the older, poorer stands. High pruning to 20 feet (6 m) will not be carried out at all until the arrears of pruning to 15 feet (4.5 m) have been completed, and then work will commence again in the higher quality stands.

High pruning in conversion stands

Treatment of Older Stands

735. Thinning or clear felling in stands which are too old for conversion to "Prescription 70" will depend on market requirements. These stands will

Old stands to be thinned to basal area 70 sq. ft. per acre (16 sq. m /ha)

provide the bulk of the pine production from plantations for many years. Thinnings will aim at reducing the stand to 70 square feet of basal area per acre (16 m^2/ha).

Clear-felling after 30 years or 40 years

736. Stands will be eligible for clear-felling when they exceed 30 years in *P. radiata* or 40 years in *P. pinaster*.

737. Priority will always be given to younger "Prescription 70" stands for thinning, where they can produce the type of product required.

Pine Log Products

738. Pine logs are marketed in W.A. under the following categories:

(a) **Posts.** Small, straight pine logs are manufactured into fence posts (de-barked and pressure treated) by a number of firms. Specifications vary and are defined for particular orders.

(b) **Chipwood.** Logs for chipwood range from 2½ in. (64 mm) to 7 in. (178 mm) crown diameter under bark.

(c) **Case Logs.** Five in. (127 mm) to 9 in. (229 mm) crown d.u.b.

(d) **Mill Logs.** Over 9 in. (229 mm) crown d.u.b.

(e) **Peeler Logs.** Over 9 in. (229 mm) crown d.u.b.

Price lists and specifications for these log categories are notified from time to time.

Log Measurement

Tree volume under bark

739. All logs are sold on the basis of True Volume Underbark. Some larger logs are measured individually and the volume determined from the mean diameter and the length. Smaller material is measured by either bin volume or weight with a conversion to underbark volume.

Planning Thinning Programmes

Working plans to be drawn up by D.F.O.

740. Our plantations have reached the stage of providing a permanent output of thinnings, and factories and sawmills are being kept in production by this output. As each plantation reaches the age when a thinning programme is necessary, the D.F.O. concerned is required to draw up working plan proposals, giving the order of thinning by compartments with the object of determining the sustained yield and thinning programme for the plantation. This plan should cover five years in detail and up to ten years in a broader way. Areas listed for clear-felling to be included. See Section 8.

741. Although sustained yield is worked out for each plantation, it rests with management to adjust outputs by groups of plantations to meet the many varied demands, and D.F.O.'s therefore will appreciate that the cut allocated to any plantation for a period is not necessarily the sustained yield figure which was calculated.

SECTION 8 MANAGEMENT OF PLANTATIONS

General

801. Plantation management involves the planning and implementation of works for the establishment and maintenance of plantations and for the utilisation of the product. This is facilitated by the use of working plans and their control systems.

802. Plantations in W.A. are scattered over several Divisions and cover a range of sites which present different problems in different localities. Each Division maintains a Pine Working Plan for the management of its plantations.

Each division maintains a pine working plan

803. The Divisional Pine Working Plan provides a description of the plantations in the Division together with detailed planning of works for the next five years. Control of the works, programmed in the Working Plan, is ensured by the Plantation Operations Control System, described later in this section.

Divisional Pine Working Plans

804. It is the responsibility of the D.F.O. to prepare the Divisional Pine Working Plan and ensure that it is kept up to date.

D.F.O. responsibility to maintain the working plan

805. Pine Working Plans are prepared according to a standard pro forma. Sections requiring regular updating are prepared on printed forms which are available as blanks. Maps are used as far as possible in lieu of detailed written statements.

Standard proforma

806. All sections of the Working Plan must be checked annually and updated as necessary.

Annual updating essential

807. The Working Plan consists of two parts. Part I, the "Description", provides a statement of the present situation and Part II, "Working Plan Schedules", details planning of works for the next five years. Both parts require updating annually.

Working plans in two parts

Part I Description

808. A brief description of plantation areas, existing and proposed, by Groups and species. This is to be supported by a plan and by the Plantation Area Statement. The Area Statement is produced by Head Office and updated annually by reference to reports from Divisions of areas planted and clear-felled during the year.

Areas planted and available for planting

809. A brief statement of staff responsibilities and manpower requirements.

Administration

810. Statement of current and future planting rates, pine timber outputs and market outlets.

Planning

811. A description of any special techniques employed in the establishment and maintenance of plantations.

Record of special techniques

Viz.—

Site preparation.
Weed control.
Fertilisers.
Other tending.

812. A list of current research projects in the division are to be supported by plan.

Research Projects

Part II Working Plan Schedules

813. A five-year programme, setting out the sequence of works for pine establishment showing annually the acreage, location and method for the following operations:—

Clearing and planting programme

Utilisation.
Initial clearing.
Final clearing.
Scrub control.
Planting.

Areas to be identified on supporting plan

This programme must be supported by plan.

Tending operations Schedules maintained 5 years ahead

814. For each of the following tending operations a schedule is required showing areas coming due for treatment during the next five years. For each year the acreage, the P. Year, and the method of treatment is to be shown. These schedules are to be updated annually, noting discrepancies and carrying forward any arrears.

Tending operations requiring schedules:—

Re-fertilising.
Weed Control.
Low Pruning and Cleaning.
High Pruning—First lift.
High Pruning—Second lift.

Thinning schedules

Assistance from working plans officers

815. Schedules for thinning showing areas to be thinned and forecasts of thinnings yields are to be prepared in detail five years ahead and in a broader way up to 10 years ahead. The assistance of Working Plans officers and Marketing staff should be sought in preparing these schedules.

Clear-felling schedules

816. Clear-felling schedules are to be prepared as for Thinning schedules.

D.F.O. responsible for updating working plan

817. Working Plan schedules are to be updated annually and maintained five years ahead. This is the responsibility of the D.F.O. Copies of the plan will be maintained in Head Office.

Plantation Operations Control System

818. Detailed planning and control of plantation operations is facilitated by means of a Control System.

Planting year or "P Year", the unit of management

The system is based on the Planting Year (P. Year) as the unit of management. A "P. Year" is the area planted in a particular year in one plantation Group.

820. Prescriptions for proposed works are represented on a plan of the "P. Year" (P. Year Print), and these prints become *Operations Sheets* for recording details of work done. The yearly works programme is represented on a sheaf of Operations Sheets (Current Operations File). Details of all works done are recorded as a file of completed Operations Sheets for each "P. Year" (Record File). A summary of all works done on each "P. Year" is maintained on a card index with one visible edge card for each "P. Year" (P. Year Index).

"P. Year" Prints

821. This is a map depicting the "P. Year" on a foolscap sized sheet, at a suitable scale (usually 1 in 12,500). The Prints are prepared as copies of the appropriate parts of the P2 Plantation plans. The "P. Year" Print is identified by its Group name and year of planting. Planted areas are summarised on the print by Section and by Species.

"P.Year" prints used as operations sheets

822. "P. Year" Prints are produced in quantity and are used as Operations Sheets for describing and recording of works:

(a) To support Estimates by showing location of prescribed works.
(b) As a record of prescribed works.
(c) As a job description sheet for field use and for field recording of progress of work.
(d) To support Half-yearly Reports showing work done.
(e) As a permanent detailed record of work completed.

823. No legends are proposed for use with the Operations Sheets. Free use should be made of notations to record any information that may be useful. The only rule for Operations Sheets is that a separate sheet be used for each operation. Photo-copying facilities eliminate the need for hand copying of information shown on the sheets.

Current Operations File

Current years work on a set of operations sheets

824. The Estimates Works Programme will be supported by a set of Operations Sheets covering all the operations proposed for the year ahead. Following approval of the Estimates, the Operations Sheets will be copied and returned to Division. These sheets will then form the Current Operations File for that year.

825. It is important that the Estimates Works Programme should show a clear breakdown into individual jobs and that each job be described in terms of "P. Year" and Group and well as other specifications. Each job is allocated a Job Number.

Record File

826. The Record File contains the Operations Sheets for all completed operations. The sheets are filed by "P. Years" so that each "P. Year" file contains a set of Operations Sheets showing details of all work carried out on that area of plantation to date.

Record of all completed operations

827. Partly completed Operations Sheets for operations such as thinning would be stored in the Record File if work ceased before completion. The sheet would be retrieved and replaced in the Current Operations File when work recommenced.

P. Year Index

828. The P. Year Index consists of a set of visible edge cards, one card for each "P. Year". Each P. Year Index Card contains:

Card index provides summary of progress of works

(a) Group name and Planting Year.

(b) Statement of areas by Section, species and strata (when available).

(c) Description of operations carried out to date. Entries are in chronological order, one entry for each operation, showing date commenced and completed, type of treatment and area treated.

(d) Prescription. Future operations, particularly the next operation due, and date due, are shown.

(e) The visible edge at the bottom of the card is divided into a series of cells, each cell being reserved for a particular piece of information, *i.e.*, the "P. Year", area by species, and a cell for each expected operation. As operations are completed the cell is marked with the year of completion. Coloured markers or "flags" are used on the visible edge to indicate uncompleted operations, operations in progress, and the next operation due.

829. This set of cards thus gives a complete history for the whole plantation or any particular area, both in detail and in summary. A P. Year Print can be attached to each card to provide a fuller description of the area.

830. All entries on the Index cards are made in pencil so that they can be readily updated or amended in the light of better information. All entries are kept deliberately brief. Full details are provided by the Record File.

831. Operations carried out prior to planting must be recorded an plan in the form of an Operations Sheet, using prints of the subdivision plan. Provisional cards ahead of the current year should be included in the Index to carry a summary of these pre-planting works.

Operating the System

832. A duplicate set of Index Cards and Operations Sheets will be maintained in Head Office and updated by reference to the Estimates and Half-yearly Reports.

833. The following notes describe how the system will be maintained:—

Operations sheets to support the estimates works programme

(a) Preparation of Estimates includes preparation of Operations Sheets for the current year. These are forwarded to Head Office for approval, copied, and returned to Division to form the Current Operations File.

Obviously some operations such as thinning cannot be fully preplanned in detail. In this case Operations Sheets will be prepared as the need arises.

Operations sheets for field control

(b) Copies of the Operations Sheets are to be used for field control, for job description and field record of progress.

(c) Progress of work. The marking up of progress on the Operation Sheet should be fully descriptive and notations should be freely used to describe details of the work.

Operations sheets support half yearly reports

(d) The current Operations Sheets are forwarded to Head Office in support of the Half-yearly Report, if any work has been done on this operation during the period. A brief one-line entry summarising the work for the period to be included at the bottom of the sheet. The sheets will be copied and returned to Division.

(e) The Index Card is updated from the Half-yearly Report, either by a new entry (for a new operation) or by amendment (for a continuing operation). A statement listing any new entries on the Prescription side of the Index Cards should accompany the Half-yearly Report, to enable updating of the Head Office cards.

(f) When an operation is completed, the year of completion is entered in the appropriate cell on the visible edge of the Index Card, and the Operations Sheet is placed in the Record File.

Implementation of the System

834. The system is to be introduced into all divisions. P. Year Prints will be prepared by Head Office. Special officers will assist divisions in setting up the Record File and P. Year Index, but the compilation and use of the system is the responsibility of the local staff.

835. The system must be kept up to date and actively used as a tool in plantation operations planning and control.

Pine Inventory

Young stands assessed for inventory

836. An Inventory of Pine Plantations is maintained by carrying out an assessment of all stands as they reach a suitable age. This is generally 8 years for *P. radiata* and 10 years for *P. pinaster.*

Stands stratified by height index

837. The assessment is based on a stratification of the stands by means of a Height Index System. This defines areas of good, average and poor quality forest. The strata limits for the two species are as follows:—

	Stratum 1	Stratum 2	Stratum 3
P. radiata .... (Top Height at 8 years)	over 45′	38′-45′	less than 38′
P. pinaster .... (5 year Height-Intercept)	over 20′	16′-20′	less than 16′

Definitions

838. Some of the terms used in this work are defined as follows:—

(a) **Top height** is the average height of the 30 tallest trees per acre. This is normally obtained from the three tallest trees on 0.1 acre (within a radius of 37 ft. 3 in. (11.38 m) from the plot centre).

(b) **Height intercept** is the distance between the six consecutive annual branch whorls representing the five consecutive years of most rapid height growth. It is only used with uninodal species such as *P. pinaster* and is normally obtained from the three trees having the largest height intercepts on 0.1 acre.

(c) **Uninodal.** Produces only one branch whorl each year, *e.g., P. pinaster, Araucaria cunninghamii* (Norfolk Island Pine).

(d) **Multinodal.** Produces more than one branch whorl each year, *e.g., P. radiata, P. canariensis.*

Method of Stratification

Stands stratified by strip survey

839. This is carried out by the Working Plans Branch just before assessment. A systematic grid of measurements of top height for *P. radiata* and height intercept for *P. pinaster* is produced by walking strip lines at suitable intervals apart, commonly 200 metres. Strata boundaries are drawn in, favouring existing roads, tracks and firebreaks where possible. Depending on the variability of measurements, a closer grid may be walked for more data in selected areas. The final stratification plan is prepared by Drafting Branch.

Assessment

Assessment by sample plots

840. Assessment is carried out by measuring sample plots within each stratum. These plots are called "temporary variable radius plots". Sufficient plots are measured to ensure that the total per acre volume estimated by the sample is within 5 per cent of the true volume for a planting year in a plantation group. It is fairly common for 90 plots to be measured in a planting year of 125 hectares. These plots are not marked in the field and no attempt is made to relocate them after they are measured.

841. Trees are selected for measurement by using an optical prism, commonly a 10 factor prism. Each tree selected has diameter, bark thickness, total height and other relevant statistics recorded.

842. A "paper thinning" based on current silvicultural practice, is applied to trees in the plot to enable a thinning yield to be calculated.

843. Plot data are transferred to punched cards at the University computing centre and processed by a computer programme written by Officers of the Forests Department.

Inventory Results

Results summarised

844. In 1972 there were three ways of expressing inventory results:—

(a) Detailed Data—used by Working Plans and available on request to divisions—gives volumes by diameter classes in strata and planting years within a plantation group.

(b) The D.F.O.'s summary—sent to each division—gives volumes in strata and planting years within a plantation group.

(c) The Inspector's summary—gives volume in planting years only, within a plantation group.

Updating of Inventory Results

Results updated

845. Inventory results will be brought up to date by means of an annual inventory statement for each plantation group which will allow for cutting since assessment, growth since assessment, new assessment, and new area figures. This will involve some subsequent assessment. This system is still being developed.

Permanent Sample Plots

Growth data from permanent sample plots

846. Accurate predictions of future yields require growth data, and permanent plots are the most satisfactory way of measuring this. Permanent plots are of the same kind and the measurements are the same as for temporary plots, but each tree is marked in such a way that it can be relocated and remeasured. As the marking is "hidden" there is no apparent evidence for the presence of a permanent plot and trees in them should receive the same treatment as those in the stand nearby. On the nearest break, a white marker post is placed as a tie point. Remeasurement periods will vary with growth and treatment between three and five years.

SECTION 9 PROTECTION OF PLANTATIONS

Forest Pests and Diseases

901. Pines are subject to many diseases and damaging insect pests, notably Sirex Wasp, *Sirex noctilio*, and the leaf cast disease caused by *Dothistroma pini*. Fortunately in W.A., our plantations are, so far, free of serious disease, no doubt due to our isolation and vigilant plant quarantine precautions. Careful tending to maintain the trees in a vigorous condition is also a safeguard against disease.

902. Early detection of disorders is most important and constant surveillance of the plantations is therefore necessary to record any sign of trouble at an early stage.

Early detection of problems

Nutritional Disorders

903. Disorders due to incorrect nutrition occur on some sites. These may be recognised by abnormal appearance or abnormally slow growth of the trees. The symptoms may appear early in the life of the pine or at a later stage. The most common nutritional disorders in Western Australia are deficiencies of either phosphorus or zinc. Symptoms of these deficiencies are described in F.D. Bulletin No. 30, "Nutrition of the Pine". Other disorders may be due to deficiency of other elements, toxicity due to certain elements such as lime, or to an imbalance of nutrients. Unexplained disorders should be brought promptly to the attention of Research staff.

Deficiencies of phosphorus and zinc

Unexplained disorders to be reported

Damage by Insects

904. *Sirex noctilio* has caused serious damage to pine plantations in New Zealand, Tasmania and Victoria. Vigilant quarantine measures have so far prevented its establishment in Western Australia, but it remains a potential threat to our pine plantations. Publications are available describing this insect. All staff should be familiar with its appearance and habits and maintain a constant watch for Sirex.

Constant watch for Sirex

905. The Bark Beetle, *Ips grandicollis*, is present in most of our plantations. It is normally found only in dead trees or log material but it is also known to attack living trees which are in a weak condition due to drought or other causes. *Ips* attack undoubtedly causes the death of some trees which would otherwise have survived a period of drought stress. There is no economic control measure for this insect and the best protection is by maintaining the trees in a vigorous, healthy condition.

Ips attacks weak trees

906. Other damaging insects may appear and D.F.O.'s should initiate and encourage collection and identification of insect specimens for the education of their staff. This subject is covered in more detail in "Forestry in Western Australia".

Damage by Animals and Birds

907. Rabbits are a major cause of loss in the early years in many plantations. Complete eradication of rabbits from new planting areas must be attempted. Various techniques have been developed and the advice and co-operation of the Agriculture Protection Board officers should be sought in this work.

908. Any sign of damage to trees by other animals or birds should be recorded. Action taken will depend on the seriousness of the damage, but it must be borne in mind that our forests are also the home of many valuable native species.

Fungal Diseases

909. *Dothistroma pini*, the "Pine Needle Blight", is a disease which attacks the current year's needles. It has caused widespread damage to *P. radiata* and other pines in New Zealand and Africa, but has not become established in Australia. Other less virulent needle cast fungi such as *Lophodermium* and *Naemacyclus* occur in some of our plantations but do not appear to be causing serious damage. Any abnormal discolouration of needles should be reported to Research Branch.

Abnormal appearance of needles to be reported

910. *Diplodia pinea* is suspected of causing damage to leading shoots in *P. pinaster* in some areas, but this has not been positively identified.

Drought Damage

Heavy early thinning to avoid drought stress

911. Even in the high rainfall areas of the south-west of Western Australia, prolonged summer droughts are experienced. On many plantation sites, this results in heavy mortalities if appropriate treatment is not carried out. The problem is overcome by the heavy early thinning now adopted under "Prescription 70".

Protection from Fire

912. Pine plantations represent a large capital investment and, in W.A., they are very susceptible to fire. The risk of fire is ever-present each summer, and it is essential that all plantations be protected by efficient organisation for the detection and suppression of fires.

Fire control instructions in Pamphlet 7

913. Details of the fire control measures for plantation protection are covered in detail in Pamphlet 7 of this manual.

WILLIAM C. BROWN, Government Printer, Western Australia